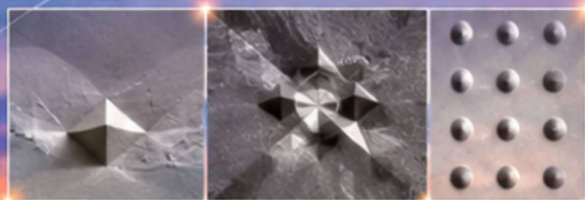


8th International Indentation Workshop IIW8

November 1 - 5, 2026

KINTEX, Goyang, Republic of Korea

Abstract Book



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Program Overview

Technical Sessions

AS Advanced Structural Alloys
EE Extreme Environments (Rate & Temp)
HI Effects of Hydrogen & Irradiation
MS Methodologies & Standards
SE Semiconductors & Electronic Materials

CC Ceramics & Composites
GA Glasses & Amorphous Materials
IC In-Situ Characterization
SA Simulations & AI
TF Thin Films & Multilayers

Presentation Types

Keynote Talk : 40 min.
Invited Talk : 25 min.
Oral Presentation : 20 min.

Sun, November 1, 2026

Time	Room 304
17:00–19:00	Registration Desk Open
18:00–20:00	Welcome Reception

Mon, November 2, 2026

Time	Room 306	Room 307	Room 305
09:00–17:00	Registration		
10:00–10:10	Opening Ceremony		
10:10–11:30	Chair Ju-Young Kim		
	Keynote Talk I John B. Pethica Nanoindentation - Origins and Two Recent Developments		
	Keynote Talk II Christopher A. Schuh Indentation at Extreme Strain Rates and the Quantitative Study of Phonon Drag-Limited Plasticity		
11:30–13:30	Group Photo & Lunch		
13:30–15:10	Chair Dongchan Jang	Chair Yu Zou	Chair Junggho Shin
	MS Dongil Kwon From Mechanical Properties to Material State: A Standardized Multi-Scale Indentation Approach	SE Bo-Shiuan Li Nanomechanics for Semiconductor Industries - Case Studies in Hybrid Bonding and Wafer Machining	HI Ruth Schwaiger A Multi-Technique Micromechanical Study of Hydrogen Effects in Austenitic Stainless Steel
	MS Nathan Mara Structure-Mechanical Property Correlations in Pharmaceutical Crystals: Insights from Nanomechanical and Impact Testing	SE Yang Lu Nanoindenter-Based Deep Elastic Strain Engineering of Semiconductors	HI Dong-Hyun Lee Nanoindentation-Based Evaluation of Hydrogen Diffusivity in Advanced Alloys: Methodology and Case Studies
	MS Jiri Nohava The Challenges of Low Load Nanoindentation and Property Mapping for Reliable Understanding Materials Behavior	SE Atsutomo Nakamura Photoindentation of Semiconductors: Light-Environment Effects on Dislocation Nucleation and Motion	HI Yakai Zhao Small-Scale Mechanical Testing for Unraveling Hydrogen Embrittlement in Advanced Alloys
15:10–15:30	MS Xiaodong Hou Recent Developments of ISO 14577 for Instrumented Indentation Testing	SE Haechan Jo Mechanical Strengthening of Ti Protective Coatings for PEMWE Bipolar Plates Through Residual Stress Control	HI Seung-gun Lee Evaluation of Hydrogen Embrittlement and Microstructural Response via Instrumented Indentation Testing
	Coffee break		
15:30–17:10	Chair Yue Liu	Chair Bo-Shiuan Li	Chair Yakai Zhao
	MS Mathias Göken Probing Mechanical Properties and Back Stress in Heterogeneous Lamellar Composites by Nanoindentation	SE Yang-Tse Cheng Instrumented Indentation Studies of Materials for Advanced Batteries	HI Jorge Alcalá Cabrelles Assessing Hydrogen Embrittlement and Hydrate Formation in BCC-Fe Through Nanoindentation
	MS Shinya Sasaki Nanoindentation in Tribology: Its Importance and Practical Applications	SE You Shuting Multi-Scale Insights into the Enhanced Electrical Conductivity of Copper by Nitrogen-Doped Graphene: Competing Mechanisms of Carrier Concentration and Mobility	HI Kotaro Murakami Instrumented Indentation Study on the Hydrogen Effect in Additively Manufactured CoCrNi Alloy
	MS Diancheng Geng Understanding the Indenter Wear Effect in Nanoindentation with Continuous Stiffness Measurement	SE Wonjun Shin Evolutionary Design Framework for Anisotropic Mechanical Metamaterials with Tailored Directional Stiffness	HI Dongchan Jang Defect-Driven Plasticity in Irradiated Nanotwinned Cu
	MS Xianghai An Play with Defects: New Insights into the Small-Scale Plasticity	SE Yu Zou Nanomechanical Testing of Semiconductors under an Electric Field or Light Illumination	HI Hoe-Yeon Jeong Precipitation Effect on the Mechanical Properties and Microstructure of NiCuAl Alloys for Spent Nuclear Fuel Canisters

Time	Room 306	Room 307	Room 305
08:30–09:40	Chair Jeffrey M. Wheeler	Chair Gi-Dong Sim	Chair Jong-hyoung Kim
	MS Seok-Woo Lee Finite-Size Scaling as a Unified Framework for Strengthening and Hardening in Micropillar Plasticity	SE Seung-Kyun Kang Application of Small-Scale Mechanics in Soft, Biodegradable Electronics	HI Ryuta Kasada Nanoindentation of Ion-Irradiated Materials: From Depth-Sensing Measurements to Reliable Fusion Materials Evaluation
	MS Yue Liu From Nanoindentation-Derived Strain-Rate Sensitivity to Dislocation-Mediated Plasticity Across Interfaces and Slip Systems	SE Yingwen Zhu Nanoscale Characterization of Local Electronic States at Defects via Kelvin Probe Force Microscopy	HI Jungho Shin Depth-Resolved Evaluation of Irradiation Hardening in Electron-Beam-Welded XM-19 Stainless Steel
	MS Edoardo Rossi A New Depth of Information: 4D Nanoindentation Mapping of Microstructures	SE Yuichi Hirai Nanomechanical Characterization of Stimuli-Responsive Molecular Crystals	HI Henri Nela Micromechanical Evaluation of Interfacial Properties in SiC/SiC Composites for Fusion Environments
09:40–10:00	Coffee Break		
10:00–11:30	Chair Seok-Woo Lee	Chair Seung-Kyun Kang	Chair Ryuta Kasada
	IC Takahito Ohmura Micro Plasticity Probing Through TEM in-Situ Straining	AS Qian Zhang Micro-/Nanoscale Plasticity and Super-Elongation in Single-Crystalline High-Entropy Alloy Pillars	SA Dan Mordehai A Combined Experimental-Computational Study of the Compression of Nanoporous Gold Nanoparticles
	IC Jeffrey M. Wheeler Operando Correlated Mechanical Microscopy	AS Jin Wang Indentation and Micromechanical Analysis of Room-Temperature Plasticity in Refractory Compositionally Complex Alloys	SA Ill Ryu Defect Dynamics Modeling of Incipient Plasticity under Nanoindentation: From Single Crystals to Polycrystalline Metals
	IC Shreehard Sahu Challenges in in-Situ Small-Scale Mechanics of Iron Oxides: From FIB-Induced Artefacts to High-Temperature Phase Stability	AS Gi-Dong Sim Yield Point Phenomenon in Al-C Thin Films	SA Xu Long Phase-Field Simulation of Indentation-Induced Fracture in Brittle Materials
	IC Alexey Useinov Mapping of Phase and Morphological Changes in-Situ under the Local Loading using a Transparent Diamond Indenter	AS Qian Zhang Chemical Local-Range Order Mediated Dislocation Nucleation in High-Entropy Alloys	SA Jong-hyoung Kim AI-Based Indentation–Tensile Conversion Considering Measurement Uncertainty
11:30–12:30	Lunch		
12:30–14:00	Poster Presentation		
14:00–15:10	Chair Kyeongjae Jeong	Chair Siyuan Wei	Chair Won-Seok Ko
	IC Jaafar A. El-Awady Microscale Fatigue Damage Evolution in Wire-Arc Additive Manufactured Nickel-Aluminum Bronze Revealed by in Situ Microcantilever Testing	AS Yinmin (Morris) Wang High-Throughput Indentation Characterization of Additively Manufactured Metals: Location Dependence and Tabor Equation	SA Quan Jiao A Machine Learning Perspective on the Inverse Indentation Problem
	IC Jixiang Cai A Novel in Situ TEM Platform for Nanoindentation, Multi-Field Coupling, And Atomic-Scale Observation	AS Subin Lee Effects of Residual Elements in Martensitic Steels using Nanoindentation-Based Approaches	SA Xiaochuan Sun Nanoindentation-Derived Strain-Rate Sensitivity for Dislocation-Informed Constitutive Modeling and AI-Assisted Prediction
	IC Nicholas Randall Recent Innovation in in-Situ Extreme Mechanics at the Micro and Nanoscale	AS Jaroslav Cech Characterization of Pseudoelastic Behavior and Functional Fatigue in NiTi Shape Memory Alloys via Nanoindentation	SA Tae Joo Lee Data-Driven Analysis and Machine Learning-Based Property Prediction for Ni- and Co-Based Superalloys
15:10–15:30	Poster Awards Announcement & Coffee Break		
15:30–17:10	Chair Nicholas Randall	Chair Subin Lee	Chair Ill Ryu
	GA Upadrasta Ramamurty Statistical Aspects of the Elastic-Plastic Transition in Metallic Glasses and High Entropy Alloys Probed using Nanoindentation	AS Yasuhito Kawahara Relationship Between Serrated Load-Displacement Curves and Dislocation Structures Underneath Indents in Al-Mg Alloys	SA Won-Seok Ko Atomistic Simulations of Phase Transformation and Deformation Behaviors of Shape-Memory Alloys at the Nanoscale
	GA Reza Rashidi From Nanoindentation to 4D-STEM: The Structural Origin of Elastic Fluctuations in Metallic Glasses	AS Siyuan Wei Interface-Mediated Plasticity in CoCrFeNi Multi-Principal Element Alloys Revealed by Nanoindentation-Based Micromechanics	SA Jaehun Kim A Local Thermo-Mechanical Field-Based Framework for Single-Test Constitutive Model Calibration
	GA R. Lakshmi Narayan Effect of Cryo-Thermal Cycling-Induced Structural State Modulation on the Pressure-Sensitivity of a Bulk Metallic Glass	AS Sun Guanghua Indentation Energy Method for in-Situ Evaluation of Multiple Post-Weld Heat Treatment Effects in Pressure Vessel Welds	SA Tae Young Go Physics-Informed Neural Posterior Estimation of Stress-Strain Curves from Indentation via a Mechanism-Based Constitutive Model
	GA Silvia Pomes Nanoindentation Reveals Local Anelasticity in Metallic Glasses	AS Bokyu Kim Nanoindentation-Based Surface Response Evaluation of Pure Al and 6061 Al Alloys	SA Kyeongjae Jeong Advancing Indentation-Based Mechanical Characterization with AI
	IC In-Suk Choi Electron-Beam-Driven in-Situ Modification of Small Scale Plasticity in Oxide Ceramics	AS David Ugi Concurrent Acoustic Emission Monitoring of PLC-Related Plastic Instabilities During Nanoindentation and Micropillar Compression	
17:10–18:30	Break Time		
18:30–20:30	Conference Banquet (Sono Calm Goyang)		

Wed, November 4, 2026

Time	Room 306	Room 307	Room 305
08:30–09:40	Chair Finn Giuliani	Chair Kwang Seok Lee	Chair Rajaprakash Ramachandramoorthy
	GA Morten M. Smedskjaer Visualizing Indentation-Induced Deformation in Glasses using Nanofocus X-Ray Scattering	AS Jiangwei Wang Dislocation Evolution in Cyclic-Loaded Cu Nanopillars with Different Configurations	SA Yoon Suk Choi A Comprehensive Microstructure-Based Fatigue Life Prediction Methodology for Hypo-Eutectoid Steels
	GA Theany To Indentation as a Crack Initiator for Studying Crack Propagation Resistance in Glasses	AS Priyanka Saini Impression Creep Behavior of Twin Roll Cast A356–5 Wt.% SiCp Composites	SA Minwoo Park Indentation-Based Characterization of the Bauschinger Effect using Physics-Guided Deep Learning
	GA Johan F. S. Christensen Probing Local Deformation and Directional Strain in Glasses During Indentation by X-Ray Scattering	AS Byung-Gil Yoo Nanoindentation-Guided Development of 2.0 GPa Hot Stamping Steel for Enhanced Crash Performance	SA Shinae Lee Orientation-Dependent Nanoindentation Analysis using CPFEM and Machine Learning
09:40–10:00	Coffee Break		
10:00–11:30	Chair Theany To	Chair Jiangwei Wang	Chair Byung-Gil Yoo
	GA Timothy Gross Damage Resistant Glasses with Mixed Indentation Deformation Modes	AS Jin-Yoo Suh Development of Nb-Based Alloys with Enhanced Strength–Ductility Balance Through Solid-Solution and Interstitial Control	EE Verena Maier-Kiener The Loading/ Unloading Stiffness Ratio-Real-Time Materials Insights under Extreme Conditions
	GA Finn Giuliani The Effect of Beam Damage on Small Scale Mechanical Properties of Forsterite Glass	AS Florian Tropper Nanoindentation-Induced Dislocation Structures in BCC Tungsten Observed via ECCI	EE Ben Beake An Experimental Capability for Nanomechanical Measurements at Cryogenic Temperatures
	GA Nathan Kail Probing Local Structural Variation of Glass Beneath a Vickers Imprint using Electron Diffraction (E-PDF) and M-Raman Spectroscopy	AS Kwang Seok Lee The Influence of Process Variables on the Interface Properties of Several Clad Sheets	EE Rajaprakash Ramachandramoorthy Nanoindentation at Extreme Conditions: High Strain Rates & Cryogenic Temperatures
	GA Yong Hao Sun Nanoindentation Reveals Universal Scaling of Pop-in Plasticity in Metallic Glasses		EE Anwesha Kanjilal In-Situ Micromechanical Deformation of Chemical Interfaces from Cryogenic to Elevated Temperatures
11:30–12:30	Lunch		
12:30–14:00	Poster Presentation		
14:00–15:10	Chair Hiroshi Masuda	Chair Seung Min Han	Chair Hansol Jeon
	GA Tanguy Rouxel What We Can Learn from Raman Scattering Spectroscopy About the Indentation Deformation Mechanisms in Oxide Glasses?	AS Dongwoo Lee Combinatorial Nanoindentation and Strengthening Analysis of Refractory Complex Concentrated Alloys of Mo–Nb–Ti and Ta–Nb–Ti	EE Karsten Durst Probing Thermally Activated Dislocation Mechanisms in MgO and BCC Metals by High Temperature Scanning Indentation
	GA Gustavo Alberto Rosales-Sosa Role of Plastic Flow on Crack Initiation by Vickers Indentation in Oxide Glasses	AS Jeongseok Kim Indentation-Based Multiscale Analysis of Deformation and Fracture Mechanisms in Potassium-Doped Tungsten	EE Bryan A. Crawford Spatially Resolved Strain Rate Sensitivity in a Dissimilar Steel Weld: Insights from High-Rate Nanoindentation
	GA Wenjuan Cheng Design of Theta Device for the Micro Tensile Testing of Silica	AS Sukwon Hong Ligament Reattachment and Connectivity-Driven Mechanical Behavior in Nanoporous Gold	EE Edyta Wyszowska Nanoindentation for Mechanical Characterization under Elevated Temperatures and Irradiation
15:10–15:30	Poster Awards Announcement & Coffee Break		
15:30–17:10	Chair Gustavo Alberto Rosales-Sosa	Chair Jin-Yoo Suh	Chair Dongwoo Lee
	CC Frantisek Lofaj Mapping of Nanoindentation Behavior of TiZrHf-Boride, -Carbide and Dual-Phase-Boride/Carbide Coatings	TF Seung Min Han 3D Architected Ni-Al2O3 Nanocomposite via Proximity-Field Nanopatterning	EE Thomas Edwards High Temperature Nanomechanical Testing of High Entropy Materials: Recent Efforts & Ongoing Challenges
	CC Oriol Gavalda Diaz FRACTURE OF BRITTLE MATERIALS AND INTERFACES AT THE NANOSCALE	TF Geummi Lee Investigation of Mechanical Properties of Ni-Co-Cr Thin Film using a High-Throughput Combinatorial Method	EE Kevin Schmalbach Probing Tungsten Deformation at Extreme Conditions Through High-Temperature, High-Strain-Rate Nanoindentation
	CC Hiroshi Masuda Indentation-Induced Plasticity in Oxide Ceramics: From Nanoindentation to Shot Peening	TF Kan Zhang Design of Strengthened and Toughened Thin Film Materials Based on Nano-Ordered Structures	EE Jian Chen Microscale Impact Deformation Mechanisms in FCC Single Crystals and Medium-Entropy Alloys
	CC Tamás Csanádi Influence of the Multi-Metal Environment on the Fracture Toughness of ZrHfNbTaC4 High-Entropy Carbide Grains	TF Hansol Jeon Effect of Structural Hierarchy on Mechanical Behavior of Nanoporous Gold	EE Kenji Matsuda Evaluation of Low-Temperature Embrittlement of Metallic Materials in Rebound Hardness Testing

Thu, November 5, 2026

Time	Room 306	Room 307	Room 305
09:00–10:10	Chair Wei Li	Chair Zaoli Zhang	Chair Dong-Hyun Lee
	CC Sung-Gyu Kang Electron–Matter Interactions in Silicon Oxides: From Irradiation-Induced Viscoplasticity to Mechanical Amorphization	TF Giovanni Maizza Mechanical Performance of an Electrodeposited Ni–Fe Film using the Loading Secant Stiffness Method of the Instrumented Indentation Test	EE Tea-Sung Jun Mechanistic Understanding of Time-, Orientation-, and Temperature-Dependent Deformation in Titanium using Nanoindentation
	CC Oliver Preuss Let's Get to the Point (Defect): How Oxygen Vacancies Alter Dislocation Mechanics in Oxides	TF Hyemin Ryu Understanding Fatigue Behavior in NiTi Thin Films for Reliable Elastocaloric Cooling	EE Hossein Besharatloo From High-Speed Mechanical Mapping to High-Temperature Micropillar Compression: Multiscale Mechanical Characterization of Ti(C,N)-FeNi Cermets
	CC Xufei Fang Enabling Dislocation Engineering in Ceramics: An Indentation-Based Deformation Toolbox and Mechanism Map	TF JungHun Park Simultaneously High Tensile and Fatigue Strengths in Thin Films with Atomic-Scale Planar Defects	EE Jeongin Paeng Seeded Dislocations Facilitate Plasticity in Strontium Titanate Micropillars under High Strain Rate Loading
10:10–10:30	Coffee Break		
10:30–11:40	Chair Sung-Gyu Kang	Chair Tea-Sung Jun	
	CC Wei Li Nanoindentation of Coordination Polymers and Hybrid Metal Halides: Selected Case Studies	TF Zaoli Zhang Atomic-Resolution Study on Nanoscale Multilayer Deformation	
	CC Eunsu Lee Orientation-Dependent Electron-Beam-Induced Plasticity in Single-Crystalline ZnO Micropillars	TF Zion Lee Achieving High Strength in 6061 Aluminum Alloy Thin Films Through Interstitial Carbon Incorporation.	
		TF Zhuo Feng Lee Membrane Deflection for High-Throughput Thin Film Tensile Characterization Across Temperatures	
11:40–12:30	Closing & Lunch		

Monday, November 2, 2026 | Room 306 + 307

Opening Remarks

10:00 AM-10:10 AM

Jae-il Jang (Chair of IIW8, Hanyang University)

Hyoung Seop Kim (President of the Korean Institute of Metals and Materials, POSTECH)

Keynote Presentation

Chair: Ju-Young Kim (UNIST)

10:10 AM-10:50 AM

[KEYNOTE] Nanoindentation - Origins and Two Recent Developments

John B. Pethica (Trinity College Dublin / University of Oxford)

10:50 AM-11:30 AM

[KEYNOTE] Indentation at Extreme Strain Rates and the Quantitative Study of Phonon Drag-Limited Plasticity

Christopher A. Schuh (Northwestern University)

Group Photo · Lobby · Following the Keynote Session

Oral Presentation

November 2-5, 2026

Monday, November 2, 2026

Session MS | 1:30 PM - 3:05 PM | Room 306

Chair: Dongchan Jang (KAIST)

1:30 PM-1:55 PM

[INVITED] From Mechanical Properties to Material State: A Standardized Multi-Scale Indentation Approach

Dongil Kwon (Seoul National University), Jung-wha Hong (Frontics Inc.)

1:55 PM-2:20 PM

[INVITED] Structure-Mechanical Property Correlations in Pharmaceutical Crystals: Insights from Nanomechanical and Impact Testing

Nathan Mara (University of Minnesota), Soumyadeep Sen (University of Minnesota), Jiahua Lu (University of Minnesota), Sushmita Majumder (University of Minnesota), Tianyi Xiang (Purdue University), Najma Jamac (University of Minnesota), Changquan Calvin Sun (Purdue University)

2:20 PM-2:40 PM

The Challenges of Low Load Nanoindentation and Property Mapping for Reliable Understanding Materials Behavior

Jiri Nohava (Anton Paar TriTec SA), Petr Hausild (Czech Technical University in Prague), Jaroslav Cech (Czech Technical University in Prague)

2:40 PM-3:05 PM

[INVITED] Recent Developments of ISO 14577 for Instrumented Indentation Testing

Xiaodong Hou (National Institute of Metrology)

Monday, November 2, 2026

Session SE | 1:30 PM - 3:05 PM | Room 307

Chair: Yu Zou (University of Toronto)

1:30 PM-1:55 PM

[INVITED] Nanomechanics for Semiconductor Industries - Case Studies in Hybrid Bonding and Wafer Machining

Bo-Shiuan Li (National Sun Yat-sen University)

1:55 PM-2:20 PM

[INVITED] Nanoindenter-Based Deep Elastic Strain Engineering of Semiconductors

Yang Lu (The University of Hong Kong)

2:20 PM-2:45 PM

[INVITED] Photoindentation of Semiconductors: Light-Environment Effects on Dislocation Nucleation and Motion

Atsutomo Nakamura (The University of Osaka)

2:45 PM-3:05 PM

Mechanical Strengthening of Ti Protective Coatings for PEMWE Bipolar Plates through Residual Stress Control

Haechan Jo (Sungkyunkwan University), Gi-Dong Sim (KAIST), Dongwoo Lee (Sungkyunkwan University)

Monday, November 2, 2026

Session HI | 1:30 PM - 3:10 PM | Room 305

Chair: Jungho Shin (Kangwon National University)

1:30 PM-1:55 PM

[INVITED] A Multi-Technique Micromechanical Study of Hydrogen Effects in Austenitic Stainless Steel

Ruth Schwaiger (Forschungszentrum Jülich)

1:55 PM-2:20 PM

[INVITED] Nanoindentation-Based Evaluation of Hydrogen Diffusivity in Advanced Alloys: Methodology and Case Studies

Hyun Jeong (Chungnam National University), Hwan-Sik Sim (Chungnam National University), Yakai Zhao (Institute of Materials Research and Engineering (IMRE)), Hyun You Kim (Chungnam National University), Soo Yeol Lee (Chungnam National University), **Dong-Hyun Lee** (Chungnam National University)

2:20 PM-2:45 PM

[INVITED] Small-Scale Mechanical Testing for Unraveling Hydrogen Embrittlement in Advanced Alloys

Yakai Zhao (A*STAR)

2:45 PM-3:10 PM

[INVITED] Evaluation of Hydrogen Embrittlement and Microstructural Response via Instrumented Indentation Testing

Seung-gun Lee (Korea Institute of Materials Science), Si-whan Lee (Korea Institute of Materials Science), Jung-yun Won (Korea Institute of Materials Science)

Monday, November 2, 2026

Session MS | 3:30 PM - 5:05 PM | Room 306

Chair: Yue Liu (Shanghai Jiao Tong University)

3:30 PM-3:55 PM

[INVITED] Probing Mechanical Properties and Back Stress in Heterogeneous Lamellar Composites by Nanoindentation

Mathias Göken (Friedrich Alexander University Erlangen-Nürnberg)

3:55 PM-4:20 PM

[INVITED] Nanoindentation in Tribology: Its Importance and Practical Applications

Shinya Sasaki (Tokyo University of Science)

4:20 PM-4:40 PM

Understanding the Indenter Wear Effect in Nanoindentation with Continuous Stiffness Measurement

Diancheng Geng (Tohoku University), Hao Yu (Tohoku University), Sosuke Kondo (Tohoku University), Ryuta Kasada (Tohoku University)

4:40 PM-5:05 PM

[INVITED] Play with Defects: New Insights into the Small-Scale Plasticity

Xianghai An (The University of Sydney)

Monday, November 2, 2026

Session SE | 3:30 PM - 5:00 PM | Room 307

Chair: Bo-Shiuan Li (National Sun Yat-sen University)

3:30 PM-3:55 PM

[INVITED] Instrumented Indentation Studies of Materials for Advanced Batteries

Yang-Tse Cheng (University of Kentucky)

3:55 PM-4:15 PM

Multi-Scale Insights into the Enhanced Electrical Conductivity of Copper by Nitrogen-Doped Graphene: Competing Mechanisms of Carrier Concentration and Mobility

Wang Yu (Shanghai Jiao Tong University), **You Shuting** (Shanghai Jiao Tong University)

4:15 PM-4:35 PM

Evolutionary Design Framework for Anisotropic Mechanical Metamaterials with Tailored Directional Stiffness

Wonjun Shin (Jeonbuk National University), Jong-Soo Bae (Jeonbuk National University), Jihoon Han (Jeonbuk National University)

4:35 PM-5:00 PM

[INVITED] Nanomechanical Testing of Semiconductors under an Electric Field or Light Illumination

Yu Zou (University of Toronto)

Monday, November 2, 2026

Session HI | 3:30 PM - 5:00 PM | Room 305

Chair: Yakai Zhao (A*STAR)

3:30 PM-3:55 PM

[INVITED] Assessing Hydrogen Embrittlement and Hydrate Formation in BCC-Fe through Nanoindentation

Jan Ocenasek (University of West Bohemia in Pilsen), Ting Yang (MIT), Cheng-Yuan Tsai (MIT), T. Venkatesh (Stony Brook University), Ming Dao (MIT), **Jorge Alcalá Cabrelles** (Polytechnic University of Catalonia)

3:55 PM-4:15 PM

Instrumented Indentation Study on the Hydrogen Effect in Additively Manufactured CoCrNi Alloy

Kotaro Murakami (Kagoshima University), Shin-ichi Komazaki (Kagoshima University), Zhe Gao (Hanyang University), Jae-Hyeok Choi (Hanyang University), Jae-il Jang (Hanyang University)

4:15 PM-4:40 PM

[INVITED] Defect-Driven Plasticity in Irradiated Nanotwinned Cu

Daehyeok Ahn (KAIST), Hadi Ghaffarian (KAIST), **Dongchan Jang** (KAIST)

4:40 PM-5:00 PM

Precipitation Effect on the Mechanical Properties and Microstructure of NiCuAl Alloys for Spent Nuclear Fuel Canisters

Hoe-Yeon Jeong (UNIST), Seonyeong Yang (UNIST), Jeong-Hyun Woo (KAERI), Hansol Jeon (Keimyung University), Ju-Young Kim (UNIST)

Tuesday, November 3, 2026

Session MS | 8:30 AM - 9:45 AM | Room 306

Chair: Jeffrey M. Wheeler (EMPA)

8:30 AM-8:55 AM

[INVITED] Finite-Size Scaling as a Unified Framework for Strengthening and Hardening in Micropillar Plasticity

Seok-Woo Lee (University of Connecticut)

8:55 AM-9:20 AM

[INVITED] From Nanoindentation-Derived Strain-Rate Sensitivity to Dislocation-Mediated Plasticity across Interfaces and Slip Systems

Yue Liu (Shanghai Jiao Tong University)

9:20 AM-9:45 AM

[INVITED] A New Depth of Information: 4D Nanoindentation Mapping of Microstructures

Edoardo Rossi (Roma Tre University), Harita Seekala (University of Hyderabad), P. Sudharshan Phani (University of Hyderabad), Marco Sebastiani (Roma Tre University), Tiberio Cuppone (University of Firenze), Giovanni Pratesi (University of Firenze)

Tuesday, November 3, 2026

Session SE | 8:30 AM - 9:40 AM | Room 307

Chair: Gi-Dong Sim (KAIST)

8:30 AM-8:55 AM

[INVITED] Application of Small-Scale Mechanics in Soft, Biodegradable Electronics

Seung-Kyun Kang (Seoul National University)

8:55 AM-9:15 AM

Nanoscale Characterization of Local Electronic States at Defects via Kelvin Probe Force Microscopy

Yingwen Zhu (Shanghai Jiao Tong University)

9:15 AM-9:40 AM

[INVITED] Nanomechanical Characterization of Stimuli-Responsive Molecular Crystals

Yuichi Hirai (National Institute for Materials Science)

Tuesday, November 3, 2026

Session HI | 8:30 AM - 9:40 AM | Room 305

Chair: Jong-hyoung Kim (Pukyong National University)

8:30 AM-8:55 AM

[INVITED] Nanoindentation of Ion-Irradiated Materials: From Depth-Sensing Measurements to Reliable Fusion Materials Evaluation

Ryuta Kasada (Tohoku University), Diancheng Geng (Tohoku University), Sumin Lee (Tohoku University), Sosuke Kondo (Tohoku University)

8:55 AM-9:20 AM

[INVITED] Depth-Resolved Evaluation of Irradiation Hardening in Electron-Beam-Welded XM-19 Stainless Steel

Jungho Shin (Kangwon National University)

9:20 AM-9:40 AM

Micromechanical Evaluation of Interfacial Properties in SiC/SiC Composites for Fusion Environments

Henri Nela (Imperial College London)

Tuesday, November 3, 2026

Session IC | 10:00 AM - 11:35 AM | Room 306

Chair: Seok-Woo Lee (University of Connecticut)

10:00 AM-10:25 AM

[INVITED] Micro Plasticity Probing through TEM In-Situ Straining

Takahito Ohmura (National Institute for Materials Science)

10:25 AM-10:50 AM

[INVITED] Operando Correlated Mechanical Microscopy

Jeffrey M. Wheeler (EMPA)

10:50 AM-11:10 AM

Challenges in In-Situ Small-Scale Mechanics of Iron Oxides: From FIB-Induced Artefacts to High-Temperature Phase Stability

Shreehard Sahu (Max Planck Institute for Sustainable Materials), Gang Liu (Max Planck Institute for Sustainable Materials), Vivek Devulapalli (Max Planck Institute for Sustainable Materials), Saba Saood (Max Planck Institute for Sustainable Materials), James P. Best (Max Planck Institute for Sustainable Materials), Gerhard Dehm (Max Planck Institute for Sustainable Materials), Anwesha Kanjilal (Max Planck Institute for Sustainable Materials)

11:10 AM-11:35 AM

[INVITED] Mapping of Phase and Morphological Changes In-Situ under the Local Loading Using a Transparent Diamond Indenter

Alexey Useinov (HPPI RAS), Sergey Votyakov (HPPI RAS), Gulnaz Sultanova (HPPI RAS)

Tuesday, November 3, 2026

Session AS | 10:00 AM - 11:30 AM | Room 307

Chair: Seung-Kyun Kang (Seoul National University)

10:00 AM-10:25 AM

[INVITED] Chemical Local-Range Order Mediated Dislocation Nucleation in High-Entropy Alloys

Qian Zhang (Taiyuan University of Technology), Yakai Zhao (A*STAR), Junwei Qiao (Taiyuan University of Technology), Upadrasta Ramamurty (Nanyang Technological University)

10:25 AM-10:45 AM

Indentation and Micromechanical Analysis of Room-Temperature Plasticity in Refractory Compositionally Complex Alloys

Jin Wang (Forschungszentrum Jülich), Ruth Schwaiger (Forschungszentrum Jülich)

10:45 AM-11:10 AM

[INVITED] Yield Point Phenomenon in Al-C Thin Films

Injong Oh (KAIST), Zion Lee (KAIST), Hojang Kim (KAIST), **Gi-Dong Sim** (KAIST)

11:10 AM-11:30 AM

Micro-/nanoscale Plasticity and Super-Elongation in Single-Crystalline High-Entropy Alloy Pillars

Qian Zhang (The University of Hong Kong), Xiaoyan Li (Tsinghua University)

Tuesday, November 3, 2026

Session SA | 10:00 AM - 11:35 AM | Room 305

Chair: Ryuta Kasada (Tohoku University)

10:00 AM-10:25 AM

[INVITED] A Combined Experimental-Computational Study of the Compression of Nanoporous Gold Nanoparticles

Ben Engelman (Technion-Israel Institute of Technology), Santhosh Mathesan (Technion-Israel Institute of Technology), Tatyana Fedyaeva (Technion-Israel Institute of Technology), Anuj Bisht (Technion-Israel Institute of Technology), Eugen Rabkin (Technion-Israel Institute of Technology), **Dan Mordehai** (Technion-Israel Institute of Technology)

10:25 AM-10:50 AM

[INVITED] Defect Dynamics Modeling of Incipient Plasticity under Nanoindentation: From Single Crystals to Polycrystalline Metals

Ill Ryu (Seoul National University)

10:50 AM-11:10 AM

Phase-Field Simulation of Indentation-Induced Fracture in Brittle Materials

Xu Long (Northwestern Polytechnical University), Ahmad Muhammad Usman (Northwestern Polytechnical University), Percy M. Iyela (Northwestern Polytechnical University)

11:10 AM-11:35 AM

[INVITED] AI-Based Indentation-Tensile Conversion Considering Measurement Uncertainty

long-hyoung Kim (Pukyong National University), Si Hyun Park (Pukyong National University), Hyun-Wook Cho (Pukyong National University), Im-Deok Kim (Seoul National University), Seung-Kyun Kang (Seoul National University), Joost J. Vlassak (Harvard University)

Tuesday, November 3, 2026

Session IC | 2:00 PM - 3:10 PM | Room 306

Chair: Kyeongjae Jeong (Sungkyunkwan University)

2:00 PM-2:25 PM

**[INVITED] Microscale Fatigue Damage Evolution in Wire-Arc Additive
Manufactured Nickel-Aluminum Bronze Revealed by in Situ Microcantilever
Testing**

Faizan Hijazi (Johns Hopkins University), Mostafa M. Omar (Johns Hopkins University), Mo-Rigen He (Johns Hopkins University), **Jaafar A. El-Awady** (Johns Hopkins University)

2:25 PM-2:45 PM

**A Novel in Situ TEM Platform for Nanoindentation, Multi-Field Coupling, and
Atomic-Scale Observation**

Jixiang Cai (Beijing University of Technology)

2:45 PM-3:10 PM

**[INVITED] Recent Innovation in In-Situ Extreme Mechanics at the Micro and
Nanoscale**

Nicholas Randall (Alemnis AG)

Tuesday, November 3, 2026

Session AS | 2:00 PM - 3:10 PM | Room 307

Chair: Siyuan Wei (IMRE)

2:00 PM-2:25 PM

**[INVITED] High-Throughput Indentation Characterization of Additively
Manufactured Metals: Location Dependence and Tabor Equation**

Yinmin (Morris) Wang (University of California Los Angeles)

2:25 PM-2:50 PM

**[INVITED] Effects of Residual Elements in Martensitic Steels Using
Nanoindentation-Based Approaches**

Eloho Okotete (Karlsruhe Institute of Technology), **Subin Lee** (Karlsruhe Institute of Technology), Christoph Kirchlechner (Karlsruhe Institute of Technology)

2:50 PM-3:10 PM

**Characterization of Pseudoelastic Behavior and Functional Fatigue in NiTi Shape
Memory Alloys via Nanoindentation**

Jaroslav Cech (Czech Technical University in Prague)

Tuesday, November 3, 2026

Session SA | 2:00 PM - 3:05 PM | Room 305

Chair: Won-Seok Ko (Korea University)

2:00 PM-2:25 PM

[INVITED] A Machine Learning Perspective on the Inverse Indentation Problem

Quan Jiao (Liaoning Academy of Materials)

2:25 PM-2:45 PM

Nanoindentation-Derived Strain-Rate Sensitivity for Dislocation-Informed Constitutive Modeling and AI-Assisted Prediction

Xiaochuan Sun (Kobe University), Yue Liu (Shanghai Jiao Tong University)

2:45 PM-3:05 PM

Data-Driven Analysis and Machine Learning-Based Property Prediction for Ni- and Co-Based Superalloys

Tae Joo Lee (Pusan National University), Yoon Suk Choi (Pusan National University)

Tuesday, November 3, 2026

Session GA | 3:30 PM - 5:25 PM | Room 306

Chair: Nicholas Randall (Alemnis)

3:30 PM-3:55 PM

[INVITED] Statistical Aspects of the Elastic-Plastic Transition in Metallic Glasses and High Entropy Alloys Probed Using Nanoindentation

Upadrasta Ramamurty (Nanyang Technological University)

3:55 PM-4:15 PM

From Nanoindentation to 4D-STEM: The Structural Origin of Elastic Fluctuations in Metallic Glasses

Reza Rashidi (Federal Institute of Materials Research and Testing (BAM)), Birte Riechers (Federal Institute of Materials Research and Testing (BAM)), Robert Maass (Federal Institute of Materials Research and Testing (BAM))

4:15 PM-4:40 PM

[INVITED] Effect of Cryo-Thermal Cycling-Induced Structural State Modulation on the Pressure-Sensitivity of a Bulk Metallic Glass

Shantanu Jain (Indian Institute of Technology Delhi), Naresh V. Datla (Indian Institute of Technology Delhi), Long Zhang (Beijing Institute of Technology), **R. Lakshmi Narayan** (Indian Institute of Technology Delhi), Upadrasta Ramamurty (Nanyang Technological University)

4:40 PM-5:00 PM

Nanoindentation Reveals Local Anelasticity in Metallic Glasses

Silvia Pomes (Federal Institute of Materials Research and Testing), Birte Riechers (Federal Institute of Materials Research and Testing), Reza Rashidi (Federal Institute of Materials Research and Testing), Takahito Ohmura (National Institute for Materials Science), Robert Maass (Federal Institute of Materials Research and Testing)

5:00 PM-5:25 PM

[INVITED] Electron-Beam-Driven In-Situ Modification of Small Scale Plasticity in Oxide Ceramics

In-Suk Choi (Seoul National University)

Tuesday, November 3, 2026

Session AS | 3:30 PM - 5:20 PM | Room 307

Chair: Subin Lee (Karlsruhe Institute of Technology)

3:30 PM-3:55 PM

[INVITED] Relationship between Serrated Load-Displacement Curves and Dislocation Structures Underneath Indents in Al-Mg Alloys

Yasuhito Kawahara (Kyushu University), Hidenari Takagi (Nihon University), Takahito Ohmura (National Institute for Material Science), Shigeto Yamasaki (Kyushu University), Masaki Tanaka (Kyushu University), Satoshi Hata (Kyushu University)

3:55 PM-4:20 PM

[INVITED] Interface-Mediated Plasticity in CoCrFeNi Multi-Principal Element Alloys Revealed by Nanoindentation-Based Micromechanics

Siyuan Wei (IMRE)

4:20 PM-4:40 PM

Indentation Energy Method for In-Situ Evaluation of Multiple Post-Weld Heat Treatment Effects in Pressure Vessel Welds

Sun Guanghua (China University of Petroleum (East China))

4:40 PM-5:00 PM

Processing Nanoindentation Data for Machine Learning in Additively Manufactured 17-4PH Stainless Steel

Bokyu Kim (Kangwon National University), Jaewoo Kim (Seoul National University), Sunghee Han (Kangwon National University), Daehyun Kim (Kangwon National University), Junhee Han (Kangwon National University), Su Bin Yun (Kangwon National University), Byung-chul Choi (Korea Institute of Industrial Technology), In-Suk Choi (Seoul National University), Jungho Shin (Kangwon National University)

5:00 PM-5:20 PM

Concurrent Acoustic Emission Monitoring of PLC-Related Plastic Instabilities During Nanoindentation and Micropillar Compression

David Ugi (Eötvös Lotánt University)

Tuesday, November 3, 2026

Session SA | 3:30 PM - 5:00 PM | Room 305

Chair: Ill Ryu (Seoul National University)

3:30 PM-3:55 PM

[INVITED] Atomistic Simulations of Phase Transformation and Deformation Behaviors of Shape-Memory Alloys at the Nanoscale

Won-Seok Ko (Korea University)

3:55 PM-4:15 PM

A Local Thermo-Mechanical Field-Based Framework for Single-Test Constitutive Model Calibration

Jaehun Kim (POSTECH), Rae Eon Kim (POSTECH), Jumi Choi (POSTECH), Tae Young Go (POSTECH), Hyejin Seo (POSTECH), Hyoung Seop Kim (POSTECH)

4:15 PM-4:35 PM

Physics-Informed Neural Posterior Estimation of Stress-Strain Curves from Indentation via a Mechanism-Based Constitutive Model

Tae Young Go (POSTECH), Renhao Wu (Tohoku University), Chuangming Li (Tohoku University), Soo Vin Ha (POSTECH), Jeong Ah Lee (POSTECH), Jihye Kwon (POSTECH), Hyoung Seop Kim (POSTECH)

4:35 PM-5:00 PM

[INVITED] Advancing Indentation-Based Mechanical Characterization with AI

Kyeongjae Jeong (Sungkyunkwan University), Minwoo Park (Seoul National University), Heung Nam Han (Seoul National University)

Wednesday, November 4, 2026

Session GA | 8:30 AM - 9:40 AM | Room 306

Chair: Finn Giuliani (Imperial College London)

8:30 AM-8:55 AM

[INVITED] Visualizing Indentation-Induced Deformation in Glasses Using Nanofocus X-ray Scattering

Morten M. Smedskjaer (Aalborg University)

8:55 AM-9:20 AM

[INVITED] Indentation as a Crack Initiator for Studying Crack Propagation Resistance in Glasses

Theany To (École Centrale Nantes)

9:20 AM-9:40 AM

Probing Local Deformation and Directional Strain in Glasses During Indentation by X-ray Scattering

Johan F. S. Christensen (Aalborg University), M. Faizal Ussama Jalaludeen (Aalborg University), Søren S. Sørensen (Aalborg University), David L. Christensen (Aalborg University), Sourav Sahoo (Aalborg University), Jonas A. Finkler (Aalborg University), Anton Davydok (Helmholtz-Zentrum Hereon), Christina Krywka (Helmholtz-Zentrum Hereon), Henning F. Poulsen (Technical University of Denmark), Etienne Barthel (CNRS/ESPCI/PSL/Sorbonne Université), Gustavo A. Rosales-Sosa (Nippon Electric Glass Co.), Morten M. Smedskjaer (Aalborg University)

Wednesday, November 4, 2026

Session AS | 8:30 AM - 9:40 AM | Room 307

Chair: Kwang Seok Lee (Korea Institute of Materials Science)

8:30 AM-8:55 AM

[INVITED] Dislocation Evolution in Cyclic-Loaded Cu Nanopillars with Different Configurations

Jiangwei Wang (Zhejiang University)

8:55 AM-9:15 AM

Impression Creep Behavior of Twin Roll Cast A356-5 Wt.% SiCp Composites

Rishikesh Patel (National Institute of Technology Rourkela), J. Sivasubramanian (National Institute of Technology Rourkela), Bushra (National Institute of Technology Rourkela), Anindya Basu (National Institute of Technology Rourkela), **Priyanka Saini** (National Institute of Technology Rourkela)

9:15 AM-9:40 AM

[INVITED] Nanoindentation-Guided Development of 2.0 GPa Hot Stamping Steel for Enhanced Crash Performance

Byung-Gil Yoo (Hyundai Steel), Seok Min Hwang (Hyundai Steel), Jewoosoo Kim (Hyundai Steel)

Wednesday, November 4, 2026

Session SA | 8:30 AM - 9:35 AM | Room 305

Chair: Rajaprakash Ramachandramoorthy (Max Planck Institute for Sustainable Materials)

8:30 AM-8:55 AM

[INVITED] A Comprehensive Microstructure-Based Fatigue Life Prediction Methodology for Hypo-Eutectoid Steels

Yoon Suk Choi (Pusan National University), Jonghoon Shin (Hanwha Aerospace), Taeyang Bang (Pusan National University), Dae-Geun Nam (Korea Institute of Industrial Technology)

8:55 AM-9:15 AM

Indentation-Based Characterization of the Bauschinger Effect Using Physics-Guided Deep Learning

Minwoo Park (Seoul National University), Deunbom Chung (Seoul National University), Seok Hyun Choi (Seoul National University), Jaeyoung Park (Hanwha Aerospace), Fusahito Yoshida (Hiroshima University), Heung Nam Han (Seoul National University)

9:15 AM-9:35 AM

Orientation-Dependent Nanoindentation Analysis Using CPFEM and Machine Learning

Shinae Lee (Pusan National University), Ji Hoon Kim (Pusan National University)

Wednesday, November 4, 2026

Session GA | 10:00 AM - 11:30 AM | Room 306

Chair: Theany To (Nantes Université)

10:00 AM-10:25 AM

[INVITED] Damage Resistant Glasses with Mixed Indentation Deformation Modes

Timothy Gross (Corning Incorporated)

10:25 AM-10:50 AM

[INVITED] The Effect of Beam Damage on Small Scale Mechanical Properties of Forsterite Glass

Lucas Li (Imperial College London), Siyang Wang (Imperial College London), Katharina Marquardt (University of Oxford), Tanguy Rouxel (Université de Rennes), **Finn Giuliani** (Imperial College London)

10:50 AM-11:10 AM

Probing Local Structural Variation of Glass Beneath a Vickers Imprint Using Electron Diffraction (e-PDF) and μ -Raman Spectroscopy

Nathan Kail (Université libre de Bruxelles), François Boland (AGC Technovation Center), Stéphane Godet (Université libre de Bruxelles), Theany To (Nantes Université), Tanguy Rouxel (Université de Rennes), Claire Fourmentin (Université libre de Bruxelles)

11:10 AM-11:30 AM

Nanoindentation Reveals Universal Scaling of Pop-in Plasticity in Metallic Glasses

Yong Hao Sun (Institute of Physics)

Wednesday, November 4, 2026

Session AS | 10:00 AM - 11:10 AM | Room 307

Chair: Jiangwei Wang (Zhejiang University)

10:00 AM-10:25 AM

[INVITED] Development of Nb-Based Alloys with Enhanced Strength-Ductility Balance through Solid-Solution and Interstitial Control

Kwang-Hyeok Lim (Korea Institute of Science and Technology), Muhammad Salman Johry (Korea Institute of Science and Technology), Wi-Geol Seo (Sunchun National University), Sang-Min Lee (Korea Institute of Science and Technology), Shi-Hoon Choi (Sunchun National University), **Jin-Yoo Suh** (Korea Institute of Science and Technology)

10:25 AM-10:45 AM

Nanoindentation-Induced Dislocation Structures in BCC Tungsten Observed via ECCI

Florian Tropper (NIMS), Takahito Ohmura (NIMS)

10:45 AM-11:10 AM

[INVITED] The Influence of Process Variables on the Interface Properties of Several Clad Sheets

Kwang Seok Lee (Korea Institute of Materials Science)

Wednesday, November 4, 2026

Session EE | 10:00 AM - 11:30 AM | Room 305

Chair: Byung-Gil Yoo (Hyundai Steel)

10:00 AM-10:25 AM

[INVITED] The Loading/ Unloading Stiffness Ratio - Real-time Materials Insights under Extreme Conditions

Verena Maier-Kiener (Montanuniversität Leoben), Stefan Zeiler (Montanuniversität Leoben)

10:25 AM-10:45 AM

An Experimental Capability for Nanomechanical Measurements at Cryogenic Temperatures

Ben Beake (Micro Materials Ltd.), Adrian Harris (Micro Materials Ltd.), Andrew Bird (Micro Materials Ltd.), Hannah Zhang (National Physical Laboratory), Stefan Stoica (National Physical Laboratory)

10:45 AM-11:10 AM

[INVITED] Nanoindentation at Extreme Conditions: High Strain Rates & Cryogenic Temperatures

Rajaprakash Ramachandramoorthy (Max Planck Institute For Sustainable Materials)

11:10 AM-11:30 AM

In-Situ Micromechanical Deformation of Chemical Interfaces from Cryogenic to Elevated Temperatures

Leiming Du (Max Planck Institute for Sustainable Materials), Hendrik Holz (Max Planck Institute for Sustainable Materials), Gerhard Dehm (Max Planck Institute for Sustainable Materials), **Anwesha Kanjilal** (Max Planck Institute for Sustainable Materials)

Wednesday, November 4, 2026

Session GA | 2:00 PM - 3:10 PM | Room 306

Chair: Hiroshi Masuda (The University of Tokyo)

2:00 PM-2:25 PM

[INVITED] What We Can Learn from Raman Scattering Spectroscopy About the Indentation Deformation Mechanisms in Oxide Glasses?

Nathan Kail (Université libre de Bruxelles), Claire Fourmentin (Université libre de Bruxelles), Stéphane Godet (Université libre de Bruxelles), Theany To (Ecole Centrale de Nantes), Théo Guerineau (University of Laval), Younes Messaddeq (University of Laval), Quentin Wets (University of Laval), Alain Moreac (Université de Rennes), Tanguy Rouxel (Université de Rennes)

2:25 PM-2:50 PM

[INVITED] Role of Plastic Flow on Crack Initiation by Vickers Indentation in Oxide Glasses

Gustavo Alberto Rosales-Sosa (Nippon Electric Glass Co. Ltd.), Taichi Nakashima (Nippon Electric Glass Co. Ltd.), Yoshinari Kato (Nippon Electric Glass Co. Ltd.), Etienne Barthel (PSL University), Hikaru Ikeda (Nippon Electric Glass Co. Ltd.), Shingo Nakane (Nippon Electric Glass Co. Ltd.), Hiroki Yamazaki (Nippon Electric Glass Co. Ltd.)

2:50 PM-3:10 PM

Design of Theta Device for the Micro Tensile Testing of Silica

Wenjuan Cheng (Roma Tre University), Meral Tuna (Roma Tre University), Edoardo Rossi (Roma Tre University), Jens Bauer (Karlsruhe Institute of Technology (KIT)), Marco Sebastiani (Roma Tre University)

Wednesday, November 4, 2026

Session AS | 2:00 PM - 3:05 PM | Room 307

Chair: Seung Min Han (KAIST)

2:00 PM-2:25 PM

[INVITED] Combinatorial Nanoindentation and Strengthening Analysis of Refractory Complex Concentrated Alloys of Mo-Nb-Ti and Ta-Nb-Ti

Taeyeop Kim (Yeungnam University), Daegun You (University of Illinois at Urbana-Champaign), **Dongwoo Lee** (Sungkyunkwan University)

2:25 PM-2:45 PM

Indentation-Based Multiscale Analysis of Deformation and Fracture Mechanisms in Potassium-Doped Tungsten

Jeongseok Kim (Seoul National University), Guensik Min (Seoul National University), Won-Seok Ko (Korea University), Phu Cuong Nguyen (The University of Texas at Dallas), Sungmin Lee (Seoul National University), Cheol-Heon Oh (Seoul National University), Hwangsun Kim (Seoul National University), Hojae Kwak (Seoul National University), Yeonju Oh (Seoul National University), Ill Ryu (Seoul National University), Dongchan Jang (KAIST), Heung Nam Han (Seoul National University)

2:45 PM-3:05 PM

Ligament Reattachment and Connectivity-Driven Mechanical Behavior in Nanoporous Gold

Sukwon Hong (UNIST), Younghoon Kim (UNIST), Hansol Jeon (Keimyung University), Ju-Young Kim (UNIST)

Wednesday, November 4, 2026

Session EE | 2:00 PM - 3:05 PM | Room 305

Chair: Hansol Jeon (Keimyung University)

2:00 PM-2:25 PM

[INVITED] Probing Thermally Activated Dislocation Mechanisms in MgO and BCC Metals by High Temperature Scanning Indentation

Karsten Durst (TU Darmstadt), Marcel Sos (TU Darmstadt), Sebastian Bruns (TU Darmstadt)

2:25 PM-2:45 PM

Spatially Resolved Strain Rate Sensitivity in a Dissimilar Steel Weld: Insights from High-Rate Nanoindentation

Bryan A. Crawford (KLA), Kurt E. Johanns (KLA), Lee W. Spencer (KLA), Yuming Lou (KLA)

2:45 PM-3:05 PM

Nanoindentation for Mechanical Characterization under Elevated Temperatures and Irradiation

Edyta Wyszowska (National Centre for Nuclear Research), Jacek Jagielski (National Centre for Nuclear Research), Łukasz Kurpaska (National Centre for Nuclear Research), Im-Deok Kim (Seoul National University), Seung-Kyun Kang (Seoul National University), JaeYong Kim (KAERI), F. J. Dominguez-Gutierrez (National Centre for Nuclear Research), Witold Chromiński (Warsaw University of Technology), Anna Kosińska (National Centre for Nuclear Research), Pavol Noga (Slovak University of Technology in Bratislava), Zoltán Száraz (Slovak University of Technology in Bratislava), Dušan Vaňa (Slovak University of Technology in Bratislava), Marcin Turek (Maria Skłodowska Curie University)

Wednesday, November 4, 2026

Session CC | 3:30 PM - 5:00 PM | Room 306

Chair: Gustavo Alberto Rosales-Sosa (Nippon Electric Glass)

3:30 PM-3:55 PM

[INVITED] Mapping of Nanoindentation Behavior of TiZrHf-Boride, -Carbide and Dual-Phase -Boride/Carbide Coatings

Frantisek Lofaj (Institute of Materials Research of SAS)

3:55 PM-4:15 PM

Fracture of Brittle Materials and Interfaces at the Nanoscale

Oriol Gavalda Diaz (Imperial College London)

4:15 PM-4:40 PM

[INVITED] Indentation-Induced Plasticity in Oxide Ceramics: From Nanoindentation to Shot Peening

Hiroshi Masuda (The University of Tokyo)

4:40 PM-5:00 PM

Influence of the Multi-Metal Environment on the Fracture Toughness of ZrHfNbTaC₄ High-Entropy Carbide Grains

Tamás Csanádi (Institute of Materials Research), Marek Vojtko (Institute of Materials Research), Zoltán Dankházi (ELTE Eötvös Loránd University), János Koltai (ELTE Eötvös Loránd University)

Wednesday, November 4, 2026

Session TF | 3:30 PM - 5:05 PM | Room 307

Chair: Jin-Yoo Suh (Korea Institute of Science and Technology)

3:30 PM-3:55 PM

[INVITED] 3D Architected Ni-Al₂O₃ Nanocomposite via Proximity-Field Nanopatterning

Seung Min Han (KAIST)

3:55 PM-4:15 PM

Investigation of Mechanical Properties of Ni-Co-Cr Thin Film Using a High-Throughput Combinatorial Method

Geummi Lee (KAIST), Semin Park (KAIST), Daeho Kim (KAIST), Seung Min Han (KAIST)

4:15 PM-4:40 PM

[INVITED] Design of Strengthened and Toughened Thin Film Materials Based on Nano-Ordered Structures

Kan Zhang (Jilin University)

4:40 PM-5:05 PM

[INVITED] Effect of Structural Hierarchy on Mechanical Behavior of Nanoporous Gold

Hansol Jeon (Keimyung University)

Wednesday, November 4, 2026

Session EE | 3:30 PM - 4:55 PM | Room 305

Chair: Dongwoo Lee (Sungkyunkwan University)

3:30 PM-3:55 PM

[INVITED] High Temperature Nanomechanical Testing of High Entropy Materials: Recent Efforts & Ongoing Challenges

Thomas Edwards (NIMS)

3:55 PM-4:15 PM

Probing Tungsten Deformation at Extreme Conditions through High-Temperature, High-Strain-Rate Nanoindentation

Eric Hintsala (Bruker), **Kevin Schmalbach** (Bruker)

4:15 PM-4:35 PM

Microscale Impact Deformation Mechanisms in FCC Single Crystals and Medium-Entropy Alloys

Jian Chen (Southeast University), Kehua Wang (Southeast University)

4:35 PM-4:55 PM

Evaluation of Low-Temperature Embrittlement of Metallic Materials in Rebound Hardness Testing

Kenji Matsuda (Kyushu Institute of Technology), Takanori Iruya (Kyushu Institute of Technology)

Thursday, November 5, 2026

Session CC | 9:00 AM - 10:10 AM | Room 306

Chair: Wei Li (Nankai University)

9:00 AM-9:25 AM

[INVITED] Electron-Matter Interactions in Silicon Oxides: From Irradiation-Induced Viscoplasticity to Mechanical Amorphization

Sung-Gyu Kang (Gyeongsang National University)

9:25 AM-9:45 AM

Let's Get to the Point (Defect): How Oxygen Vacancies Alter Dislocation Mechanics in Oxides

Chukwudalu Okafor (Karlsruhe Institute of Technology), **Oliver Preuss** (Karlsruhe Institute of Technology), Ahmad Sayyadi-Shahraki (Technical University of Darmstadt), Sebastian Bruns (Technical University of Darmstadt), Pierre Hirel (Université Lille), Karsten Durst (Technical University of Darmstadt), Xufei Fang (Karlsruhe Institute of Technology)

9:45 AM-10:10 AM

[INVITED] Enabling Dislocation Engineering in Ceramics: An Indentation-Based Deformation Toolbox and Mechanism Map

Oliver Preuss (Karlsruhe Institute of Technology), Chukwudalu Okafor (Karlsruhe Institute of Technology), Yanfei Gao (University of Tennessee), **Xufei Fang** (Karlsruhe Institute of Technology)

Thursday, November 5, 2026

Session TF | 9:00 AM - 10:05 AM | Room 307

Chair: Zaoli Zhang (Austrian Academy of Sciences)

9:00 AM-9:25 AM

[INVITED] Mechanical Performance of an Electrodeposited Ni-Fe Film Using the Loading Secant Stiffness Method of the Instrumented Indentation Test

Giovanni Maizza (Politecnico di Torino), Ahmad Atef Abdullatef Hamed (University of Rome), Hyeonjin Eom (Korea Institute of Industrial Technology)

9:25 AM-9:45 AM

Understanding Fatigue Behavior in NiTi Thin Films for Reliable Elastocaloric Cooling

Hyemin Ryu (KAIST), Jae-Hoon Choi (Jeonbuk National University), Gi-Dong Sim (KAIST)

9:45 AM-10:05 AM

Simultaneously High Tensile and Fatigue Strengths in Thin Films with Atomic-Scale Planar Defects

JungHun Park (KAIST), Yuhyun Park (KAIST), Sunkun Choi (KAIST), Gi-Dong Sim (KAIST)

Thursday, November 5, 2026

Session EE | 9:00 AM - 10:05 AM | Room 305

Chair: Dong-Hyun Lee (Chungnam National University)

9:00 AM-9:25 AM

[INVITED] Mechanistic Understanding of Time-, Orientation-, and Temperature-Dependent Deformation in Titanium Using Nanoindentation

Tea-Sung Jun (Incheon National University)

9:25 AM-9:45 AM

From High-Speed Mechanical Mapping to High-Temperature Micropillar Compression: Multiscale Mechanical Characterization of Ti(C,N)-FeNi Cermets

Hossein Besharatloo (UPC), Maria de Nicolás-Morillas (University Carlos III of Madrid), Ming Chen (ETH Zurich), Begoña Ferrari (CSIC-ICV), Elena Gordo (University Carlos III of Madrid), Jeffrey M. Wheeler (ETH Zurich), Luis Llanes (UPC)

9:45 AM-10:05 AM

Seeded Dislocations Facilitate Plasticity in Strontium Titanate Micropillars under High Strain Rate Loading

Jeongin Paeng (Max Planck Institute for Sustainable Materials), Bárbara Bellón (Max Planck Institute for Sustainable Materials), Jiawen Zhang (Southern University of Science and Technology), Gerhard Dehm (Max Planck Institute for Sustainable Materials), Wenjun Lu (Southern University of Science and Technology), Xufei Fang (Institute for Applied Materials), Rajaprakash Ramachandramoorthy (Max Planck Institute for Sustainable Materials)

Thursday, November 5, 2026

Session CC | 10:30 AM - 11:15 AM | Room 306

Chair: Sung-Gyu Kang (Gyeongsang National University)

10:30 AM-10:55 AM

**[INVITED] Nanoindentation of Coordination Polymers and Hybrid Metal Halides:
Selected Case Studies**

Wei Li (Nankai University)

10:55 AM-11:15 AM

**Orientation-Dependent Electron-Beam-Induced Plasticity in Single-Crystalline
ZnO Micropillars**

Eunsu Lee (Seoul National University), Ryosuke Kinoshita (The University of Osaka), Minsik Oh (Seoul National University), Yan Li (The University of Osaka), Atsutomo Nakamura (The University of Osaka), In-Suk Choi (Seoul National University)

Thursday, November 5, 2026

Session TF | 10:30 AM - 11:35 AM | Room 307

Chair: Tea-Sung Jun (Incheon National University)

10:30 AM-10:55 AM

[INVITED] Atomic-Resolution Study on Nanoscale Multilayer Deformation

Zhuo Chen (Erich Schmid Institute of Materials Science), Yong Huang (Erich Schmid Institute of Materials Science), Zaoli Zhang (Austrian Academy of Sciences)

10:55 AM-11:15 AM

Achieving High Strength in 6061 Aluminum Alloy Thin Films through Interstitial Carbon Incorporation.

Zion Lee (KAIST), Hojang Kim (KAIST), Sunkun Choi (KAIST), Injong Oh (KAIST), Jaehong Park (Hyundai Motors), Gi-Dong Sim (KAIST)

11:15 AM-11:35 AM

Membrane Deflection for High-Throughput Thin Film Tensile Characterization across Temperatures

Zhuo Feng Lee (KAIST), Jeehun Jeong (Korea Institute of Energy Technology (KENTECH)), Ye-Eun Lee (Jeonbuk National University), Jae-Hoon Choi (Jeonbuk National University), Sang Ho Oh (Korea Institute of Energy Technology (KENTECH)), Gi-Dong Sim (KAIST)

Poster Presentation

November 3–4, 2026 · Lobby

Tuesday, November 3, 2026

Poster Presentation I | Lobby

1. Analysis of the Correlation between Hierarchical Microstructures and Multi-Scale Mechanical Performance in L-PBF Processed 316L Stainless Steel

Jaehyeok Heo (Kumoh National Institute of Technology), In-Chul Choi (Kumoh National Institute of Technology)

2. Effects of Alloying Elements and Cold Rolling on the Microstructural Evolution and Enhanced Mechanical Properties of Ti-Based Refractory Medium-Entropy Alloys

Tae-Yeon Park (Kumoh National Institute of Technology), In-Chul Choi (Kumoh National Institute of Technology)

3. Influences of Surface Condition on Nanoindentation Behavior of FCC and BCC Medium-Entropy Alloys

Jae-Hyeok Choi (Hanyang University), Si-Yeon Lee (Hanyang University), Zhe Gao (Hanyang University), Jae-il Jang (Hanyang University)

4. Effects of Precipitation Hardening on Surface Mechanical Properties and Corrosion Behavior of Ni-Based Alloys

Jeong-Hyun Woo (Korea Atomic Energy Research Institute), Gha-Young Kim (Korea Atomic Energy Research Institute), Junhyuk Jang (Korea Atomic Energy Research Institute), Sun Young Park (Korea Atomic Energy Research Institute)

5. Precipitation Hardening Behavior of Ni-Cu Alloys: Electrochemical Corrosion Characteristics of the Strengthened Matrix

Gha-Young Kim (KAERI), Jeong-Hyun Woo (KAERI), Junhyuk Jang (KAERI), Sun Young Park (KAERI)

6. Natural Analogue Evaluation of Long-Term Corrosion Performance for Disposal Canister Using Buried Archaeological Metal Artifacts

Jeong-Hyun Woo (Korea Atomic Energy Research Institute), Ji-Hun Ryu (Korea Atomic Energy Research Institute)

7. Mechanical Properties of a Hetero-Structured Ferritic ODS Alloy Fabricated Using Different Powder Sizes Evaluated by Nanoindentation

Bae Jaeyoon (Tohoku University), Kazuki Ogawa (Tohoku University), Diancheng Geng (Tohoku University), Minha Park (Tohoku University), Sosuke Kondo (Tohoku University), Ryuta Kasada (Tohoku University)

8. Evaluation of Crack Healing Behavior in Metallic Materials for Aerospace Applications via Electropulsing Treatment

Jeongwook Kim (Korea institute of Materials Science), Hyunsung Choi (Korea institute of Materials Science), Hyeonil Park (Korea institute of Materials Science), Moo-Young Seok (Korea institute of Materials Science), Yongnam Kwon (Korea institute of Materials Science), Dongjun Lee (Korea institute of Materials Science)

9. Nanomechanical Characterization of RAFM Steel Using Nanoindentation

Hyun Woo Seo (Yonsei University), Sun-Young Park (Korea Atomic Energy Research Institute), Joowon Suh (Korea Atomic Energy Research Institute), Hyung-Ha Jin (Korea Atomic Energy Research Institute), Dong Won Lee (Korea Atomic Energy Research Institute), Young-Kook Lee (Yonsei University), Suk Hoon Kang (Korea Atomic Energy Research Institute)

10. Interpretable Multimodal Modeling of Local Microstructure-Property Relationships in Ultra-High-Strength Steels

Hangi Wang (Beihang University)

11. Nonequilibrium Boron Retention as a New Route for Strengthening Additively Manufactured Al Alloys

Gyumin Lee (KAIST), Zion Lee (KAIST), Gi-Dong Sim (KAIST)

12. Interfacial Characterization of Cu-x-Cu Diffusion Bonded Structure

Kai Ying Pong (KAIST), Kwanhyeong Lee (KAIST), Hyemin Ryu (KAIST), Gi-Dong Sim (KAIST)

13. First-Principles Analysis of Ternary Alloying Effects on Martensitic Transformation in Ti-Nb-Based Shape Memory Alloys

Hun-Min Jo (Korea University), Won-Seok Ko (Korea University)

14. Compositionally Modified AISI D2 Tool Steel with Improved Printability and High Hardness via Directed Energy Deposition

Hahun Lee (Korea University), Ji-Su Lee (POSTECH), Sung-Jae Jo (Kongju National University), Seungjin Nam (Korea University), Heechan Jung (Korea University), Chahee Jung (Korea University), Soon-Jik Hong (Kongju National University), Byeong-Joo Lee (POSTECH), Seok Su Sohn (Korea University)

15. The Compressive Properties of Laser Powder Bed Fusion Dievar Steel Lattice

Chun-Yu Hsieh (National Taipei University of Technology), Ming-Hsiang Ku (National Taipei University of Technology), Chien-Lun Li (voestalpine Technology Institute (Asia) Co. Ltd.), **Ming-Wei Wu** (National Taipei University of Technology)

16. Feature-Engineered Random Forest Model for Predicting Tensile Properties of Fe-Mn-Cr-Ni Multicomponent Alloys

Ye Min Hwang (Pukyong National University), Jun Seok Lee (Pukyong National University), Pil Wook Shin (Pukyong National University), Jae Wung Bae (Pukyong National University)

17. Nanoindentation Study on Ferrite-Martensite Hardness Mismatch and Its Influence on the Mechanical Properties of Low-Carbon Dual-Phase Steels

Dong-Kyu Oh (Seoul National University of Science and Technology), Byoungchul Hwang (Seoul National University of Science and Technology)

18. Representative Volume of Unit-Cells for Fracture Resistance Testing of Additive Manufactured Lattice Structures

Eunju Shin (Keimyung University), Hansol Jeon (Keimyung University)

19. Effect of Mg Melt Composition on the Local Mechanical Properties of Ti-6Al-4V Processed by Liquid Metal Dealloying

Jihye Seong (Dankook University), Hidemi Kato (Tohoku University), Jeong Hun Lee (Kyungpook National University), Sung Hyuk Park (Kyungpook National University), Soo-Hyun Joo (Dankook University)

20. Enhancement of Cryogenic Mechanical Properties of Fe-Ni-Co-Cr-Mo Medium-Entropy Alloy through Fine Mo-Rich Precipitation

Se Ung Yang (Dankook University), Taehyung Kim (Dankook University), Jae Hyuk Lee (Dankook University), Hyoung Seop Kim (Pohang University), Soo Hyun Joo (Dankook University)

21. Three-Dimensionally Interconnected Porous Surface on Ti-6Al-4V via Liquid Metal Dealloying for Enhanced CFRP Joining with Retained Hardness

Hyeok Min Kwon (Dankook University), Jihye Seong (Dankook University), Jae Hyuk Lee (Dankook University), Hidemi Kato (Tohoku University), Sung Hyuk Park (Kyungpook National University), Soo-Hyun Joo (Dankook University)

22. Nanomechanical Characterization of Microstructural Inhomogeneity in a Sand Casted Mn-Cu Alloy

Seung-Min Mok (Gyeongsang National University), Jun-Young Park (Gyeongsang National University), Jun-Min Lee (Gyeongsang National University), Dae-Kyung Kim (Hanwha Ocean), Sang-Sik Kim (Gyeongsang National University), Sung-Kyu Kang (Gyeongsang National University)

23. Mechanical Properties of NiCoFe Medium-Entropy Alloy-Coated 3D Glassy Carbon Architectures

Elif Nur Adalı (KAIST), Isoo Jeon (KAIST), Kneev Sharma (TUM), Vishnu Nair (TUM), Jan Torgersen (TUM), Seung Min J. Han (KAIST)

24. Plasticity in Microcompression of Single-Crystal Al₂O₃ with High-Density Dislocations Introduced by Shot Peening

Shuto Yoshida (The University of Tokyo), Hiroshi Masuda (The University of Tokyo), Hidehiro Yoshida (The University of Tokyo)

25. Strain-Dependent Mechanical Response and Twin Boundary Migration-Driven Plasticity in Tin

Xinxin Gao (Jilin University), Kan Zhang (Jilin University)

26. Nanoindentation Analysis of Depth-Dependent Hardness and Irradiation Embrittlement in Fe Ion-Irradiated RAFM Steel (ARAA)

Taewon Park (University of Ulsan), Donggyu Kim (University of Ulsan), Seunghyun Lee (Korea Atomic Energy Research Institute), Dae-sik Chang (Korea Atomic Energy Research Institute), Sangbeen Lee (Korea Atomic Energy Research Institute), Kihyun Lee (Korea Atomic Energy Research Institute), Jung Gu Lee (University of Ulsan), Eun-chae Jeon (University of Ulsan)

27. Deformation Anisotropy and Non-Schmid Behavior in Ti₃SiC₂ MAX Phase Ceramics

Eiichi Sei (Hokkaido University), Ken-ichi Ikeda (Hokkaido University), Seiji Miura (Hokkaido University), Koji Morita (NIMS), Tohru S. Suzuki (NIMS), Sakka Yoshio (NIMS)

28. Registration-Free Topography-Based Reliability Filtering for Unsupervised Classification of High-Throughput Nanoindentation Maps

Hayato Kobayashi (ELIONIX INC.), Kaiki Noma (ELIONIX INC.)

29. Effect of Composite Powder Preparation Methods on Microstructure and Properties of TiC-Reinforced AlSi10Mg Fabricated by Directed Energy Deposition.

Jaehyeong Kim (Pusan National University), Yoonsuk Choi (Pusan National University), Hyein Lee (Pusan National University)

30. Study on the Thermal and Mechanical Properties of Lanthanum-Based Ball-Type Regenerator Materials with Stacked and Mixed-Layer Structures for 4 K-Stage Regenerators

Hyeonjin Eom (Korea Institute of Industrial Technology), Giovanni Maizza (Politecnico di Torino)

31. Geometrically Constrained Plasticity and High-Temperature Mechanical Response of Cu/SiO₂ Hybrid Bonding Structures Characterized by Nanoindentation

Yuan-Fu Wang (National Yang Ming Chiao Tung University), Chih Chen (National Yang Ming Chiao Tung University)

32. Probing Serrated Flow in a Nickel-Based Superalloy at Intermediate Temperatures via Nanoindentation

Nur Liyana Nabihah Yusof (Kyushu University), Viola Paul (National Institute for Materials Science), Edwards Thomas Edward James (University of Tsukuba), Toshio Osada (National Institute for Materials Science), Takahito Ohmura (Kyushu University)

33. Mechanical Behavior of Liquid Encapsulated in Copper Microstructures under Extreme Thermo-Mechanical Conditions

Sung-Gyu Kang (Gyeongsang National University)

34. Mechanical Properties of Low Temperature CuAg Metal-to-Metal Bonding through Nano-Multilayer Alloy Films

Dong Jin Seon (Tech University of Korea), Byoung-Joon Kim (Tech University of Korea)

35. Modeling of Laser Beam Welding in an IN792 Alloy: Experimental Validation of the Predicted Stress-Strain Field Against Rate-Derived Nano-Hardness Measurements.

Giovanni Maizza (Politecnico di Torino), Peihong Cheng (University of Rome), Alessandra Varone (University of Rome), Roberto Montanari (University of Rome)

36. Experimental Considerations for High-Temperature Instrumented Micro-Indentation of Superalloys

Hoseung Kang (Seoul National University), Eunsu Lee (Seoul National University), In-Suk Choi (Seoul National University)

37. Spatially-Distributed Impact Testing – a Micro-Mechanical Test Method for Simulating Solid Particle Erosion

Ben Beake (Micro Materials Ltd.), Luis Isern (Cranfield University), John Nicholls (Cranfield University), Hannah Zhang (National Physical Laboratory), Mark Gee (National Physical Laboratory)

38. Mechanical and Thermal Performance of AlSi10Mg/316L SS/OLC Tri-Layer Composite Structures for Advanced Heat Dissipation

Jun-Yu Chen (National United University), Chao-Te Lee (Taiwan Instrument Research Institute), Wei-Chun Chen (Taiwan Instrument Research Institute), Chin-An Wang (Minghsin University of Science and Technology), PING-CHANG HSIEH (National United University), Ming-Chun Chen (National United University), Shih Chun Tseng (National United University)

39. Creep Behavior at 630°C of Ferritic/Martensitic Heat-Resistant Steel with Cu Addition

Du-Hyun Kim (Korea Institute of Science and Technology), Byeong-Hyeon Lee (Korea Institute of Science and Technology), Seong Hoon Kim (Korea Institute of Materials Science), Woo-Sang Jung (Korea Institute of Science and Technology), Dong-Ik Kim (Korea Institute of Science and Technology), Gyeong Ho Kim (Korea Institute of Science and Technology), Tae-Ho Lee (Korea Institute of Materials Science), Jong-Ho Shin (Corporate Research and Development Institute), Jin-Yoo Suh (Korea Institute of Science and Technology), Seok Su Sohn (Korea University)

40. Effect of Heat Treatment on the Fatigue Behavior of STS304J1 Stainless Steel Corrugated Pipes under Different Loading Conditions

Jae Hyun Park (Pusan National University), Yoon Suk Choi (Pusan National University)

Wednesday, November 4, 2026

Poster Presentation II | Lobby

1. Rebound Hardness Test of Glass by Using Hammer with Vickers Indenter

Lu Chen (Kyushu Institute of Technology), Shuta Okajima (Kyushu Institute of Technology), Kenji Matsuda (Kyushu Institute of Technology)

2. Nanoindentation Evaluation of Hydrogen Embrittlement in CoCrNi-Based MEAs with Composition-Dependent SFE

Ji-Hyeon Kim (Gyeongsang National University), Tae-Yeon Park (Kumoh National Institute of Technology), In-Chul Choi (Kumoh National Institute of Technology), Young-Cheon Kim (Gyeongsang National University)

3. Effect of TiB Particle on Hydrogen Embrittlement Behavior of α -Ti

Hyun Jeong (Chungnam National University), Yakai Zhao (A*STAR), Keun Hyung Lee (Chungnam National University), Soo Yeol Lee (Chungnam National University), Dong-Hyun Lee (Chungnam National University)

4. Correlation between Single-Particle Fracture Strength and Cycle Life of Li-Rich Layered Oxide Cathodes Measured by Micro-Compression Testing

Hyungcheoul Shim (University of Ulsan)

5. Indentation-Depth Criterion for Hardness Evaluation of Ion-Irradiated Reduced-Activation Ferritic/Martensitic Steel: Extended Nix-Gao Analysis and Residual-Imprint Morphology

Sumin Lee (Tohoku University), Diancheng Geng (Tohoku University), Minha Park (Tohoku University), Sosuke Kondo (Tohoku University), Ryuta Kasada (Tohoku University)

6. Microindentation Based Evaluation of Hydrogen Induced Fracture Toughness Degradation in Advanced High Strength Steels

Ehsan Norouzi (Korea Institute of Science and Technology (KIST)), Reza Miresmaeili (Tarbiat Modares University), Laura Vergani (Politecnico di Milano)

7. Characterization of Mechanical Behavior in Ion-Irradiated Tungsten for Fusion Divertor Applications

Sun-Young Park (Korea Atomic Energy Research Institute), Suk-Hoon Kang (Korea Atomic Energy Research Institute), Hyung-Ha Jin (Korea Atomic Energy Research Institute), Sangyeob Lim (Korea Atomic Energy Research Institute), Seunghyun Lee (Korea Atomic Energy Research Institute), Dong Won Lee (Korea Atomic Energy Research Institute)

8. In-Situ Electromechanical Characterization of Damage in Hydrogen-Charged Crystalline/Amorphous Nanolaminates

Jeongbin Park (KAIST), JungHun Park (KAIST), Zion Lee (KAIST), Woosuk Seo (Samsung Display), Tae-Ho Lee (Samsung Display), Gi-Dong Sim (KAIST)

9. Effect of Electrolyte on the Local Mechanical Properties of STS304 During Electrochemical Hydrogen Charging

Sang-Min Park (Gyeongbuk National University), Sang-yeob Lee (Gyeongbuk National University), Young-Cheon Kim (Gyeongbuk National University)

10. Analysis of Hydrogen Embrittlement and Corrosion Behavior of STS304 Strain-Induced Martensite in a Seawater Environment

Sang-Yeob Lee (Gyeongbuk National University), Sang Min Park (Gyeongbuk National University), Young-Cheon Kim (Gyeongbuk National University)

11. Reduced Hardness Difference between V and Cu-Rich Phases for Enhanced Malleability of V-Cu-Ni-Al Hydrogen Separation Membranes

Jung Hun Han (Korea University), Sang Yoon Song (Korea University), Ju-Hyun Baek (Korea Institute of Science and Technology), Gunjick Lee (Korea Institute of Science and Technology), Jin-Yoo Suh (Korea Institute of Science and Technology), Seok Su Sohn (Korea University)

12. Mechanical Characterization of Irradiated Tungsten Diboride

Ellen Yoo (Imperial College London), Sam Humphry-Baker (Imperial College London), Oriol Gavalda-Diaz (Imperial College London)

13. Effect of Reverted Austenite on the Hydrogen Embrittlement Resistance of Maraging Steel Produced by L-PBF

Jin Mo Park (Pukyong National University), Min Ho Lee (Pukyong National University), Junghoon Lee (Research Institute of Industrial Science & Technology (RIST)), Seungyeon Lee (Korea Institute of Materials Science (KIMS)), Park Jeong-min (Korea Institute of Materials Science (KIMS)), Jae Wung Bae (Pukyong National University)

14. Indentation-Based Comparison of Mechanical Property Changes with Hydrogen Content in Different Metallic Materials

Huicheol Shin (Yeungnam University), Gyubeom Kim (Korea Institute of Materials Science), Doo-won Kim (Korea Institute of Materials Science), Siwhan Lee (Korea Institute of Materials Science), Nokeun Park (Yeungnam University), Seung-gun Lee (Korea Institute of Materials Science)

15. Evaluation of IASCC Initiation Susceptibility of Proton-Irradiated Austenitic Stainless Steel Welds

Ji-Yun Kim (Korea Atomic Energy Research Institute), WonJoon Na (Korea Atomic Energy Research Institute), Min-Jae Choi (Korea Atomic Energy Research Institute)

16. In-Situ Detection of Machining Mode During Micro-Hole Drilling of Single-Crystal Silicon Using Acoustic Emission Sensor and Dynamometer

Hwa-Sub Lee (Korea Institute of Machinery and Materials / University of Science and Technology), Dong-hyun Seo (Korea Institute of Machinery and Materials / University of Science and Technology), Doo-Sun Choi (Korea Institute of Machinery and Materials (KIMM)), Jun Sae Han (Korea Institute of Machinery and Materials / University of Science and Technology), Eun-Ji Gwak (Korea Institute of Machinery and Materials / University of Science and Technology)

17. Investigating the Residual Stresses in the Cross-Section of an L-PBF 316L Alloy Using Instrumented Indentation Tests and X-ray Diffraction

Ahmad Atef Abdullatef Hamed (University of Rome), **Giovanni Maizza** (Politecnico di Torino), Maria José Marques (University of Porto), Antonio Castanhola Batista (University of Coimbra), Maria Richetta (University of Rome), Roberto Montanari (University of Rome)

18. Grain Boundary Effects on Slip Transmission and Dislocation Avalanches During Nanoindentation

Chanjae Shin (Seoul National University), Ill Ryu (Seoul National University)

19. Noise-Robust FEA-ANN Inverse Analysis for Tensile Property Prediction Using Instrumented Indentation Testing

Im-Deok Kim (Seoul National University), Si Hyun Park (Pukyong National University), Joost J. Vlassak (Harvard University), Jong-Hyoung Kim (Pukyong National University), Seung-Kyun Kang (Seoul National University)

20. ANN-Based Substrate Effect Correction for the Accurate Evaluation of Intrinsic Film Properties

Hyun-Wook Cho (Pukyong National University), Si Hyun Park (Pukyong National University), Tae Hyeon Park (Pukyong National University), Woo-jin Lee (Seoul National University), Gyeong-Seok Hwang (Harvard University), Ji-Hyeon Jo (UNIST), Ju-Young Kim (UNIST), Seung-Kyun Kang (Seoul National University), Jong-hyoung Kim (Pukyong National University)

21. Revealing Cryo-Loading Induced Twinning and Its Impact on Titanium via Correlative Data-Driven Mechanomicroscopy

Xiao Liang (Beihang University)

22. Deep Learning-Assisted Spherical Indentation for Simultaneous Characterization of Plastic Flow and Non-Equibiaxial Residual Stress

Deunbom Chung (Seoul National University), Minwoo Park (Seoul National University), Wanchuck Woo (Korea Atomic Energy Research Institute), Kyeongjae Jeong (Sungkyunkwan University), Heung Nam Han (Seoul National University)

23. Atomistic Investigation into the Tilting of Coherent Twin Boundaries in Cu under Tribological Loading

Dong-Hyun Kim (Korea University), Won-Seok Ko (Korea University)

24. Molecular Dynamics Study of Shape-Memory Property Control in LPBF-Processed Ni-Al Alloys

Jong-Hoon Park (Korea University), Won-Seok Ko (Korea University)

25. Atomistic Simulation Study of Tramp Element Effects on Liquid Metal Penetration in Fe-Cu-x Systems

Jong-Hoon Park (Korea University), **Hye-Ji Jo** (Korea University), Hye-Hyun Ahn (Inha University), Dong-Hwi Kim (Hyundai Motor Company), Minwoo Kang (Hyundai Motor Company), Youngjae Kim (Seoul National University), Won-Seok Ko (Korea University)

26. Classification of Duplex Stainless Steel Microstructures Using Nanoindentation Testing and Machine Learning

Jun-Hi Im (Gyeongbuk National University), Woo-ram Noh (Gyeongbuk National University), Young-Cheon Kim (Gyeongbuk National University)

27. Transfer Learning-Based Tensile Property Prediction Compensating for Indenter Tip Geometric Imperfection in Instrumented Indentation

Si Hyun Park (Pukyong National University), Hyun-Wook Cho (Pukyong National University), Seung-gun Lee (KIMS), Jong-hyoung Kim (Pukyong National University)

28. Evaluation of Intrinsic Material Properties of Multilayer Thin-Film Structures via Artificial Neural Network-Based Nanoindentation

Kwang Hee Kim (Pukyong National University), Hyun-wook Cho (Pukyong National University), Jae-yeong Choi (Pukyong National University), Dong-hwi Kim (Pukyong National University), Gyoeng-min Lee (Pukyong National University), Jong-hyoung Kim (Pukyong National University)

29. LLM-Assisted Learning for Plastic Flow Prediction from Spherical Indentation

Giuk Song (Sungkyunkwan University), Heeju Ahn (Sungkyunkwan University), Kyeongjae Jeong (Sungkyunkwan University)

30. Nanomechanical Characterization of Organic Molecular Semiconductors Using Atomic Force Microscopy

Ki-Hwan Hwang (University of Cambridge), Mateo T. R. Cervantes (University of Cambridge), Deepak Venkateshvaran (University of Cambridge)

31. Micromechanical Softening of Constituent Phases Governing the Hot Deformation of La-Fe-Co-Si Alloys

Su-mi Yang (Korea Institute of Materials Science), Seon-yeong Yang (UNIST), Min-jik Kim (Korea Institute of Materials Science), Kwang-seok Lee (Korea Institute of Materials Science), Da-seul Shin (Korea Institute of Materials Science)

32. Correlation of Phase-Specific Nanomechanical Properties with Single-Particle Strength and Electrochemical Performance of Si Alloy Anode Powders

Myungje Lee (Myongji University), Taeyun Kwon (Myongji University), Chansun Shin (Myongji University)

33. Effect of Mechanical Properties on Thermo-Warpage and Stress Analysis of Stretchable Anisotropic Conductive Films (SACFs) for Large-Area Electronic Packaging

Sang-Hyun Kim (Tech University of Korea), Byoung-Joon Kim (Tech University of Korea)

34. Precipitation Behavior and Local Mechanical Properties Near Grain Boundaries in Al-Mg-Si Alloy

Yuji Shirakami (Hokkaido University), Shuto Takeuchi (Hokkaido University), **Ken-ichi Ikeda** (Hokkaido University), Seiji Miura (Hokkaido University)

35. Micromechanical Behavior and the Role of a Compositionally Graded Zone in an Additively Manufactured Multilayer Medium-Entropy Alloy

Zhe Gao (Hanyang University), Si-Yeon Lee (Hanyang University), Jae-Hyeok Choi (Hanyang University), Dong-Hyun Lee (Chungnam National University), Yakai Zhao (A*STAR), Hyoung Seop Kim (POSTECH), Upadrasta Ramamurty (Nanyang Technological University), Jae-il Jang (Hanyang University)

36. Morphological Analysis on Hierarchical Nanoporous Gold

Hansol Jeon (Keimyung University)

37. Deformation and Fracture Behavior of APS Y_2O_3 Coatings Investigated by Micropillar Compression

Inseop Baek (Gyeongsang National University), Jun-Ha Kim (Korea Institute of Materials Science (KIMS)), Yeon-Woo Yoo (Korea Institute of Materials Science (KIMS)), Sung-Gyu Kang (Gyeongsang National University)

38. Effect of Interface Architecture on the Uniaxial Tensile Behavior of Cu-Nb Nanolaminates

Krittichok Rattanakodsakun (Korea Advanced Institute of Science & Technology), Haechan Jo (Korea Advanced Institute of Science & Technology), Gi-Dong Sim (Korea Advanced Institute of Science & Technology)

39. Geometric Tailoring of Nitinol Thin Film and Sheet for Improved Elastocaloric Cooling

Juyoung Lee (KAIST), Hyemin Ryu (KAIST), Jae-Hoon Choi (Jeonbuk National University), Gi-Dong Sim (KAIST)

40. Coupled Effects of Grain and Ligament Sizes on the Mechanical Behavior of Nanoporous Gold

Minwoo Bang (Keimyung University), Hansol Jeon (Keimyung University)

41. Tensile Behavior of Hierarchical Nanoporous Gold Fabricated by 3D Printing and Dealloying

Sinu Kang (Keimyung University), Hansol Jeon (Keimyung University)

Oral Session Abstract

Keynote & Opening Session

2026-11-02 10:10 ~ 11:30 | 306 | Chair: Ju-Young Kim

[10:10~10:50] Nanoindentation - Origins and two recent developments

John Pethica (University of Oxford)

Type: Keynote

This talk will first briefly describe the early development of nanoindentation. Some of the experimental results were unexpected at the time, and had wide ranging effects for both indentation and AFM. I will then discuss two recent developments and results. 1. Pyramidal indentation benefits from axial symmetry, confined deformation, and self-similar geometry, but a wide range of stresses and strains are present. Flat punch indentation of thin films on harder substrates gives a single, uniform and controllable stress state. The technical requirements for flat punch measurement, and some results on polymer films will be presented. The confined compression shows a clear yield point, followed by extrusion flow, and good agreement with polymer properties measured by macroscopic methods. Unexpectedly, density continues to increase with increasing load and stress during the extrusion phase, which is unlike regular unconfined polymer shear. 2. The origins of hardness measurement lie in tribology. A new 2 orthogonal axis nano-indentation system will be described, enabling measurement of the initial stages of deformation and sliding under both lateral and normal loading. Metals show an initial surface normal sink-in upon application of lateral load and a small peak in friction, followed by rising back up as sliding starts. Ceramics do not show the same depth effect. Frictional energy dissipation is shown to be dominated by slip at the interface rather than bulk deformation. The results also suggest that static friction, traditionally used to explain stick-slip motion, is actually not an inherent material property of the interface. Rather it is an effect of the experimental apparatus used, its dynamics, and the loading procedure and indent geometry.

[10:50~11:30] Indentation at Extreme Strain Rates and the Quantitative Study of Phonon Drag-Limited Plasticity

Chris Schuh (McCormick School of Engineering, Northwestern University)

Type: Keynote

The deformation mechanisms that prevail in materials deformed at extreme strain rates have been quantitatively underexplored, largely because mechanical tests at high rates also produce shock phenomena that tend to swamp out the physics of material deformation. However, micro- and nano-indentation present a unique opportunity to separate the effects of shock from high strain rate, and therefore to quantitatively study mechanisms like dislocation drag-limited plasticity. This talk will review our development of the "LIPIT"—Laser Induced Particle Impact Test—as a quantitative extreme strain rate indentation experiment. In the first indentation experiments at strain rates above 10^7 s^{-1} , we report a large increase in hardness of various metals and alloys. Beginning with the hypothesis that this increase reflects a change in dominant deformation mechanism to phonon drag-limited plasticity, we proceed to test a variety of unusual signatures that this mechanism should produce. These include a visible inflection in rate hardening at the cross-over strain rate; a

counterintuitive negative temperature dependence (metals strengthen when hot); a change in the plastic zone that leads to an anomalous Tabor factor; and tunability of these features by alloying. Together these results verify the prominence of phonon-drag plasticity at extreme rates and point to a future in which materials strength under extreme conditions can be tuned cognizant of the unique mechanisms there.

Session MS

2026-11-02 13:30 ~ 15:10 | 306 | Chair: Dongchan Jang

[13:30~13:55] From Mechanical Properties to Material State: A Standardized Multi-Scale Indentation Approach

Dongil Kwon (Seoul National University), Jung-wha Hong (Frontics Inc.)

Type: Invited

The load–depth curve obtained from an instrumented indentation test contains far more information than hardness alone. Through mechanics-based interpretation and international standardization, this information can be transformed into quantitative descriptors of the material state, including elastic-plastic behavior, residual stress, fracture-related characteristics, and material degradation from a single, minimally invasive measurement. This capability has transformed instrumented indentation from a conventional hardness test into a standardized approach for material-state assessment. Rather than evaluating individual mechanical properties independently, the material-state concept provides an integrated description of local mechanical behavior and its evolution during processing and service. More importantly, instrumented indentation establishes a quantitative bridge across material scales. The same methodology provides a consistent description of the material state from individual phases and microstructural constituents to engineering components and large infrastructures. This unique capability links local material behavior to macroscopic structural performance while providing quantitative information for microstructure-guided materials engineering and design. This presentation reviews the evolution of standardized instrumented indentation and demonstrates representative applications in nuclear power, pipelines, welding, batteries, and additive manufacturing. Rather than simply a mechanical test, instrumented indentation is presented as a standardized platform that connects microstructure, material state, and structural performance, providing a common engineering language for multi-scale materials evaluation and future digital engineering.

[13:55~14:20] Structure-Mechanical Property Correlations in Pharmaceutical Crystals: Insights from Nanomechanical and Impact Testing

Nathan Mara (University of Minnesota), Soumyadeep Sen (University of Minnesota), Jiahua Lu (University of Minnesota), Sushmita Majumder (University of Minnesota), Tianyi Xiang (Purdue University), Najma Jamac (University of Minnesota), Changquan Calvin Sun (Purdue University)

Type: Invited

In recent years, instrumented nanoindentation has proven to be a useful method for investigating the mechanical properties of pharmaceuticals. Advantages include the ease of sample preparation (only a smooth surface is needed), small volumes of material probed (~1 micron³), and high throughput nature, where each indent may only need ~1 second to carry out. The current state of the art in determining mechanical behavior of pharmaceutical materials consists of calculating a brittleness index from nanoindentation data. While useful as a comparative measure of fracture toughness, it does not describe the detailed fracture behavior and

associated toughening mechanisms needed to develop predictive fracture models for milling and tableability, and limits pharmaceutical materials design to empirical approaches. Here, we present an integrated approach to determining the fundamental mechanical behavior of pharmaceutical single crystals that will provide the critical datasets needed to inform predictive models for powder compaction and fracture of pharmaceutical crystals. Utilizing Laser Induced Particle Impact Testing (LIPIT), complemented by quasistatic nanoindentation testing, we probe the mechanical behavior of APIs (Active Pharmaceutical Ingredients), including Ibuprofen, Acetaminophen, D-Mannitol, Celecoxib and Indomethacin, across strain rates to mimic milling conditions. The post-indentation/ post-impact surface morphology (slip steps vs. fracture) is analyzed via SEM, Optical Microscopy, AFM, and XRD. Mechanical behavior will be discussed in terms of the energetic competition between plastic deformation and fracture, and its dependence upon crystal structure and chemistry.

[14:20~14:40] The challenges of low load nanoindentation and property mapping for reliable understanding materials behavior

Jiri Nohava (Anton Paar TriTec SA), Petr Hausild (Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering), Jaroslav Cech (Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering)

Type: Oral

Modern metallic materials increasingly rely on fine and ultrafine microstructures to achieve high strength, toughness and corrosion resistance. Characterization of these microstructures often requires low-load nanoindentation, both for individual measurements and high-resolution property mapping, because the characteristic structural features are comparable in size to the indentation itself. To ensure that a single phase or feature is probed, indentation depths are typically limited to a few hundred nanometers and often even less. However, interpretation of such shallow measurements requires careful consideration of several factors, particularly the indentation size effect (ISE) and the actual geometry of the indenter tip. The first part of this work investigates the ISE in Fe₃Si single crystals over a range of temperatures, indentation depths and strain rates. The results demonstrate that the apparent hardness increase observed below contact depths of approximately 500 nm is better described by the model based on the extension of the effective plastic zone than by the classical Nix-Gao approach. These findings provide guidance for correct interpretation of hardness values obtained from shallow nanoindentation experiments. The second part focuses on the influence of Berkovich indenter tip geometry on measured mechanical properties. Several indenters were intentionally damaged in a controlled manner and the influence of projected area calibration near the indenter apex on hardness and elastic modulus was evaluated. Direct observations by atomic force microscopy and scanning electron microscopy, together with indirect calibration on fused silica, showed that the commonly used spheroconical tip model cannot accurately represent the three most frequent damage modes: progressive blunting, scratch damage and brittle fracture. Nevertheless, appropriate recalibration of the indenter area function can largely compensate for these effects and the measurements can provide reliable hardness and elastic modulus measurements. Together, these two studies contribute to more reliable analysis shallow nanoindentation and high-resolution property mapping of fine-structured materials.

[14:40~15:05] Recent Developments of ISO 14577 for Instrumented Indentation Testing

Xiaodong Hou (National Institute of Metrology, China)

Type: Invited

ISO 14577 is the key international standard series for instrumented indentation testing (IIT), covering the testing method, testing procedures, verification and calibration of testing machines, and reference blocks. With the rapid development of IIT techniques and data analysis methods, ISO 14577 Parts 1–3 are being revised to better reflect current practice, improve consistency in terminology and procedures, and strengthen the metrological basis for reliable and traceable indentation measurements. In addition, new parts have been developed to extend the application of IIT beyond conventional quasi-static testing. ISO 14577-5 addresses linear elastic dynamic instrumented indentation testing, while ISO 14577-6 supports indentation measurements at elevated temperature. These developments respond to increasing demands for local mechanical property measurements of advanced materials, thin coatings, additive-manufactured components, and materials operating in complex service environments. This presentation will review the main changes in the ISO 14577 series, discuss their implications for users and calibration laboratories, and highlight future standardization needs. Future standardization needs will also be discussed, particularly indentation creep and the extraction of stress–strain curves from IIT data. Key challenges include defining robust measurands, validating inverse analysis methods, improving comparability between laboratories, and developing suitable reference materials and interlaboratory comparisons. The presentation aims to provide an overview of how ISO 14577 is evolving to support more reliable, quantitative, and application-oriented indentation measurements.

Session SE

2026-11-02 13:30 ~ 15:10 | 307 | Chair: Yu Zou

[13:30~13:55] Nanomechanics for Semiconductor Industries - Case Studies in Hybrid Bonding and Wafer Machining

Bo-Shiuan Li (Department of Mechanical & Electro-mechanical Engineering, National Sun Yat-sen University, Taiwan)

Type: Invited

Advanced electronic packaging and machining of next generation semiconductor materials are key research areas in Taiwan's semiconductor industry. Both require fundamental understanding of its mechanical strength to ensure optimal structural integrity during service. First, I will present how micro-cantilever fracture tests can be used to measure the interfacial strength of hybrid-bonded chiplets, providing a high-resolution, site-specific solution along the interface. Second, I will demonstrate the combination of nanoindentation mapping with micro-Raman spectroscopy for evaluating the wafer machining quality, which can provide direct correlation to the laser-machined SiC die strength. Third, a novel indentation-based fracture toughness method using 3D-FIB tomography will be presented, showing fracture toughness results can be obtained from an non-ideal crack patterns for SiC at 700 °C. Overall, this talk will present a combination of novel nanomechanical testing techniques which can be used for solving emerging issues in semiconductor industries.

[13:55~14:20] Nanoindenter-Based Deep Elastic Strain Engineering of Semiconductors

Yang Lu (The University of Hong Kong)

Type: Invited

Under strain, the physical properties of semiconductors can undergo significant changes. However, bulk semiconductor crystals are usually rigid and brittle, making it challenging to achieve sufficient strain levels for desired functional characteristics. Driven by advanced in situ SEM and TEM nanoindentation techniques, our experimental research has shown that, by microfabricating semiconductors (such as silicon and diamond) into micro/nanostructures, they can approach their theoretical strength and sustain ultralarge elastic deformation, opening a new pathway for deep elastic strain engineering of semiconductors via nanomechanics. To realize such strain-engineered device applications, we further microfabricated single-crystalline diamond microbridge arrays and have mechanically achieved sample-wide uniform, up to ~10 %, ultralarge elastic strains under uniaxial tensile loading by utilizing nanoindenter-based platforms. This ultralarge strain significantly reduced the diamond bandgap by >2eV or convert diamond from indirect bandgap to direct bandgap semiconductor, demonstrating its promising applications and immense potential in wide bandgap semiconductors and optoelectronic technologies. Moreover, we have extended this nanoindentation-driven approach to GaN and two-dimensional material systems, exploring their future applications in integrated circuits and electronic devices. This includes pioneering the first in situ tensile and shear tests on free-standing monolayer 2D materials, such as graphene, hexagonal boron nitride and Transition Metal Dichalcogenides, as well as their homo- and heterostructures (e.g., twisted bilayer graphene). These studies, enabled by high precision

nanoindentation manipulation and real-time electron microscopy observation, not only reveal the anomalous nanomechanical properties of 2D materials, but also underscore the potential of elastic strain engineering (up to ~6%) for tuning 2D electronic and optoelectronic devices.

[14:20~14:45] Photoindentation of Semiconductors: Light-Environment Effects on Dislocation Nucleation and Motion

Atsutomo Nakamura (*The University of Osaka*)

Type: Invited

Nanoindentation is a powerful method for probing incipient plasticity, but its use under controlled optical environments remains less established, particularly for semiconductors in which electronic excitation can alter defect processes. We present photoindentation, a light-controlled nanoindentation approach for quantifying light-environment effects on dislocation nucleation and motion in semiconductor crystals. Using wide-bandgap semiconductors including ZnS, ZnO, and GaN, we combine low-load indentation, statistical analysis of pop-in events, nanoindentation creep, and cross-sectional transmission electron microscopy. In ZnS, illumination increased the first pop-in stress and suppressed indentation creep, indicating that light affects both dislocation nucleation and subsequent dislocation mobility. In wurtzite ZnO, the creep response under illumination showed a marked crystallographic orientation dependence, demonstrating that the photoplastic response is governed by the activated slip systems and dislocation configurations. Cross-sectional TEM observations further revealed that indentation-induced dislocation structures are modified by illumination, providing direct microstructural evidence for light-controlled dislocation motion. In GaN, atomically ordered surfaces enabled highly reproducible low-load pop-in measurements, highlighting the importance of surface structure control and statistical treatment for reliable evaluation of incipient plasticity. These results establish photoindentation as a quantitative platform for studying optically controlled crystal plasticity in semiconductors. By linking indentation statistics, time-dependent deformation, and defect microstructures, the method provides a route to evaluate semiconductor materials under controlled light environments and to clarify how electronic excitation couples with dislocation-mediated mechanical response.

[14:45~15:05] Mechanical Strengthening of Ti Protective Coatings for PEMWE Bipolar Plates through Residual Stress Control

Haechan Jo (*Sungkyunkwan University*), Gi-Dong Sim (*Korea Advanced Institute of Science and Technology*), Dongwoo Lee (*Sungkyunkwan University*)

Type: Oral

The mechanical integrity of protective coatings is critical for preventing cracking and subsequent corrosion in harsh environments. Here, we investigate the effect of deposition conditions on the nanomechanical properties and corrosion resistance of sputtered Ti coatings on SUS316L bipolar plates for proton exchange membrane water electrolyzers (PEMWEs). Nanoindentation measurements revealed that increasing the deposition temperature significantly enhanced hardness, H/E ratio, and elastic recovery. These improvements were attributed to higher compressive residual stress arising from thermal-expansion mismatch between the coating

and substrate, which promoted film densification and suppressed defect and crack formation. Notably, pitting potential showed strong correlations with elastic recovery, H/E ratio, and hardness, demonstrating a direct relationship between mechanical integrity and corrosion performance. These findings show that tailoring deposition conditions provides an effective strategy for controlling residual stress and simultaneously improving the mechanical robustness and corrosion resistance of protective coatings.

Session HI

2026-11-02 13:30 ~ 15:10 | 305 | Chair: Jungho Shin

[13:30~13:55] A multi-technique micromechanical study of hydrogen effects in austenitic stainless steel

Ruth Schwaiger (Forschungszentrum Juelich, Institute of Energy Materials and Devices - Structure and Function of Materials (IMD-1))

Type: Invited

Austenitic stainless steels are promising structural materials for hydrogen energy systems, but their integrity depends on how hydrogen uptake influences the local mechanical response and deformation mechanisms. In this talk, a multi-technique investigation of a high-Ni austenitic stainless steel following electrochemical hydrogen charging will be presented, combining thermal desorption spectroscopy, confocal microscopy, advanced electron microscopy, nanoindentation, and micromechanical testing. Hydrogen charging was observed to induce pronounced surface slip steps. An analytical model coupling hydrogen diffusion with lattice expansion accurately predicts the activated slip systems based on grain orientation. Nanoindentation further revealed a pronounced yet fully reversible hardening at an unchanged elastic modulus, attributed to an increased dislocation density together with enhanced lattice resistance arising from short-range hydrogen-dislocation interactions. Hydrogen also promoted localized pile-up formation and resulted in a contracted plastic zone, establishing pile-up morphology as a readily accessible surface indicator of restricted dislocation mobility. Our ongoing work on micrometre-sized shear-compression specimens, extends this framework to well-defined shear-dominated stress states. Together, these results provide a consistent picture linking hydrogen trapping, slip planarity, and localized plasticity in FCC austenitic stainless steels.

[13:55~14:20] Nanoindentation-Based Evaluation of Hydrogen Diffusivity in Advanced Alloys: Methodology and Case Studies

Hyun Jeong (Chungnam National University), Hwan-Sik Sim (Chungnam National University), Yakai Zhao (Institute of Materials Research and Engineering (IMRE)), Hyun You Kim (Chungnam National University), Soo Yeol Lee (Chungnam National University), Dong-Hyun Lee (Chungnam National University)

Type: Invited

Hydrogen diffusivity plays a critical role in hydrogen transport and hydrogen embrittlement of structural alloys. In this study, a nanoindentation-based approach combined with continuous stiffness measurement (CSM) is employed to evaluate hydrogen diffusivity from hydrogen-induced hardness variations. By considering the indentation plastic zone and the through-thickness hydrogen concentration profile, hydrogen diffusivity can be quantitatively determined. The methodology was first validated using two representative FCC alloys, 316L stainless steel and CoCrNi medium-entropy alloy (MEA), where the measured diffusivities showed good agreement with literature values. CoCrNi MEA exhibited lower hydrogen diffusivity than 316L and hydrogen-induced softening after long-term room-temperature aging, unlike 316L. The distinct hydrogen behaviors were

interpreted using density functional theory calculations. The applicability of the proposed method was further demonstrated through two case studies. First, hydrogen diffusivities of the FCC and HCP phases in a dual-phase high-entropy alloy were separately evaluated, revealing the influence of crystal structure on hydrogen transport. Second, the effect of V addition on hydrogen diffusivity was systematically investigated in FCC CoCrNiV MEAs with different V contents, demonstrating the capability of the proposed method to quantify composition-dependent hydrogen diffusion. These results demonstrate that nanoindentation provides a simple and versatile technique for evaluating hydrogen diffusivity in compositionally and microstructurally complex alloys, offering a practical tool for hydrogen-related alloy design.

[14:20~14:45] Small-Scale Mechanical Testing for Unraveling Hydrogen Embrittlement in Advanced Alloys

Yakai Zhao (*Agency for Science, Technology and Research (A*STAR)*)

Type: Invited

Small-scale mechanical testing techniques, particularly nanoindentation and micropillar compression, have become powerful tools for probing deformation mechanisms at the length scales where hydrogen-defect interactions control the onset of hydrogen embrittlement (HE). This presentation provides an overview of how nanomechanical testing can be used to investigate HE in advanced structural alloys, emphasizing the complementary insights offered by different methodologies such as hardness mapping, incipient plasticity analysis, and single-crystal micropillar compression. The talk will first showcase how combining nanoindentation, micropillar compression, and electron microscopy reveals hydrogen-induced softening and localized plasticity in laser powder bed fusion (L-PBF) 316L stainless steel, clarifying the role of hydrogen in dislocation-mediated deformation. Then the talk will also demonstrate how statistical analysis of nanoindentation pop-in events captures the stochastic nature of incipient plasticity in high-/medium-entropy alloys and how hydrogen modifies the balance between homogeneous and heterogeneous yielding. Together, these examples highlight the unique ability of nanomechanical testing to access hydrogen-driven deformation processes that are difficult to resolve by conventional methods and point toward integrated experimental approaches for a more complete understanding of hydrogen embrittlement in advanced materials.

[14:45~15:10] Evaluation of Hydrogen Embrittlement and Microstructural Response via Instrumented Indentation Testing

Seung-gun Lee (*Korea Institute of Materials Science*), Si-whan Lee (*Korea Institute of Materials Science*), Jung-yun Won (*Korea Institute of Materials Science*)

Type: Invited

Hydrogen embrittlement (HE) causes severe degradation of mechanical properties in structural alloys, necessitating non-destructive methods to assess localized hydrogen-material interactions. This study proposes an advanced evaluation framework for HE susceptibility using instrumented indentation testing (IIT) by analyzing true stress-strain behavior, plastic cavity depth beneath the indenter, and lateral pile-up formation. Under high-pressure hydrogen pre-charging, contrasting mechanical responses were observed depending on

the crystal structure: FCC alloys exhibited strain hardening due to hydrogen-dislocation pinning, whereas BCC steels demonstrated local softening driven by Hydrogen-Enhanced Localized Plasticity (HELP). These macro-scale true stress-strain alterations were directly reflected in the micro-scale indentation response. For BCC alloys undergoing hydrogen-induced softening, reduced strain-hardening capacity prevented deep stress propagation, resulting in a shallower plastic cavity depth and magnified lateral plastic flow (increased pile-up height). Conversely, hydrogen-hardened FCC alloys effectively transferred stress into deeper regions, reducing pile-up formation while increasing the plastic cavity volume. Notably, metastable FCC alloys with low stacking fault energy (SFE), such as SUS304, exhibited anomalous behavior. Hydrogen exposure accelerated deformation-induced martensitic phase transformation, leading to plastic strain resetting that suppressed expected pile-up growth despite initial softening trends. These findings demonstrate that indentation-derived parameter analysis—specifically tracking the ratio of plastic cavity depth to lateral pile-up topography—provides a robust, highly sensitive probe to trace hydrogen-dislocation mobility interactions and phase transformation dynamics, offering a powerful tool for hydrogen infrastructure integrity assessment.

Session MS

2026-11-02 15:30 ~ 18:00 | 306 | Chair: Yue Liu

[15:30~15:55] robing mechanical properties and back stress in heterogeneous lamellar composites by nanoindentation

Mathias Göken (Friedrich Alexander University Erlangen-Nürnberg, Germany)

Type: Invited

Heterogeneous lamellar composites — such as those produced by accumulative roll bonding (ARB) — combine soft and hard constituents on a well-defined length scale. Their remarkable combination of strength and ductility is now widely attributed to hetero-deformation-induced (HDI) strengthening: strain gradients across the soft/hard interfaces generate geometrically necessary dislocations that pile up at phase and grain boundaries, producing a long-range back stress. This back stress is routinely extracted from macroscopic loading–unloading–reloading (LUR) tension tests, but such measurements yield only a volume-averaged value and cannot resolve how stresses and back strain are partitioned between the individual lamellae. In this work we introduce a new nanoindentation method that resolves the local back strain in heterogeneous composites through a cyclic indentation approach. Using spherical indenters, the technique analyzes the evolution of the loading–unloading response over successive cycles to separate the reversible, back-stress-driven contribution from the irreversible plastic response, yielding a quantitative local measure of the back strain within each constituent and across the interface-affected zone. The method is demonstrated on a range of laminate systems — aluminum-based laminates, iron–aluminum, and copper–niobium composites — where hardness and modulus mapping across the lamellar stack additionally reveal how the mechanical contrast and back strain evolve as the layer thickness is refined toward the optimal strength–ductility length scale. Local values are compared with macroscopic LUR data, providing microstructural design guidance for optimizing the mechanical performance of heterostructured materials.

[15:55~16:20] Nanoindentation in Tribology: Its Importance and Practical Applications

Shinya SASAKI (Tokyo University of Science, Japan)

Type: Invited

Tribology, the science of friction, wear, and lubrication, is governed by complex phenomena occurring at sliding interfaces, often within micro- and nanoscale surface regions. With the rapid development of advanced engineering materials, thin-film coatings, surface treatments, and tribo-films, conventional macroscopic mechanical testing is often insufficient to accurately evaluate the local properties that determine tribological performance. Nanoindentation has therefore become an indispensable technique in modern tribological research, enabling the quantitative characterization of hardness, elastic modulus, and time-dependent mechanical responses at penetration depths comparable to the thickness of near-surface layers. In this lecture, the importance and applications of nanoindentation in tribology will be discussed. First, the necessity of nanoscale mechanical characterization will be introduced, with emphasis on how the mechanical properties of

the topmost surface layers influence friction, wear, crack initiation, coating durability, and lubrication performance. The ability of nanoindentation to evaluate tribo-films, native oxides, thin-film coatings, and surface-modified layers provides valuable insights into the mechanisms governing tribological behavior. Representative applications will then be presented, including the evaluation of solid lubricant films, hard coatings, surface-hardened layers, and multi-phase materials through high-resolution mechanical property mapping. Advanced techniques, such as nano-scratch testing, will also be discussed as powerful tools for investigating single-asperity wear resistance, coating adhesion, and interfacial failure. By linking nanoscale mechanical responses to macroscopic friction and wear performance, nanoindentation provides a deeper understanding of tribological phenomena and supports the rational design of advanced surfaces and materials. This lecture will demonstrate that nanoindentation has evolved beyond a simple hardness measurement technique to become an essential platform for understanding tribological mechanisms and guiding the design of next-generation high-performance surfaces and materials.

[16:20~16:40] Understanding the Indenter Wear Effect in Nanoindentation with Continuous Stiffness Measurement

Diancheng Geng (Institute for Materials Research, Tohoku University, Japan), Hao Yu (Institute for Materials Research, Tohoku University, Japan), Sosuke Kondo (Institute for Materials Research, Tohoku University, Japan), Ryuta Kasada (Institute for Materials Research, Tohoku University, Japan)

Type: Oral

Enter description here. High-throughput nanoindentation testing has become increasingly prevalent in recent research, particularly for size-limited materials. The continuous stiffness measurement (CSM) method enables depth-resolved measurements that, in combination with the Nix-Gao model, allow bulk mechanical properties to be predicted even for materials exhibiting the indentation size effect (ISE). Nevertheless, the indenter wear effect (IWE) cannot be neglected following extensive use of the indenter tip. Previous studies have investigated IWE only under shallow indentation depths using the load-unloading method, and its impact at large indentation depths has been assumed to be limited. Yet, this assumption has not been systematically verified for CSM-based nanoindentation. In this study, nanoindentation tests were performed using the CSM method with three Berkovich indenters of different wear states on fused silica, pure Cu, SUS304 stainless steel, and tempered martensitic steel F82H. Confocal laser microscopy was employed to characterize the tip geometry of the three indenters and the pile-up/sink-in behavior at indentation edges. The results demonstrate that under conventional modulus-based calibration (E-calibration), a blunter indenter yields a higher bulk-equivalent nanoindentation hardness (H_0) extrapolated by the Nix-Gao model, which is attributed to the elastic-plastic response of the worn indenter tip. A combined elastic modulus and hardness calibration (E-H calibration) is proposed to correct for IWE, by simultaneously accounting for the tip-induced overestimation in both contact stiffness and projected contact area. Application of E-H calibration reduces the deviation in H_0 evaluated with a blunt indenter from ~10% to ~5%. Furthermore, Cu, as a material with pronounced pile-up behavior, exhibited lower sensitivity to IWE compared to the steel specimens, likely due to the compensating effect of pile-up on the projected contact area. These findings provide a practical calibration strategy for maintaining measurement reliability in long-term, high-throughput nanoindentation campaigns.

[16:40~17:05] Play with defects: new insights into the small-scale plasticity

Xianghai An (*School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney*)

Type: Invited

The deformation plasticity of small-scale metals that are the critical components to the architecture of micro/nano-electro-mechanical systems (M/NEMS) has been attracting dramatic attention over the last two decades. The well-known size effect manifested as “smaller is stronger” indicates that at micron and submicron scales, the sample dimensions of materials play essential roles in controlling the mechanical properties and deformation physics. Classic crystal plasticity enlightens us that tailoring stacking fault energy (SFE) via alloying provides a robust protocol to manipulate deformation mechanism and consequently the mechanical properties of metallic materials. However, the effects of SFE on the size-dependent plasticity have rarely been studied. Herein, we firstly employed quantitative in-situ deformation transmission electron microscopy to systematically uncover the size effects on the mechanical properties and deformation mechanisms of Cu–Al single-crystalline nanopillars because the SFE was controlled by adjusting the Al content in Cu–Al alloys. Size-dependent mechanical behaviour and deformation mechanism were comprehensively explored, which were controlled by the interplay among sample size, SFE and alloying induced short-range ordering. Moreover, compared to the conventional metals with single SFE, the novel high-entropy alloy with high compositional complexity exhibits a wide spectrum of “local” SFE due to the statistical fluctuation in the compositional and packing arrangements of the various elements. We found that the joint and/or sequential activations of the displacive deformation mechanisms originated from chemical compositional heterogeneities at the atomic level enables the room-temperature super-elongation in high-entropy alloy nanopillars, which was rarely observed in small-volume metals with high strength and low ductility.

Session SE

2026-11-02 15:30 ~ 18:00 | 307 | Chair: Bo-Shiuan Li

[15:30~15:55] Instrumented indentation Studies of Materials for Advanced Batteries

Yang-Tse Cheng (University of Kentucky)

Type: Invited

Understanding the mechanical behavior of materials is critical to developing batteries for many applications, including electric vehicles and grid energy storage. Specifically, the mechanical behavior, which often changes with the state-of-charge and the cycle number, can affect battery performance, durability, and safety. In this presentation, I will provide several examples of using instrumented indentation techniques to investigate the mechanical behavior of battery materials, including porous silicon/polymer composite,¹ lithium,^{2,3} lithium-metal oxides,⁴ polymer,⁵ solid electrolytes,⁶ and electrodes made using conventional wet slurry and novel dry processes.⁷ These examples highlight the usefulness and challenges in measuring and understanding the mechanical behavior of materials for battery applications.¹ Y. K. Wang, et al., "Mechanical Property Evolution of Silicon Composite Electrodes Studied by Environmental Nanoindentation," *Advanced Energy Materials* 8 (10), 1702578 (2018).² Y. K. Wang and Y. T. Cheng, "A nanoindentation study of the viscoplastic behavior of pure lithium," *Scr. Mater.* 130, 191–195 (2017).³ Y. K. Wang, et al., "Mechanical behavior of electroplated mossy lithium at room temperature studied by flat punch indentation," *Appl. Phys. Lett.* 115 (4), 043903 (2019).⁴ D. Y. Dang, et al., "Fracture Behavior of Single LiNi_{0.33}Mn_{0.33}Co_{0.33}O₂ Particles Studied by Flat Punch Indentation," *Journal of the Electrochemical Society* 166 (13), A2749–A2751 (2019).⁵ S. Thapa, et al., "Reversible Polymer-Metal Mechanical Transitions Enabled by Electrochemical Modulation," *Nano Lett* 26 (11), 3698–3702 (2026).⁶ J. L. Hempel, et al., "Probing the elastic modulus and hardness of superionic boron cluster solid electrolytes," *J. Power Sources* 641, 236800 (2025).⁷ H. Alolaywi, et al., "An investigation of two dry processes: Fibrillation and electrostatic spray deposition for making high loading electrodes," *Journal of Energy Storage* 154, 121050 (2026).

[15:55~16:15] Multi-Scale Insights into the Enhanced Electrical Conductivity of Copper by Nitrogen-Doped Graphene: Competing Mechanisms of Carrier Concentration and Mobility

Wang Yu (Shanghai Jiao Tong University), You Shuting (Shanghai Jiao Tong University)

Type: Oral

Heterointerfaces in multilayer thin films possess nanoscale dimensions and exhibit non-additive physical properties that differ from both the matrix and a simple superposition of constituent materials. Nanoscale characterization is therefore essential for elucidating interface-induced functionalities and their evolution mechanisms. Nitrogen-doped graphene/copper (NGr/Cu) composite films offer a pathway to enhance the electrical conductivity of copper other than high-purity or single-crystal copper, yet the microscopic scattering

mechanisms underlying their non-monotonic resistivity evolution remain unresolved. We synthesized NGr/Cu foils by chemical vapor deposition with systematically tunable nitrogen content (0–4.2 at%) and employed a multi-scale characterization approach to correlate interfacial microstructure with carrier transport, including Raman spectroscopy, X-ray photoelectron spectroscopy, Kelvin probe force microscopy, density functional theory calculations, and four-probe resistivity measurements. The electrical conductivity showed an initial increase and then a decrease with increasing nitrogen concentration, peaking at 104.7% IACS (International Annealed Copper Standard) for 2.7 at% N, which exhibited a remarkable 14% improvement compared to the annealed Cu counterpart. The observed non-monotonic resistivity evolution can be attributed to two competing mechanisms governed by the carrier concentration and chemical configuration of interfacial defects, as resolved by multi-scale characterization across the Cu/graphene heterointerface. Kelvin probe force microscopy and density functional theory calculations reveal that dual doping of copper-electrons and nitrogen induces a Fermi-level upshift. The resulting increase in carrier concentration and surface potential difference dominates the conductivity enhancement at low-to-moderate nitrogen doping. Meanwhile, nitrogen-introduced chemical configurations suppress electron–phonon coupling, thereby enhancing the intrinsic carrier mobility. At higher doping levels, these configurations also act as additional scattering centers that reduce graphene’s carrier mobility. This study experimentally demonstrates that precise doping control can balance carrier concentration and mobility in layered heterogeneous materials through microstructural defects at surfaces and interfaces, providing a feasible strategy for developing high-conductivity copper-based composite films.

[16:15~16:35] Evolutionary design framework for anisotropic mechanical metamaterials with tailored directional stiffness

Wonjun Shin (Jeonbuk National University), Jong-Soo Bae (Jeonbuk National University), Jihoon Han (Jeonbuk National University)

Type: Oral

Mechanical metamaterials derive their effective properties largely from the geometry, connectivity, and spatial arrangement of their internal structures. Conventional lattice designs have demonstrated a wide range of mechanical responses, yet many are still derived from predefined unit-cell families. Although such design spaces are well suited to parametric optimization, they can restrict the exploration of unconventional architectures exhibiting pronounced direction-dependent mechanical behavior. In this study, an evolutionary discovery framework is developed for the design of anisotropic mechanical metamaterials with designer-specified directional stiffness. The framework explores a weak-symmetry structural design space in which material distribution and the associated load-transfer paths evolve according to prescribed mechanical preferences. The framework searches across different structural configurations rather than limiting the design process to geometric tuning of a predefined lattice family or convergence to a single optimum. The proposed approach was evaluated through multi-directional stiffness design problems in which the relative stiffnesses along the three principal axes were prescribed together with the material usage. The evolutionary search yielded distinct lattice architectures that achieved the desired anisotropic stiffness relationships while maintaining comparable relative densities. The resulting designs showed distinct elastic responses along

different loading directions, reflecting the role of directional material distribution within the unit cell in determining mechanical anisotropy. The directional stiffness trends were further verified by uniaxial compression tests of additively manufactured specimens. These results indicate that evolutionary structural discovery offers an alternative to the conventional approach of tuning predefined lattice families. The proposed framework can therefore be used to design mechanical metamaterials with application-specific anisotropic responses while retaining multiple structural candidates for subsequent consideration of manufacturability and other engineering requirements.

[16:35~17:00] Nanomechanical testing of semiconductors under an electric field or light illumination

Yu Zou (*University of Toronto*)

Type: Invited

Dislocations in semiconductors can carry charges. In this presentation, I present observations of (1) dislocation motion controlled solely by using an external electric field in single-crystalline ZnS—the dislocations can move back and forth, depending on the direction of the electric field. (2) I will provide both experimental evidence and atomic simulations for reduced dislocation mobility in semiconductors under UV light. By combining photo-nanoindentation, transmission electron microscopy (TEM), and atomic simulations, we visualized dislocation distribution in both darkness and under illumination. (3) I will show the photo-creep behavior in ZnS and halide perovskites. (4) I reveal the non-stoichiometric nature of dislocation cores and determine their charge characteristics. Both negatively and positively charged dislocations are directly resolved, and their glide barriers decrease under an electric field, explaining the experimental observations. This study provides direct evidence of dislocation dynamics controlled by a non-mechanical stimulus and opens up the possibility of modulating dislocation-related properties.

Session HI

2026-11-02 15:30 ~ 17:10 | 305 | Chair: Yakai Zhao

[15:30~15:55] Assessing hydrogen embrittlement and hydrate formation in BCC-Fe through nanoindentation

Jan Ocenasek (New Technologies Research Centre, University of West Bohemia in Pilsen), Ting Yang (Department of Materials Science and Engineering, MIT), Cheng-Yuan Tsai (Department of Materials Science and Engineering, MIT), T. Venkatesh (Stony Brook University), Ming Dao (Department of Materials Science and Engineering, MIT), Jorge Alcalá (Polytechnic University of Catalonia)

Type: Invited

This presentation address hydrogen embrittlement in BCC iron through nanoindentation experiments and simulations. Our Molecular dynamics (MD) and density-functional theory (DFT) simulations provide evidence of hydrate formation in supersaturated Fe-H solid solutions, thereby identifying potential mechanisms for H trapping. The simulation results consistently predict the progressive nucleation of embryonic hydrates through the clustering of H atoms along directions of the BCC Fe lattice, followed by their growth into fully coherent monatomic hydrate discs via diffusional processes. Although hydrate formation is generally assumed to occur only at elevated pressures, a key finding of this investigation is that both hydrate embryos and disc-shaped precipitates exhibit lower energies than highly supersaturated Fe-H solid solutions, thereby providing a thermodynamic force for nanoscopic hydrate formation at atmospheric pressure. Our experimental results and MD simulations demonstrate the use of nanoindentation as a tool for assessing hydrate formation and H trapping in Fe-H systems. Although a random distribution of dissolved H atoms has only a limited influence on the critical pop-in load, a key finding of our investigation is that the formation of embryonic hydrates already leads to significant reductions in critical load relative to uncharged Fe surfaces. The effectiveness of these precipitates in promoting defect nucleation is governed by both the volumetric expansion they generate and their proximity to the highly stressed lattice sites in the subsurface. To our knowledge, the current experiments represent the first evidence accounting for the formation of nanoscopic hydrates in supercharged BCC Fe-surfaces at atmospheric pressure. While the nanoindentation pop-ins caused by early defect nucleation can be potentially used as an indicator of hydrogen embrittlement in BCC-Fe, our MD simulations provide further evidence to the underlying defect processes by which hydrogen atoms and hydrates interact with dislocations and twins.

[15:55~16:15] Instrumented Indentation Study on the Hydrogen Effect in Additively Manufactured CoCrNi Alloy

Kotaro Murakami (Kagoshima University), Shin-ichi Komazaki (Kagoshima University), Zhe Gao (Hanyang University), Jae-Hyeok Choi (Hanyang University), Jae-il Jang (Hanyang University)

Type: Oral

This study aims to investigate the local mechanical properties and deformation behavior of an additively manufactured (AM) CoCrNi medium-entropy alloy in a hydrogen environment using indentation testing. To clarify the influence of unique AM microstructures, such as grain boundaries and dislocation networks, on susceptibility to hydrogen embrittlement, indentation tests are performed on both hydrogen-charged and uncharged specimen. We will present the effects of hydrogen on indentation hardness behavior in the load–displacement curves, along with microstructural observations around the indents. Based on these results, the underlying mechanisms of hydrogen-induced deformation in the AM CoCrNi alloy will be discussed.

[16:15~16:40] DEFECT-DRIVEN PLASTICITY IN IRRADIATED NANOTWINNED Cu

Daehyeok Ahn (Korea Advanced Institute of Science and Technology), Hadi Ghaffarian (Korea Advanced Institute of Science and Technology), Dongchan Jang (Korea Advanced Institute of Science and Technology)

Type: Invited

A commonly accepted fact in materials science is that immobile crystallographic defects typically restrict plasticity in metallic materials as they impede the glide of dislocations, the primary plasticity carrier within the crystal lattice. Consequently, an increase in the number of such defects amplifies strength but sacrifices ductility- an undesired effect that undermines the stability of engineering systems operating under conditions that generate additional defects, such as irradiation. In this study, we present experimental evidence of defect-driven plasticity in proton-irradiated nanotwinned Cu through in-situ nano-tensile testing. Contrary to conventional radiation hardening, our results demonstrate that radiation-induced defects can facilitate softening and improve ductility. This is achieved by intentionally disturbing interfacial coherency through radiation-induced defects, where local lattice discontinuities serve as dislocation nucleation sites. Furthermore, these discontinuities are readily eliminated by partial dislocations gliding along twin boundaries, thereby limiting the extent of radiation hardening.

[16:40~17:00] Precipitation effect on the mechanical properties and microstructure of NiCuAl alloys for spent nuclear fuel canisters

Hoe-Yeon Jeong (Department of Materials Science and Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Republic of Korea), Seonyeong Yang (Graduate School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Republic of Korea), Jeong-Hyun Woo (Advanced Disposal Technology R&D Division, Korea Atomic Energy Research Institute (KAERI), Daejeon, Republic of Korea), Hansol Jeon (Department of Advanced Materials Engineering, Keimyung University, Daegu, Republic of Korea), Ju-Young Kim (Department of Materials Science and Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Republic of Korea; Graduate School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Republic of Korea)

Type: Oral

As the global capacity for spent nuclear fuel storage becomes increasingly limited, deep geological repositories at depths greater than 500 m have been proposed as a permanent disposal solution. In such environments, spent nuclear fuel must be stored for more than 100,000 years, necessitating the use of disposal canisters to

protect it from external conditions. Disposal canisters must maintain both corrosion resistance and high mechanical strength, as they are required to withstand environmental changes as well as the weight of internal structures. Accordingly, extensive research has been conducted on both structural design and material selection. To date, a dual-layer structure consisting of corrosion-resistant oxygen-free copper and structurally robust cast iron has been widely investigated. In this study, however, a novel material was developed to enable a single-structure design, thereby achieving process simplification and improved space efficiency while satisfying both high strength and corrosion resistance. By adding Al to a NiCu alloy, which exhibits superior corrosion resistance compared to oxygen-free copper, Ni₃Al precipitates were formed, leading to simultaneous enhancement of corrosion resistance and mechanical strength. Notably, the relationship between precipitate size and strength is neither directly nor inversely proportional; instead, the maximum strength is achieved at a specific precipitate size. Therefore, nanoindentation was employed to evaluate hardness variations as a function of precipitate size, enabling identification of the precipitate size corresponding to high strength. Furthermore, by correlating these results with microstructural observations, the strengthening mechanism associated with precipitate size was systematically investigated.

Session MS

2026-11-03 08:30 ~ 09:40 | 306 | Chair: Jeffrey M. Wheeler

[08:30~08:55] Finite-Size Scaling as a Unified Framework for Strengthening and Hardening in Micropillar Plasticity

Seok-Woo Lee (University of Connecticut)

Type: Invited

The "smaller-is-stronger" size effect is a defining feature of micron-scale plasticity, yet existing models struggle to capture size-dependent strengthening and strain hardening within a single framework. Flow stress in micropillars is conventionally described by an empirical power law in diameter, with the size exponent treated as a fitting constant while hardening is handled separately. Because dislocation plasticity proceeds through intermittent, scale-free slip avalanches, it shares statistical signatures of critical phenomena. Here we extend finite-size scaling (FSS), a framework for critical systems, from avalanche statistics to the constitutive response itself. Treating micropillar diameter as the cutoff that truncates correlated dislocation activity, we show size-dependent stress-strain curves collapse onto a single universal master curve. The resulting law separates into an intrinsic strength term and a product of two independent power laws: one in plastic strain, governed by a universal hardening exponent, and one in diameter, governed by the size exponent. Analysis of published FCC and BCC micropillar data confirms the size exponent is nearly strain-insensitive once a stable dislocation network develops, showing hardening and size strengthening are decoupled. Practically, the full stress-strain response of any pillar size can be reconstructed from just two pillars of different size, removing the need for size-by-size fitting. Mapping exponents shows FCC metals have larger size exponents and smaller correlation-length exponents than BCC metals, consistent with stronger finite-size truncation of collective slip versus localized lattice-friction glide. We recover the size exponent from avalanche cutoff statistics, connecting the framework to self-organized criticality. Hardening reflects evolution of a correlated dislocation network toward a moving critical state, with the size effect emerging only after plastic flow begins as finite dimensions constrain the structure. These results reframe "smaller-is-stronger" as finite-size truncation of correlated dislocation activity rather than geometric reduction of source length, integrating statistical physics of criticality into dislocation mechanics.

[08:55~09:20] From Nanoindentation-Derived Strain-Rate Sensitivity to Dislocation-Mediated Plasticity Across Interfaces and Slip Systems

Yue Liu (Shanghai Jiao Tong University)

Type: Invited

Strain-rate sensitivity (SRS) is a key descriptor of rate-dependent plasticity, but for many small-volume crystals the relevant quantity is local SRS rather than a bulk-averaged response. This is because thermally activated deformation is governed by nanoscale dislocation events near interfaces, boundaries, and crystallographic slip systems. Meanwhile, many emerging materials, including thin films, nanolayers, two-dimensional crystals, and

micrometer-scale energetic crystals, are difficult to examine using conventional large-scale deformation systems. Nanoindentation therefore provides a practical route to extract local SRS and connect it to small-scale plasticity mechanisms. To make this route reliable, we first developed a stiffness-based nanoindentation analysis that suppresses thermal-drift-induced uncertainty at low indentation strain rates. By calculating contact area from contact stiffness and elastic modulus rather than drift-sensitive displacement, the method enables robust hardness and SRS measurements in low-dimensional metallic films. Using this foundation, we quantified SRS in highly textured Cu/Ni and Cu/V multilayers with layer thicknesses from 1 to 100 nm. The measured SRS signatures reveal distinct interface-controlled dislocation mechanisms. In Cu/Ni multilayers, SRS increases with decreasing thickness above 10 nm but decreases below 10 nm, because coherent interfaces expand the effective dislocation activation volume. In contrast, Cu/V multilayers maintain nearly unchanged SRS below 10 nm, as semi-coherent interfaces and misfit dislocations continue to confine dislocation activation. We further extended this indentation-based SRS framework to single-crystal α -RDX, where pop-in statistics and SRS-derived activation volumes identify slip-system-dependent dislocation behavior. First pop-ins quantify orientation-dependent critical resolved shear stresses for primary slip systems, whereas subsequent pop-ins distinguish dislocation migration, pinning-depinning, and multiplication. The corresponding energy analysis shows that dislocation multiplication on {010} most effectively accommodates plastic work. Together, these studies demonstrate that nanoindentation-derived SRS is a mechanism-sensitive bridge from local property extraction to dislocation-mediated plasticity across interfaces and slip systems.

[09:20~09:45] A new depth of information: 4D nanoindentation mapping of microstructures

Edoardo Rossi (Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Via Vito Volterra 62, 00146 Rome, Italy), *Harita Seekala* (School of Engineering Sciences and Technology, University of Hyderabad, India), *P. Sudharshan Phani* (School of Engineering Sciences and Technology, University of Hyderabad, India), *Marco Sebastiani* (Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Via Vito Volterra 62, 00146 Rome, Italy), *Tiberio Cuppone* (Department of Earth Science, University of Firenze, Firenze, Italy), *Giovanni Pratesi* (Department of Earth Science, University of Firenze, Firenze, Italy)

Type: Invited

High-speed nanoindentation now maps mechanical properties almost as densely as electron microscopy does, yet interpreting these maps lags behind their collection. In a heterogeneous material, every indent probes its own small volume, and its response depends on the local microstructure: the phase it sits in, its nearness to an interface, the crystal orientation, and the subsurface. A conventional map reduces this to a single hardness or modulus value per point (a 3D map), in which phase mixing, compositional gradients, and boundaries blur together. 4D nanoindentation mapping reveals a new depth of information: at every point, it retains the full load–depth curve and follows contact stiffness as the tip goes deeper, so materials that look alike at one depth are still separated by how their response unfolds, too rich to untangle by histogram fitting or by eye. This is where machine learning earns its place. For 3D maps, unsupervised clustering groups measurements into mechanically coherent domains without prior labels, and the results are checked against independent microstructural evidence. For 4D data, curve-aware deep learning reads the entire response rather than a single

slice, thereby separating phases that are indistinguishable at a single depth and flagging substrate effects and layer transitions in coatings. To tie clusters to the material, each indent is correlated point-by-point with electron backscatter diffraction, energy-dispersive spectroscopy, or electron probe microanalysis, attaching a crystallographic, compositional, and phase identity; where such labels exist, they train a supervised classifier that carries the assignment across the whole map. We demonstrate it on four contrasting systems: an L6 ordinary chondrite, a CrN/Cr bilayer hard coating, and an aluminum–copper eutectic; in the chondrite, the clusters align point-for-point with olivine, low-calcium pyroxene, and minor Fe–Ni metal. This turns a statistical partition into physically anchored material domains, surfacing structure–property links that neither technique alone reveals.

Session SE

2026-11-03 08:30 ~ 09:40 | 307 | Chair: Dongwoo Lee

[08:30~08:55] Application of Small-Scale Mechanics in Soft, Biodegradable Electronics

Seung-Kyun Kang (Seoul National University)

Type: Invited

Soft wearable and implantable devices capable of seamless integration with the human body are emerging as key technologies for healthcare, medical, and human-machine interface applications, including advanced display systems. This presentation aims to highlight the convergence of small-scale mechanics and biodegradable soft electronics by introducing representative examples in which thin-film-based micro/nanomechanical design principles are applied to environmentally friendly and bioresorbable electronic systems. In this field, devices are engineered to minimize mechanical mismatch with biological tissues while maintaining both softness and tissue-level stretchability. In particular, this presentation will introduce the development of stretchable inorganic electrodes based on amorphous biodegradable metallic materials. Compared with conventional crystalline thin films, these materials exhibit superior elastic deformability, enabling enhanced resistance to cyclic mechanical fatigue and improved device durability. In addition, strain-controlled design strategies for minimizing fracture of inorganic electronic components during syringe-based deployment in the brain environment will be discussed.

[08:55~09:15] Nanoscale Characterization of Local Electronic States at Defects via Kelvin Probe Force Microscopy

Yingwen Zhu (Shanghai Jiao Tong University)

Type: Oral

Defects, including boundaries and interfaces, govern the electrical transport, microwave response, as well as the resistance to dislocation motion. The defect-induced local electronic states modify the atomic bonding, thus reflecting nanoindentation mechanical response at electronic scale. Clarifying how defects regulate local electronic states is therefore critical to provide theoretical basis for understanding underlying mechanical mechanisms. Kelvin probe force microscopy (KPFM) sensitively detects local density of states variations, enabling correlation analysis with defect structures. By integrating KPFM with density functional theory (DFT), we establish an experimental-theoretical framework to resolve electronic structure and defect configuration at nanoscale precision. We perform a comparative study on twin boundaries (TBs) and grain boundaries (GBs) in copper. KPFM measurements reveal that TBs exhibit 62.1 mV higher surface potential than GBs, and DFT calculations further demonstrate that TBs possess a lower density of states at the Fermi level. This electronic structure difference leads to distinct transport behaviors: TBs with smaller lattice disorder suppress electron scattering and carry 0.93 nA higher current than GBs, while their lower electron concentration (estimated reduction of $1.12 \times 10^{21} \text{ cm}^{-3}$ from Fermi level shift) in turn aggravates electromagnetic loss under high-frequency skin effect. Moreover, the reduced density of states can provide a potential explanation for their

higher dislocation nucleation barrier and deformation resistance. This methodology can be extended to heterogeneous interfaces such as graphene/copper, where KPFM is capable of reflecting work function mismatch via contact potential difference. From Fermi level alignment, we deduce an estimated interfacial charge transfer of $1.51 \times 10^{21} \text{ cm}^{-3}$ from copper to graphene, reflecting the charge redistribution that governs interfacial bonding. Such interfacial charge transfer could modulate atomic bonding and thus affect dislocation activity at the interface. This method enables quantitative correlation of KPFM-derived electronic states with local transport and mechanical responses, providing a robust basis for defect-level electromechanical interpretation.

[09:15~09:40] Nanomechanical Characterization of Stimuli-Responsive Molecular Crystals

Yuichi Hirai (National Institute for Materials Science)

Type: Invited

Mechanically responsive molecular crystals have attracted increasing attention as functional materials whose optical properties can be modulated by external stimuli. While remarkable progress has been made in understanding their photophysical behaviour, the relationship between crystal mechanics, structural evolution, and luminescence remains poorly understood. Nanoindentation provides a powerful means of quantitatively evaluating the local mechanical properties of molecular crystals and offers new opportunities to correlate mechanical response with structural and optical characteristics. In this presentation, recent studies on mechanically responsive molecular crystals will be introduced with particular emphasis on the relationship between crystal structure, intermolecular interactions, nanomechanical properties, and luminescence. By combining nanoindentation with crystallographic and spectroscopic characterization, it becomes possible to investigate how subtle variations in molecular packing and intermolecular interactions influence both mechanical and optical responses. Particular attention will be given to fluorescent organic molecular crystals containing intrinsic voids, where mechanical properties and luminescence can change concurrently through modifications of the intermolecular interaction network. These studies demonstrate that nanomechanical measurements provide valuable information that complements conventional crystallographic and spectroscopic techniques, enabling a more comprehensive understanding of structure–property relationships in molecular solids. The integration of mechanical characterization with optical and structural analyses provides a versatile framework for exploring adaptive molecular materials and offers new insights into the design of mechanically responsive functional crystals.

Session HI

2026-11-03 08:30 ~ 09:40 | 305 | Chair: Jong-hyoung Kim

[08:30~08:55] Nanoindentation of Ion-Irradiated Materials: From Depth-Sensing Measurements to Reliable Fusion Materials Evaluation

Ryuta Kasada (Tohoku University), Diancheng Geng (Tohoku University), Sumin Lee (Tohoku University), Sosuke Kondo (Tohoku University)

Type: Invited

Ion irradiation provides an indispensable accelerated approach for investigating radiation effects and screening candidate materials for future fission and fusion reactor systems. Its principal limitation is that irradiation damage is generally confined to a near-surface layer ranging from several hundred nanometres to a few micrometres. The development of depth-sensing indentation, pioneered by Pethica and co-workers through hardness measurements at penetration depths of only several tens of nanometres, opened a practical route for mechanically characterizing such small ion-irradiated volumes. Since these early studies, nanoindentation of ion-irradiated materials has evolved from a comparative measurement of apparent hardness into a method for examining irradiation-induced plasticity. Major advances include continuous stiffness measurement, correction for indenter-tip geometry, treatment of the indentation size effect, evaluation of the contribution from the unirradiated substrate, and quantitative analysis of pop-in, pile-up, slip steps, and spatial hardness heterogeneity. These developments have revealed that the measured response is governed not only by irradiation-induced defect obstacles, but also by the interaction of the indentation plastic zone with damage gradients, microstructural heterogeneity, strain localization, and the underlying substrate. Recent combinations with electron microscopy, surface profilometry, crystal plasticity modelling, and dislocation-based indentation models have further enabled relationships between irradiation defects, local deformation, and macroscopic mechanical behavior to be investigated. This presentation reviews the historical and methodological development of nanoindentation for ion-irradiated metallic materials, with emphasis on ferritic/martensitic steels and so on for fusion applications. Particular attention is given to persistent uncertainties associated with indentation size effects, indenter geometry, deformation localization, and substrate influence. Recent approaches developed by our group, including extended Nix–Gao analysis, identification of an irradiation-dependent substrate-transition depth, and assessment of indenter-edge effects, are discussed as steps toward more reproducible interpretation. Finally, requirements for connecting local indentation responses to constitutive properties and engineering-scale assessments of irradiated fusion materials are considered.

[08:55~09:20] Depth-Resolved Evaluation of Irradiation Hardening in Electron-Beam-Welded XM-19 Stainless Steel

Jungho Shin (Kangwon National University)

Type: Invited

XM-19 austenitic stainless steel is a candidate structural material for advanced nuclear systems because of its high strength, corrosion resistance, and irradiation tolerance. For thick-section components, electron beam welding (EBW) offers an effective joining route, but the steep thermal gradients produced during welding generate spatially heterogeneous microstructures. As a result, the fusion zone, heat-affected zone, and base metal may exhibit different local responses to irradiation damage, which is important for assessing the long-term integrity of welded nuclear components. In this study, irradiation hardening in electron-beam-welded XM-19 stainless steel was evaluated using proton irradiation and depth-resolved nanoindentation. The EBW joint was divided into fusion zone (FZ), coarse-grained heat-affected zone (CG-HAZ), fine-grained heat-affected zone (FG-HAZ), and base metal (BM) regions based on microstructural characterization. Cross-sectional nanoindentation was then used to quantify local hardness evolution across the shallow proton-damaged layer and to compare the hardening sensitivity of each weld region. The results show that irradiation-induced hardening is strongly dependent on the initial weld microstructure. The base metal and fine-grained HAZ exhibited relatively high hardening sensitivity, whereas the coarse-grained HAZ showed the lowest hardening response. Depth-resolved hardness profiles further indicated that the irradiation response is not uniform through the damaged layer, highlighting the need for local mechanical characterization when evaluating proton-irradiated weldments.

[09:20~09:40] Micromechanical evaluation of interfacial properties in SiC/SiC composites for fusion environments

Henri Nela (*Imperial College London, UKAEA*)

Type: Oral

The development of reliable SiC/SiC composites for advanced nuclear systems depends on controlling the behaviour of the fibre/matrix interphase. Although pyrolytic carbon remains the standard interphase in nuclear-grade materials, its long-term stability under extreme conditions is still a key concern. In this abstract/talk, a systematic micromechanical approach is presented to examine how interphase design, testing geometry and temperature interact in determining interface performance. A common SiC/SiC material platform is used to compare complementary in-situ SEM micromechanical methods at room temperature, not as isolated measurements, but as a way of understanding which aspects of interfacial strength, frictional sliding and fracture are shared across techniques and which are geometry-dependent. This baseline is then extended to temperatures approaching 1000C, relevant to next-generation fission and fusion systems, where temperature changes in constituent response and residual-stress state become important. The overall aim is to establish a framework for SiC/SiC interphases by understanding processing, structure and properties. The aim is also to support the development of more durable high-temperature ceramic composites for nuclear and other extreme-environment applications such as aerospace.

Session IC

2026-11-03 10:00 ~ 11:30 | 306 | Chair: Seok-Woo Lee

[10:00~10:25] Micro plasticity probing through TEM in-situ straining

Takahito Ohmura (National Institute for Materials Science)

Type: Invited

Applications of TEM in-situ straining is presented as a method for directly linking mechanical behavior at the microscopic scale with the dynamic behavior of dislocations. Dislocation-grain boundary interaction was observed for various cases. In the case of ultra-fine grain steel, dislocations in grain interior can sink at the grain boundary with no remarkable pile-up¹). This behavior indicates a dislocation density dominance for the extra-hardening in the UFG steel. Dislocation-Dislocation interaction was also captured through TEM in-situ straining²). The dislocation reaction forms a stable grain boundary, which could be an elementary step of grain refining during plastic deformation. The critical stress for a slip transfer was estimated for $\Sigma 3$ boundary of pure Al³). The mechanism of the slip transfer can be modeled in a simple dislocation reaction generating a grain boundary dislocation. The conditions under which dislocation motion and twinning deformation compete are important for understanding the elementary processes of deformation mechanisms. In CoCrNi high-entropy alloys, the addition of Si suppresses dislocation motion and promotes twinning deformation⁴). In Mg alloys, twinning initiation at grain boundaries occurs at lower applied stress⁵). References¹) H. Li, et al., *Acta Mater.*, 206, (2021) 116621.2) H. Li, et al., *Scripta Mater.*, 207, (2022) 114275.3) S. Li, et al., *Scripta Mater.*, 221, (2022) 114953.4) C.H. Tai, et al., *Scripta Mater.*, 255, (2025) 116405.5) H. Somekawa, et al., *Scripta Mater.*, 260, (2025) 116575.

[10:25~10:50] Operando Correlated Mechanical Microscopy

Jeffrey M. Wheeler (Empa)

Type: Invited

Correlative mechanical microscopy enables rapid, statistical characterization of structure-property relationships within individual microstructural features. Mechanical microscopy advances nanoindentation from a localized one-dimensional probe into a two-dimensional imaging technique that resolves mechanical property variations across a microstructure with sub-micron resolution. By registering nanoindentation maps to electron backscatter diffraction (EBSD) and energy-dispersive X-ray spectroscopy (EDX) data on common coordinate axes, crystallographic and compositional parameters including phase, orientation, texture, misorientation, grain boundary character, and dislocation density are directly linked to local mechanical response. The relationship between local dislocation density and hardness is first investigated in pure nickel and iron. Annealed samples are bent to impose a controlled deformation gradient, then mapped by correlated EBSD and nanoindentation. Kernel average misorientation is converted to geometrically necessary dislocation (GND) density via Nye's relation, producing spatially resolved GND maps. Hardness correlates positively with GND density in proportion to the imposed bending strain. H/Er maps yield the strongest correlation by normalizing intergranular modulus

variations, and plastic deformation broadens the orientation dependence of hardness. These correlated datasets also allow the determination of the relationships between crystal orientation and mechanical response across a wide variety of crystal structures. The orientation dependence of indentation property distributions, governed by elastic and plastic anisotropy, is correlated with the operative slip systems within each structure. Finally, operando correlative mechanical microscopy extends these measurements to elevated temperatures. Orientation-hardness relationships are tracked as a function of temperature in the transition metal carbides TaC and HfC to monitor temperature-dependent changes in active slip systems. Measurements across a range of temperatures further yield the thermal activation parameters of each microstructural feature, providing statistical insight into the operative deformation mechanisms of individual phases.

[10:50~11:10] Challenges in in-situ small-scale mechanics of Iron oxides: From FIB-induced artefacts to high-temperature phase stability

Shreehard Sahu (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany), Gang Liu (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany), Vivek Devulapalli (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany), Saba Saood (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany), James P. Best (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany), Gerhard Dehm (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany), Anwesha Kanjilal (Max Planck Institute for Sustainable Materials, 40237, Düsseldorf, Germany)

Type: Oral

Hydrogen-based direct reduction of iron oxide pellets is limited by slow outward diffusion of reduction byproducts. Attrition-assisted reactors could promote controlled pellet breakdown, exposing unreduced regions to nascent hydrogen and improving kinetics. Designing such processes requires reliable mechanical property data for iron oxide feedstock—hematite, magnetite, and Wüstite—at room and reduction-relevant temperatures (~700 °C). This study elucidates micromechanical deformation in iron oxides, focusing on experimental challenges in in-situ small-scale testing. This includes focused ion beam (FIB)-induced artefacts in micropillar compression and elevated-temperature phase stability of hematite during in-situ scanning electron microscopy (SEM) testing. FIB-induced artefacts were examined by comparing micropillar compression of [0001]-oriented hematite single crystals prepared using Ga⁺-FIB and Xe⁺-plasma FIB (PFIB). Tests were performed in near dislocation-free and dislocation-engineered conditions, the latter produced by nano-scratching. In pristine hematite, Xe⁺-PFIB fabricated pillars exhibited ~65% higher critical resolved shear stress for rhombohedral twinning than Ga⁺-FIB fabricated counterparts. This is attributed to differences in ion beam–solid interaction volume, defect density, and chemical stability of implanted species. In contrast, no measurable strength difference was observed in dislocation-engineered hematite or Wüstite, where dislocation interactions and intrinsic cation vacancies act as pre-existing defects. During elevated-temperature testing, Ga⁺ FIB-fabricated hematite pillars developed cracks and pores at 400 °C due to surface reduction to magnetite, confirmed by Raman spectroscopy, whereas Xe⁺-PFIB milled pillars remained stable up to 600 °C. Nanoindentation up to 500 °C and post-mortem transmission electron microscopy revealed a 10–15 nm magnetite surface layer, attributed to oxygen-lean in-situ SEM vacuum conditions and possible electron-stimulated surface desorption. The findings demonstrate that FIB-induced artefacts in micromechanical testing

are governed by intrinsic defect concentration, providing practical guidance for ion-source selection in low-defect-density brittle oxides. Further, this work demonstrates for the first time the phase instability of oxide in the form of 'reduction' under high-temperature in-situ SEM testing.

[11:10~11:35] Mapping of phase and morphological changes in-situ under the local loading using a transparent diamond indenter

Alexey Useinov (HPPI RAS), Sergey Votyakov (HPPI RAS), Gulnaz Sultanova (HPPI RAS)

Type: Invited

A transparent diamond tip, featuring Berkovich pyramids formed on opposite ends, functions not only as an indenter but simultaneously as an optical objective. Such an indenter-objective allows for the investigation of the sample surface both prior to and during the material's contact with the tip, as well as the measurement of the contact area during indentation and the acquisition of a fully resolved optical image. This expanded set of capabilities enables the combination of mechanical testing with spectroscopic surface analysis techniques. Consequently, it has become possible to measure the stress-strain state of materials in situ using Raman and Brillouin spectroscopy. A dual-mode Raman mapping protocol through the transparent indenter was developed. The method combines rapid boundary mapping of indenter segments with prolonged spectral accumulation at selected coordinates. Verified on a GaN single crystal, this approach significantly reduces experimental duration. Depending on the magnification of the optical system, the field of view reaches 40–60 μm from the center of the indent, allowing for the simultaneous study of the contact, elastoplastic, and peripheral deformation zones within a single experiment. In monocrystalline silicon under loads of 100–1500 mN, a peak near 120 cm^{-1} revealed the metastable metallic Si-II phase extending beyond the calculated contact boundary. This demonstrates the transparent indenter's advantage over systems restricted strictly to the contact zone. Furthermore, photoluminescence mapping of a ruby single crystal (R1 and R2 lines) tracked plastic pile-ups on three segments, revealing characteristic size changes due to elastic recovery after unloading. Finally, this indenter-lens facilitates photoindentation by directing fully controlled illumination to loaded area. This simultaneously records mechanical responses, enabling advanced studies of photogenerated carrier influences on dislocation processes in photoplastic materials.

Session AS

2026-11-03 10:00 ~ 11:30 | 307 | Chair: Seung-Kyun Kang

[10:00~10:25] Chemical Local-Range Order Mediated Dislocation Nucleation in High-Entropy Alloys

Qian Zhang (Taiyuan University of Technology, China), Yakai Zhao (A*STAR, Singapore), Junwei Qiao (Taiyuan University of Technology, China), Upadrasta Ramamurty (Nanyang Technological University, Singapore)

Type: Invited

In high-entropy alloys, multiple elements tend to form chemical local ordered structures with varying degrees under the influence of mixing enthalpy. As the degree of order increases, short-range chemical ordered structures begin to emerge within the high-entropy alloys. When the degree of chemical order in the alloy reaches its upper limit, phase separation occurs, thereby forming ordered precipitated phases with distinct interfaces from the matrix. Additionally, changes in the local atomic environment within high-entropy alloys significantly affect the deformation behavior and mechanical properties of the alloys. In nanoindentation tests, chemical local ordered structures of different scales exert an extremely complex effect on the alloy and its microscopic yield behavior. The revelation of the evolution laws and characteristics of relevant mechanisms under the action of chemical local ordered structures can provide an important basis for the regulation of the characteristic structures and mechanical properties of such alloys.

[10:25~10:45] Indentation and micromechanical analysis of room-temperature plasticity in refractory compositionally complex alloys

Jin Wang (Forschungszentrum Jülich, Institute of Energy Materials and Devices (IMD-1)), Ruth Schwaiger (Forschungszentrum Jülich, Institute of Energy Materials and Devices (IMD-1))

Type: Oral

High-aluminum refractory compositionally complex alloys combine high-temperature strength with low density but often exhibit limited ductility at room temperature. In NbMoCrTiAl, the origin of the brittleness is difficult to isolate because the microstructure contains both an ordered B2 matrix and C14/A15 grain-boundary precipitates. In this work, correlative nanoindentation and site-specific micromechanical testing were used to separate their contributions by probing grain-boundary regions and single-crystalline matrix. Nanoindentation showed that grain-boundary precipitates increase hardness and the stress required for dislocation nucleation. Micropillars containing these precipitates also exhibit higher stress than single-crystalline pillars. Both types of pillars showed large compressive strains, but cracks initiated preferentially at matrix-precipitate interfaces and eventually caused failure. Although single-crystalline NbMoCrTiAl pillars reached compressive strains above 40%, deformation was governed mainly by crystallographic slip and cross-slip of screw dislocations. In the reference ductile disordered A2 TaNbHfZrTi, additional non-screw dislocations, high-order slip and kink-band formation were observed, indicating a broader range of deformation mechanisms associated with atomic disorder. Rapid laser thermal cycling was then used to suppress ordering and precipitation in NbMoCrTiAl.

Homogeneous nanoindentation hardness maps reflected the removal of the mechanically distinct precipitate-containing state. Micro-bending of the A2-indexed regions showed enhanced post-yield deformation compared with B2 microcantilevers, while retaining comparable yield stresses (>1.2 GPa). These results show that the room-temperature brittleness in NbMoCrTiAl arises from combined effects of grain-boundary precipitates and the limited deformation mechanism of the B2 matrix. Rapid thermal cycling suppresses the equilibrium formation of these phases, thereby retaining a disordered A2 state with improved room-temperature plasticity.

[10:45~11:10] Yield point phenomenon in Al-C thin films

Injong Oh (KAIST), Zion Lee (KAIST), Hojang Kim (KAIST), Gi-Dong Sim (KAIST)

Type: Invited

Aluminum (Al) offers advantages such as low residual stress, corrosion resistance, and strong oxidation resistance. However, its relatively low strength necessitates enhancement through microstructural modification via alloying, deposition control, or heat treatment. One promising approach is alloying Al with strong carbon-based nanomaterials, such as carbon nanotubes and graphene. Nevertheless, homogeneous dispersion of these nanomaterials within the Al matrix remains challenging due to the poor solubility between Al and carbon (C). In this study, we report the exceptional mechanical properties of aluminum-carbon (Al-C) thin films deposited by multi-source co-sputtering. A high-throughput combinatorial approach was employed to investigate the mechanical and electrical properties of compositionally graded Al-C films. Hardness increased with carbon addition, albeit at the expense of electrical conductivity. Rapid screening revealed that regions containing 6.4 at% C achieved a favorable balance between hardness (2.8 GPa) and conductivity ($142 \Omega \cdot \text{nm}$). Micro-tensile experiments on freestanding Al, Al-C 6.4 at%, and Al-C 10.3 at% films were conducted to evaluate tensile properties and elucidate the strengthening mechanism. Both Al-C 6.4 at% and 10.3 at% films exhibited markedly higher yield stresses exceeding 300 MPa while retaining ductility. In both cases, plastic flow initiated at an upper yield point, followed by a stress drop to a lower flow stress. The magnitude of the stress drop was $\sim 5\%$ for Al-C 6.4 at% and $>10\%$ for Al-C 10.3 at%. This distinct yield-drop behavior resembles that of low-carbon steel, where it is attributed to the formation of a "Cottrell atmosphere." Uniaxial tensile tests with repeated unloading-aging-reloading cycles confirmed that the yield drop intensified with longer aging times and higher temperatures. Comprehensive microstructural analysis demonstrated that the formation of a Cottrell atmosphere is the primary deformation mechanism in Al-C thin films.

[11:10~11:30] Micro-/nanoscale plasticity and super-elongation in single-crystalline high-entropy alloy pillars

Qian Zhang (The University of Hong Kong), Xiaoyan Li (Tsinghua University)

Type: Oral

The rapid development of micro-/nanodevices has created a growing demand for small-volume structural materials that combine high strength, ductility, and mechanical reliability. High-entropy alloys (HEAs), also known as multi-principal-element alloys (MPEAs), have demonstrated excellent mechanical performance and

offer a promising materials platform. However, their mechanical response and underlying deformation mechanisms at micro- and nanoscale remain insufficiently understood. Here, we present a systematic investigation of the mechanical behavior of single-crystalline HEA micro-/nanopillars by integrating in situ micro-/nanomechanics, microstructural characterization, large-scale molecular dynamics simulations and theoretical modelling. We first establish orientation-dependent size effects in representative FCC CoCrFeNi and BCC AlCoCrFeNi HEA micro-/nanopillars, revealing how crystal structure and crystallographic orientation govern the activation and competition of dislocation slip, deformation twinning, and dislocation interactions. Building on this mechanistic framework, we further demonstrate exceptional room-temperature tensile ductility in single-crystalline γ -oriented CoCrFeNi nanopillars, which exhibit uniform elongation up to ~110% while sustaining high flow stress of 0.6–1.0 GPa. This unusual nanoscale super-elongation arises from the spatially coordinated and sequential activation of deformation twinning and dislocation slip, which effectively promotes deformation delocalization and delays necking failure. The unique plasticity is rooted in atomic-scale compositional heterogeneity in HEAs, which induces broad variations in generalized stacking fault energy and thereby enables extensive dislocation and twinning activities. These findings provide a quantitative, mechanism-based understanding of micro-/nanoscale mechanical behaviors in HEAs, offering guidance for designing strong, ductile, and mechanically reliable metallic nanomaterials for next-generation micro/nano-devices.

Session SA

2026-11-03 10:00 ~ 11:30 | 305 | Chair: Ryuta Kasada

[10:00~10:25] A Combined Experimental-Computational Study of the Compression of Nanoporous Gold Nanoparticles

Ben Engelman (Faculty of Mechanical Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel), Santhosh Mathesan (Faculty of Mechanical Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel), Tatyana Fedyaeva (Department of Materials Science and Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel), Anuj Bisht (Department of Materials Science and Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel), Eugen Rabkin (Department of Materials Science and Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel), Dan Mordehai (Faculty of Mechanical Engineering, Technion-Israel Institute of Technology, Haifa 3200003, Israel)

Type: Invited

Quantifying the mechanical properties of nanoporous metallic structures presents a significant challenge due to the complex interplay between intricate ligament architectures, high surface-to-volume ratios, and localized deformation mechanisms. While computational studies are steadily progressing to uncover this complex interplay, achieving precise experimental quantification remains a major hurdle. In this talk, we present a novel methodology designed to overcome these characterization complexities, focused on sub-micrometer scale, hemispherical nanoporous gold (NPG) nanoparticles fabricated via a combined dewetting and dealloying approach. Under compression, the experimental load-displacement behavior exhibits a distinctive linear regime followed by a prominent rise in slope. To accurately quantify and elucidate the underlying physical phenomena, large-scale molecular dynamics (MD) simulations were conducted, systematically varying nanoparticle size, porosity, and ligament diameter. The computational results show excellent agreement with experimentally observed features of the load-displacement curves. Our analysis reveals that plastic densification is highly inhomogeneous and localized directly beneath the punch. This behavior is strongly correlated with the mean-free path of dislocations and their subsequent depletion at free surfaces. Furthermore, the observed slope increase is explicitly attributed to the mechanical interaction between the evolving densification zone and the underlying rigid substrate. Finally, we propose a comprehensive model for inhomogeneous deformation that enables the accurate evaluation of contact stresses, establishing a powerful framework for interpreting the nanoindentation response of porous nanostructures.

[10:25~10:50] Defect Dynamics Modeling of Incipient Plasticity under Nanoindentation: From Single Crystals to Polycrystalline Metals

ILL RYU (Seoul National University)

Type: Invited

Nanoindentation provides a unique experimental platform for probing the onset of plasticity and the underlying defect mechanisms at submicron length scales. However, interpreting indentation responses—

including pop-in events, indentation size effects, and microstructural confinement—requires computational models capable of directly resolving defect evolution beneath the indenter. In this talk, I present a defect dynamics modeling framework that concurrently couples three-dimensional discrete dislocation dynamics with the finite element method to bridge microscopic defect activities and macroscopic indentation responses. The framework first elucidates the origin of incipient plasticity in single crystals by capturing the transition from source-controlled plasticity to dislocation nucleation as the indentation length scale decreases. The simulations further reproduce experimentally observed dislocation structures, including prismatic loop formation through successive cross-slip. The model is subsequently validated through combined nanoindentation experiments and simulations of potassium-doped tungsten, revealing how nanoscale bubbles modify local stress fields and promote dislocation nucleation, thereby altering pop-in statistics and yield behavior. Finally, the framework is extended to polycrystalline materials to investigate how grain-boundary proximity governs geometrically necessary dislocation accumulation, slip transmission, and surface nucleation avalanches under nanoindentation. These studies demonstrate that defect dynamics modeling provides a physically interpretable framework for quantitatively connecting nanoindentation measurements with the underlying evolution of crystalline defects, enabling predictive characterization and design of advanced structural materials.

[10:50~11:10] Phase-field simulation of indentation-induced fracture in brittle materials

Xu Long (Northwestern Polytechnical University), Ahmad Muhammad Usman (Northwestern Polytechnical University), Percy M. Iyela (Northwestern Polytechnical University)

Type: Oral

Nanoindentation is widely used to characterize the mechanical behavior and fracture resistance of brittle materials at the microscopic scale. However, accurately predicting crack initiation and propagation in brittle materials during indentation remains challenging using conventional finite element methods due to the need for predefined crack paths. In this study, a phase-field fracture model is proposed and implemented through the user-defined material subroutine in Abaqus to simulate nanoindentation-induced fracture in soda-lime glass. Different types of indenters are used to investigate the indentation response, and a parametric study is performed to evaluate the influence of the phase-field length scale parameter and fracture energy on the applied load–penetration depth response and cracking behaviour. The numerical model is developed using a coupled displacement–temperature formulation, where the phase-field variable is represented through the thermal degree of freedom. Mesh refinement is carried out in the contact region to accurately capture crack initiation and propagation while maintaining computational efficiency. The simulated applied load–penetration depth curves and phase-field contours are analyzed to identify the optimal fracture parameters that provide stable crack evolution and realistic fracture behavior. The study demonstrates the capability of the phase-field approach to predict indentation-induced fracture without predefined crack paths and provides calibrated modeling parameters for future investigations of brittle materials.

[11:10~11:35] AI-based Indentation–Tensile Conversion Considering Measurement Uncertainty

Jong-hyoung Kim (Pukyong National University), Si Hyun Park (Pukyong National University), Hyun-Wook Cho (Pukyong National University), Im-Deok Kim (Seoul National University), Seung-Kyun Kang (Seoul National University), Joost J. Vlassak (Harvard University)

Type: Invited

Instrumented indentation testing enables the quantitative evaluation of local mechanical behavior at micro- and nano-scales. With recent advances in high-speed and automated testing technologies, indentation mapping has enabled multi-scale characterization of materials. This technique provides not only local mechanical properties but also insights into microstructural distribution and heterogeneity, expanding the potential of indentation testing as a next-generation materials characterization tool. Moreover, when conventional tensile testing is difficult due to specimen size limitations or geometric constraints, indentation testing can serve as a useful non-destructive or minimally destructive alternative. Recent advances in computational power and data analysis techniques have stimulated increasing efforts to learn the complex nonlinear relationship between indentation responses and tensile properties using data-driven approaches. In particular, artificial neural networks have been widely explored to predict tensile properties, such as yield strength, ultimate tensile strength, and strain-hardening behavior, from indentation load–displacement curves. However, neural network models for indentation–tensile property conversion are sensitive to measurement uncertainty and noise in indentation data, where small experimental errors may cause significant deviations in predicted results. Furthermore, discrepancies between idealized simulation data and real experimental data—arising from differences in boundary conditions, simplified material models, and measurement errors—can degrade model generalization. In this study, an artificial neural network model for indentation–tensile property conversion was developed using a hybrid learning strategy that combines experimental and simulation data. To improve robustness against measurement uncertainty, perturbations representing potential experimental variability were introduced into simulation-based indentation data for data augmentation. As a result, the model trained with noise-aware data exhibited more robust and stable predictions when applied to experimental indentation data. The proposed methodology improves the reliability of indentation-based tensile property prediction and highlights the applicability and limitations of AI-based mechanical property estimation.

Session IC

2026-11-03 14:00 ~ 15:10 | 306 | Chair: Kyeongjae Jeong

[14:00~14:25] Microscale Fatigue Damage Evolution in Wire-Arc Additive Manufactured Nickel-Aluminum Bronze Revealed by In Situ Microcantilever Testing

Faizan Hijazi (Johns Hopkins University), Mostafa M. Omar (Johns Hopkins University), Mo-Rigen He (Johns Hopkins University), Jaafar A. El-Awady (Johns Hopkins University)

Type: Invited

Wire-arc additively manufactured nickel-aluminum bronze (WAAM-NAB) is increasingly considered for large-scale marine components, yet the microstructural mechanisms governing fatigue-crack initiation and early propagation remain insufficiently understood. In this work, in situ scanning electron microscopy fatigue testing of focused-ion-beam-fabricated microcantilevers was combined with electron backscatter diffraction, high-resolution backscattered-electron imaging, and site-specific transmission electron microscopy to examine cyclic damage evolution in as-fabricated WAAM-NAB. The microcantilevers were subjected to fully reversed cyclic bending, with surface deformation and crack development monitored in real time. Cyclic deformation localized along favorably oriented {111} planes within the α -Cu matrix, producing surface extrusions and microcracks that subsequently developed into dominant fatigue cracks. Within the α -Cu regions, cracks propagated predominantly along crystallographic {111} planes. Their paths were repeatedly interrupted upon encountering the κ -precipitate-rich interdendritic-zone network, where cracks exhibited apparent local arrest, deflection, and increased tortuosity while interacting with κ II and κ III precipitates. Post-fatigue transmission electron microscopy further revealed stacking faults and deformation nanotwins aligned with {111} planes near crack tips, along secondary microcracks, and in regions without an observed surface crack. The spatial extent and crystallographic distribution of these nanotwins indicate that their formation is not controlled exclusively by the immediate crack-tip stress field. Instead, the observations support a fatigue-damage sequence in which repeated Shockley-partial activity and stacking-fault accumulation contribute to nanotwin formation and subsurface strain localization, facilitating extrusion development and microcrack nucleation. These results provide a coupled mechanistic framework in which stacking-fault and nanotwin-associated localization governs fatigue damage within the α -Cu matrix, while the interdendritic-zone architecture controls subsequent crack-path evolution.

[14:25~14:45] A Novel In Situ TEM Platform for Nanoindentation, Multi-Field Coupling, and Atomic-Scale Observation

Dr. Jixiang Cai (Beijing University of Technology)

Type: Oral

Understanding the deformation and functional responses of materials under realistic working conditions requires simultaneous control of external stimuli and direct observation of structural evolution at the atomic scale. Here, we present a highly integrated in situ TEM platform combining mechanical loading, heating,

electrical biasing, and orthogonal double tilt, with particular emphasis on nanoscale indentation loading. The platform is based on micro piezoelectric ceramic actuator and dedicated designs of MEMS chips. The mechanical module provides more than 4 μm displacement with a resolution down to 0.1 nm and supports multiple loading modes, including tension, compression, nanoindentation, and bending. A truss-like MEMS heater enables heating from room temperature to 1200 °C with ± 1 °C accuracy, while dedicated electrical chips support bias application together with pA-level current and μV -level voltage measurements. The actuator and MEMS chips are integrated into a rigid cartridge connected through a flexible printed circuit to an external control unit. During mechanical, thermal, electrical, or coupled loading, the specimen can be tilted about two orthogonal axes over $\pm 15^\circ$, enabling continuous crystallographic alignment for high-resolution imaging. The platform has been applied to in situ nanoindentation studies of grain-boundary thinning in nanopolycrystalline diamond[1], atomic-scale studies of grain-boundary sliding in Pt bicrystals[2], and high-temperature deformation and fracture in W[3]. These demonstrations verify stable mechanical actuation and atomic-resolution observation during dynamic loading. This platform provides a versatile route for in situ TEM nanoindentation and coupled-field experiments, enabling direct correlation of local deformation, defect evolution, phase transformation, and electrical response with atomic-scale structure.

[14:45~15:10] Recent Innovation in In-situ Extreme Mechanics at the Micro and Nanoscale

Nicholas Randall (Alemnis AG)

Type: Invited

In situ SEM micro- and nanomechanical testing is an indispensable technique for materials design and fundamental mechanics research. New protocols and geometries beyond traditional nanoindentation now enable detailed studies of microstructure–property relationships, intrinsic material behavior including orientation dependence and plasticity, fracture dynamics, and the performance of micro-3D-printed metamaterials. Owing to its versatility, SEM-based micromechanics contributes to fields such as thin films and coatings, metallurgy, glasses and ceramics, semiconductors, biomechanics, and architected materials. Its key advantages are precise positioning, high stability, and the ability to combine mechanical testing with direct imaging or EBSD-based correlative analysis. Nanoindentation was traditionally restricted to room temperature and quasi-static strain rates of 10^{-5} to 10^{-2} s^{-1} . Recent advances have extended testing to temperatures from -150 to 1150 °C and strain rates up to 10^5 s^{-1} . Current efforts increasingly focus on combining variable temperature conditions with high strain rate testing in a single experimental framework. This talk highlights nanoindentation under such coupled conditions, emphasizing technological and methodological advances as well as experimental challenges related to stability, deformation control, and reliable data acquisition under non-ambient conditions. A customized piezoelectric in situ nanomechanical test setup will also be presented, enabling the study of rate-dependent hardness at strain rates from 10^1 to 10^5 s^{-1} . For the first time, constant indentation strain rates up to 10^5 s^{-1} can be achieved, overcoming limitations of conventional macro- and microscale testing. Combined with post-deformation microstructural analysis, this approach provides new insight into rate-dependent deformation mechanisms at varying temperatures. These developments open

previously inaccessible parameter spaces and support the design of next-generation materials for extreme environments.

Session AS

2026-11-03 14:00 ~ 15:10 | 307 | Chair: Siyuan Wei

[14:00~14:25] High-throughput indentation characterization of additively manufactured metals: location dependence and Tabor equation

Yinmin (Morris) Wang (University of California Los Angeles (USA))

Type: Invited

Indentation is an efficient, high-throughput tool for mapping location-dependent mechanical properties in additively manufactured (AM) metals, serving as critical feedback for machine learning-driven process optimization. However, directly converting hardness (H) to yield strength (σ_y) using the standard Tabor relation ($\sigma_y = H/C$ with $C=3$) often introduces significant errors in AM alloys. In this work, we systematically evaluate the hardness–strength scaling across several representative FCC and BCC alloys fabricated via laser powder bed fusion (L-PBF) and laser directed energy deposition (L-DED). We demonstrate how process-induced features, including hierarchical cellular structures, crystallographic texture, and residual stress fields, cause C to deviate markedly from 3. Finally, we propose calibrated modification factors to restore the fidelity of high-throughput indentation for rapid mechanical property screening.

[14:25~14:50] Effects of Residual Elements in Martensitic Steels Using Nanoindentation-Based Approaches

Eloho Okotete (Karlsruhe Institute of Technology), Subin Lee (Karlsruhe Institute of Technology), Christoph Kirchlechner (Karlsruhe Institute of Technology)

Type: Invited

The steelmaking industry is a major contributor to greenhouse gas emissions because conventional production routes generate substantial CO₂. Major stakeholders in the global steel industry are seeking to reduce these emissions by switching to electric arc furnaces and using recycled steel scrap as feedstock, thereby making steel production more sustainable. A key obstacle to this transition is the presence of potentially harmful residual impurities in steel scrap, which may lead to a loss of mechanical properties. Studies have shown that P in ferritic steel grades can promote segregation-induced intergranular fracture and ductile-to-brittle transitions. However, other impurities have been investigated only sparingly, and their impact on industry-relevant martensitic steels remains largely unexplored. In this work, we aim to elucidate the local effects of residual impurities, including Cu, Sn, Sb, As, and P, on martensitic steels using nanoindentation and related micromechanical techniques. The talk will show how impurity-induced changes in the hierarchical martensitic microstructure affect the mechanical properties of steel. Initial nanoindentation measurements indicate that the impurities have only a marginal effect on hardness, largely independent of the processing route. Tempering, however, reveals more pronounced differences, with Sn causing substantial hardness degradation compared with the reference sample and the other residual-containing compositions. Micro-compression experiments further show that Sn and P reduce the yield strength of as-quenched martensite, while Sn remains the dominant

source of degradation after tempering. These changes in mechanical properties indicate that the martensitic microstructure is affected by the residual elements, particularly in the tempered state. Initial results from experiments on the damage resistance of the affected steels, together with the remaining findings, will also be presented in the talk.

[14:50~15:10] Characterization of Pseudoelastic Behavior and Functional Fatigue in NiTi Shape Memory Alloys via Nanoindentation

Jaroslav Cech (*Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering*)

Type: Oral

Shape memory alloys (SMAs) are characterized by their capacity for large, reversible deformation, exceeding the elastic limits of conventional metals. This unique property results from a reversible phase transformation between martensite and austenite. Nickel-titanium alloy (NiTi or Nitinol) is the most prominent representative of SMAs with extensive use in medicine, robotics, aerospace, etc. Presented study investigates the response of NiTi alloys to nanoindentation loading, a critical technique when material volume is too limited for traditional mechanical (e.g., tensile) testing or the characterization of local properties is required. The specimens were prepared via spark plasma sintering and cold rolling, with various heat treatments to adjust transformation temperatures. At room temperature, these alloys exhibited pseudoelastic (superelastic) behavior. The results show that spherical indenters, thanks to their not self-similar shape and progressive increase of deformation with penetration depth, are more convenient for SMA characterization than commonly used Berkovich indenter. At shallow depths, the response remains elastic or pseudoelastic; however, exceeding the pseudoelastic limit at higher loads leads to irreversible plastic deformation. Thus, the materials pseudoelastic capacity and indentation representative stress-strain curves can be evaluated by spherical indentation. To assess functional fatigue (i.e., damage induced by cyclic repetition of the shape memory effect), multicycle indentation tests were conducted at various loads. The results showed a strong correlation between uniaxial cyclic tests and indentation data. This confirms that nanoindentation, despite its complex deformation field, is a viable and effective tool for characterizing the pseudoelastic capabilities and fatigue resistance of shape memory alloys.

Session SA

2026-11-03 14:00 ~ 15:10 | 305 | Chair: Won-Seok Ko

[14:00~14:25] A machine learning perspective on the inverse indentation problem

Quan Jiao (*Liaoning Academy of Materials*)

Type: Invited

The inverse analysis of indentation curves, aimed at extracting the stress-strain curve of a material, has been under intense development for decades, with progress relying mainly on the use of analytical expressions derived from small data sets. Here, we take a fresh, data-driven perspective to this classic problem, leveraging machine learning techniques to advance indentation technology. Using a neural network (NN), we efficiently assess uniqueness and identify materials that have indistinguishable indentation responses without the need for complex, domain knowledge based algorithms. We then demonstrate that inclusion of the residual imprint information resolves the non-uniqueness problem. We show that the elasto-plastic properties of a material can be learned directly from indentation pile-up. Notably, an accurate stress-strain curve can be derived using solely the applied indentation load and pile-up information, thereby eliminating the need for depth-sensing. We also present a systematic analysis of the machine learning model, covering important aspects such as prediction performance, sensitivity, feature selection, and permutation importance, providing insight for model development and evaluation. This study introduces and provides the groundwork of a machine-learning-based profilometry-informed indentation inversion (PI3) technique. It showcases the potential of machine learning as a transformative alternative when analytical solutions are difficult or impossible to obtain.

[14:25~14:45] Nanoindentation-Derived Strain-Rate Sensitivity for Dislocation-Informed Constitutive Modeling and AI-Assisted Prediction

Xiaochuan Sun (*Kobe University*), Yue Liu (*Shanghai Jiao Tong University*)

Type: Oral

Nanoindentation provides localized mechanical responses from small material volumes, where the measured load–displacement and hardness responses can vary with indentation rate, loading position, and crystallographic orientation. From these rate-dependent responses, local strain-rate sensitivity (SRS) can be extracted and used as a quantitative indicator of thermally activated plasticity. Since SRS is closely associated with activation volume, dislocation motion, defect accumulation, and other microstructure-mediated deformation processes, it offers a critical pathway for inferring dynamic defect evolution from indentation-derived mechanical information. With improved indentation analysis, local SRS can now be captured with sufficient reliability to serve as a mechanistic descriptor rather than only an empirical fitting parameter. To directly connect nanoindentation-derived SRS with microstructural evolution, we developed a strain-rate-dependent constitutive framework based on crystal plasticity. The model interprets SRS by separating the contributions from dislocation accumulation and evolution, which alter the internal resistance to plastic flow, and thermally activated dislocation motion, which controls rate-dependent slip kinetics. This provides a

constitutive basis for linking indentation-scale mechanical responses to underlying defect mechanisms. The framework is applied to two independent indentation scenarios. In polycrystalline steel, crystal-plasticity finite element nanoindentation distinguishes intragranular deformation from grain-boundary-mediated response, showing that grain boundaries can promote early dislocation nucleation while later acting as barriers to plastic flow. In anisotropic energetic crystals, the model reproduces orientation-dependent indentation responses and provides local dislocation-density evolution beneath the indenter, revealing how different slip systems govern the measured nanoscale mechanical behavior. Finally, these constitutive links between SRS and microstructure are extended toward mechanics-informed AI modeling. By coupling strain history, strain rate, stress response, and internal variables such as dislocation density and twinning evolution, the AI framework learns the relationship from SRS-related mechanical signatures to microstructural evolution. This work demonstrates a route for transforming nanoindentation-derived SRS into interpretable constitutive and AI-assisted descriptions of rate-sensitive materials.

[14:45~15:05] Data-Driven Analysis and Machine Learning-Based Property Prediction for Ni- and Co-Based Superalloys

Tae Joo Lee (*Pusan National University*), Yoon Suk Choi (*Pusan National University*)

Type: Oral

Superalloys are critical structural materials utilized in high-temperature and high-pressure environments, where precise alloy composition and process design are essential to achieve target mechanical properties. However, conventional experiment-driven approaches face inherent limitations in design efficiency and screening speed due to the prohibitive costs associated with actual alloy fabrication and long-term high-temperature testing. Consequently, recent research has actively focused on accelerating new alloy exploration and process optimization by leveraging artificial intelligence models with limited experimental datasets. In this study, we constructed a comprehensive database of high-temperature compressive properties for Ni-based and Co-based superalloys, incorporating key features such as chemical composition and microstructure. Using techniques like data distribution and correlation analyses, we investigated the relationships and influences of each feature on material properties, validating their consistency with metallurgical domain knowledge. Furthermore, various machine learning models were developed and optimized for the constructed dataset. Through a comparative analysis, the optimal prediction model was selected. We then examined the prediction results to identify specific regions where prediction errors were concentrated, analyze their underlying causes, and determine the individual impact of each feature on property prediction. Finally, the feasibility of utilizing this approach for data-driven alloy design was evaluated.

Session GA

2026-11-03 15:30 ~ 17:10 | 306 | Chair: Nichola Randall

[15:30~15:55] Statistical aspects of the elastic-plastic transition in metallic glasses and high entropy alloys probed using nanoindentation

Upadrasta Ramamurty (Nanyang Technological University)

Type: Invited

The load at which a discrete displacement burst or pop-in occurs during nanoindentation with a spherical indenter tip is a measure of the transition from elastic to elasto-plastic deformation. By experimentally measuring the first pop-in loads, P_1 , and assuming that their statistical distribution is caused by the thermal fluctuations affecting the nucleation rate of the incipient plastic events, the activation volumes, L , for the elastic-plastic transition in crystals can be determined. In this presentation, I will provide an overview of our efforts in this direction with the results on amorphous alloys, high entropy alloy, molecular crystals, and ceramics. New insights we gained through these experiments and analyses will be discussed.

[15:55~16:15] From Nanoindentation to 4D-STEM: The Structural Origin of Elastic Fluctuations in Metallic Glasses

Reza Rashidi (Federal Institute of Materials Research and Testing (BAM), Berlin, Germany), Birte Riechers (Federal Institute of Materials Research and Testing (BAM), Berlin, Germany), Robert Maass (Federal Institute of Materials Research and Testing (BAM), Berlin, Germany)

Type: Oral

Metallic glasses (MGs) are amorphous alloys that lack the periodic order of their crystalline counterparts, a structural distinction that might suggest an otherwise uniform, featureless solid. Nanomechanical testing tells a different story. It uncovers a hierarchical elastic microstructure whose characteristic length scale (ξ) ranges from a few nanometers in sputter-quenched thin films, to ~ 100 nm fluctuations in cast bulk MGs, up to tens of micrometers in additively manufactured MGs. The small ξ observed in thin films aligns well with atomistic model glasses, yet the origin of the ~ 100 nm scale and larger in bulk MGs remains unresolved. Our earlier work ruled out chemical composition as the source of this 100 nm microstructure (Mater. Des. 229 (2023) 111929), pointing instead to processing history as the dominant factor governing its formation. Across a range of cast geometries, we find via nanoindentation that ξ grows from the sample core toward the outer shell, whereas thermal relaxation smoothens these internal gradients and dampens the elastic fluctuations with the strongest recovery in the stiffest regions (Scr. Mater. 255 (2025) 116380). To connect these mesoscale mechanical signatures to their structural origin, we used four-dimensional scanning transmission electron microscopy (4D-STEM) to map local atomic strain. Local diffraction patterns reveal systematic alternation between positive and negative volumetric strains, and power-spectrum analysis of this strain field isolates a dominant length scale that matches the nanoindentation measurements (Acta Mater. 308 (2026) 121982). Together, these results identify the elastic microstructure as a structural fingerprint of the cooling-induced constraints and residual

stresses set during solidification, offering an atomic-scale explanation for the fluctuations observed in nanoscale contact mechanics.

[16:15~16:40] Effect of cryo-thermal cycling-induced structural state modulation on the pressure-sensitivity of a bulk metallic glass

Shantanu Jain (Indian Institute of Technology Delhi), Naresh V. Datla (Indian Institute of Technology Delhi), Long Zhang (Beijing Institute of Technology, Zhuhai), R. Lakshmi Narayan (Indian Institute of Technology Delhi), Upadrasta Ramamurty (Nanyang Technological University, Singapore)

Type: Invited

Constraint factor, C , defined as the hardness, H , and yield strength, σ_y , ratio is used as an indirect measure of pressure sensitivity. The influence of cryo-thermal cycling (CTC)-induced structural state change of a Zr-based bulk metallic glass (BMG) on C , is studied. CTC led to non-monotonic variations in relaxation enthalpy, ΔH_{rel} , implying structural changes in BMG. An inverse correlation between ΔH_{rel} and σ_y and H was observed, while a higher ΔH_{rel} results in higher plastic strain in indentation and compression. For structural states with ΔH_{rel} in the range of 0.82-8.48 J/g, C increases from 3.19 to 3.34 with increasing ΔH_{rel} , indicating enhanced pressure sensitivity. In structural states where $\Delta H_{rel} > 10$ J/g, C is

[16:40~17:00] Nanoindentation reveals local anelasticity in metallic glasses

Silvia Pomes (Federal Institute of Materials Research and Testing), Birte Riechers (Federal Institute of Materials Research and Testing), Reza Rashidi (Federal Institute of Materials Research and Testing), Takahito Ohmura (National Institute for Materials Science), Robert Maass (Federal Institute of Materials Research and Testing)

Type: Oral

Nanoindentation provides a powerful approach for probing early-stage deformation mechanisms and time-dependent structural mechanisms in metallic glasses, offering unique sensitivity to localized changes within the amorphous matrix. In this study, several nanoindentation protocols are implemented to investigate how mechanical history and time-dependent relaxation influence incipient plasticity. The results suggest that low load nanoindentation cycling promotes localized structural rearrangements, which gradually recover once the applied stress is removed and sufficient waiting time is allowed. We demonstrate how this time-dependent response is the origin of pressure-induced hardening. Beyond providing insight into the reversible nature of stress-assisted structural evolution in metallic glasses, this work highlights the exceptional potential of nanoindentation as a sensitive tool for probing spatially-resolved anelasticity and other related phenomena in amorphous materials.

[17:00~17:25] Electron-Beam-Driven In-Situ Modification of Small Scale Plasticity in Oxide Ceramics

In-Suk Choi (Department of Materials Science and Engineering, Seoul National University)

Type: Invited

Electron-beam-induced electronic excitation is emerging as a powerful route for accessing non-equilibrium pathways in oxide ceramics, enabling new opportunities to control deformation mechanisms and nanostructure formation beyond conventional thermal processing. By altering electronic states, electron-matter interactions can fundamentally change mechanical behavior across both amorphous and crystalline systems, allowing controlled nanoscale structural evolution. In amorphous silica, focused low-voltage electron beam irradiation induces athermal viscoplastic deformation and densification at room temperature during in situ nanoscale compression, enabling localized shaping without external heating. Electron irradiation further promotes solid-state amorphization of crystalline α -quartz under ambient conditions. This behavior arises from beam-induced delocalized electrons that screen interatomic repulsion and lower the energy barrier for atomic rearrangement. These effects further extend to both twinning- and dislocation-mediated plasticity. In sapphire, in situ compression experiments show reduced critical resolved shear stress and activation of twinning, consistent with density functional theory predictions of lowered twin-formation barriers. In single-crystalline MgO, combined in situ testing, post-deformation TEM, and modeling reveal enhanced dislocation nucleation and glide, enabling slip systems otherwise inactive at room temperature and introducing beam-intensity-dependent deformation behavior. Collectively, these results establish electronic-state manipulation via electron-beam excitation as a unified strategy for tuning deformation mechanisms from amorphous flow to twinning and dislocation plasticity offering a pathway toward defect-engineered and mechanically robust ceramic materials.

Session AS

2026-11-03 15:30 ~ 17:10 | 307 | Chair: Subin Lee

[15:30~15:55] Relationship between serrated load-displacement curves and dislocation structures underneath indents in Al-Mg alloys

Yasuhito Kawahara (Kyushu University), Hidenari Takagi (Nihon University), Takahito Ohmura (National Institute for Material Science), Shigeto Yamasaki (Kyushu University), Masaki Tanaka (Kyushu University), Satoshi Hata (Kyushu University)

Type: Invited

Al-Mg alloys are typical solid-solution-hardened alloys that exhibit serrated load-displacement curves during indentation deformation. This serrated deformation behavior has been explained by the formation and propagation of deformation bands at the micrometer scale, possibly originating from the pinning and depinning of dislocations by Mg atoms at the atomic scale. However, the displacement bursts observed during indentation are several hundred nanometers, which are several orders of magnitude larger than those expected for single-dislocation events, indicating that the collective motion of dislocation groups is the underlying mechanism. In this study, dislocation structures beneath the indents were characterized by transmission electron microscopy (TEM) and correlated with the load-displacement curves obtained from indentation tests, aiming to bridge the understanding of serrated deformation behavior between the atomic and micrometer scales. An Al-2 at.% Mg fully solid-solution alloy was fabricated, and the grain interiors were selectively deformed by micro-indentation using a Vickers indenter. TEM specimens were then lifted out from the edges of the indents using a Helios Xe plasma FIB and characterized using a JEM-ARM300F2 operated at 200 kV. Serrated load-displacement curves were obtained from indentation tests in Al-Mg alloys, where the displacement bursts gradually increased with increasing applied load. TEM investigations revealed the formation of low-angle tilt grain boundaries (LATGBs) extending from the edges of the indents, which were attributed to the rearrangement of edge dislocations introduced by indentation deformation. Compositional analysis further revealed the enrichment of Mg along the LATGBs, suggesting that the LATGBs migrated while collecting solute Mg atoms. In this presentation, the displacement bursts and load fluctuations will be discussed based on TEM-based analyses of dislocation structures beneath the indents.

[15:55~16:20] Interface-mediated plasticity in CoCrFeNi multi-principal element alloys revealed by nanoindentation-based micromechanics

Siyuan Wei (IMRE, A*star)

Type: Invited

Microstructural interfaces play a central role in governing the strength, strain-rate sensitivity, and environmental resistance of face-centered cubic multi-principal element alloys, yet their individual contributions are difficult to decouple in bulk-scale testing. In this talk, I will discuss how nanoindentation-based micromechanical testing provides a site-specific platform to isolate the role of grain boundaries and twin boundaries in the plastic

deformation of equiatomic CoCrFeNi alloy. By selectively fabricating and compressing single-crystal, bi-crystal, and twinned-crystal micropillars with controlled crystallographic orientations, we first show that the strain-rate sensitivity and plastic flow behavior of CoCrFeNi are strongly dependent on activated slip systems and their interactions with interfaces. High-angle grain boundaries act as strong barriers to dislocation motion, leading to deformation governed by the harder grain, whereas coherent twin boundaries permit partial slip transmission and produce an averaged mechanical response. These results suggest that the scattered strain-rate sensitivity values reported for FCC high-entropy alloys may partly originate from varying annealing twin fractions. Building on this framework, we further examine hydrogen-affected deformation by compressing twinned CoCrFeNi micropillars before and after hydrogen charging. By activating orientation-dependent twin boundary–dislocation interactions, we show that hydrogen increases the barrier for slip transmission across coherent twin boundaries, resulting in enhanced yield strength and orientation-dependent strain hardening. The results reveal a hydrogen-induced twin-boundary passivation mechanism, in which twin boundaries modulate dislocation storage and hardening under hydrogen exposure. Together, these studies demonstrate the power of indentation-based micromechanics for resolving interface-specific deformation mechanisms in complex alloys, providing insights that are difficult to obtain from conventional bulk testing alone.

[16:20~16:40] Indentation Energy Method for In-Situ Evaluation of Multiple Post-Weld Heat Treatment Effects in Pressure Vessel Welds

SunGuanghua (*China University of Petroleum (East China)*)

Type: Oral

This study evaluates the feasibility of using indentation testing to assess post-weld heat treatment (PWHT) effectiveness in a 12Cr2Mo1VR circumferential weld of a hot high-pressure separator. Local tensile properties and residual stresses were examined in the vessel body and companion production test coupons after dehydrogenation heat treatment (DHT), stress relief annealing (SRA), and final heat treatment (FHT). Orthogonal Knoop indentation was used for residual stress measurement, while spherical indentation was used for local strength evaluation and validated by selected tensile tests. The results show that, after SRA, the local strength of the circumferential welded joint changes only slightly, whereas the residual stress decreases substantially and becomes more uniformly distributed. After FHT, both yield strength and tensile strength decrease markedly in the weld metal and heat-affected zone, the strength distribution across the joint becomes more uniform, and the residual stress is further reduced to a low level. The welded production test coupon shows some local differences from the vessel body, but it can still characterize the overall strength evolution caused by heat treatment. Finite element analysis further indicates that, under the present spherical indenter size with a radius of 0.25 mm, the prestress field has only a limited influence on spherical-indentation-based strength evaluation. Over the studied biaxial stress range, the peak indentation load changes by about -5.0% to +2.5%, and the calculated strength varies within about 5%. Overall, indentation testing provides a practical near-nondestructive method for evaluating PWHT effectiveness and local property evolution in large welded pressure vessels.

[16:40~17:00] Processing Nanoindentation Data for Machine Learning in Additively Manufactured 17-4PH Stainless Steel

Bokyu Kim (Kangwon National University), Jaewoo Kim (Seoul National University), Sunghee Han (Kangwon National University), Daehyun Kim (Kangwon National University), Junhee Han (Kangwon National University), Su Bin Yun (Kangwon National University), Byung-chul Choi (Korea Institute of Industrial Technology), In-Suk Choi (Seoul National University), Junggho Shin (Kangwon National University)

Type: Oral

Nanoindentation mapping generates large, spatially resolved mechanical datasets for machine-learning analysis of heterogeneous alloys. Reliable use of these data requires accurate processing and microstructural labels for individual indents. This study examines these requirements in additively manufactured 17-4PH stainless steel. A hardness map was spatially registered with electron backscatter diffraction (EBSD) and electron channeling contrast imaging (ECCI) data. EBSD distinguished FCC-indexed and BCC-indexed regions, while correlative observations supported tentative assignments of martensite-like and δ -ferrite-like BCC populations. Registration accuracy, annotation uncertainty, and boundary proximity were considered. Preliminary results show lower hardness in initially FCC-indexed regions than in either BCC population. The BCC populations exhibit overlapping hardness distributions, with small differences in mean hardness and differences in scatter. Boundary-adjacent responses are consistent with mixed mechanical sampling and require separate treatment. These results emphasize the importance of retaining microstructural labels, spatial context, and data-quality information when preparing nanoindentation datasets for machine learning. Correlative microscopy identifies both meaningful mechanical contrasts and limitations in constituent discrimination.

[17:00~17:20] Concurrent Acoustic Emission Monitoring of PLC-Related Plastic Instabilities during Nanoindentation and Micropillar Compression

David Ugi (Eötvös Loránd University)

Type: Oral

The Portevin–Le Chatelier (PLC) effect, arising from dynamic interactions between mobile dislocations and solute atoms, is one of the best-known manifestations of dynamic strain aging and has traditionally been investigated by macroscopic tensile testing. Although intermittent serrated plasticity has been reported during nanoindentation in several alloy systems, its direct connection to PLC-type deformation remains largely unresolved. In the present work, nanoindentation combined with concurrent acoustic emission (AE) is employed to investigate PLC-related plastic instabilities in an Al–3 wt.% Mg alloy. Constant penetration-rate Berkovich nanoindentation experiments were performed while continuously recording AE signals. The continuously evolving indentation strain rate enables the deformation response to be monitored over a continuous range of strain-rate conditions. The nanoindentation measurements are complemented by in-situ SEM micropillar compression experiments performed on the same material, allowing intermittent plasticity to be compared under localized contact loading and uniaxial compression. Pronounced PLC-like serrated plastic flow was observed at low indentation rates, where individual load drops exhibit strong temporal correlation with AE bursts, providing direct evidence that these instabilities originate from collective dislocation processes.

Preliminary analysis further reveals systematic relationships between load-drop magnitude, indentation depth, and the waiting time separating consecutive serration events. Interestingly, AE activity persists even under loading conditions where visible load serrations disappear, indicating that intermittent plastic deformation continues beyond the resolution of conventional load–displacement measurements. Micropillar compression experiments performed near the characteristic PLC strain-rate regime likewise exhibit PLC-like intermittent plasticity, enabling direct comparison between the two deformation geometries. The presented methodology demonstrates that concurrent nanoindentation and acoustic emission provide a sensitive experimental approach for investigating dynamic strain aging and localized plasticity at the micro- and nanoscale, offering quantitative insight into the temporal evolution of intermittent plastic events and their underlying dislocation dynamics.

Session SA

2026-11-03 15:30 ~ 17:10 | 305 | Chair: Ill Ryu

[15:30~15:55] Atomistic simulations of phase transformation and deformation behaviors of shape-memory alloys at the nanoscale

Won-Seok Ko (Department of Materials Science and Engineering, Korea University)

Type: Invited

The martensitic transformation that underlies the shape-memory effect and superelasticity is intrinsically an atomic-scale process, involving nucleation of martensite variants, migration of coherent interfaces, and competition with conventional plasticity. When shape-memory alloys (SMAs) are reduced to small dimensions or loaded locally, these processes deviate substantially from bulk behavior: free surfaces and internal interfaces alter the relative stability of the parent and product phases, and strongly inhomogeneous stress fields activate several deformation mechanisms at once. Separating the individual contributions experimentally is difficult, whereas atomistic simulation provides direct access to them, provided that the interatomic description reproduces the delicate energy differences between competing phases. This talk overviews our work on constructing such descriptions and applying them to the phase transformation and deformation behaviors of SMAs. Interatomic potentials based on the second nearest-neighbor modified embedded-atom method have been developed for a range of binary and multicomponent systems by force matching against density functional theory data, combined with validation of transformation temperatures, free energies, and the microstructures formed during transformation. Machine learning potentials are now being employed to reach near first-principles accuracy for chemically more complex alloys. Applications are then surveyed across loading conditions and geometries. Molecular dynamics simulations reproduce both temperature- and stress-induced transformations and reveal how the transformation pathway depends on crystallographic orientation, how the transformation temperature decreases as the system size approaches the nanometer scale, and how grain boundaries, free surfaces, and amorphous regions govern the accumulation of residual strain under cyclic loading. Contact loading, pillar compression, and constrained composite geometries are compared to show how the local stress state selects the operative mechanism. Implications for interpreting small-scale mechanical tests and for guiding alloy design are discussed.

[15:55~16:15] A Local Thermo-Mechanical Field-Based Framework for Single-Test Constitutive Model Calibration

Jaehun Kim (Pohang University of Science and Technology), Rae Eon Kim (Pohang University of Science and Technology), Jumi Choi (Pohang University of Science and Technology), Tae Young Go (Pohang University of Science and Technology), Hyejin Seo (Pohang University of Science and Technology), Hyung Seop Kim (Pohang University of Science and Technology)

Type: Oral

Accurate constitutive models are essential for finite element simulations of hot-forming processes, where flow stress is strongly influenced by strain, strain rate, and temperature. Conventional constitutive model calibration requires numerous tensile tests performed under different deformation conditions to independently determine material parameters, resulting in substantial experimental cost and time. Moreover, reliable characterization of high-temperature mechanical behavior remains challenging because resistance-heating systems, widely employed to reproduce hot-forming thermal histories, inherently generate temperature gradients along the gauge section. These temperature variations produce spatially varying flow stresses, leading to heterogeneous deformation, strain localization, and premature necking, thereby limiting the accuracy of conventional stress–strain measurements. Rather than treating these thermo-mechanical heterogeneities as experimental limitations, the present study exploits them as a source of local constitutive information. A single tensile test performed at 780 °C and an initial strain rate of 0.005 s^{-1} was combined with high-temperature digital image correlation (DIC) and local temperature measurements to simultaneously obtain local strain, strain rate, and temperature histories throughout deformation. Local true stresses were calculated from the corresponding cross-sectional reduction measured by DIC, enabling constitutive model calibration using continuously evolving local thermo-mechanical fields within a single specimen. The proposed methodology was validated by comparing finite element simulations using the identified constitutive parameters with those obtained from a conventional calibration based on more than nine stress–strain curves measured using extensometer under multiple deformation conditions. The proposed approach showed substantially improved agreement with the experimental deformation behavior while requiring only a single tensile test for parameter identification. The present methodology transforms the inherent thermo-mechanical heterogeneity of resistance-heated tensile testing from an experimental limitation into a valuable source of constitutive information, providing an efficient framework for constitutive model calibration in hot-forming applications.

[16:15~16:35] Physics-informed neural posterior estimation of stress-strain curves from indentation via a mechanism-based constitutive model

Tae Young Go (POSTECH), Renhao Wu (Tohoku University), Chuangming Li (Tohoku University), Soo Vin Ha (POSTECH), Jeong Ah Lee (POSTECH), Jihye Kwon (POSTECH), Hyoung Seop Kim (POSTECH)

Type: Oral

Accurate determination of stress–strain curves from indentation of metallic materials remains a significant challenge. In this study, we propose a physics-informed neural posterior estimation (PI-NPE) framework to infer the parameters of the Kocks–Mecking–Estrin (KME) constitutive model from micro-scale indentation load–displacement responses and thereby reconstruct stress–strain behavior. Unlike conventional indentation-inversion approaches based on phenomenological curve fitting, the present framework targets a mechanism-based constitutive description associated with dislocation storage, dynamic recovery, and strain-rate sensitivity. A large synthetic dataset was generated through finite element analysis-based indentation simulations, in which the KME parameter space was systematically explored using Latin hypercube sampling to improve coverage efficiency while reducing unnecessary sampling redundancy. A central challenge in this inverse problem is the non-uniqueness arising from the coexistence of intrinsic material properties and calibration-dependent constants within the KME formulation. To address this, the PI-NPE algorithm incorporates a physics-based loss

function derived from the KME ordinary differential equations, constraining the solution space to physically admissible parameter sets. Furthermore, a hierarchical two-step training strategy is introduced to decouple the inference of intrinsic properties from the identification of strain-hardening coefficients, thereby improving reconstruction fidelity without compromising the inter-parameter relationships inherent to the constitutive model. Experimental validation against uniaxial tensile data from three compositionally and mechanically distinct metallic systems — Cantor high entropy alloy, stainless steel, and oxygen-free copper — demonstrates good agreement within the investigated material and loading range. The results show that the feasibility of mechanism-aware constitutive parameter identification from local indentation measurements, providing a physically interpretable route for stress–strain reconstruction and a basis for future extension to broader microstructural states and deformation conditions.

[16:35~17:00] Advancing indentation-based mechanical characterization with AI

Kyeongjae Jeong (*Sungkyunkwan University*), Minwoo Park (*Seoul National University*), Heung Nam Han (*Seoul National University*)

Type: Invited

Recent advances in artificial intelligence (AI) have created new opportunities to extract comprehensive mechanical information from indentation responses. By integrating experimentally validated finite element simulations with AI-enabled inverse analysis, a series of frameworks have been established to decode increasingly complex material behavior from localized deformation data. Starting from the prediction of uniaxial plastic flow, the methodology has been progressively extended to characterize anisotropic deformation, identify material parameters associated with advanced constitutive models, and quantify residual stress states directly from indentation data. The underlying premise is that indentation contains substantially richer information than traditionally utilized. When combined with data-driven learning and physics-based modeling, such information provides access to mechanical descriptors that would otherwise require extensive mechanical testing, specialized experiments, or computationally intensive optimization procedures. Applications to a broad range of engineering alloys demonstrate the robustness and generality of the methodologies developed across diverse deformation mechanisms and material states. The results highlight the emerging role of AI-assisted indentation as a versatile platform for constitutive characterization, structural integrity assessment, and accelerated materials development. This work illustrates a pathway toward next-generation mechanical characterization, where indentation serves not merely as a hardness measurement technique but as an information-rich probe capable of revealing the fundamental mechanical state of materials.

Session GA

2026-11-04 08:30 ~ 09:40 | 306 | Chair: Finn Giuliani

[08:30~08:55] Visualizing indentation-induced deformation in glasses using nanofocus X-ray scattering

Morten M. Smedskjaer (Aalborg University)

Type: Invited

Stronger oxide glasses are critically needed to enable new applications and reduce their carbon footprint by making them thinner. In turn, this requires an in-depth understanding of how strength-reducing surface damages form under sharp contact loading. This is typically tested using instrumented indentation and it has been found that the structural deformation mechanism varies among different glass families. However, structural probing is typically performed after indentation although it is known that certain stress-induced structural changes are reversible upon unloading. To this end, we here use state-of-the-art synchrotron techniques to perform indentation of different oxide glasses while simultaneously observing their local structural response using an indenter coupled to a nanofocus X-ray scattering setup. These experiments provide spatially resolved information at different stages of the indentation process, showing the formation and evolution of the induced densification zone and different types of cracking with resolution on the nanoscale.

[08:55~09:20] Indentation as a crack initiator for studying crack propagation resistance in glasses

Theany TO (CNRS - GeM - École Centrale Nantes)

Type: Invited

Indentation, even on highly brittle materials such as glass, can induce stresses underneath a sharp contact area, leading to densification, plastic deformation, viscous flow, and cracking. Different microcrack patterns have been observed in different glass materials, even when using the same indenter, such as a Vickers indenter. Based on their cracking patterns, more than 30 empirical equations, originating in the 1950s, were developed to determine the crack propagation resistance, namely the fracture toughness K_{Ic} , of ceramics and glasses. Half a century later, the indentation method has been shown not to be a self-consistent method for measuring K_{Ic} of both ceramics and glasses. Nevertheless, indentation remains an important technique in measuring the local properties/mechanisms of ceramics and glasses. In this review presentation, the use of indentation, particularly Vickers, as a crack initiation method to access to the fracture toughness of different glasses will be lectured. First of all, the measurement of the crack initiation resistance of glasses via different indentation methods will be introduced, followed by the use of indentation as a starter to produce a long precrack in the single-edge precracked beam SEPB method, and by the use of indentation as a micro-precrack in the surface crack in flexure SCF method. Last but not least, I will summarize the differences between the misunderstanding and misuse of the terms crack resistance and fracture toughness, the advantages of indentation for measuring

both crack initiation and crack propagation resistance, and how the indentation pattern affects the two important cracking parameters.

[09:20~09:40] Probing local deformation and directional strain in glasses during indentation by X-ray scattering

Johan F. S. Christensen (Aalborg University, Denmark), M. Faizal Ussama Jalaludeen (Aalborg University, Denmark), Søren S. Sørensen (Aalborg University, Denmark), David L. Christensen (Aalborg University, Denmark), Sourav Sahoo (Aalborg University, Denmark), Jonas A. Finkler (Aalborg University, Denmark), Anton Davydok (Helmholtz-Zentrum Hereon, Germany), Christina Krywka (Helmholtz-Zentrum Hereon, Germany), Henning F. Poulsen (Technical University of Denmark, Denmark), Etienne Barthel (CNRS/ESPCI/PSL/Sorbonne Université, France), Gustavo A. Rosales-Sosa (Nippon Electric Glass Co., Ltd., Japan), Morten M. Smedskjaer (Aalborg University, Denmark)

Type: Oral

In situ characterization of the deformation behavior of materials during contact-induced damage, such as indentation, remains a significant experimental challenge. Such insight is particularly important for oxide glasses, where sharp contact events can produce complicated cracking patterns. In turn, this can deteriorate the glass strength, as such surface flaws can act as stress concentrators. To investigate the local deformation of vitreous silica in situ during contact loading with a wedge indenter, we employed nanofocus X-ray scattering at the Nanofocus Endstation of beamline P03, PETRA III, Germany. In detail, we probed the local atomic structure with submicron spatial resolution in two dimensions, gaining information on the local deformation state of the sample. Based on this, local density estimation enabled visualization of the two-dimensional densification zone. In addition, directional strains were extracted, yielding local two-dimensional strain tensors with high spatial resolution. We show how the deformation of the glass structure is highly directional, providing a more in-depth description of the indentation-induced deformation than that obtained from probing only the overall densification. The development of the deformation zone with stepwise increments in the indentation load was followed and compared with the residual deformation zone after unloading. Comparison of the experimental deformation behavior with that calculated from finite element simulations showed generally good agreement. This work highlights the capability of in situ nanofocus X-ray scattering to directly probe the evolving local deformation state during indentation with submicron spatial resolution, and the ability to measure directional strains provides a unique experimental perspective on indentation-induced deformation.

Session AS

2026-11-04 08:30 ~ 09:40 | 307 | Chair: Kwang Seok Lee

[08:30~08:55] Dislocation Evolution in Cyclic-Loaded Cu Nanopillars with Different Configurations

Jiangwei Wang (Zhejiang University)

Type: Invited

Small-sized metals generally exhibit unusual deformation responses subjected to cyclic loading, since their limited volume cannot effectively accommodate micro-sized dislocation patterns typically found in their bulk counterparts. Here, the cyclic behaviors in Cu nanopillars with different configurations are investigated using in situ transmission electron microscopy fatigue test. Dislocation tangles formed in single- and twinned-crystal nanopillars as a result of cycling-induced operations of multiple slip systems and further unpinning and absorption of pinned dislocations. While, nanopillars configured with low-angle grain boundary (LAGB) underwent the degradation and eventual decomposition of the LAGB due to the cycling-induced emission of grain boundary dislocations, which resulted in high-density mobile dislocations to withstand the cyclic loading. These findings contribute to a systematic and comprehensive understanding of the micro-mechanics of dislocation-related phenomena in the cyclic response of nanoscale metals.

[08:55~09:15] Impression creep behavior of twin roll cast A356–5 wt.% SiCp composites

Rishikesh Patel, J. Sivasubramanian, Bushra, Anindya Basu, Priyanka Saini (National Institute of Technology Rourkela)

Type: Oral

The impression creep behavior of a twin-roll continuous cast (TRCC) A356–5 wt.% SiCp composite was examined over a temperature range of 448–523 K and applied stresses of 150–450 MPa. The composite shows steady-state impression creep velocities in the range of $(0.006\text{--}53) \times 10^{-5}$ mm/s. The improved creep resistance is primarily due to the refined microstructure produced by TRCC with secondary dendrite arm spacing (SDAS) of ~ 8 μm . A smaller SDAS suggests a higher density of interdendritic boundaries, which reduces dislocation mean free paths and suppresses diffusion-assisted deformation. In addition, the uniform distribution of SiCp promotes stress transfer from the matrix to the reinforcement and stabilizes the microstructure during high-temperature deformation. The stress exponent, n , varied from ~ 2.98 at 448 K to ~ 6.1 at 523 K, indicating a shift from glide-assisted creep to dislocation climb-controlled power-law creep. The activation energy, Q , ranged from ~ 62 to ~ 127 kJ/mol, and increased with applied stress. The lower Q values suggest a significant contribution from dislocation-pipe diffusion at lower stresses, whereas the higher Q value indicates lattice-diffusion-controlled dislocation climb.

[09:15~09:40] Nanoindentation-Guided Development of 2.0 GPa Hot Stamping Steel for Enhanced Crash Performance

Type: Invited

The automotive steel industry is undergoing a significant transformation, driven by the global demand for vehicle lightweighting and increasingly stringent crash safety regulations. These trends have accelerated the need for ultra-high strength steels (UHSS), particularly hot-stamped products with tensile strengths exceeding 1.5 GPa. To address these challenges, a novel 2.0 GPa-class hot-stamping steel has been developed for crash-critical structural components. The alloy design incorporates precise control of carbon and manganese contents together with optimized precipitation behavior to suppress manganese banding and promote the formation of a homogeneous martensitic microstructure during the hot-stamping process. Furthermore, nanoindentation-based microstructural analysis was employed to quantitatively evaluate the local mechanical properties of individual microstructural constituents and to assess microstructural homogeneity at the microscale. The nanoindentation results provided critical insights into phase-specific hardness distributions and mechanical heterogeneity, enabling the establishment of microstructure–property relationships that guided alloy and process optimization.

Session SA

2026-11-04 08:30 ~ 09:40 | 305 | Chair: Rajaprakash Ramachandramoorthy

[08:30~08:55] A Comprehensive Microstructure-Based Fatigue Life Prediction Methodology for Hypo-Eutectoid Steels

Yoon Suk Choi (Pusan National University), Jonghoon Shin (Hanwha Aerospace), Taeyang Bang (Pusan National University), Dae-Geun Nam (Korea Institute of Industrial Technology)

Type: Invited

A comprehensive fatigue life prediction methodology based on microstructures of hypo-eutectoid steels was proposed. As a first step, a statistically equivalent synthetic microstructure generation algorithm was developed by applying the cellular automata under the multi-level microstructure generation approach, and verified by comparing to the real microstructure. A second step involved the development of crystal plasticity-based elasto-viscoplastic constitutive models for the primary ferrite and pearlite of the hypo-eutectoid steel, and the calibration of major constitutive parameters using uniaxial and incremental step fatigue test results. For a third step, synthetic microstructure-based crystal plasticity finite element method (CP-FEM) simulations were performed for stress-controlled uniaxial, torsional, and in-phase and out-of-phase axial plus torsional fatigue loading conditions, and cyclic increments of fatigue indicator parameters (dFIPs) were extracted from fatigue-simulated microstructures for the local fatigue damage quantification. Four different fatigue indicator parameters, Smith-Watson-Topper, Brown-Miller, Fatemi-Socie and Garud parameters, were adopted for the dFIP quantification. As a final step, four different simulated dFIPs were coupled with the power law-based model to predict fatigue lives, and their fatigue life predictability was assessed. In particular, simulated dFIP hot spots were used to predict the fatigue life variability under the framework of the extreme value analysis.

[08:55~09:15] Indentation-based characterization of the Bauschinger effect using physics-guided deep learning

Minwoo Park (Seoul National University), Deunbom Chung (Seoul National University), Seok Hyun Choi (Seoul National University), Jaeyoung Park (Hanwha Aerospace), Fusahito Yoshida (Hiroshima University), Heung Nam Han (Seoul National University)

Type: Oral

The Bauschinger effect, the reduction in yield stress upon load reversal, governs springback in sheet-metal forming and structural reliability under cyclic loading. Its characterization conventionally relies on the tension–compression test (TCT), which requires anti-buckling fixtures and becomes impractical for thin sheets, weldments, or locally deformed regions where specimen extraction is restricted. We propose a physics-guided deep-learning framework that couples finite element (FE) simulation with a convolutional neural network (CNN) to inversely identify the Bauschinger effect from spherical instrumented indentation. The framework takes the load–depth (P–h) curves of pre-strained specimens and the directional surface profiles around the indent as inputs to identify the key kinematic hardening parameters of the Yoshida–Uemori (Y-U) model: the back-stress

evolution rate C , the isotropic saturation of the bounding surface R_{sat} , and its kinematic component b . Because R_{sat} and b are observable only as a sum in the uniaxial response, this inverse problem is fundamentally non-unique. A mechanism-based sensitivity analysis shows that this non-uniqueness is resolved by the directional asymmetry of the indentation surface profile, whose position-dependent parameter fingerprints require the full spatially distributed measurement, rather than any single scalar metric, as the input. A dual-branch CNN integrating the scalar P - h response with the directional profile information was trained on an FE database spanning five pre-strain levels, and the framework was further extended to the simultaneous identification of all six Y - U parameters, yielding a standalone tool for materials whose uniaxial properties are unknown. For three steels of different crystal structures and strength grades (SNT355M, SUS304, and SPC980Y), the indentation-identified parameters reproduced experimental TCT responses with high accuracy, enabling local, non-destructive assessment of the Bauschinger effect from surface indentation alone.

[09:15~09:35] Orientation-dependent Nanoindentation Analysis Using CPFEM and Machine Learning

Shinae Lee (Pusan National University), Ji Hoon Kim (Pusan National University)

Type: Oral

Nanoindentation behavior is influenced by crystal orientation, local stress state, and slip system activity. These effects are often reflected in the load-displacement curve and the pile-up morphology around the indentation. This study proposes an integrated experimental-computational framework for analyzing orientation-dependent nanoindentation behavior. Nanoindentation tests were conducted on an aluminum alloy using a Berkovich indenter. Electron backscatter diffraction was used to measure the crystal orientation at each indentation position, and atomic force microscopy was used to obtain the surface profile after indentation. Crystal plasticity finite element analysis was performed under the same indentation conditions. The effects of crystal orientation on the local stress distribution, resolved shear stress, and slip system activity were investigated. The calculated slip behavior was compared with the measured pile-up direction and surface shape. Based on the analysis result, a method was developed to interpret pile-up formation by considering the combined contribution of major slip systems. Furthermore, a machine learning model was developed to estimate Euler angles from the indentation surface profile and the load-displacement curve. The results suggest that the surface morphology contains information related to crystal orientation and local deformation behavior. The proposed framework may be used to develop evaluate crystal orientation from indentation-induced surface features.

Session GA

2026-11-04 10:00 ~ 11:30 | 306 | Chair: Theany To

[10:00~10:25] Damage resistant glasses with mixed indentation deformation modes

Timothy Gross (Corning Incorporated)

Type: Invited

Historically, Vickers indentation deformation and cracking studies were primarily conducted on commercially available soda-lime silicate and silica glasses. Conveniently, these glass types serve as extreme endpoints in the indentation response spectrum. Soda-lime glass, categorized as normal glass, deforms with a significant volume-conserving shear contribution, whereas silica, categorized as anomalous glass, deforms primarily by volume-reducing densification. In the continuum of indentation responses between these two endpoint behaviors, mechanically advantaged indentation responses are identified. First, high crack resistance is demonstrated in glasses that deform with shear and densification contributions directly in between soda-lime and silica. The reduction in densification reduces the surface stresses that result in ring cracking in anomalous glass, while the reduction in shear deformation reduces subsurface damage when compared to normal glass. By further tailoring glass so that the shear contribution consists of delocalized shear bands, the indentation cracking threshold is shown to exceed 2 kilograms force (kgf). A second mechanically advantaged glass is found by moving further along the indentation response continuum in the direction of increased densification contribution. This glass produces a large annular crack by a residual stress-driven redirection of a traditional cone crack back to the surface. The annular crack acts as a boundary to the extension of radial cracks as demonstrated by thermal shock testing.

[10:25~10:50] The effect of beam damage on small scale mechanical properties of forsterite glass

Lucas Li (Imperial College London), Siyang Wang (Imperial College London), Katharina Marquardt (University of Oxford), Tanguy Rouxel (Université de Rennes), Finn Giuliani (Imperial College London)

Type: Invited

A bulk forsterite (Mg_2SiO_4) glass was produced through a containerless levitation process. This glass, with a composition corresponding to the magnesium-rich end member of the olivine solid-solution series, is capable of coexisting with olivine minerals within Earth's mantle and demonstrates outstanding mechanical behaviour. Indentation testing reveals remarkably high elastic moduli ($E=116$ GPa and $G=49$ GPa, approximately 60% greater than those measured for amorphous silica or conventional window glasses. Furthermore, its fracture toughness (K_{1c}), evaluated using the microscale double cantilever beam splitting technique, reaches $0.84 \text{ MPa}\cdot\text{m}^{1/2}$, positioning it among the highest values documented for oxide glasses and approaching that of silicon oxynitride glasses. Micropillar compression testing yields a yield stress of 2.9 GPa. In situ experiments additionally reveal that electron-beam irradiation significantly alters the material's deformation behaviour. Collectively, these findings confirm the remarkable mechanical properties of forsterite glass, while underscoring

the importance of carefully managing electron-beam conditions during in situ microscale mechanical testing of amorphous silicates.

[10:50~11:10] Probing local structural variation of glass beneath a Vickers imprint using electron diffraction (e-PDF) and μ -Raman spectroscopy

Nathan KAIL (4MAT - Université Libre de Bruxelles), François BOLAND (AGC Technovation Center), Stéphane GODET (4MAT - Université Libre de Bruxelles), Theany TO (Nantes Université, École Centrale Nantes), Tanguy ROUXEL (Université de Rennes, IPR - UMR CNRS 6251), Claire FOURMENTIN (4MAT - Université Libre de Bruxelles)

Type: Oral

Glasses are widely regarded as the archetypal brittle material, exhibiting purely elastic behavior prior to catastrophic failure under macroscopic loading. Nevertheless, a permanent deformation shows up upon loading with a sharp indenter and two mechanisms were identified: namely densification and shear flow¹. These mechanisms allow the glass to partially relax the contact stresses, so that the ability of glasses to develop such deformation processes prior to failure was found to be intrinsically linked to their crack resistance (CR)². However, elucidating the structural rearrangements that underlie these dissipative mechanisms remains a real challenge. In particular, the absence of long-range order at the atomic scale makes the characterization of the structural changes more complex than in the case of their crystalline counterparts.³ Interest in these changes is twofold: i) it shed light on the behavior of a "disordered" network under a combination of shear and pressure (GPa order), and ii) it brings fundamental information of paramount importance for the development of novel glass compositions with improved CR⁴. In this study, innovative characterization techniques were used to get insight into the indentation region, including electron diffraction mapping (4D-STEM). Combined with micro-Raman spectroscopy these techniques enable the depiction of a clear image of the structural changes. This study focuses on two glass systems: amorphous silica (a-SiO₂), which has been extensively studied under pressure using conventional methods, and which exhibits a CR of around 1.5 N; and a potassium aluminoborate glass (K₂O-B₂O₃-Al₂O₃), which exhibits the highest value of CR ever measured for an oxide glass obtained by the conventional melting-quenching method and without strengthening treatments, at around 52 N. The relationship between structural evolution and crack resistance is discussed.

[11:10~11:30] Nanoindentation reveals universal scaling of pop-in plasticity in metallic glasses

Yong Hao Sun (Institute of Physics, Chinese Academy of Sciences)

Type: Oral

Plastic flow of metallic glasses proceeds intermittently in the inhomogeneous deformation regime. Mediated via shear bands, quasi-static straining gives rise to plastic instabilities that are measured as abrupt displacement bursts or pop-ins. The latter is a well-known feature in nanoindentation, where its first occurrence probes the critical and site-specific stress of nano-scale incipient shear deformation. Here we show that the statistical distribution of the stress and magnitude of the first shear instability, as well as its successive higher-order events, universally follow Weibull statistics across ten different metallic glasses. This indicates a fundamentally

identical plastic process across glass-forming alloys and progressing deformation that is governed by a weakest-link phenomenon. This finding stands in strong contrast to crystalline alloys, where both defect nucleation and defect-structure evolution control shear instabilities and depend on the deformation history. The paper is published on Scripta Materialia 259 (2025) 116549.

Session AS

2026-11-04 10:00 ~ 11:30 | 307 | Chair: Jiangwei Wang

[10:00~10:25] Development of Nb-Based Alloys with Enhanced Strength–Ductility Balance through Solid-Solution and Interstitial Control

Kwang-Hyeok Lim (Korea Institute of Science and Technology), Muhammad Salman Johry (Korea Institute of Science and Technology), Wi-Geol Seo (Sunchun National University), Sang-Min Lee (Korea Institute of Science and Technology), Shi-Hoon Choi (Sunchun National University), Jin-Yoo Suh (Korea Institute of Science and Technology)

Type: Invited

Nb-based alloys are promising candidates for structural applications at temperatures beyond the operating range of conventional Ni-based superalloys because of their high melting point, relatively low density, and excellent solid-solution strengthening capability. However, achieving high strength while maintaining sufficient ductility remains a major challenge, particularly owing to the strong influence of interstitial elements such as oxygen. In this study, a series of Nb-based alloys containing various substitutional alloying elements were designed, fabricated by vacuum arc melting, cold rolled, and subsequently recrystallized. Atomic size mismatch (δ) was employed as a key design parameter for alloy selection, and heat treatments under different levels of vacuum were used to systematically control oxygen uptake without changing the nominal alloy compositions. Mechanical properties were evaluated using Vickers hardness, tensile testing, ONH analysis, and EBSD characterization. The results demonstrate that controlling both alloy chemistry and interstitial oxygen content provides an effective route for tailoring the strength–ductility balance. Several newly designed alloys exhibited yield strengths exceeding 550–700 MPa while maintaining elongations above 30%, outperforming conventional reference alloys such as C103. Oxygen uptake during heat treatment increased hardness through interstitial strengthening, whereas appropriate alloy design effectively minimized the associated loss of ductility.

[10:25~10:45] Nanoindentation-induced dislocation structures in BCC tungsten observed via ECCI

Florian Tropper (NIMS), Takahito Ohmura (NIMS)

Type: Oral

Tungsten serves as an ideal model material for investigating BCC plasticity as its high strength renders experimental observations and measurements clearly resolvable down to small deformations and forces. This study investigates the fundamental mechanisms governing early plastic deformation in BCC metals under conditions of severe localized constraint as imposed by nanoindentation. While traditional deformation models prioritize screw dislocation glide, this research explores the role of prismatic dislocation loop emission as an essential, alternative pathway for strain accommodation in triaxial stress environments. Using electron channeling contrast imaging (ECCI), we characterize and analyze the nucleation and propagation of dislocation structures during progressive stages of imposed deformation. The ability of ECCI to image dislocations close to their native bulk state provides important insights complementing previous TEM studies. By examining the

evolution of the generated dislocation arrays, this work contributes to a more general understanding of strain accommodation mechanisms in BCC metals.

[10:45~11:10] The influence of process variables on the interface properties of several clad sheets

Kwang Seok LEE (*Korea Institute of Materials Science (KIMS)*)

Type: Invited

Clad metal is a prime example of a metallic material designed to simultaneously provide mutually exclusive multifunctional properties; various combinations of constituent metals are being explored to meet specific customer requirements. When manufacturing such clad metals, the roll bonding process is the most widely used approach, given its economic advantages—including process convenience, productivity, and the ease of combining materials. One of a key properties required by end-users of clad metals is the bonding strength between dissimilar metals, which is directly related to microstructural variations in the base metals and the interface resulting from roll-bonding process conditions. In this regards, effects of roll bonding and annealing condition on the microstructural evolution and subsequent mechanical properties of several clad sheets such as Al/Cu and Al/Mg were introduced.

Session EE

2026-11-04 10:00 ~ 11:30 | 305 | Chair: Byung-Gil Yoo

[10:00~10:25] The Loading/ Unloading Stiffness Ratio – Real-Time Materials Insights under Extreme Conditions

Verena Maier-Kiener (Montanuniversität Leoben), Stefan Zeiler (Montanuniversität Leoben)

Type: Invited

We introduce a dynamic nanoindentation framework centered on the stiffness ratio, in detail the loading slope over unloading stiffness, to probe mechanical transitions and flow behavior under extreme conditions. Using continuous stiffness measurement (CSM) during a single indentation, this metric quantitatively tracks elastic-to-plastic deformation. In alloys from -150 °C to 25 °C, the stiffness ratio unambiguously identifies the brittle-to-ductile transition temperature (BDTT) and resists thermal drift. The approach extends to operando environments, including in situ electrochemical charging via a side-charging cell and high-temperature testing, yielding real-time deformation insights. A geometric calibration corrects for tip imperfections and enables strain-rate-controlled spherical indentations to extract localized flow curves. Under electrochemical charging, stiffness ratio shifts correlate with increased hardness and reduced constraint factor, revealing charge-driven plasticity changes. These protocols harness the stiffness ratio to connect lab-scale precision with application-relevant extremes, providing a high-throughput pathway for next-generation materials design.

[10:25~10:45] An experimental capability for nanomechanical measurements at cryogenic temperatures

Dr Ben Beake (Micro Materials Ltd.), Adrian Harris (Micro Materials Ltd.), Andrew Bird (Micro Materials Ltd.), Dr Hannah Zhang (National Physical Laboratory, UK), Dr Stefan Stoica (National Physical Laboratory, UK)

Type: Oral

Streamlining the development of materials and advanced coating systems for cryogenic applications in the transportation and energy generation sectors requires accurate measurements of their nanomechanical properties at the very low application temperatures (e.g. to -180 °C). These properties are temperature-dependent and it is not generally possible to accurately predict performance at these temperatures from measurements at higher temperature, for example when materials become more brittle and susceptible to fracture under load when below their ductile to brittle transition temperature. This presentation describes the development of an experimental capability for cryogenic nanomechanical testing in a commercial nanomechanical instrument (NanoTest Xtreme, Micro Materials Ltd). This involved overcoming broadly analogous challenges to those present in making reliable nanoindentation measurements at high temperatures, as detailed in ISO14577-6, i.e. accurate temperature matching of indenter and sample to achieve iso-thermal contact and minimise thermal drift, combined with environmental control. Since measurements using Peltier-based cooling in nitrogen gas purged environments are limited to -30 °C a completely different approach was required to reach much lower temperatures, and without frosting developing on the test sample and indenter

surfaces. This was achieved by switching to an alternative cooling technology – cryogenically cooled nitrogen gas cooling - together with performing measurements in a high vacuum environment to minimise condensation/frosting. With a novel indenter cooling design, active cooling of the sample and the diamond indenter, with independent electrically resistive heating for precise control at intermediate testing temperatures, and maintaining the vacuum level better than 10^{-5} mbar it has been possible to perform measurements at -150 °C with low thermal drift (0.01 nm/s) through precise thermal matching of the temperatures of the indenter and sample. Preliminary measurements on copper at a sample temperature of -185 °C are also presented.

[10:45~11:10] Nanoindentation at extreme conditions: High strain rates & cryogenic temperatures

Rajaprakash Ramachandramoorthy (Max Planck Institute For Sustainable Materials)

Type: Invited

Materials used under extreme conditions - such as during machining, high-speed transport impacts, and micrometeoroid collisions in space applications - must withstand very high strain rates, cryogenic temperatures, or a combination of both. Understanding material behavior under these conditions is essential for predicting performance and designing more resilient engineering materials. To address this challenge, we have developed a piezo-based in situ nanoindentation platform and complementary signal post-processing protocols, which enable high-throughput mechanical testing and hardness extraction at constant strain rates ranging from $1\text{e}1\text{ s}^{-1}$ to $1\text{e}5\text{ s}^{-1}$. Recently, we have further modified the system to enable rate-dependent nanoindentation at cryogenic temperatures down to 100 K. This talk will introduce the instrumentation and the protocols developed to achieve reliable measurements under these extreme conditions and their application in two material systems, namely single-crystal molybdenum and nanocrystalline nickel. In molybdenum, experiments reveal that beyond a strain rate of $1\text{e}3\text{ s}^{-1}$, the hardness increases sharply, a phenomenon called hardness upturn. Transmission electron microscopy (TEM) shows a significant increase in dislocation density at these high strain rates. Contrary to the conventional interpretation that attributes the upturn primarily to phonon drag, our thermal activation analysis suggests that dislocation density increase could be the dominant underlying mechanism. The second part of the talk focuses on nanoindentation of nanocrystalline nickel over a wide range of strain rates at both room temperature and down to 100 K. Nanocrystalline nickel interestingly shows a double transition in rate-sensitivity at $1\text{e}-1\text{ s}^{-1}$ and $5\text{e}2\text{ s}^{-1}$. The transition from high to negligible strain rate sensitivity at $1\text{e}-1\text{ s}^{-1}$, which happens to be temperature sensitive, indicates a transition from single dislocation-based processes to collective dislocative processes. Furthermore, at strain rates above $5\text{e}2\text{ s}^{-1}$, the hardness upturn occurs and remains temperature independent, suggesting a transition from thermally activated grain-boundary-mediated deformation to dislocation nucleation/multiplication events.

[11:10~11:30] In-situ micromechanical deformation of chemical interfaces from cryogenic to elevated temperatures

Leiming Du (Max Planck Institute for Sustainable Materials, Dusseldorf, Germany), Hendrik Holz (Max Planck Institute for Sustainable Materials, Dusseldorf, Germany), Gerhard Dehm (Max Planck Institute for Sustainable Materials, Dusseldorf, Germany), Anwesha Kanjilal (Max Planck Institute for Sustainable Materials, Dusseldorf, Germany)

Type: Oral

Chemical hetero-interfaces are key to maintaining the mechanical and functional integrity of advanced materials operating in multi-physical environments under coupled temperature and mechanical loading. Microscale interfacial degradation can critically compromise the longevity of these materials. This can be caused by decohesion or stress-corrosion cracking in structural alloys, delamination in multi-layered thin films and coatings, or chemo-mechanically driven interfacial failure in energy materials. Designing high performance materials with advanced functionality therefore requires precise knowledge of interfacial strength and deformation under relevant environmental conditions. However, a major bottleneck in this area is the lack of suitable techniques for direct quantification of isolated microscale interfacial deformation across temperatures and strain rates. To address this gap, the present study utilizes in-situ indentation based microshear testing inside scanning electron microscope to investigate temperature dependent microscale deformation of interfaces with different chemistry. Two different bilayered films comprising of (a) an intermetallic-metal interface relevant for structural alloys and coatings, and (b) a chemically reduced oxide-metal interface of NiO-Ni representative of cermet anodes in fuel cells have been investigated using a recently developed single micro-push-to-shear geometry. The micro-specimens were fabricated by focused ion beam milling for direct measurement of interfacial strength locally at microscale. By combining parametric geometry optimization using finite element modelling with cryogenic to elevated temperature in-situ micromechanical testing inside scanning electron microscope, different stages of interfacial deformation - from elastic behavior to sliding were identified - and the strength quantified and compared for both chemical interfaces. Thermal activation and strain rate sensitivity of hetero-interface deformation were determined through interface testing across temperatures and strain rates, complemented by mechanistic understanding using post-mortem transmission electron microscopic characterization. The results provide insights into micromechanics of chemical hetero-interfaces in advanced materials, and design strategies for reliable interface engineering. Keywords: Chemical interfaces, in-situ micromechanics, cryogenic and high temperature effects

Session GA

2026-11-04 14:00 ~ 15:10 | 306 | Chair: Hiroshi Masuda

[14:00~14:25] What we can learn from Raman scattering spectroscopy about the indentation deformation mechanisms in oxide glasses?

Nathan KAIL (Université libre de Bruxelles, B), Claire FOURMENTIN (Université libre de Bruxelles, B), Stéphane GODET (Université libre de Bruxelles, B), Theany TO (Ecole Centrale de Nantes, FR), Théo GUERINEAU (University of Laval, Quebec, CA), Younes MESSADDEQ (University of Laval, Quebec, CA), Quentin WETS (University of Laval, Quebec, CA), Alain MOREAC (Université de Rennes, FR), Tanguy ROUXEL (Université de Rennes, FR)

Type: Invited

The atomic network structure of oxide glasses consists of relatively stiff units, such as SiO₄ tetrahedra or BO₃ triangles, embedded in a more compliant “sea”, where alkaline and alkaline earth cations concentrate for example. Therefore, under mechanical loading, the structural characteristics (bond distances and angles) of the relatively stiff units centered on the main glass forming species (such as Si for silicate glasses), are weakly affected, while the inter-unit regions experience significant changes. For example, changes in the inter-tetrahedral angle (Si-O-Si) in silicate glasses are detected at relatively low stresses, while pressure over a few tens of GPa are required to observe changes in the silicon coordination. In this presentation, we will show that Raman scattering is a very powerful tool to get insight into the structural changes occurring beneath an indent and therefore to shed some light on the deformation mechanism and the characteristics of the affected area (shape and size). The case of vitreous silica, alkali-boroaluminate glass and a hydrated window glass will be presented. References H. Sugiura and T. Yamadaya, J. of Non-Cryst. Sol., 144 151–158 (1992). A. Perriot et al., J. of the Amer. Ceram. Soc., 89(2) 596–601 (2006). D. Vandembroucq et al., J. of Phys. Cond. Matter, 20(48) 485221 (2008). T. Rouxel, H. Ji, J.P. Guin, F. Augereau, B. Rufflé, J. Appl. Phys., 107 (9) 094903 (2010). Y. Kato et al., J. of Non-Cryst. Sol., 357 176–181 (2011). A. Kassir-Bodon et al., Intern. J. of Appl. Glass Sci., 3 29–35 (2012). T. Rouxel, Phil. Trans. R. Soc. A, 373 20140140 (2015). K. Januchta and M. M. Smedskjær, J. of Non-Cryst. Sol. X, 1 100007 (2019). S. Bruns et al., J. of the Amer. Ceram. Soc., 103 3076–3088 (2020).

[14:25~14:50] Role of plastic flow on crack initiation by Vickers indentation in oxide glasses

Gustavo Alberto Rosales-Sosa (Fundamental Technology Division, Nippon Electric Glass Co. Ltd., Otsu, Japan.), Taichi Nakashima (Fundamental Technology Division, Nippon Electric Glass Co. Ltd., Otsu, Japan.), Yoshinari Kato (Fundamental Technology Division, Nippon Electric Glass Co. Ltd., Otsu, Japan.), Etienne Barthel (Soft Matter Sciences and Engineering, ESPCI Paris, PSL University, CNRS, Sorbonne University, 75005, Paris, France), Hikaru Ikeda (Fundamental Technology Division, Nippon Electric Glass Co. Ltd., Otsu, Japan.), Shingo Nakane (Fundamental Technology Division, Nippon Electric Glass Co. Ltd., Otsu, Japan.), Hiroki Yamazaki (Fundamental Technology Division, Nippon Electric Glass Co. Ltd., Otsu, Japan.)

Type: Invited

Indentation cracking in silicate glasses has been of interest in glass science and technology for several decades, as it indicates the susceptibility of glass products to failure during normal use conditions. In this sense, plastic deformation occurring around the indentation has been considered key to understanding the variety of indentation cracking behaviors in glasses. Over a decade ago, Kato et al. (2010) proposed plastic volumetric strain (densification) as the dominant mechanism behind indentation crack initiation under the Vickers indenter, and subsequent studies have correlated cracking with densification. However, this relationship breaks down when extended to a wider range of compositions. Here, we present a comprehensive Vickers indentation study across a broad range of laboratory-made and commercial oxide glasses, assessing the relative contributions of plastic flow and densification to crack initiation. We find that densification correlates poorly with crack resistance, whereas shear flow localization shows a consistent relationship with crack resistance across the same set of compositions, as reflected in the correlation between crack resistance and plastic-zone surface roughness. These results clearly indicate that shear localization—not densification—is the primary mechanism of crack initiation under Vickers indentation, further supporting our recent findings (Bourguignon et al., 2026). Crack initiation mainly follows the mechanism proposed by Hagan et al. decades ago, in which intersecting shear faults nucleate cracks during unloading. Together, by clarifying this mechanism, the present work provides a predictive and grounded framework for understanding contact damage in oxide glasses. The effects of network former and network modifier type on the shear response, and their possible relation to glass structure, will be discussed.

[14:50~15:10] Design of Theta Device for the Micro Tensile Testing of Silica

Wenjuan Cheng (Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Rome, Italy), *Meral Tuna* (Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Rome, Italy), *Edoardo Rossi* (Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Rome, Italy), *Jens Bauer* (Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344, Eggenstein-Leopoldshafen, Germany), *Marco Sebastiani* (Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Rome, Italy)

Type: Oral

Microscale tensile and fracture testing of brittle materials remains challenging because direct gripping and alignment are difficult at small length scales. Consequently, mechanical characterization of microfabricated silica structures still relies mainly on compression, bending, or nanoindentation, although these methods do not provide a direct uniaxial tensile fracture response. Push-to-pull and theta-like specimens offer an attractive solution by converting an externally applied compressive load into tensile loading in a central gauge section; however, many existing designs require complex calibration, digital image correlation, or nontrivial specimen preparation. Here, we introduce a theta-type push-to-pull device for evaluating the tensile fracture behavior and mode-I fracture toughness of microscale 3D-printed silica. The devices are fabricated by two-photon polymerization direct laser writing followed by pyrolysis, enabling monolithic silica test structures with controlled gauge and frame geometries. Unnotched specimens are used to determine tensile fracture strength and probability of failure. The device design is established through an analytical–numerical–experimental framework. First, an analytical model is derived from the theta geometry to describe the transfer relationship

between the external tip load/displacement and the local gauge load/displacement. The model defines two geometry-dependent transfer factors, n and k , where $P_{\text{gauge}}/P_{\text{tip}}=n$, and $u_{\text{gauge}}/u_{\text{tip}}=k$. Finite element modelling is then used to verify the analytical prediction and examine the stress and displacement distributions. The FEM results confirm linear load and displacement transfer within the elastic range, consistent with the analytical model. Finally, in situ experiments on pyrolyzed silica theta devices are performed to validate the transfer relationship and confirm fracture in the designed gauge. This calibrated theta-type geometry enables reconstruction of the local tensile response from external measurements, without direct local strain measurement or digital image correlation, and provides a route toward high-throughput ex situ fracture testing of brittle 3D-printed ceramic microstructures.

Session AS

2026-11-04 14:00 ~ 15:10 | 307 | Chair: Seung Min Han

[14:00~14:25] Combinatorial Nanoindentation and Strengthening Analysis of Refractory Complex Concentrated Alloys of Mo–Nb–Ti and Ta–Nb–Ti

Taeyeop Kim (Yeungnam University), Daegun You (University of Illinois at Urbana-Champaign), Dongwoo Lee (Sungkyunkwan University)

Type: Invited

Strengthening in refractory complex concentrated alloys (RCCAs) is governed by multiple factors, including grain size, lattice distortion, chemical interactions, and local atomic ordering. To efficiently investigate these effects across broad compositional spaces, combinatorial synthesis and high-throughput nanoindentation provide an effective approach. Thin-film alloy libraries spanning wide compositional gradients can be fabricated by magnetron co-sputtering and subsequently characterized through nanoindentation mapping together with microstructural analyses. As a case study, we systematically investigated Mo–Nb–Ti and Ta–Nb–Ti thin-film alloy libraries with broad composition ranges. Composition-dependent X-ray diffraction and electron microscopy showed that Mo–Nb–Ti alloys retained ultrafine grain structures with minimal temperature sensitivity, whereas Ta–Nb–Ti alloys underwent significant grain coarsening at elevated temperatures. Nanoindentation mapping revealed that Mo–Nb–Ti alloys consistently exhibited higher hardness and resistance to plastic deformation than Ta–Nb–Ti alloys, with strengthening largely affected by solid-solution effects. On the other hand, the hardness reduction in Ta–Nb–Ti films deposited at high temperature was directly correlated with grain coarsening. Molecular dynamics simulations demonstrated that short-range ordering plays a critical role in strengthening and plasticity in the RCCAs.

[14:25~14:45] Indentation-Based Multiscale Analysis of Deformation and Fracture Mechanisms in Potassium-Doped Tungsten

Jeongseok Kim (Seoul National University), Guensik Min (Seoul National University), Won-Seok Ko (Korea University), Phu Cuong Nguyen (The University of Texas at Dallas), Sungmin Lee (Seoul National University), Cheol-Heon Oh (Seoul National University), Hwangsun Kim (Seoul National University), Hojae Kwak (Seoul National University), Yeonju Oh (Seoul National University), Ill Ryu (Seoul National University), Dongchan Jang (Korea Advanced Institute of Science and Technology), Heung Nam Han (Seoul National University)

Type: Oral

Understanding how nanoscale defects govern the competition between plastic deformation and fracture is essential for assessing the mechanical reliability of potassium-doped tungsten. In this work, nanoindentation and multiscale simulations were combined to clarify the roles of potassium bubbles and pre-existing dislocations in incipient plasticity and grain-boundary fracture. Pop-in statistics of potassium-doped tungsten with a relatively low dislocation density (WK_LD) in load-displacement curves revealed that potassium bubbles influence the initiation of plastic deformation. Dislocation dynamics simulations reproduced this behavior and

showed how the stress fields associated with potassium bubbles modify dislocation nucleation and activation beneath the indenter. The simulations were then extended to model a more complex microstructure in which potassium bubbles and pre-existing dislocations coexist, allowing their competing contributions to the first pop-in event to be evaluated. To experimentally examine the predicted interaction between these defects, nanoindentation was performed on potassium-doped tungsten with a high dislocation density (WK_HD). The results confirmed that, when sufficient pre-existing dislocations are present, the first pop-in is governed primarily by their activation and glide, while potassium bubbles exert a secondary influence on incipient plasticity. The results also showed temperature-dependent stress for incipient plasticity. The microstructure of WK_HD was further represented using molecular dynamics simulations to quantify the temperature-dependent fracture stress of WK_HD containing potassium bubbles at grain boundaries. These calculations showed that bubbles at grain boundaries reduce the resistance to intergranular fracture, in contrast to the beneficial role of pre-existing dislocations in facilitating local plasticity. The combined results demonstrate that nanoindentation, supported by computational simulations, can distinguish the competing effects of nanoscale defects on deformation and fracture and provide a mechanistic basis for evaluating the ductile-to-brittle transition of potassium-doped tungsten.

[14:45~15:05] Ligament reattachment and connectivity-driven mechanical behavior in nanoporous gold

Sukwon Hong (Ulsan National Institute of Science and Technology), Younghoon Kim (Ulsan National Institute of Science and Technology), Hansol Jeon (Keimyung University), Ju-Young Kim (Ulsan National Institute of Science and Technology)

Type: Oral

Nanoporous gold has a bi-continuous open-cell structure composed of ligament and pore networks, where structural randomness and spatial heterogeneity introduce dangling ligaments that do not contribute to load-bearing. As a result, load-bearing capability is limited even at identical relative density due to disconnected ligaments within the network. Mechanical properties of nanoporous metals are generally described by relative density, and conventional approaches have primarily focused on morphology control, including ligament size variation. However, such approaches do not sufficiently address mechanical variation arising from differences in network connectivity. In this study, hydrostatic-assisted thermo-mechanical conditions are introduced to activate ligament reattachment within the random network. Thermo-mechanical conditions under hydrostatic pressure provide isotropic confinement, enabling selective activation of ligament reattachment during thermal processes. This approach aims to modify load-bearing pathways at constant relative density by increasing the population of load-bearing ligaments without significant ligament coarsening. As a result, a topology-based framework is considered to distinguish connectivity-related contributions from morphological effects. Elastic modulus and hardness are measured by nanoindentation to determine mechanical properties, which are used to assess variations associated with ligament reattachment. These variations are interpreted in relation to reconfiguration of load-bearing ligament population and network connectivity in nanoporous gold.

Session EE

2026-11-04 14:00 ~ 15:10 | 305 | Chair: Hansol Jeon

[14:00~14:25] Probing Thermally Activated Dislocation Mechanisms in MgO and bcc metals by High Temperature Scanning Indentation

Karsten Durst (TU Darmstadt), Marcel Sos (TU Darmstadt), Sebastian Bruns (TU Darmstadt)

Type: Invited

High temperature scanning indentation (HTSI) enables the real-time acquisition of mechanical properties during controlled heating or cooling of a sample, delivering hardness, elastic modulus and the strain rate sensitivity m , as well as the apparent activation volume V^* as a quasi-continuous function of temperature. Compared to conventional strain rate jump testing, this yields an order-of-magnitude higher data density from a single test, allowing the direct identification of transition temperatures and thermally activated deformation mechanisms across a wide temperature range (up to 1100°C). We illustrate this capability with two examples. In refractory bcc metals, HTSI on Mo and Cr resolves the brittle-to-ductile transition (BDT) through the characteristic peak in strain rate sensitivity followed by a sharp rise in activation volume. These transitions are benchmarked against strain rate jump tests and uniaxial compression data, allowing an assessment of the brittle to ductile transition from short, high-speed relaxation segments. In the ceramic model system MgO, quasi-continuous HTSI measurements from room temperature to 800°C reveal an analogous sequence of transitions: from kink-pair-controlled plasticity to an obstacle-controlled regime near 240°C, followed by a peak in strain rate sensitivity and a marked increase in activation volume above 675°C. These changes in hardness and activation parameters can be linked to a dislocation mechanism change. Together, these examples demonstrate HTSI as a helpful new methodology for mapping thermally activated deformation and transition-temperature phenomena across metals and ceramics, with direct relevance to understanding fundamental deformation mechanism. [description here](#).

[14:25~14:45] Spatially Resolved Strain Rate Sensitivity in a Dissimilar Steel Weld: Insights from High-Rate Nanoindentation

Bryan A. Crawford (KLA), Kurt E. Johanns (KLA), Lee W. Spencer (KLA), Yuming Lou (KLA)

Type: Oral

Dissimilar welds, such as joints between austenitic stainless steels and low-carbon steels, exhibit complex microstructural gradients that strongly influence local deformation behavior and fracture susceptibility. While conventional mechanical testing provides bulk-averaged properties, it lacks the spatial resolution required to capture localized variations in strain rate sensitivity (SRS) - a critical parameter governing deformation mechanisms under dynamic loading. In this work, we present the SRX™ methodology capable of measuring strain rate sensitivity under well-controlled deformation conditions spanning multiple orders of magnitude in strain rate. This approach integrates high-speed feedback control, time-synchronized load-displacement acquisition, and minimized measurement time constants, enabling accurate extraction of SRS with micron-scale

spatial resolution. To demonstrate this capability, a dissimilar weld joint between 316 stainless steel and 1018 low-carbon steel was fabricated and characterized across the weld metal, heat-affected zones (HAZ), and base materials. While elastic modulus remained relatively uniform, hardness and SRS exhibited pronounced spatial heterogeneity. The base materials showed consistent positive SRS (~ 0.023), whereas the HAZ regions displayed reduced sensitivity. Most notably, the weld center exhibited near-zero to negative SRS, suggesting localized deformation instability. This behavior is attributed to the chemically heterogeneous weld microstructure, where solute-dislocation interactions may promote dynamic strain aging or related mechanisms. The rapid transition in SRS over length scales of tens of microns highlights the importance of spatially resolved measurements. These results demonstrate that high strain-rate nanoindentation extends beyond bulk validation to enable direct mapping of deformation mechanisms, providing new insight into structure-property relationships in dissimilar welded systems under dynamic loading.

[14:45~15:05] Nanoindentation for mechanical characterization under elevated temperatures and irradiation

Edyta Wyszowska (National Centre for Nuclear Research, Poland), Jacek Jagielski (National Centre for Nuclear Research, Poland), Łukasz Kurpaska (National Centre for Nuclear Research, Poland), Im-Deok Kim (Seoul National University, South Korea), Seung-Kyun Kang (Seoul National University, South Korea), JaeYong Kim (Korea Atomic Energy Research Institute (KAERI), South Korea), F. J. Dominguez-Gutierrez (National Centre for Nuclear Research, Poland), Witold Chromiński (Warsaw University of Technology, Poland), Anna Kosińska (National Centre for Nuclear Research, Poland), Pavol Noga (Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Advanced Technologies Research Institute, Slovakia), Zoltán Száraz (Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Advanced Technologies Research Institute, Slovakia), Dušan Vaňa (Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Advanced Technologies Research Institute, Slovakia), Marcin Turek (Maria Skłodowska Curie University, Lublin, Poland)

Type: Oral

Nanoindentation is a well-established technique for probing the mechanical properties of a wide range of materials, from soft polymers to hard metals and protective coatings used in demanding industrial applications. In this presentation, I will discuss two research topics that demonstrate the capabilities of nanoindentation in evaluating mechanical behaviour under extreme conditions. The first part focuses on a joint Korean–Polish research project, Development of Functional Properties Evaluation Technology for Coated Accident Tolerant Fuel (ATF) Cladding. The project aims to characterize the mechanical response of Cr and Cr/Al protective coatings at room temperature, at elevated temperatures up to 600°C, and after ion irradiation. Stress–strain curves are determined using spherical nanoindentation and validated by tensile testing performed over the same temperature range, enabling reliable evaluation of key mechanical parameters, including yield strength (YS) and ultimate tensile strength (UTS). These experimental data serve as input for numerical simulations aimed at establishing a universal methodology for predicting tensile properties directly from nanoindentation measurements, ultimately supporting the assessment of materials operating in harsh nuclear environments. The second part addresses irradiation-induced hardening in fcc single crystals of pure Ni, $\text{Ni}_{0.88}\text{Fe}_{0.12}$, and $\text{Ni}_{0.77}\text{Fe}_{0.23}$. By combining ion irradiation, nanoindentation, transmission electron microscopy (TEM), and

atomistic simulations, the study provides insight into the relationship between irradiation damage and nanoscale mechanical response. Molecular dynamics simulations reproduce experimentally relevant irradiation doses via successive displacement cascades, thereby generating defect structures comprising vacancies, interstitial clusters, and dislocation loops. Simulated nanoindentation reveals the interaction of these defects with plastic deformation mechanisms, while post-processing analysis quantifies surface pile-up, dislocation nucleation and propagation, localized strain, and defect evolution. The combined experimental and computational approach provides a comprehensive understanding of the influence of irradiation-induced defects on the mechanical behaviour of Ni-Fe alloys.

Session CC

2026-11-04 15:30 ~ 17:10 | 306 | Chair: Gustavo Alberto Rosales-Sosa

[15:30~15:55] Mapping of nanoindentation behavior of TiZrHf-boride, -carbide and dual-phase -boride/carbide coatings

Frantisek Lofaj (*Institute of Materials Research of SAS*)

Type: Invited

Non-equimolar multi-metal carbide and boride ceramics, commonly called compositionally complex ceramics, represent a novel and extensive class of materials often exhibiting improved properties. They can be controlled via the type and number of cations (metals), anions (such as boron, carbon, and nitrogen), and compound stoichiometry. In contrast to sintering of bulks, co-sputtering and or reactive sputtering offer a relatively easy way to produce coatings with variable composition, stoichiometry, and properties. This work aims to map the mechanical properties of TiZrHf-based carbide, boride, and dual-phase carbide/boride coatings over a wide range of stoichiometry deposited by reactive High Target Utilization Sputtering (HiTUS) using nanoindentation. The obtained carbide coatings were found to form homogeneous solid solutions with cubic structures, transforming from bcc toward fcc when the stoichiometry increases. Borides were also homogeneous; however, they crystallized as hcp structure, which is not compatible with fcc carbides. Thus, a dual-phase fcc carbide/hcp boride structure was obtained during simultaneous boron and carbon co-sputtering. The hardness and indentation moduli showed strong dependences on the anion (B and C) supply. The maxima within the 37-45 GPa and 280-350 GPa ranges were achieved at approximately stoichiometric composition. The highest values were found in the borides; however, the values in the carbides and boride/carbide coatings were only marginally lower. The obtained hardness values were in full consent with the values reported for similar bulk systems, whereas indentation moduli were substantially lower. Acknowledgements This work was supported by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under project No. 09I03-03-V04-00281, and by the Slovak Research and Development Agency (project APVV 24-0038).

[15:55~16:15] FRACTURE OF BRITTLE MATERIALS AND INTERFACES AT THE NANOSCALE

Oriol Gavalda Díaz (*Imperial College London*)

Type: Oral

Developing tougher brittle materials requires an understanding of the fracture mechanisms that govern crack initiation and propagation. In these systems, the processes that control failure are often highly localized to the immediate vicinity of the crack tip, making experimental approaches with nanoscale resolution essential. In this presentation, I will show how the combination of in-situ transmission electron microscopy (TEM) testing and 4D-STEM provides a powerful platform for directly probing fracture processes in brittle materials and interfaces. I will first present our work on single crystals, including SiC and yttria-stabilized zirconia (YSZ), with a particular focus on transformation toughening in YSZ. By linking stable crack growth experiments with 4D-STEM measurements, we are able to resolve the tetragonal-to-monoclinic phase transformation at the crack

tip and relate it to the local mechanisms governing crack advance and shielding. I will then discuss recent studies of brittle-brittle interfaces using ceramic composites and hard coatings as model systems. These experiments reveal how cracks propagate towards and across interfaces, and how crack speed is influenced by the local microstructure and by strain fields within the different layers. Finally, I will show work on ductile-brittle interfaces, highlighting the role of layer thickness in promoting crack bridging and, consequently, enhanced toughness. Overall, this presentation will show how in-situ TEM combined with 4D-STEM is a powerful approach for studying fracture in brittle materials, enabling direct correlation between crack-tip behavior, microstructure, and the nanoscale mechanisms responsible for toughening.

[16:15~16:40] Indentation-induced plasticity in oxide ceramics: From nanoindentation to shot peening

Hiroshi Masuda (*The University of Tokyo, Japan*)

Type: Invited

Ceramics are brittle materials that exhibit limited plasticity at macroscopic scales, whereas they can undergo dislocation-mediated plasticity at small scales without crack initiation even at room temperature. This presentation highlights the plastic deformation behavior of oxide ceramics investigated by nanomechanical testing, with particular emphasis on the nanoindentation experiments and molecular dynamics simulations of yttria-stabilized zirconia (YSZ). Furthermore, the concept of nanoindentation is extended to microparticle shot peening, which can be regarded as the accumulative process of numerous small indentations. Using this approach, high dislocation densities on the order of 10^{14} m^{-2} were introduced at room temperature throughout the subsurface regions of oxide ceramics including YSZ. This presentation would discuss the connection between the atomistic-scale dislocation dynamics and the evolution of mesoscale dislocation structures, providing a perspective on indentation-induced plasticity in ceramics across length scales.

[16:40~17:00] Influence of the multi-metal environment on the fracture toughness of ZrHfNbTaC₄ high-entropy carbide grains

Tamás Csanádi (*Institute of Materials Research, Slovak Academy of Sciences*), Marek Vojtko (*Institute of Materials Research, Slovak Academy of Sciences*), Zoltán Dankházi (*Institute of Physics and Astronomy, ELTE Eötvös Loránd University*), János Koltai (*Institute of Physics and Astronomy, ELTE Eötvös Loránd University*)

Type: Oral

Ultra-high-temperature high-entropy carbides (UHTCs) represent promising candidates for extreme environment applications, as the room-temperature deformability of their grains can be tuned by altering the effective valence electron concentration of the constituent metals. This study investigates the fracture toughness of ZrHfNbTaC₄ grains compared to HfC and TaC, which are traditionally identified as the most and least brittle rock-salt carbides, respectively. Fracture toughness was evaluated along the low-energy {001} cleavage planes utilising microcantilever bending of notched bars alongside first-principles density functional theory (DFT) calculations. Bulk samples were consolidated via spark plasma sintering, and individual grain orientations were mapped using electron backscatter diffraction (EBSD). Notched microcantilevers were micro-

machined via focused ion beam (FIB) milling from grains presenting {001} and {101} facets, ensuring beam directions were oriented perpendicular to the {001} cleavage planes prior to bending experiments. Concurrently, DFT simulations determined the relaxed crystal elastic constants and surface energies via large supercell separation to theoretically calculate fracture toughness. Experimental results revealed that the lowest fracture toughness corresponds to HfC ($K_{IC}=3.0 \text{ MPam}^{0.5}$) and the (Hf-Ta-Zr-Nb)C high-entropy carbide ($K_{IC}=3.1 \text{ MPam}^{0.5}$), whereas TaC exhibits an approximate 10% increase ($K_{IC}=3.3 \text{ MPam}^{0.5}$). The simulations yielded a comparable, lower-bound trend matching the experimental hierarchy, originating from the underlying differences in their electronic structures.

Session TF

2026-11-04 15:30 ~ 17:10 | 307 | Chair: Jin-Yoo Suh

[15:30~15:55] 3D Architected Ni-Al₂O₃ Nanocomposite via Proximity-Field Nanopatterning

Seung Min Han (Korea Advanced Institute of Science and Technology)

Type: Invited

An inch-scale metal/ceramic/metal (MCM) nanocomposite reinforced by ceramic nanoarchitectures, overcoming conventional prediction of the strength of an existing composite system will be presented. Proximity-field nanopatterning (PnP), which shows simultaneous enhancement of the large production area and high spatial resolution, enables inch-scale production of the nanocomposite in a single fabrication step. 3D Ni/Al₂O₃/Ni nanocomposite system shows significantly higher compressive strength (1.78 GPa), ~30 % increase compared to that calculated by upper bounds of conventional rule of mixture (1.36 GPa). Such high strength of the 3D MCM nanocomposite is attributed to the extrinsic size effect of ceramic thin-shell, where the thinner ceramic layer has higher fracture strength eventually leading to brittle-to-ductile transition of the ceramic layer. By combining the size-induced strengthening of ceramics into the conventional strengthening law in composite, a new strengthening model is derived and experimentally demonstrated using 3D Ni/Al₂O₃/Ni nanocomposite system

[15:55~16:15] Investigation of mechanical properties of Ni-Co-Cr thin film using a high-throughput combinatorial method

Geummi Lee (KAIST), Semin Park (KAIST), Daeho Kim (KAIST), Seung Min Han (KAIST)

Type: Oral

NiCoCr medium-entropy alloys have gained considerable interest for use in extreme environments owing to their exceptional low-temperature strength and ductility. Nevertheless, their comparatively limited yield strength at room temperature has driven the exploration of non-equiatomic alloy designs to further enhance mechanical properties. Here, a compositionally graded Ni-Co-Cr thin film covering a broad compositional space of 17–57 at.% for each constituent element was fabricated by co-sputtering elemental Ni, Co, and Cr targets. The deposited coating contained both a single-phase face-centered cubic (FCC) domain and a multiphase domain consisting of hexagonal close-packed (HCP) and sigma phases. To assess composition-dependent mechanical behavior while reducing substrate effect, high-throughput nanoindentation was employed to generate hardness and elastic modulus maps. Within the single-phase FCC region, the Ni₂₀Co₄₀Cr₄₀ composition exhibited the highest hardness of 7.45 GPa, which is attributed to strengthened nonlinear Co–Cr interactions that hinder dislocation motion. In the multiphase region, the maximum hardness reached 9.11 GPa at the Ni₂₀Co₂₅Cr₅₅ composition. These results highlight the utility of combinatorial thin-film approaches for efficiently discovering optimized non-equiatomic compositions beyond the conventional equiatomic NiCoCr alloy. The findings provide important insight into composition–microstructure–property relationships in NiCoCr-

based alloys and support the applicability of thin-film combinatorial screening for predicting mechanical trends in corresponding bulk alloy systems.

[16:15~16:40] Design of Strengthened and Toughened Thin Film Materials Based on Nano-Ordered Structures

Kan Zhang (*Jilin University*)

Type: Invited

Hard protective thin film materials generally suffer from an inherent trade-off between hardness and toughness, where improving hardness often leads to brittle fracture. To overcome this challenge, we propose a series of nanoscale microstructural engineering strategies that simultaneously enhance hardness, strength, and toughness. Specifically, we exploited the intrinsic immiscibility arising from the near-zero mixing enthalpy between Cu and B to fabricate a vertically aligned bamboo-like nanocolumnar Cu film reinforced by an amorphous boron framework via magnetron co-sputtering. The resulting architecture achieves an indentation hardness of 10.8 GPa while retaining excellent mechanical performance, including a yield strength of ~1.36 GPa, a flow stress of ~2.58 GPa, and a failure strain exceeding 50% [1]. We then proposed an atomic-scale tailoring strategy using "negative mixing enthalpy + high lattice distortion" to induce localized disordered clusters. This approach transforms the topologically ordered structure of transition-metal high-entropy alloys into a novel high-entropy paracrystalline structure composed of sub-nanoscale sub-crystals. This innovation achieved a 100% increase in hardness and a 69.2% increase in compressive strength, together with a significant enhancement in ultimate plastic deformation capacity [2]. Furthermore, we introduced an extra-large mixing enthalpy difference strategy to engineer high-entropy alloy self-assembled multilayers. The pronounced mixing enthalpy difference between Pt and the other constituent elements tailors interatomic attractive interactions, driving spontaneous multilayer formation that effectively suppresses dislocation motion and achieves a hardness of 12.9 GPa [3]. This series of works demonstrates the simultaneous enhancement of hardness, strength, and toughness through bamboo-like nanostructures, sub-nanoscale paracrystalline structures, and self-assembled multilayers. These findings provide new insights into the microstructural design and performance optimization of structural materials. Keywords: Thin film; Nanostructure; Strengthening; Toughening. Reference [1] Nature Communications, 2023, 14, 4836. [2] Nature Communications, 2023, 14, 775. [3] Acta Materialia, 2024, 267, 119729.

[16:40~17:05] Effect of structural hierarchy on mechanical behavior of nanoporous gold

Hansol Jeon (*Keimyung University*)

Type: Invited

Fabrication routes for hierarchical nanoporous gold (HNPG), multiple levels of an open-cell structure with nano-sized ligaments and pores in the material, have been recently developed. A comparison of the mechanical behavior of unimodal nanoporous gold (NPG) and HNPG usually has the drawback of different solid fractions for both materials. Here, we studied mechanical properties of NPG and HNPG with the same solid fraction by conducting compressive tests at micro-scale in electrochemical environment. We prepared NPG and HNPG

pillars from the same master alloy Ag₈₅Au₁₅. We found that (1) the flow stress in HNPG is much higher than in NPG, (2) the OH- adsorbed surface layer is responsible for enhancement of flow stress, and (3) a ligament-size effect exists in the lower-level structure of HNPG in terms of flow stress and stress variation by OH- adsorption. Connectivity and dislocation activity as the origin for the difference in mechanical properties were discussed.

Session EE

2026-11-04 15:30 ~ 17:10 | 305 | Chair: Gi-Dong Sim

[15:30~15:55] High temperature nanomechanical testing of high entropy materials: recent efforts & ongoing challenges

Thomas EDWARDS (NIMS)

Type: Invited

High entropy alloys and ceramics pose a particular challenge to high temperature nanomechanical testing due to their vast range of chemistries, which inevitably leads to opportunities for reaction with the indenter. In this talk, results from our recent in-SEM investigations of the strength and fracture toughness of both refractory HEA and high & medium entropy nitrides (HENs) at temperatures up to 1000 °C will be presented, along with the impact on the probe, and potential pitfalls of such testing. Notably, studies on Al and Si doping of equimolar (TiHfNbVZr)N-base magnetron sputtered hard coatings are particularly challenging due to their extreme hardness that approximates diamond at such high temperatures. Furthermore, we shall discuss several ongoing mitigative efforts – from indenter material selection & barrier coatings, to alternative, more tolerant test geometries.

[15:55~16:15] Probing Tungsten Deformation at Extreme Conditions Through High-Temperature, High-Strain-Rate Nanoindentation

Eric Hintsala (Bruker), Kevin Schmalbach (Bruker)

Type: Oral

The development of next-generation energy and aerospace technologies places increasing demands on structural materials exposed to severe thermomechanical environments. Nanoindentation provides a unique means of probing localized deformation processes, yet experimental access to the combined regime of elevated temperature and high strain rate has emerged only recently. Using tungsten as a representative refractory material, this study explores nanoindentation responses at temperatures and controlled strain rates approaching 1000 s⁻¹. The commonly applied contact assumptions will also be explored alongside their effect on both the directly measured properties and extracted parameters such as activation volume and strain-rate sensitivity.

[16:15~16:35] Microscale Impact Deformation Mechanisms in FCC Single Crystals and Medium-Entropy Alloys

Jian Chen (Southeast University), Kehua Wang (Southeast University)

Type: Oral

Understanding dynamic mechanical response is crucial for applications such as micro-electromechanical systems (MEMS), where localized deformation at micro/nanoscales occurs. Conventional techniques (Hopkinson

bar, light gas gun, dynamic indentation) are limited by size, while a pendulum-based nano-impact tester derived from instrumented nanoindentation can mimic dynamic failure. However, detailed investigations of the underlying physical processes remain scarce. This study systematically examines dynamic indentation responses of face-centered cubic (FCC) single crystals (Al, Ni, Cu) and CoCrNi-based medium-entropy alloys to elucidate microscale impact deformation mechanisms.(1) Al(110): Quasi-static nanoindentation produced 97.58% plastic work with cellular sub-grains containing low-angle grain boundaries (LAGBs, 30.27%). Under high-strain-rate nano-impact, plastic work dropped to 89.46% and the microstructure evolved into a surface microband-subgrain mix with LAGBs surging to 80.50%. A microband evolution model, stabilized by Lomer-Cottrell locks, is proposed.(2) Ni(100) and Cu(100): Distinct pile-up symmetries under quasi-static indentation shifted to suppressed pile-up under impact. High strain rates promoted LAGB formation in Ni, but high-angle grain boundaries in Cu, attributed to stacking fault energy differences.(3) (CoCrNi)_{100-x}Al_x alloys: Increasing Al content enhanced dynamic hardness via solid-solution strengthening and B2 phase precipitation. Deformation structures stratified by strain rate: dense twin/stacking fault bundles near the surface, transitioning to dislocation-dominated regions deeper inside. A hierarchical model involving V-shaped intersections and lateral faulting explains strain accommodation. These findings provide fundamental insights into dynamic deformation behavior at micro/nanoscales, guiding the design of advanced structural materials.

[16:35~16:55] Evaluation of Low-Temperature Embrittlement of Metallic Materials in Rebound Hardness Testing

Kenji Matsuda (*Kyushu Institute of Technology*), Takanori Iruya (*Kyushu Institute of Technology*)

Type: Oral

It is known that metals become embrittled due to low-temperature environments or neutron irradiation. This study investigated whether the degree of material embrittlement could be evaluated using the rebound hardness test, with a view to applying the method to the integrity assessment of structures from which it is difficult to extract test specimens. We developed a rebound hardness testing apparatus capable of operating at temperatures as low as -80°C . Specimens made of cold-drawn SS400 (JIS G 3101) steel and cold-drawn free-cutting brass were set in the apparatus, then three types of hammers, each equipped with a diamond square-pyramidal indenter having a different apex angle, were dropped freely from a height of approximately 4 mm onto the surface of test specimens. Their rebound behavior was measured using a laser Doppler vibrometer. As a result, it was confirmed that for cold-drawn SS400, which exhibited a significant decrease in Charpy impact value at -80°C , the coefficient of restitution at that temperature was several percent higher than at room temperature. On the other hand, for cold-drawn free-cutting brass, in which no decrease in Charpy impact value was observed even at -80°C , no clear difference in the coefficient of restitution was found either. The cause of the increase in the coefficient of restitution of cold-drawn SS400 at low temperatures was investigated through tensile tests conducted at both room and low temperatures and finite element analysis of rebound hardness. The results revealed that changes in the stress-strain curve due to low-temperature embrittlement lead to the increase in the coefficient of restitution.

Session CC

2026-11-05 09:00 ~ 10:10 | 306 | Chair: Wei Li

[09:00~09:25] Electron–Matter Interactions in Silicon Oxides: From Irradiation-Induced Viscoplasticity to Mechanical Amorphization

Sung-Gyu Kang (*Gyeongsang National University*)

Type: Invited

Electron-beam irradiation is generally employed for imaging and microstructural characterization, yet it can also influence the intrinsic deformation behavior of materials through electron–matter interactions. In this work, we explore the mechanical response of silicon oxides subjected to electron-beam irradiation using in-situ scanning electron microscopy mechanical testing, with a focus on amorphous silica and single-crystalline α -quartz. Under electron-beam irradiation, amorphous silica exhibits substantial room-temperature plastic flow, allowing significant shape modification without external heating. The magnitude of this deformation is closely linked to the volume affected by electron–matter interactions. In contrast, single-crystalline α -quartz responds to irradiation by undergoing facilitated mechanical amorphization during compression. The irradiation-assisted formation of amorphous regions occurs at markedly reduced stress levels, and the transformed regions subsequently accommodate further deformation through viscoplastic flow. To understand the origin of these phenomena, experimental results were correlated with electron–matter interaction simulations and atomistic modeling. The analyses suggest that inelastic electron scattering generates excess electronic charges that alter the bonding characteristics of the Si–O network. This electronic modification reduces local repulsive interactions and facilitates bond rearrangement, thereby lowering the barriers to structural transformation and amorphization. Consequently, deformation mechanisms that are normally activated only under high temperatures or extreme pressures can operate at ambient conditions. These findings highlight the potential of electron beams as a means of manipulating deformation pathways in oxide materials and open new possibilities for small-scale glass processing and manufacturing.

[09:25~09:45] Let's get to the point (defect): how oxygen vacancies alter dislocation mechanics in oxides

Chukwudalu Okafor (Institute for Applied Materials, Karlsruhe Institute of Technology, Karlsruhe, Germany), Oliver Preuss (Institute for Applied Materials, Karlsruhe Institute of Technology, Karlsruhe, Germany), Ahmad Sayyadi-Shahraki (Department of Materials and Earth Sciences, Technical University of Darmstadt, Darmstadt, Germany), Sebastian Bruns (Department of Materials and Earth Sciences, Technical University of Darmstadt, Darmstadt, Germany), Pierre Hirel (Université Lille, CNRS, INRAE, Centrale Lille, Unité Matériaux et Transformations, Lille, France), Karsten Durst (Department of Materials and Earth Sciences, Technical University of Darmstadt, Darmstadt, Germany), Xufei Fang (Institute for Applied Materials, Karlsruhe Institute of Technology, Karlsruhe, Germany)

Type: Oral

Understanding the interplay between mechanical behaviour and point defects is critical for developing next-generation functional oxides. While traditional defect-tuning relies heavily on chemical doping strategies, dislocations have recently emerged as a promising pathway to manipulate both the physical and mechanical properties of ceramic oxides. This study investigates the direct interaction between dislocations and point defects in strontium titanate (SrTiO₃), a model perovskite oxide. By employing electric field induced stoichiometry polarization (electromigration), we systematically altered the local defect chemistry, specifically creating an oxygen vacancy concentration gradient. Nanoindentation experiments, supported by molecular dynamics simulations, reveal that these changes in defect chemistry significantly shift the threshold shear stress required for dislocation nucleation. To further understand this coupling, we systematically explored how indenter tip size and geometry influence dislocation nucleation across specimens with varying point defect concentrations. Our results demonstrate that acceptor(Fe)-doped strontium titanate, which possesses a high density of oxygen vacancies, facilitates dislocation nucleation, validating the findings of the electromigration experiment. Donor(Nb)-doped material, with low density of oxygen vacancies, however, shows higher nucleation stress. Collectively, these insights clarify how vacancies facilitate dislocation nucleation in perovskites, providing a fundamental framework for evaluating and tailoring the mechanical stability of dislocation-engineered functional ceramics.

[09:45~10:10] Enabling dislocation engineering in ceramics: an indentation-based deformation toolbox and mechanism map

Oliver Preuss (Karlsruhe Institute of Technology), Chukwudalu Okafor (Karlsruhe Institute of Technology), Yanfei Gao (University of Tennessee), Xufei Fang (Karlsruhe Institute of Technology)

Type: Invited

Dislocations in ceramics are sparking renewed interest for their great potential in tuning both mechanical and functional properties. In the conventional picture, ceramics are perceived as brittle solids exhibiting little dislocation plasticity at room temperature. In order to harvest the versatile dislocation-based properties in ceramics, a key challenge is to engineer dislocations into brittle ceramic materials effectively and efficiently, without inducing cracks. To this end, we have separately examined dislocation nucleation, multiplication, and motion using various indentation techniques. This has enabled us to tailor dislocations into some ceramics at room temperature in a fast and simple manner. We can now achieve a dislocation density ranging from, e.g., $\sim 10^{10}/\text{m}^2$ to $\sim 10^{15}/\text{m}^2$ with a plastic zone size of up to macroscale using a variety of methods in our deformation toolbox at room temperature. In this talk, we will present an indentation deformation mechanism map based on spherical indentation across the length scale, addressing the competition between plastic deformation and fracture during indentation. This indentation deformation mechanism map is useful for guiding dislocation engineering in various brittle ceramics. A few examples will also be showcased for dislocation-engineered functional and mechanical properties in ceramics.

Session TF

2026-11-05 09:00 ~ 10:10 | 307 | Chair: Zaoli Zhang

[09:00~09:25] Mechanical Performance of an Electrodeposited Ni-Fe Film using the Loading Secant Stiffness Method of the Instrumented Indentation Test

Giovanni Maizza (Department of Applied Science and Technology, Politecnico di Torino, Torino, 10129, Italy), Ahmad Atef Abdullatef Hamed (Department of Industrial Engineering, University of Rome "Tor Vergata", 00133 Rome, Italy), Hyeonjin Eom (Low-Carbon Emission Control R&D Department, Korea Institute of Industrial Technology, Seobuk-gu, Cheonan-si, 31056, Republic of Korea)

Type: Invited

The outstanding mechanical properties of electrodeposition Ni-Fe films have frequently been investigated as a function of Fe concentration and grain size, although the number of parameters and factors affecting the film fabrications are numerous, such as, fabrication parameters (bath temperature, current density and feeding mode, substrate material and shape, additives, etc.), microstructure factors (texture, lattice defects, fabrication defects, impurities), film factors (roughness, thickness, macro-residual stress). Most of these factors may influence the film growth from its first stage until the end of deposition leading to different film properties at its top and bottom. Previous investigations, although not specifically addressing the mechanical performance, have shown some differences in Fe content, HIT and EIT between bottom (adjacent to the cathode) and top (the last deposited layers) of the deposited Ni-Fe film. The current research aims at analyzing the difference in mechanical performance between the bottom and top sides of a freestanding Ni-Fe (200 μm thick) film by carrying on both sides instrumented indentation test (IIT) in the nano- and macro-scale under multiple peak loads. The standard indentation hardness (HIT) and modulus (EIT) are complemented with the rate-derived hardness (HR), derived from the loading secant stiffness rate (LSR), to overcome the indentation size effect (ISE) problem. The loading secant stiffness rate versus depth curves provide a useful means to analyzed the stability strength of the residual stress induced during fabrication (if any) upon indentation. X-ray diffraction (XRD) measurements were carried out on both sides to measure the full width at half maximum (FWHM) of the preferred orientation peaks. The results show that significant residual stress relaxation can accompany the indentation tests and that the mechanical performance were enhanced at the top side due to higher values of all measured indentation properties, HIT, EIT, and HR than the bottom side of the film.

[09:25~09:45] Understanding fatigue behavior in NiTi thin films for reliable elastocaloric cooling

Hyemin Ryu (Korea Advanced Institute of Science and Technology), Jae-Hoon Choi (Jeonbuk National University), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Oral

Shape memory alloys (SMAs) have attracted considerable interest as elastocaloric cooling materials because of their high cooling efficiency and environmental compatibility. The elastocaloric effect arises from the

reversible, stress-induced phase transformation between austenite and martensite. Although bulk NiTi alloys have been widely investigated for solid state cooling, the elastocaloric performance of NiTi thin films remains relatively unexplored despite their potential for compact cooling applications. Moreover, practical implementation requires a fundamental understanding of their fatigue behavior and improved functional performance during repeated cyclic loading. In this study, we first investigate the fatigue behavior and cyclic stability of NiTi-based SMA thin films. Fatigue experiments were conducted using a custom-built microscale tensile testing system, and cyclic stability was evaluated from the evolution of the stress-strain response during repeated loading. Ni-rich NiTi thin films exhibited greater cyclic stability than near-equiatom NiTi thin films, which was attributed to the homogeneous distributed Ni_4Ti_3 precipitates and the refined grain structure. Building on this mechanical assessment, the elastocaloric response of the thin films was evaluated by measuring their temperature evolution using an infrared camera. A pronounced temperature change was observed during loading and unloading under vacuum. These results demonstrate that a substantial elastocaloric effect can be realized in NiTi-based thin films while highlighting the importance of fatigue resistance for maintaining their functional performance. Overall, this study establishes a foundation for the use of SMA thin films in compact elastocaloric cooling devices for microscale thermal management.

[09:45~10:05] Simultaneously high tensile and fatigue strengths in thin films with atomic-scale planar defects

JungHun Park (Korea Advanced Institute of Science and Technology), Yuhyun Park (Korea Advanced Institute of Science and Technology), Sunkun Choi (Korea Advanced Institute of Science and Technology), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Oral

Fatigue failure remains one of the most pervasive yet intractable challenges in structural materials. Unlike monotonic deformation, largely governed by the ability to resist global plastic deformation, cyclic damage is highly sensitive to localized stress concentrations. As a result, microstructures optimized for high monotonic strength do not necessarily yield commensurate fatigue strength enhancement; the fatigue strength often exhibits a plateau or a declining trend beyond a certain tensile strength. While nanotwinned alloys with high-density coherent twin boundaries (CTBs) show a good balance of tensile and fatigue strengths, previous studies suggest that the fatigue strength eventually diminishes as the TB spacing is refined below a critical value. Here, we conduct a systematic study on nickel-based alloy thin films with low and high solute concentrations. The former predominantly comprises CTBs with an average spacing of 3.6 nm, while the latter comprises stacking faults (SFs) with an average spacing of 0.6 nm. While both films demonstrate high tensile strengths of 2.3 and 2.8 GPa, respectively, the fatigue strength of the dilute film is comparable to those of nanocrystalline nickel and other nanotwinned metals. In contrast, the SF-dominant film demonstrates superior high-cycle fatigue strength exceeding 2 GPa, approximately 80% of its UTS. The simultaneously high tensile and fatigue strengths are attributed to the synergistic role of atomic-scale SFs, high density of low-angle grain boundaries (GBs), and solute segregation to the GBs. Although further validation is warranted, comparisons with films of similar compositions and microstructures indicate that all three features are crucial in achieving the tensile-fatigue strength synergy.

Session EE

2026-11-05 09:00 ~ 10:10 | 305 | Chair: Dong-Hyun Lee

[09:00~09:25] Mechanistic understanding of time-, orientation-, and temperature-dependent deformation in titanium using nanoindentation

Tea-Sung Jun (Incheon National University)

Type: Invited

Titanium exhibits complex deformation behaviour owing to its hexagonal close-packed crystal structure, where the activation of deformation mechanisms strongly depends on crystallographic orientation, loading time, and temperature. Understanding the interplay among these factors is essential for improving the structural integrity and reliability of titanium components used under demanding service conditions. This presentation provides a comprehensive overview of recent insights into the local deformation behaviour of titanium utilizing nanoindentation-based micromechanical testing. The discussion highlights how crystallographic orientation governs local plasticity, how time-dependent deformation evolves under sustained loading, and how temperature alters the underlying deformation mechanisms. By integrating nanoindentation with complementary microstructural characterization techniques, including electron backscatter diffraction (EBSD), the relationship between microstructure and local mechanical response is critically examined across diverse deformation regimes. These studies demonstrate the robust capability of nanoindentation to probe deformation behaviour over a wide range of loading and environmental conditions while providing mechanistic insights into slip activity, crystallographic anisotropy, and thermally activated deformation. This work highlights the role of nanoindentation as a versatile experimental tool for advancing the fundamental understanding of titanium metallurgy and supporting the microstructure-informed design of advanced titanium alloys.

[09:25~09:45] From High-Speed Mechanical Mapping to High-Temperature Micropillar Compression: Multiscale Mechanical Characterization of Ti(C,N)-FeNi Cermets

Hossein Besharatloo (UPC (Spain)), Maria de Nicolás-Morillas (University Carlos III of Madrid), Ming Chen (ETH Zurich), Begoña Ferrari (CSIC-ICV (Spain)), Elena Gordo (University Carlos III of Madrid), Jeffrey.M Wheeler (ETH Zurich), Luis Llanes (UPC (Spain))

Type: Oral

Ti(C,N)-FeNi cermets are promising materials for cutting applications because they combine hard ceramic particles with a metallic binder capable of plastic deformation and crack-energy dissipation. Their performance depends not only on the average mechanical properties of the composite, but also on the local response and spatial distribution of the constituent phases and on load transfer across the ceramic-metal interfaces. Moreover, these materials frequently operate under elevated temperatures generated by friction and severe contact loading. Since temperature may substantially modify binder plasticity, interfacial response, and failure mechanisms, high-temperature mechanical characterization is essential to assess their service-relevant behavior. In this study, high-speed nanoindentation mapping, statistical analysis, and in situ micropillar

compression at different temperature were combined to characterize Ti(C,N)-FeNi cermets at different length scales. Large indentation grids provided spatially resolved hardness maps and allowed the responses of the constituent phases to be distinguished. Stress-strain behavior was then assessed by compressing focused-ion-beam-milled micropillars with diameters of 2 and 4 μm . The 2 μm pillars showed considerable scatter because their response depended strongly on the local phase distribution. The 4 μm pillars contained phase fractions closer to those of the bulk microstructure and produced a more reproducible composite response. Once the representative pillar size was established, the effects of ceramic/binder ratio, processing route, and temperature were evaluated. Compression at 400 °C resulted in a pronounced reduction in yield strength and a change in deformation behavior from predominantly constrained plastic flow of the FeNi binder at room temperature toward increased ceramic-metal interfacial sliding and binder extrusion. The study shows that high-speed mapping and micropillar compression can be used together to determine local and effective mechanical properties of heterogeneous cermets and to evaluate how their response evolves at elevated temperature.

[09:45~10:05] Seeded dislocations facilitate plasticity in strontium titanate micropillars under high strain rate loading

Jeongin Paeng (Department of Structure and Nano-/Micromechanics of Materials, Max Planck Institute for Sustainable Materials, Düsseldorf, Germany), *Bárbara Bellón* (Department of Structure and Nano-/Micromechanics of Materials, Max Planck Institute for Sustainable Materials, Düsseldorf, Germany), *Jiawen Zhang* (State Key Laboratory of Quantum Functional Materials, Department of Mechanical and Energy Engineering, Southern University of Science and Technology, Shenzhen, China), *Gerhard Dehm* (Department of Structure and Nano-/Micromechanics of Materials, Max Planck Institute for Sustainable Materials, Düsseldorf, Germany), *Wenjun Lu* (State Key Laboratory of Quantum Functional Materials, Department of Mechanical and Energy Engineering, Southern University of Science and Technology, Shenzhen, China), *Xufei Fang* (Institute for Applied Materials, Karlsruhe Institute of Technology, Karlsruhe, Germany), *Rajaprakash Ramachandramoorthy* (Department of Structure and Nano-/Micromechanics of Materials, Max Planck Institute for Sustainable Materials, Düsseldorf, Germany)

Type: Oral

Dislocation seeding has been recently proposed as a new strategy to improve plasticity in normally brittle oxide ceramics. This strategy tackles the bottleneck of dislocation nucleation in ceramics (which are nearly dislocation-free) and promotes dislocation motion and multiplication, which occur more readily at stresses far below the fracture strength to enhance plasticity. However, it remains largely unexplored whether such seeded dislocations can remain effective under high strain rate deformation for potential applications under dynamic loading. Addressing this, we investigated the strain rate dependent deformation behavior of strontium titanate micropillars with seeded dislocations using in situ scanning electron microscopy (SEM) compression testing. Approximately 8 μm -high micropillars were FIB-milled from dislocation-seeded and nearly dislocation-free reference substrates, with the seeded dislocations initially confined to the upper $\sim 2 \mu\text{m}$ with a density of $\sim 10^{14} \text{ m}^{-2}$. In situ compression experiments were performed at room temperature over strain rates ranging from 0.0004 s^{-1} to 870 s^{-1} . The dislocation-seeded pillars showed stable plastic deformation up to a total strain of $\sim 25\%$ without detectable catastrophic failure even at the highest strain rate of 870 s^{-1} , whereas the pristine pillars fractured immediately upon reaching the elastic limit across all tested strain rates. Furthermore,

the seeded pillars exhibited an increase in strain hardening around a certain strain level. TEM characterization supports the interpretation that, by this strain, the seeded dislocations had propagated throughout the entire pillar, followed by a further increase in dislocation density that promotes dislocation interactions and debris hardening. Analysis of strain rate dependence shows a decreasing apparent activation volume with increasing plastic strain, supporting a transition from the glide and propagation of seeded dislocations to multiplication and eventual heterogeneous nucleation. These results demonstrate that dislocation seeding remains effective for suppressing fracture under high-rate loading and provide a route toward dislocation engineering of oxide ceramics for dynamic environments.

Session CC

2026-11-05 10:30 ~ 11:40 | 306 | Chair: Sung-Gyu Kang

[10:30~10:55] Nanoindentation of Coordination Polymers and Hybrid Metal Halides: Selected Case Studies

Wei Li (Nankai University)

Type: Invited

Nanoindentation has become an increasingly important technique to characterize coordination polymers (including metal-organic frameworks) and hybrid organic-inorganic metal halides. The mechanical properties (i.e. Young's modulus, hardness, stress-strain relation) of these crystals can be well obtained using nanoindentation, which offer useful information for pharmaceutical, photovoltaic, and chemical industry. In this talk, I will briefly introduce the structure-property relationship of both classes of hybrid crystals in the beginning. Then I will show a few selected case studies with more details. In the first example, I will demonstrate that nanoindentation can provide insightful information for the tableting of coordination polymer-based dietary supplements. In the second example, I will show that how nanoindentation results can be used to quantify the ease level of the mechanical exfoliation of 2D and 3D coordination polymer crystals. Finally, I will share our recent work about bendable hybrid crystals using nanoindentation technique. Refs: Angew. Chem., Int. Ed., 2014, 53, 5583; Chem. Sci., 2019, 10, 1309; Nat. Commun., 2022, 13, 6645; Adv. Mater., 2024, 36, 2404756; J. Am. Chem. Soc., 2026, 147, 43674.

[10:55~11:15] Orientation-Dependent Electron-Beam-Induced Plasticity in Single-Crystalline ZnO Micropillars

Eunsu Lee (Department of Materials Science and Engineering, Seoul National University, 08826 Seoul, Republic of Korea), Ryosuke Kinoshita (Department of Mechanical Science and Bioengineering, The University of Osaka, Toyonaka, Osaka, Japan), Minsik Oh (Department of Materials Science and Engineering, Seoul National University, 08826 Seoul, Republic of Korea), Yan Li (Department of Mechanical Science and Bioengineering, The University of Osaka, Toyonaka, Osaka, Japan), Atsutomo Nakamura (Department of Mechanical Science and Bioengineering, The University of Osaka, Toyonaka, Osaka, Japan), In-Suk Choi (Department of Materials Science and Engineering, Seoul National University, 08826 Seoul, Republic of Korea)

Type: Oral

Ceramic materials generally exhibit limited plastic deformation at room temperature because of their strong ionic and covalent bonding and the high resistance to defect motion. Recent in-situ electron microscopy studies have shown that electron-beam irradiation can modify the mechanical response of oxide ceramics without significant thermal effects or permanent irradiation damage. While such effects have been reported in silica-based oxides through mechanisms such as viscoplastic deformation and mechanically assisted amorphization, it remains important to clarify how electron-beam irradiation influences dislocation-mediated plasticity in crystalline oxides. In this study, we investigate the electron-beam effect on room-temperature plastic

deformation in single-crystalline ZnO, with particular emphasis on crystallographic orientation dependence. ZnO has a wurtzite crystal structure and exhibits highly anisotropic plasticity because the activation of basal, prismatic, and pyramidal slip systems depends strongly on loading orientation. To examine how electron-beam irradiation affects slip activation, ZnO micropillars with different crystallographic orientations were fabricated and compressed using an in-situ SEM picoindenter under controlled beam conditions. This study examines the possibility that the effect of electron-beam irradiation on plastic deformation in single-crystalline ZnO may vary with crystallographic orientation. By comparing the yielding behavior, flow response, and post-deformation morphology under different loading orientations, we explore whether the degree of the electron-beam effect could be associated with the activated slip system rather than with a uniform softening mechanism. These findings extend the concept of electron-beam-assisted ceramic plasticity to orientation-dependent dislocation activity in ZnO. They also highlight the importance of considering electron-beam-sample interactions in in-situ indentation and micropillar compression experiments, while suggesting a possible route for probing and controlling slip-system-dependent plasticity in small-scale oxide ceramics.

Session TF

2026-11-05 10:30 ~ 11:40 | 307 | Chair: Tea-Sung Jun

[10:30~10:55] Atomic-resolution study on nanoscale multilayer deformation

Zhuo Chen (Erich Schmid Institute of Materials Science, Austrian Academy of Sciences), Yong Huang (Erich Schmid Institute of Materials Science, Austrian Academy of Sciences), Zaoli Zhang (Austrian Academy of Sciences)

Type: Invited

The mechanical properties of nanoscale nitride multilayer coatings are governed primarily by the number and characteristics of interfaces. While increased strength and toughness have been reported with reduced layer thickness, properties degrade at layer thicknesses of just several nanometers. Here, we report an entirely overlooked phenomenon that occurs during the indentation of nanolayers, which presumably explains the degradation of properties. Nanoindentation disrupts and intermixes the multilayer structure due to the imposed deformation. Detailed advanced electron microscopy studies, supplemented by atomistic simulations (MD simulations), provide evidence of intermixing in epitaxial transition-metal nitride superlattice films induced by nanoindentation. The formation of a solid solution reduces the interfacial density and leads to a sharp drop in the dislocation density. Our results confirm that plastic deformation causes instability in the microstructure of nitride multilayers, which may further improve our understanding of multilayer strength mechanisms. Moreover, it is found that the mechanical responses of monolithic and polycrystalline multilayers differ. (a) In a monocrystalline superlattice, the mechanisms include nanocrystalline solid solution, interfacial distortion, slip, and cracking. (b) In a polycrystalline superlattice, deformation can involve delamination, grain-boundary sliding, microcracking, or small-scale solid solution at the crack tip. The authors thank David Holec, Matthias Bartosik, and Paul H. Mayrhofer for contributing to the calculations and depositing films. The authors acknowledge FWF for financial support via the project PAT1946623. Reference [1] Z. Chen, et al, Atomic insights on intermixing of nanoscale nitride multilayer triggered by nanoindentation, *Acta Materialia*, 214 (2021)117004. [2] Z. Chen, et al., Atomic-scale understanding of the structural evolution in TiN/AlN superlattice during nanoindentation—Part 2: Strengthening. *Acta Materialia*, 234 (2022)118009 [3] Y. Huang et al., Harvesting superior intrinsic plasticity in nitride ceramics with negative stacking fault energy. *Acta Materialia* 286 (2025)120774.

[10:55~11:15] Achieving high strength in 6061 aluminum alloy thin films through interstitial carbon incorporation.

Zion Lee (Korea Advanced Institute of Science and Technology), Hojang Kim (Korea Advanced Institute of Science and Technology), Sunkun Choi (Korea Advanced Institute of Science and Technology), Injong Oh (Korea Advanced Institute of Science and Technology), Jaehong Park (Hyundai Motors), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Oral

6061 aluminum alloy (6061AA) is a heat-treatable Al-Mg-Si alloy known for its excellent formability, corrosion resistance, and moderate tensile strength. This study aims to enhance the strength of 6061AA while maintaining its inherent advantages by fabricating 6061AA-carbon (6061AA-C) thin films through co-sputter deposition of 6061AA and graphite targets. Microstructural analysis showed that the carbon atoms were uniformly distributed within the aluminum alloy matrix through this fabrication technique. Subsequently tensile tests were conducted using a custom-built micro-tensile tester. The 6061AA-C films exhibited an increased tensile strength while maintaining its failure strain compared to pure 6061AA films. However, it was demonstrated that excessive carbon content resulted in a decrease in both tensile strength and ductility. This result can be explained by the different strengthening mechanisms occurring in the co-sputtered 6061AA-C thin films: the aluminum alloy undergoes substitutional solid solution strengthening, while the carbon addition induces interstitial solid solution strengthening and grain refinement. The annealing effect of 6061AA-C thin films was also investigated. Precipitate formation and microcrack annihilation were observed in the films annealed at 300°C, thereby overcoming the strength-ductility trade-off. Furthermore, interstitial C provides additional strengthening through Cottrell atmosphere formation without forming brittle aluminum carbides, as demonstrated by the observed yield point phenomenon following annealing. Consequently, this study demonstrates that C incorporation into the 6061 aluminum alloy system effectively improves the mechanical properties.

[11:15~11:35] Membrane deflection for high-throughput thin film tensile characterization across temperatures

Zhuo Feng Lee (Korea Advanced Institute of Science and Technology (KAIST)), Jeehun Jeong (Korea Institute of Energy Technology (KENTECH)), Ye-Eun Lee (Jeonbuk National University), Jae-Hoon Choi (Jeonbuk National University), Sang Ho Oh (Korea Institute of Energy Technology (KENTECH)), Gi-Dong Sim (Korea Advanced Institute of Science and Technology (KAIST))

Type: Oral

Nanoindentation has been regarded as a high-throughput characterization technique to construct material property databases at diverse operating temperatures. However, a fundamental limitation of this methodology lies in assessing the complete elastoplastic response of thin film materials, which highly reduces the breadth of databases created for alloy design and exploration. To address this drawback, various micro-tensile testing techniques capable of evaluating thin film tensile responses at different temperatures have been developed, yet their characterization efficiency remains limited compared to nanoindentation. This study introduces the high-temperature membrane deflection experiment (HTMDE) as a breakthrough in thin film tensile testing with high-throughput capability and variable-temperature instrumentation. Alongside in-situ transmission electron microscopy observations and HT nanoindentation experiments, we demonstrated the versatility of this technique in capturing the stress-temperature response and characteristic transformation temperatures of shape memory alloy thin films at elevated temperatures accurately. This methodology offers substantial potential in improving the existing thin film characterization efficiency to accelerate the screening of novel alloy combinations operating at elevated temperatures.

Poster Session Abstract

Poster Presentation

2026-11-03 12:30 ~ 14:00

1. Analysis of the Correlation between Hierarchical Microstructures and Multi-Scale Mechanical Performance in L-PBF Processed 316L Stainless Steel

Jaehyeok Heo (Kumoh National Institute of Technology), In-Chul Choi (Kumoh National Institute of Technology)

Type: Poster

316L stainless steel is a key material in biomedical and hydrogen industries due to its excellent corrosion and hydrogen embrittlement resistance. However, conventional manufacturing faces limitations in fabricating complex geometries and overcoming the strength-ductility trade-off. To address this, Laser Powder Bed Fusion (L-PBF) additive manufacturing utilizes rapid solidification to form a unique hierarchical microstructure—spanning macro-scale melt pools, meso-scale crystallographic textures, and micro/nano-scale dislocation cell structures—providing remarkable strengthening mechanisms. However, this hierarchical structure inherently induces localized microstructural heterogeneity and anisotropy. Therefore, quantitatively understanding the micro-to-macro correlation across multi-scale mechanical properties—from the nano- to bulk scale—is essential. In this study, L-PBF process parameters were precisely controlled to fabricate four distinct specimens with tailored crystallographic textures (Random, , , and CLM), and epitaxial columnar grain growth was confirmed via EBSD and OM analyses. Multi-scale mechanical evaluations were sequentially conducted using nanoindentation, micro-Vickers hardness, and bulk tensile tests. Statistical analysis (CDF/PDF) of nanoindentation data revealed a distinct bimodal hardness distribution, originating from the mechanical contrast between soft cell interiors (~2.8 GPa) and hard cell boundaries (3.0–3.1 GPa) characterized by dislocation entanglements and solute segregation. In micro-Vickers hardness testing, this nanoscale heterogeneity was averaged out, exhibiting a macroscopically uniform bulk hardness of ~220 HV0.1—over a 40% improvement compared to conventional cast material—driven by grain refinement and Hall-Petch strengthening. Tensile testing demonstrated that the strength-ductility trade-off was effectively overcome through strain partitioning between cell boundaries and interiors, along with heterostructure-induced (HDI) strengthening. Specifically, the CLM and specimens with activated multi-slip systems achieved an outstanding elongation of ~90%. Conversely, the specimen exhibited premature failure due to strain localization, while the Random specimen showed degraded properties caused by lack-of-fusion (LOF) defects from insufficient energy density. This study provides fundamental mechanisms for designing tailored additive-manufactured 316L STS components for high-reliability applications.

2. Effects of Alloying Elements and Cold Rolling on the Microstructural Evolution and Enhanced Mechanical Properties of Ti-Based Refractory Medium-Entropy Alloys

Tae-Yeon Park (Kumoh National Institute of Technology), In-Chul Choi (Kumoh National Institute of Technology)

Type: Poster

Titanium-based refractory medium-entropy alloys (RMEAs) have attracted significant attention for high-strength structural applications. In this study, TiHfNb, TiHfNbZr, TiHfNbV, and TiHfNbVZr alloys were fabricated via vacuum arc remelting (VAR) to systematically investigate their microstructural evolution, solid solution strengthening mechanisms, and deformation behavior. In both as-cast and homogenized states, all alloy compositions exhibited a single-phase body-centered cubic structure. To fundamentally elucidate the localized mechanical responses, Vickers microindentation and instrumented nanoindentation techniques were employed. This multi-scale indentation approach, correlated with theoretical hardening values derived from the Labusch model, was utilized to isolate matrix strengthening and probe local plastic deformation behavior. The comparative analysis demonstrated that the alloy strengthening is predominantly governed by solid solution hardening. Specifically, Zr contributes to the strength primarily through atomic size mismatch (Δr), whereas V significantly enhances the matrix strength through the synergistic effects of both atomic size mismatch (Δr) and shear modulus mismatch ($\Delta \mu$). In the homogenized state, the V-containing alloys exhibited excellent macroscopic tensile properties, with both yield strength and ultimate tensile strength (UTS) exceeding 1 GPa. To further optimize the mechanical performance, cold rolling was applied. Post-rolling X-ray diffraction (XRD) and electron backscatter diffraction (EBSD) analyses revealed the deformation-induced transformation to a hexagonal close-packed (HCP) phase within the deformation bands of the TiHfNb and TiHfNbZr alloys. This behavior was interpreted as a transformation-induced plasticity (TRIP) phenomenon driven by the mechanical metastability of the BCC phase. Consequently, the 30% cold-rolled TiHfNbVZr alloy achieved an exceptional strength–ductility synergy, exhibiting a high UTS of 1428 MPa and an elongation of 5–10%. This work highlights the utility of indentation techniques in capturing localized solid solution behavior and underscores the critical role of cold rolling in enhancing the mechanical properties of titanium-based refractory RMEAs.

3. Influences of surface condition on nanoindentation behavior of FCC and BCC medium-entropy alloys

Jae-Hyeok Choi (Division of Materials Science and Engineering, Hanyang University, Seoul 04763, Republic of Korea), *Si-Yeon Lee* (Division of Materials Science and Engineering, Hanyang University, Seoul 04763, Republic of Korea), *Zhe Gao* (Division of Materials Science and Engineering, Hanyang University, Seoul 04763, Republic of Korea), *Jae-il Jang* (Division of Materials Science and Engineering, Hanyang University, Seoul 04763, Republic of Korea)

Type: Poster

Equiatomic CoCrNi and NbTiZr are representative ternary medium-entropy alloys (MEAs) with face-centered cubic (FCC) and body-centered cubic (BCC) structures, respectively, and have been widely investigated as structural materials. In this study, the effects of surface conditions produced by different polishing methods on the nanoindentation behavior of the two MEAs were examined. Specimens were prepared by electropolishing or vibratory polishing for 24–72 h, followed by systematic nanoindentation tests using indenters with different geometries. Surface roughness was characterized by atomic force microscopy (AFM) to understand the changes in nanoindentation behavior in relation to the surface condition. In addition, electrochemical hydrogen charging was performed to introduce hydrogen into the near-surface region, and the effects of surface conditions on hydrogen uptake and nanoindentation behavior were comparatively assessed.

4. Effects of precipitation hardening on surface mechanical properties and corrosion behavior of Ni-based alloys

Jeong-Hyun Woo (Korea Atomic Energy Research Institute), Gha-Young Kim (Korea Atomic Energy Research Institute), Junhyuk Jang (Korea Atomic Energy Research Institute), Sun Young Park (Korea Atomic Energy Research Institute)

Type: Poster

One widely studied disposal canister design consists of an inner nodular cast iron shell that provides mechanical strength and an outer copper shell that ensures long-term corrosion resistance. Although this dual-layer structure can maintain long-term stability in deep geological environments, the manufacturing process is complex and costly. The development of alternative materials with both high mechanical strength and excellent corrosion resistance is required to simplify canister design and improve manufacturability. Precipitation hardening is an effective method for improving the mechanical strength. However, compositional and electrochemical heterogeneity between the precipitates and the matrix promotes micro-galvanic coupling, thereby increasing susceptibility to localized corrosion. Therefore, control of precipitate size and distribution is required to achieve both enhanced mechanical properties and corrosion resistance. In this study, Ni-based alloys were used to investigate the effects of precipitates on mechanical properties and corrosion behavior. The alloys were fabricated by vacuum arc remelting (VAR) to minimize the influence of impurities such as carbon and oxygen on their properties. Alloy compositions were varied to compare the properties of materials with and without precipitate formation, while aging treatments were conducted under different conditions to control the size and distribution of the precipitates. Mechanical properties were evaluated by microhardness testing, and electrochemical tests were conducted to examine the effects of precipitation on corrosion behavior. Based on these results, the effects of alloy composition and aging condition on microstructure, mechanical properties and corrosion behavior were comparatively analyzed to establish optimized processing conditions. Acknowledgements This research was supported by the Nano & Material Technology Development Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (RS-2025-25441247).

5. Precipitation hardening behavior of Ni-Cu alloys: Electrochemical corrosion characteristics of the strengthened matrix

Gha-Young Kim (KAERI), Jeong-Hyun Woo (KAERI), Junhyuk Jang (KAERI), Sun Young Park (KAERI)

Type: Poster

Enter description here. Deep geological disposal (DGD) is considered a promising option for managing spent nuclear fuels (SNFs). It aims to completely isolate SNFs from human society using canisters, bentonite buffers, and bedrock at depths greater than 500 m below the ground surface. DGD canisters are typically designed with a double-layer concept: an inner cast iron shell for mechanical strength and an outer Cu shell for corrosion resistance. However, manufacturing this double-layered canister is complicated and economically disadvantageous. In this regard, alternative research on single-layer metallic materials exhibiting both high corrosion resistance and mechanical strength is required. Ni-Cu alloys are promising candidates, as Ni-based

alloys offer excellent mechanical strength and resistance to chloride-containing environments, while Ni-Cu components resist sulfur-containing environments—both of which are key corrosive agents in DGD environments. To further enhance the mechanical properties of Ni-Cu alloys for DGD canisters, precipitation hardening was applied with varying compositions and aging conditions. In this study, the effects of precipitates on the electrochemical corrosion characteristics of Ni-Cu alloys were investigated. The alloys were fabricated via vacuum arc remelting (VAR) and homogenized at 1100 °C for 3 h, followed by hot rolling. Alloy compositions and aging conditions were systematically varied to control precipitate formation, size, and distribution. Electrochemical measurements, including open-circuit potential and impedance spectroscopy, were carried out to evaluate corrosion behavior. Based on these results, the feasibility of precipitation-hardened Ni-Cu alloys for SNF canisters was comparatively analyzed.

6. Natural analogue evaluation of long-term corrosion performance for disposal canister using buried archaeological metal artifacts

Jeong-Hyun Woo (Korea Atomic Energy Research Institute), Ji-Hun Ryu (Korea Atomic Energy Research Institute)

Type: Poster

Spent nuclear fuel is nuclear fuel that has been removed from a reactor after irradiation and contains highly radioactive products and long-lived radionuclides. Because these radioactive materials should be isolated from the nature for extremely long periods, many countries are considering deep geological disposal as a long-term management strategy. In such disposal systems, disposal canisters are designed as key engineered barriers that contain the spent fuel and block the release of radionuclides. Therefore, understanding the long-term behavior of canister materials is important for evaluating the reliability of disposal systems. However, direct experimental verification over repository-relevant time scale is inherently limited. In this study, buried archaeological metal artifacts were investigated as natural analogues to provide insight into long-term corrosion processes under natural underground environments. Iron and bronze artifacts were selected to compare differences in corrosion behavior, corrosion product formation, and the preservation of the original metallic matrix after long-term burial. In general, iron artifacts are extensively corroded, resulting in the loss of the original metallic matrix, whereas bronze artifacts can retain residual metallic regions beneath the corrosion layer. The corrosion products and remaining metallic regions were characterized using X-ray diffraction (XRD) and SEM-EDS. XRD analysis was used to identify crystalline corrosion products, while SEM-EDS observations were conducted to examine the morphology, microstructure, and elemental distribution across the corrosion products. By comparing the corrosion products and residual matrix of iron and bronze artifacts, this study examines how long-term burial conditions can lead to different corrosion states depending on the metallic systems. The results provide analogue-based microstructural and chemical evidence that complements laboratory corrosion studies and supports the interpretation of long-term degradation processes relevant to disposal canisters.

7. Mechanical Properties of a Hetero-structured Ferritic ODS Alloy Fabricated Using Different Powder Sizes Evaluated by Nanoindentation

Bae Jaeyoon (IMR, Tohoku university), Kazuki Ogawa (IMR, Tohoku university), Diancheng Geng (IMR, Tohoku university), Minha Park (IMR, Tohoku university), Sosuke Kondo (IMR, Tohoku university), Ryuta Kasada (IMR, Tohoku university)

Type: Poster

Oxide Dispersion Strengthened (ODS) alloys are promising candidate structural materials for fusion reactors because they contain thermally stable oxide particles dispersed within the matrix. These dispersed oxides hinder dislocation motion, thereby strengthening the material and providing excellent high-temperature strength. However, improved ductility is still required for their practical application as structural materials. A hetero-structure has recently attracted attention as a potential approach to address this issue. However, conventional powder metallurgy processes have limitations in forming hetero-structures, and the achievable hetero-structure fraction is limited. Therefore, in this study, hetero-structured ferritic ODS alloys were fabricated by mixing mechanically alloyed powders with different particle sizes. The fabricated alloy exhibited a network structure in which ODS regions were surrounded by Non-ODS regions. The ODS regions provide high strength through finely dispersed oxide particles, whereas the Non-ODS regions accommodate deformation and contribute to ductility enhancement. However, the distribution of these regions is heterogeneous, resulting in local variations in mechanical properties. Conventional Vickers hardness testing has limitations in evaluating the intrinsic properties of each region because the indentation area may include both ODS and Non-ODS regions simultaneously. Therefore, nanoindentation test was conducted to evaluate the local mechanical properties of the ODS and Non-ODS regions. The results showed that the ODS regions exhibited higher hardness than the Non-ODS regions, quantitatively confirming the mechanical property differences between the two regions. These findings contribute to a better understanding of the roles of individual regions in hetero-structured ODS alloys and provide fundamental guidelines for microstructural design aimed at simultaneously improving strength and ductility.

8. Evaluation of Crack Healing Behavior in Metallic Materials for Aerospace Applications via Electropulsing Treatment

Jeongwook Kim (Korea institute of Materials Science), Hyunsung Choi (Korea institute of Materials Science), Hyeonil Park (Korea institute of Materials Science), Moo-Young Seok (Korea institute of Materials Science), Yongnam Kwon (Korea institute of Materials Science), Dongjun Lee (Korea institute of Materials Science)

Type: Poster

Recent increases in global air transport demand and advancements in space launch vehicle development have brought maintenance, repair, and overhaul (MRO) and life-extension technologies for aerospace structures into focus as key issues. Conventional techniques such as welding, bonded patch repair, and stop-hole methods have been applied; however, they exhibit limitations in fully resolving structural defects and may lead to re-initiation of damage. To overcome these limitations, this study investigates the fatigue crack healing behavior in metallic materials using electropulsing treatment (EPT) through both numerical and experimental approaches. Due to the nature of EPT, where thermal, electromagnetic, and mechanical responses occur within a very short time, a multiphysics finite element analysis (FEA) was employed to analyze the electromagnetic effects and plastic deformation induced by pulsed current. Among various EPT methods, different electrical parameters of a non-damped sinusoidal waveform were applied to predict the electromagnetic–thermal–mechanical

interactions at the crack region and to identify optimal processing conditions. After the EPT process, microstructural analysis was conducted using electron microscopy, and the mechanical properties of the healed crack regions were evaluated.

9. Nanomechanical Characterization of RAFM Steel using Nanoindentation

Hyun Woo Seo (Department of Materials Science and Engineering, Yonsei University, Seoul 120-749, Republic of Korea, Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, 34057, Republic of Korea), Sun-Young Park (Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, 34057, Republic of Korea), Joowon Suh (Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, 34057, Republic of Korea), Hyung-Ha Jin (Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, 34057, Republic of Korea), Dong Won Lee (Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, 34057, Republic of Korea), Young-Kook Lee (Department of Materials Science and Engineering, Yonsei University, Seoul 120-749, Republic of Korea), Suk Hoon Kang (Materials Safety Technology Research Division, Korea Atomic Energy Research Institute, Daejeon, 34057, Republic of Korea)

Type: Poster

In fusion reactors, the deuterium-tritium (D-T) fusion reaction produces helium ions and high-energy neutrons. The generated helium is vented to the divertor, a critical component subjected to extreme heat loads ($\sim 20\text{MW/m}^2$) and intense fast neutron irradiation. Consequently, structural materials for divertors must exhibit exceptional high-temperature strength and low neutron activation. Reduced Activation Ferritic/Martensitic (RAFM) steels are considered as promising structural materials for fusion reactor components including plasma-facing and blanket because they can withstand severe thermal and irradiation environments while minimizing radioactive waste after service. In this study, the nanomechanical behavior of unirradiated RAFM steel was investigated using nanoindentation to establish baseline mechanical properties for future irradiation studies. lab-scale ingots (45 kg) were produced using by vacuum induction melting (VIM) and preheated at 1200 °C for 3 h. The ingots were then hot-rolled using a two-high mill to a final plate thickness of 15 mm. The plates were normalized at temperatures between 980 °C and 1050 °C for 40 min, followed by tempering at 760 °C for 70 min. The resulting microstructures and secondary precipitates were characterized using scanning electron microscopy (SEM), transmission electron microscopy (TEM), and electron backscatter diffraction (EBSD). Nanoindentation test was conducted to obtain load-depth curves. The indentation size effect (ISE) was analyzed by fitting the experimental data to the Nix-Gao model to evaluate the intrinsic bulk hardness of the RAFM alloy. These calculated values were compared with conventionally measured bulk hardness, validating the reliability of the nanoindentation-based evaluation. established methodology will be highly useful for calculating the bulk hardness of irradiated materials via future nanoindentation testing

10. Interpretable multimodal modeling of local microstructure–property relationships in ultra-high-strength steels

Hanqi Wang (Beihang University)

Type: Poster

Nanoindentation provides exceptional spatial resolution for probing local mechanical properties in heterogeneous microstructures, yet extracting quantitative microstructure–property relationships from indentation data across multiple length scales remains a critical challenge in ultra-high-strength steels. To address this, we developed a multimodal framework that synergistically integrates high-resolution nanoindentation mapping with electron backscatter diffraction (EBSD) and energy dispersive spectroscopy (EDS) to predict local hardness and reduced modulus in 300M and Aermet100 steels. A spatially aligned dataset correlating nanoindentation-derived mechanical response with local microstructure and composition was established. A boundary-enhanced four-channel convolutional neural network was constructed to learn directly from EBSD-derived images, where three channels encode crystallographic orientation via inverse pole figure maps and the fourth captures grain-boundary architecture. The independent grain-boundary channel significantly improved representation of boundary effects and identified a characteristic interaction length scale of 2 μm governing local mechanical response. To enhance both prediction accuracy and physical interpretability, deep-learning outputs were fused with physically informed descriptors including orientation, grain geometry, boundary features, and compositional parameters. The fused multimodal model outperformed single-modality approaches in predicting both hardness and reduced modulus. Interpretable analysis revealed that hardness is governed by grain-boundary and compositional descriptors: high-angle boundary density increases hardness by introducing effective barriers to dislocation motion, geometric parameters reflect atomic-size-mismatch-induced solid solution strengthening, and valence electron concentration influences hardness through its effect on martensitic phase stability. This framework demonstrates a scalable strategy for leveraging nanoindentation data within machine-learning and physics-informed models to achieve quantitative prediction and mechanistic understanding of complex microstructure–property relationships in metallic materials.

11. Nonequilibrium boron retention as a new route for strengthening additively manufactured Al alloys

Gyumin Lee (Korea Advanced Institute of Science and Technology), Zion Lee (Korea Advanced Institute of Science and Technology), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Poster

AlSi10Mg alloys are widely used as lightweight structural materials in the aerospace and advanced transportation industries due to their high specific strength. In particular, AlSi10Mg fabricated by laser powder bed fusion (LPBF) exhibits good mechanical properties derived from the aluminum (Al) matrix and Si-rich cellular/eutectic structures formed during rapid solidification. However, these nonequilibrium microstructures are thermally unstable and undergo decomposition and coarsening at elevated temperatures, leading to a deterioration in mechanical properties. At the microscale, Al-B thin films have exhibited enhanced strength while retaining ductility through the formation of a nonequilibrium microstructure. Building on this concept, we fabricated AlSi10Mg-B by LPBF to induce a nonequilibrium microstructure. Boron exhibits poor wettability with Al and preferentially forms thermodynamically stable borides. However, the rapid solidification conditions of LPBF can promote solute trapping by restricting boron redistribution at the solidification front, thereby increasing the amount of boron retained in the Al matrix. In this study, LPBF AlSi10Mg-B alloys are fabricated using mechanically mixed AlSi10Mg and boron powders. These alloys are characterized to elucidate the

distribution and evolution of boron during solidification and repeated thermal cycling, including whether boron is retained in solid solution, segregates to dislocations or grain boundaries, or forms nanoclusters and borides. Ultimately, this work seeks to demonstrate the feasibility of nonequilibrium boron retention as a new route for strengthening additively manufactured Al alloys.

12. Interfacial characterization of Cu-X-Cu diffusion bonded structure

Kai Ying Pong (Korea Advanced Institute of Science and Technology), Kwanhyeong Lee (Korea Advanced Institute of Science and Technology), Hyemin Ryu (Korea Advanced Institute of Science and Technology), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Poster

Copper-copper (Cu-Cu) direct bonding, a technique gaining interest in advanced semiconductor packaging, refers to the bonding of two copper surfaces via diffusion facilitated by high temperature and pressure. This technique can significantly reduce interconnect pitch for design optimization of high-density 3D microelectronics as compared to traditional solder bumps. However, the high oxidation susceptibility of Cu promotes native surface oxide formation that could potentially degrade interfacial adhesion. Subsequently, this necessitates additional surface treatment procedures (chemical mechanical polishing, plasma activation, etc.) or bonding at high temperatures ($> 300\text{ }^{\circ}\text{C}$) for oxide layer removal to ensure bonding quality. On the other hand, deposition of a few nanometers-thick gold (Au), silver (Ag), or titanium (Ti) passivation layer onto Cu can act as barriers against oxidation, which lowers the bonding temperature required to facilitate atomic diffusion of Cu across the interface. This is beneficial towards lowering thermal stress and preventing wafer warpage in microelectronics applications. However, the mechanical behavior of such bonded structures has yet to be extensively quantified. Therefore, this study investigates the effect of employing different passivation layers towards the interfacial adhesion energy of Cu-X-Cu (X = Au, Ag, Ti) interlayer structures. The adhesion energies of different interfaces are evaluated using 4-point bending test to determine the critical energy release rate (G_c). This work allows for direct comparison of the bond quality of Cu-Cu direct bonding with different passivation layers, which enables further process optimization in microelectronics fabrication.

13. First-principles analysis of ternary alloying effects on martensitic transformation in Ti-Nb-based shape memory alloys

Hun-Min Jo (Korea University), Won-Seok Ko (Korea University)

Type: Poster

Ti-Nb-based shape memory alloys have attracted significant attention as Ni-free, biocompatible alternatives to conventional Ni-Ti alloys, whose biomedical use is constrained by Ni-induced hypersensitivity and toxicity. In Ti-Nb binary alloys, however, the martensitic transformation temperature is highly sensitive to composition, decreasing by approximately 43 K per 1 at% Nb, restricting room-temperature superelasticity to a narrow composition window. Within this window, the critical stress for slip deformation reaches a minimum, allowing irreversible slip to precede the martensitic transformation and thereby limiting the recoverable strain to approximately 3%. Overcoming this intrinsic limitation while independently controlling the transformation

temperature requires alloy design through the introduction of a ternary solute element. In this study, first-principles density functional theory calculations were performed on 40 ternary solute elements to systematically investigate their influence on the phase stability and martensitic transformation temperatures of Ti-Nb-based shape memory alloys. The site preference of each solute element was determined in both stoichiometric and off-stoichiometric compositions by systematically considering possible anti-site defect configurations, thereby reflecting conditions relevant to experimental alloy processing. Based on the identified site preferences, the martensitic transformation temperature was quantitatively predicted by combining two energy descriptors—the relative energy difference between the austenite and martensite phases (ΔE_1) and the structural distortion energy accompanying the transformation (ΔE_2)—within an anharmonicity-based prediction model. The predictive validity of this approach was confirmed through comparison with experimentally reported transformation temperatures. Furthermore, to establish broader alloy design criteria, the physical mechanisms governing the transformation temperatures were examined, with particular attention to the role of solute elements in independently modulating the transformation temperature—previously controlled solely by the Nb content—and in stabilizing the high-temperature β phase. The proposed methodology is expected to provide a first-principles theoretical foundation for the systematic screening and rational design of Ti-Nb-based shape memory alloys with properties tailored to specific applications.

14. Compositionally modified AISI D2 tool steel with improved printability and high hardness via directed energy deposition

Hahun Lee (Korea University), Ji-Su Lee (POSTECH), Sung-Jae Jo (Kongju National University), Seungjin Nam (Korea University), Heechan Jung (Korea University), Chahee Jung (Korea University), Soon-Jik Hong (Kongju National University), Byeong-Joo Lee (POSTECH), Seok Su Sohn (Korea University)

Type: Poster

AISI D2 is a representative high-carbon, high-chromium tool steel with excellent hardness and wear resistance, yet its poor machinability makes the fabrication of geometrically complex tools by conventional manufacturing difficult, motivating the use of additive manufacturing. In directed energy deposition (DED), however, strong segregation of C and Cr to interdendritic regions promotes the formation of Cr-rich eutectic M_7C_3 carbides during terminal solidification, increasing susceptibility to solidification and liquation cracking. Here, we designed a modified D2 tool steel to improve DED printability while retaining high hardness. The C and Cr contents were reduced to mitigate interdendritic Cr-rich carbide formation, whereas the V content was increased to compensate for the resulting loss of hardness. Thermodynamic and Scheil–Gulliver calculations were used to optimize the alloy composition by evaluating carbide stability and solidification segregation behavior. The modified alloy was successfully fabricated without baseplate preheating and exhibited high printability over a wide range of DED processing conditions. After post-heat treatment, the alloy developed a predominantly martensitic microstructure containing carbide precipitates, including fine V-rich clusters that are expected to contribute to hardness recovery. Despite its reduced C content relative to conventional D2 steel, the modified alloy achieved hardness exceeding the ASTM requirement for D2 tool steel and mechanical properties competitive with previously reported additively manufactured D2 alloys. These results demonstrate that DED processability and hardness can be simultaneously improved by balancing the suppression of Cr-rich

eutectic carbide formation with V-assisted carbide strengthening. This study provides an alloy-design strategy for crack-resistant DED processing of high-carbon tool steels.

15. The compressive properties of laser powder bed fusion Dievar steel lattice

Chun-Yu Hsieh (National Taipei University of Technology), Ming-Hsiang Ku (National Taipei University of Technology), Chien-Lun Li (voestalpine Technology Institute (Asia) Co. Ltd.), Ming-Wei Wu (National Taipei University of Technology)

Type: Poster

Laser powder bed fusion (LPBF) is the predominant additive manufacturing (AM) process for metallic materials. LPBF Dievar hot work tool steel has been applied as the mold material with conformal cooling channel in the die casting industry because it exhibits excellent mechanical properties. To estimate the applicability of LPBF Dievar steel on light-weight structural material, the purpose of this study was to investigate the compressive properties and fracture behaviors of LPBF-fabricated Dievar steel lattice structures, including Cubic, face-centered cubic with Z-struts (FCCZ), and Hybrid structures. Cubic and FCCZ lattice structures were hybridized to generate Hybrid one. The effects of aging treatment on the compressive properties was also studied. Uniaxial compression tests and digital image correlation were conducted to evaluate compressive strength, energy absorption, deformation, and failure behavior. Among the as-built structures, the FCCZ specimen exhibited the highest specific strength of 139 kN•m/kg, indicating superior load-bearing capability per unit mass, whereas the Cubic specimen achieved the highest specific energy absorption of 32 kJ/kg, demonstrating excellent deformation stability and resistance to catastrophic collapse. After aging treatment (AT), the mechanical properties of all three structures were significantly improved. The FCCZ structure retained the highest specific strength of 158 kN•m/kg, while the Cubic structure exhibited the highest specific energy absorption of 47 kJ/kg. Regarding failure behavior, the Cubic and Hybrid structures exhibited layer-by-layer collapse with progressive deformation and enhanced energy absorption, whereas the FCCZ structure primarily failed through shear, resulting in higher compressive strength.

16. Feature-Engineered Random Forest Model for Predicting Tensile Properties of Fe-Mn-Cr-Ni Multicomponent alloys

Ye Min Hwang (Pukyong National University), Jun Seok Lee (Pukyong National University), Pil Wook Shin (Pukyong National University), Jae Wung Bae (Pukyong National University)

Type: Poster

Face-centered cubic multicomponent alloys exhibit attractive combinations of strength and ductility at cryogenic temperatures, making them promising candidates for cryogenic structural applications. However, the large composition-processing-property space arising from their multicomponent chemistry and diverse thermo-mechanical processing windows limits efficient exploration using conventional trial-and-error approaches. Here, we develop and experimentally validate a random forest (RF) model for predicting the room-temperature and cryogenic tensile properties of Fe-Mn-Cr-Ni multicomponent alloys. A dataset literature-derived dataset was used to construct a feature pool consisting of composition-derived physical descriptors, including valence electron concentration, atomic size difference, electronegativity difference, and Gibbs free

energy difference associated with phase stability, together with processing descriptors describing homogenization, cold-rolling, and annealing conditions. Feature subsets were evaluated using fivefold cross-validation, and the combination yielding the lowest root-mean-square error was selected to construct the optimized RF model. Bootstrap sampling was subsequently employed to estimate the mean (μ) and uncertainty (σ) for ultimate tensile strength and elongation under individual composition-process condition. Based on these predictions, candidate conditions were selected for experimental validation. The selected alloys were fabricated and tensile-tested at 298 and 77 K, and their measured properties were compared with the corresponding model predictions and bootstrap distributions. These results demonstrate a prediction-experiment framework for efficiently exploring the high-dimensional composition-process space of multicomponent alloy system.

17. Nanoindentation Study on Ferrite-Martensite Hardness Mismatch and Its Influence on the Mechanical Properties of Low-Carbon Dual-Phase Steels

Dong-Kyu Oh (Department of Materials Science and Engineering, Seoul National University of Science and Technology),
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Type: Poster

The mechanical properties of dual-phase (DP) steels are largely governed by the volume fraction, morphology, and distribution of soft ferrite and hard martensite. The hardness mismatch between the two constituents gives rise to a high work-hardening rate, a low yield-to-tensile strength ratio, and continuous yielding, which are rarely achieved in conventional high-strength low-alloy (HSLA) steels. Quantifying the local mechanical response of each constituent is therefore essential to understand the global mechanical behavior of DP steels. The ferrite-martensite microstructure is developed by intercritical annealing, and its characteristics are strongly influenced by the chemical composition and heat-treatment conditions; variations in the volume fraction, grain size, morphology, and distribution of the constituent phases significantly affect the strength-ductility balance and can cause anomalous behavior such as discontinuous yielding or premature fracture, particularly in low-carbon steels. In this study, a series of low-carbon DP steels with different ferrite-martensite characteristics was prepared by direct quenching followed by intercritical annealing, with systematic variations in chemical composition and annealing conditions. Microstructural evolution during intercritical annealing was characterized by SEM, EBSD, and TEM, and the experimental results were compared with Thermo-Calc/DICTRA calculations. Nanoindentation was performed to quantify the local hardness and strain-hardening behavior of the individual ferrite and martensite constituents, and the resulting hardness mismatch was correlated with the tensile and Charpy V-notch impact properties. Despite the increased martensite fraction at higher intercritical annealing temperatures, the tensile strength decreased. This anomalous behavior was attributed to reduced martensite carbon content and tetragonality, which decreased the ferrite-martensite hardness mismatch.

18. Representative Volume of Unit-cells for Fracture Resistance Testing of Additive Manufactured Lattice Structures

eunju Shin (Department of Advanced Materials Engineering, Keimyung University), Hansol Jeon (Department of Advanced Materials Engineering, Keimyung University)

Type: Poster

The discrete structure of additively manufactured lattices raises a specimen-design question for fracture testing: how many unit cells are required within the initial remaining ligament to obtain representative measurements. This study investigates the influence of unit-cell size on fracture resistance and crack-growth behavior using compact tension (CT) specimens with different unit-cell sizes. The number of unit cells in the initial remaining ligament is defined as $N = b_0/L = (W-a_0)/L$, where W is the specimen width, a_0 is the initial crack length, and L is the unit-cell size. Repeated fracture tests were performed, and the response was assessed using load-displacement records, J-resistance curves, and crack-growth observations. Larger unit cells were associated with abrupt crack extension and earlier failure, whereas specimens with $N \geq 10$ exhibited comparatively stable crack growth. These observations identify $N \geq 10$ as a candidate specimen-design guideline for the lattice system examined. The findings emphasize the need to account for the number of cells within the initial remaining ligament when comparing the fracture response of lattice structures.

19. Effect of Mg Melt Composition on the Local Mechanical Properties of Ti-6Al-4V Processed by Liquid Metal Dealloying

Jihye Seong (Dankook University), Hidemi Kato (Tohoku University), Jeong Hun Lee (Kyungpook National University), Sung Hyuk Park (Kyungpook National University), Soo-Hyun Joo (Dankook University)

Type: Poster

Liquid Metal Dealloying (LMD) is a dealloying process based on the selective dissolution of constituent elements from a precursor alloy into a liquid metal. In this study, coin-type Ti-6Al-4V specimens were treated in pure Mg, Mg-0.2 at.% Zr, and Mg-2 at.% Si melts at 900 °C to investigate the effect of melt composition on the resulting microstructure, phase formation, and local mechanical properties. The LMD-treated specimens were characterized using SEM, EDS, and XRD. Vickers hardness was measured at loads of 1 and 0.01 kgf. Distinct surface and cross-sectional microstructures were formed depending on the Mg melt composition. The Si-added specimen showed the additional formation of Ti₅Si₃ and V₅Si₃ phases. At 1 kgf, the hardness values of the pure Mg-, Si-, and Zr-treated specimens were 320.5, 393.6, and 359.5 HV, respectively. At 0.01 kgf, the corresponding values were 339.3, 471.4, and 458.6 HV, showing a more pronounced influence of Si and Zr additions at the lower indentation load. Except for the Si-added specimen, the indent size at 0.01 kgf was smaller than the characteristic ligament size, suggesting that low-load indentation is more sensitive to the local mechanical behavior of the LMD-formed microstructure. These results demonstrate that Mg melt composition effectively controls the microstructure and local mechanical properties of LMD-treated Ti-6Al-4V without adversely affecting cellular responses.

20. Enhancement of Cryogenic Mechanical Properties of Fe-Ni-Co-Cr-Mo Medium-Entropy Alloy through Fine Mo-Rich Precipitation

Se Ung Yang (Dankook University), Taehyung Kim (Dankook University), Jae Hyuk Lee (Dankook University), Hyoung Seop Kim (Pohang University), Soo Hyun Joo (Dankook University)

Type: Poster

The growing demand for structural materials for liquid hydrogen systems and aerospace applications has increased interest in materials with excellent mechanical properties at cryogenic temperatures. High-entropy alloys (HEAs) and medium-entropy alloys (MEAs) have attracted considerable attention as promising cryogenic structural materials because of their high strength and ductility at low temperatures. In particular, Fe-Co-Ni-Cr-Mo-based low-thermal-expansion MEAs have exhibited a favorable combination of high strength and a low coefficient of thermal expansion (CTE) at 77 K, demonstrating their potential for cryogenic structural applications. However, further improvement in strength through increased Mo content and compositional optimization remains necessary. In this study, a Fe-Co-Ni-Cr-Mo-based MEA with an increased Mo content and optimized composition was developed. Cold rolling followed by heat treatment was employed to promote the formation of fine Mo-rich precipitates and enhance the cryogenic strength. Vickers hardness measurements were performed under different heat-treatment conditions, and FE-SEM, EDX, and XRD analyses were used to examine the precipitation behavior, elemental partitioning, grain structure, and phase evolution. Based on these results, the relationships between microstructural evolution, precipitation behavior, and strengthening were systematically analyzed.

21. Three-Dimensionally Interconnected Porous Surface on Ti-6Al-4V via Liquid Metal Dealloying for Enhanced CFRP Joining with Retained Hardness

Hyeok Min Kwon (Dankook University, Korea), Jihye Seong (Dankook University, Korea), Jae Hyuk Lee (Dankook University, Korea), Hidemi Kato (IMR, Tohoku University, Japan), Sung Hyuk Park (Kyungpook National University, Korea), Soo-Hyun Joo (Dankook University, Korea)

Type: Poster

Dissimilar joining between carbon fiber-reinforced polymer (CFRP) composites and titanium alloys is important for lightweight structural applications; however, their low surface reactivity and mismatch in coefficients of thermal expansion can hinder reliable bonding [1]. Introducing a porous surface can enhance mechanical interlocking, but pore formation may also reduce the surface hardness of the metallic substrate. In this study, liquid metal dealloying (LMD) [2] was investigated as a surface modification technique for forming a three-dimensionally interconnected porous layer on Ti-6Al-4V while retaining its surface hardness and improving Ti-6Al-4V/CFRP joint performance. The LMD temperature and immersion time were varied to control the ligament and pore structures. The treated surfaces were characterized by scanning electron microscopy, electron backscatter diffraction, and X-ray diffraction. Surface hardness was evaluated by Vickers indentation, and Ti-6Al-4V treated under the optimized LMD condition was subsequently bonded to CFRP using a structural epoxy adhesive. Joint performance was evaluated by single-lap shear testing and fracture surface analysis. Under the optimized LMD condition, a three-dimensionally interconnected porous ligament structure was formed, while the mean surface hardness remained essentially unchanged compared with untreated Ti-6Al-4V. Microscopic observations confirmed penetration of the adhesive into the porous layer. Compared with the conventionally sanded joint, the LMD-treated joint exhibited an approximately 59% increase in apparent lap-shear strength.

The dominant failure mode also shifted from interfacial failure to cohesive failure, consistent with enhanced mechanical interlocking at the Ti-6Al-4V/CFRP interface. These results demonstrate that LMD can produce a three-dimensionally interconnected porous surface that significantly enhances Ti-6Al-4V/CFRP joint strength without compromising the surface hardness of the Ti-6Al-4V substrate.[1] R. Olsson et al., Appl. Compos. Mater. (2024).[2] Y. Fukuzumi et al., Interface Oral Health Sci. (2015).Keywords: Liquid metal dealloying, Vickers indentation, Surface hardness, Porous surface, Ti-6Al-4V/CFRP joint

22. Nanomechanical characterization of microstructural inhomogeneity in a sand casted Mn-Cu alloy

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Type: Poster

Mn-Cu alloys are attractive high-damping materials; however, their as-cast microstructure is characterized by pronounced dendritic segregation, consisting of Mn-rich dendrites and Cu-rich interdendritic regions, which may affect their mechanical properties and stress corrosion cracking (SCC) susceptibility. In this study, the SCC behavior of a Mn-Cu alloy in 3.5 wt.% NaCl solution was investigated by slow strain rate testing (SSRT), with a particular focus on the correlation between microstructure-dependent local mechanical properties and crack initiation and propagation. In 3.5 wt.% NaCl solution, preferential anodic dissolution of Mn led to localized corrosion in the Mn-rich regions, and these corrosion sites served as the dominant crack nucleation sites. In contrast, specimens tested in air exhibited intergranular cracking, with cracks initiating and propagating predominantly along grain boundaries. To elucidate the underlying cracking mechanisms, nanoindentation was performed on the Cu-rich regions, grain boundaries, and dendrite cores. Distinct variations in local mechanical properties were identified among these microstructural constituents, which are believed to cause local strain concentration, thereby facilitating crack initiation and propagation in relatively brittle regions. These results suggest that the SCC behavior of the Mn-Cu alloy in 3.5 wt.% NaCl solution is primarily controlled by the electrochemical contribution of selective Mn dissolution, while the heterogeneity in local mechanical properties arising from the as-cast microstructure further contributes to crack initiation and growth

23. Mechanical Properties of NiCoFe Medium-Entropy Alloy-Coated 3D Glassy Carbon Architectures

Elif Nur Adalı (KAIST), *Isoo Jeon* (KAIST), *Kneev Sharma* (TUM), *Vishnu Nair* (TUM), *Jan Torgersen* (TUM), *Seung Min J. Han* (KAIST)

Type: Poster

Glassy carbon (GC) architectures fabricated by two-photon polymerization and high-resolution advanced additive manufacturing methods offer low density, thermal stability, and chemical inertness, but their intrinsic brittleness and relatively low load-bearing capability limit their use in engineering systems. Introducing a conformal secondary phase onto architected scaffolds has appeared as an effective method to overcome such mechanical limitations. For instance, recent work on Ni- Al_2O_3 nanoarchitectures (Kang et al.) showed that a conformal ceramic coating improves compressive strength due to the nanoscale size effects and dislocation blocking at the interface. Based on this strategy, this study investigates NiCoFe medium-entropy alloy (MEA) coatings as a metallic reinforcement for three-dimensional porous GC architectures. Compared with single-component metallic coatings, MEA coating offers a method to obtain higher mechanical strength, while electroless plating enables uniform, conformal deposition over complex porous geometries. Porous GC structures of different architectures are coated with NiCoFe via electroless plating, and the coating morphology, elemental composition, and uniformity are characterized by SEM, EDS and FIB. The effect of coating thickness on the effective modulus and compressive strength is investigated through nanoindentation and micropillar compression. This work aims to strengthen architected carbon materials and to investigate the effective design of MEA-coated GC electrodes for anion exchange membrane (AEM)-based electrolysis.

24. Plasticity in microcompression of single-crystal Al_2O_3 with high-density dislocations introduced by shot peening

Shuto YOSHIDA (The University of Tokyo), Hiroshi MASUDA (The University of Tokyo), Hidehiro YOSHIDA (The University of Tokyo)

Type: Poster

Ceramic materials exhibit excellent mechanical properties and chemical stability; however, efforts to overcome their intrinsic brittleness have so far achieved only limited success. In recent years, dislocations introduced by mechanical surface treatments or high-temperature deformation have been reported to enhance the room-temperature plasticity of ceramics in micromechanical testing. Here, we focused on shot peening, which has been shown to introduce high-density dislocations and significantly suppress crack propagation during the subsequent Vickers indentation on high-strength ceramics. To clarify the effect of high-density dislocations on the room-temperature plasticity of high-strength ceramics, shot peening was applied to Al_2O_3 single crystals with (0001) C, (11-20) A, (10-10) M and (10-12) R orientations, and their plasticity was evaluated through micropillar compression tests at room temperature. Shot peening with appropriate pressure and duration enabled the fabrication of samples exhibiting fine surface steps along specific crystallographic planes without forming severe surface cracks. These surface steps are likely slip traces resulting from plastic deformation caused by the impacts of the media particles. Transmission electron microscopy observations of C-oriented sample after shot peening confirmed that a high density of dislocations was introduced to a depth of approximately 5 μm from the surface. Micropillars fabricated from non-shot-peened samples fractured at orientation-dependent critical stresses without exhibiting plastic deformation, accompanied by a strain burst of several percent. The fractured micropillars exhibited cleavage along specific crystallographic planes. In

contrast, micropillars fabricated from shot-peened samples, with all sample orientations, yielded at lower stresses than the strength of untreated samples and fractured after undergoing several percent plastic deformation with strain hardening. Such plastic deformability is attributed to the existing dislocations introduced by the shot peening, and these dislocations may act as multiplication sources for new dislocations at relatively low stresses.

25. Strain-Dependent Mechanical Response and Twin Boundary Migration–Driven Plasticity in TiN

Xinxin Gao (Jilin University), Kan Zhang (Jilin University)

Type: Poster

Transition-metal light-element compounds, such as transition-metal nitrides, combine high hardness and strength but often exhibit complex, load-dependent mechanical responses and an intrinsic trade-off between strength and plasticity. Understanding their strain-dependent deformation behavior and developing routes to activate plasticity in brittle ceramics remain key challenges. Here, we first investigate the deformation behavior of single-crystalline TiN using first-principles calculations. TiN exhibits strain-induced stress strengthening and improved mechanical homogeneity under compression-constrained shear deformation, leading to more isotropic responses, while showing distinct ductile–brittle behavior under indentation and wear loading depending on the stress state. Orientation-dependent strength analysis and bonding evolution further reveal the atomistic origins of its load-sensitive mechanical response [1]. Building on this intrinsic deformation landscape, we further demonstrate that introducing coherent twin boundaries (CTBs) enables a twin boundary migration–driven detwinning mechanism, in which collective CTB motion and annihilation accommodate plastic deformation while maintaining high strength. This process is facilitated by CTB-induced symmetry breaking and bond reconfiguration, as confirmed by electronic structure analysis [2]. These results provide a unified understanding of deformation in transition-metal nitrides, spanning intrinsic strain-controlled responses and defect-mediated plasticity, and offer insights into the design of transition-metal light-element compounds with simultaneous high hardness and toughness. **Keywords:** Large strains; Mechanical deformation; Transition-metal nitrides; Twin boundary migration **Reference**[1] Physical Review B, 2022, 106, 054112.[2] Nano Letters, 2026, 26, 7655.

26. Nanoindentation Analysis of Depth-Dependent Hardness and Irradiation Embrittlement in Fe Ion-Irradiated RAFM Steel (ARAA)

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Type: Poster

The practical application of fusion power as a next-generation clean energy source requires fusion reactor structural materials that maintain excellent performance under extreme conditions where high-energy neutrons generated by fusion reactions in ultra-high-temperature plasmas strike the materials at high speed. Accordingly, Korea has developed ARAA (Advanced Reduced-Activation Alloy), a reduced-activation ferritic/martensitic (RAFM) steel for fusion reactors, and ensuring its reliability requires quantitative analysis of embrittlement caused by neutron irradiation damage. Because neutrons are small and uncharged, accumulating sufficient damage requires long irradiation times and involves radiation exposure risks; therefore, Fe ion irradiation is used to rapidly simulate neutron irradiation damage. Fe ion irradiation forms a shallow damaged layer extending only a few micrometers below the surface, requiring nanoscale embrittlement analysis. Moreover, ion penetration peaks at a specific depth and irradiation effects diminish beyond it, causing depth-dependent embrittlement and requiring continuous analysis with depth. Furthermore, although embrittlement is generally evaluated using fracture toughness, conventional tests require standard specimens of sufficient thickness, making it difficult to evaluate the shallow damaged layer alone. In this study, hardness was selected as an embrittlement indicator, and nanoindentation in Continuous Stiffness Measurement (CSM) mode, which enables continuous hardness measurement with depth from a single nanoscale indentation test, was used to quantitatively analyze irradiation embrittlement in Fe ion-irradiated ARAA. The results showed that the degree of embrittlement varied with irradiation temperature and dose and could be quantitatively expressed using hardness changes with the indentation size effect excluded. This work was supported by the National R&D Program through the National Research Foundation of Korea (NRF), funded by the Korea Government (Ministry of Science and ICT) (No. RS-2022-00156205), and supported by Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) (RS-2024-00349003, Support for on-site practical training linked to public enterprises).

27. Deformation anisotropy and non-Schmid behavior in Ti_3SiC_2 MAX phase ceramics

Eiichi Sei (Hokkaido University), Ken-ichi Ikeda (Hokkaido University), Seiji Miura (Hokkaido University), Koji Morita (NIMS), Tohru S. Suzuki (NIMS), Sakka Yoshio (NIMS)

Type: Poster

Ti_3SiC_2 is a MAX phase that exhibits both metallic and ceramic properties. Due to these unique properties, it is a promising material, particularly for coatings on fuel cladding and high-temperature components. Because Ti_3SiC_2 has a hexagonal crystal structure with a high c/a ratio, it undergoes deformation primarily through basal slips and kink deformation, which involves buckling accompanied by delamination. Understanding the deformation behavior of thin films is important for these applications; however, the mechanical properties of Ti_3SiC_2 are highly anisotropic, and their details remain unclear. Therefore, we investigated the mechanical properties of Ti_3SiC_2 using nanoindentation (NI) and micro-pillar compression (MP) tests. Ti_3SiC_2 samples were fabricated by spark plasma sintering using Ti_3SiC_2 commercial powder and a mixture of Ti, Si, and C powders. Micro-mechanical tests were performed using a Hysitron TI-950 nanoindenter. NI was conducted with a Berkovich indenter in load-controlled mode. Crystal orientation dependence was investigated at a maximum load of 3 mN, which is the optimal load to prevent delamination. The NI results were analyzed using the

Oliver–Pharr method. MP was conducted with a flat punch in displacement-controlled mode. Single-crystal pillars fabricated by FIB were compressed at a strain rate of 1×10^{-4} s⁻¹. Their microstructures were characterized by SEM and SEM-EBSD. The nanohardness and elastic modulus of Ti₃SiC₂ depended on the crystal orientation, increasing as the angle from the base plane increased. Furthermore, the critical resolved shear stress (CRSS) for the pop-in phenomenon is also anisotropic, indicating non-Schmid behavior. Single-crystal pillars were deformed by basal slip, and their CRSS was consistent with previous studies. Moreover, the CRSS exhibited non-Schmid behavior, increasing with the normal stress on the basal plane.

28. Registration-Free Topography-Based Reliability Filtering for Unsupervised Classification of High-Throughput Nanoindentation Maps

Hayato Kobayashi (ELIONIX INC.), Kaiki Noma (ELIONIX INC.)

Type: Poster

High-throughput nanoindentation mapping provides spatially resolved mechanical-property data, but measurements near inclined surfaces may produce unreliable responses. During nanoindentation testing, the surface-detection position recorded at each indentation point can provide a height map inherently aligned with the corresponding hardness and modulus data. This registration-free topographic information requires neither additional measurements nor image registration, yet its potential use for evaluating measurement reliability has received limited attention. This study investigates surface-topography-based reliability filtering for unsupervised classification of a TiN/TiCN multilayer coating deposited on JIS SKD11 tool steel. Eight indentation maps were obtained from the same specimen. Hardness and modulus were used for clustering, while the simultaneously acquired height maps were used only as independent reliability indicators. Points with high local surface gradients were excluded, and classification performance was compared with random removal and removal based on extreme mechanical responses. Local-gradient filtering improved classification more consistently than random removal at comparable data coverage. Mechanical-response-based removal showed a similar effect at low rejection fractions, but stronger removal discarded minority high-hardness and high-modulus populations representing genuine microstructural regions, thereby reducing classification performance. These results demonstrate the within-specimen repeatability of registration-free topography-based filtering and its potential to improve classification while preserving mechanically distinctive minority phases. Future work should evaluate different specimens and polishing conditions and compare nanoindentation-derived height maps with independently measured topography, such as scanning probe microscopy, to clarify the reliability and spatial resolution of the proposed approach.

29. Effect of Composite Powder Preparation Methods on Microstructure and Properties of TiC-Reinforced AlSi10Mg Fabricated by Directed Energy Deposition.

Jaehyeong Kim (Pusan National University), Yoonsuk Choi (Pusan National University), Hyein Lee (Pusan National University)

Type: Poster

Metal matrix composites (MMCs) are composites in which ceramic reinforcements are dispersed within a metallic matrix, forming a heterostructure that arises from the substantial property mismatch between the hard ceramic phase and the ductile metal matrix. Directed energy deposition (DED) is an additive manufacturing process that utilizes a high-energy laser to melt and deposit powder, and its high cooling rate and localized melting can produce MMCs with unique interfacial microstructures. However, to ensure uniform and reliable composite deposits, the powder preparation step must satisfy reinforcement dispersion uniformity, suppression of agglomeration, adhesion stability during powder feeding, and preservation of powder flowability simultaneously. These powder preparation strategies fundamentally determine the quality of the resulting composite microstructure. In this study, three methods were used to attach TiC reinforcements onto AlSi10Mg powder surfaces: mechanical Turbula mixing, and binder-assisted adhesive coating, ball milling, binder-ethanol wet coating. The uniformity of reinforcement dispersion, degree of reinforcement agglomeration, powder sphericity, and flowability were evaluated for each preparation method. After the DED process, microstructural analysis via SEM, porosity evaluation, and hardness testing were conducted to compare the influence of powder preparation methods on the formation of the final composite microstructure. This work was supported by Korea Research Institute for Defense Technology Planning and Advancement (KRIT) - Grant funded by Defense Acquisition Program Administration (DAPA) (KRIT-CT-23-007)

30. Study on the Thermal and Mechanical Properties of Lanthanum-Based Ball-Type Regenerator Materials with Stacked and Mixed-Layer Structures for 4 K-Stage Regenerators

Hyeonjin Eom (Low-Carbon Emission Control R&D Department, Korea Institute of Industrial Technology), *Giovanni Maizza* (Department of Applied Science and Technology, Politecnico di Torino)

Type: Poster

Recent interest in superconducting quantum computers has been increasing, and operation of superconducting quantum computers requires cooling at the mK level. For this, multi-stage cryocoolers such as 4 K and 80 K stages are essential. In this study, a fundamental investigation was conducted on the thermal and mechanical properties of regenerator materials used in a 4 K-stage cooling system. First, when rare-earth-based materials known as 4 K-stage regenerator materials were placed in a specific domain in ball form, the thermal properties (temperature) according to stacking and mixed-layer configurations were calculated. In addition, local thermal and mechanical properties of the materials were also calculated. Through this work, we aim to examine the basic structures of stacking and mixed-layer configurations that should be considered when applying 4 K-stage regenerator materials in ball form to a regenerator.

31. Geometrically Constrained Plasticity and High-Temperature Mechanical Response of Cu/SiO₂ Hybrid Bonding Structures Characterized by Nanoindentation

Yuan-Fu Wang (Department of Materials Science and Engineering, National Yang Ming Chiao Tung University, Taiwan), *Chih Chen* (Department of Materials Science and Engineering, National Yang Ming Chiao Tung University, Taiwan)

Type: Poster

As advanced packaging drives the continuation of Moore's Law, Cu-Cu hybrid bonding has emerged as a critical solution for maximizing interconnect density enhancing the device's performance. This architecture relies on the coefficient of thermal expansion (CTE) mismatch between Cu pads and the surrounding SiO₂ dielectric; during annealing, the rigid SiO₂ matrix constrains the Cu, driving the vertical thermal expansion essential for joint formation. However, this phenomenon is highly size-dependent, as smaller pad diameters restrict thermal expansion and plasticity. To systematically investigate this geometry-dependent constraint effect, electroplated Cu thin films and nanocrystalline Cu/SiO₂ heterogeneous structures with pad diameters of 2, 3, 4, and 9 μm were fabricated. High-temperature nanoindentation utilizing the partial unload method was employed to characterize the mechanical response and plasticity constraints from room temperature (RT) to 300 °C. The evolution of elastic modulus (E) and hardness (H) was quantified on 9 mm pads. The average elastic modulus remained within 129–156 GPa, peaking at 200 °C. Meanwhile, the average saturation hardness held steady at 1.7–1.8 GPa up to 200 °C, but dropped by 37% to 1.1 GPa at 300 °C. Furthermore, size-dependent plasticity behaviors were revealed at RT under identical indentation depths: hardness increased from 1.8 ± 0.2 GPa (9 μm) to 2.2 ± 0.7 GPa (4 μm), 2.4 ± 0.5 GPa (3 μm), and 2.7 ± 0.1 GPa (2 μm). This trend demonstrates that Cu pad plasticity is strictly confined by the boundary conditions imposed by the via sidewalls, where smaller dimensions significantly elevate deformation resistance. Understanding this boundary-condition-dependent effect plays a pivotal role in optimizing the reliability of advanced packaging technologies.

32. Probing Serrated Flow in a Nickel-based Superalloy at Intermediate Temperatures via Nanoindentation

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Type: Poster

Nickel-based superalloys are widely used in aeronautical applications owing to their outstanding mechanical strength and resistance to creep at elevated temperatures. These alloys consist of a γ face-centered cubic (FCC) matrix strengthened by coherent γ' (L12) precipitates. At intermediate temperatures, it has been observed that nickel-based superalloy has been reported to exhibit serrated flow behavior also known as Portevin-Le Chatelier (PLC) which is associated with localized plastic instability. Although serration mechanisms have been extensively investigated in simple alloy systems, their origin in nickel-based superalloys remains a subject of discussion due to the complexity of their microstructure and multicomponent alloy chemistry. Nanoindentation offers a unique opportunity to probe localized deformation at small scales. Therefore, in this study, nanoindentation is

employed to investigate serration behavior in nickel-based superalloy at intermediate temperatures, with the aim of providing insight into the mechanisms governing serrated flow and localized plastic deformation.

33. Mechanical Behavior of Liquid Encapsulated in Copper Microstructures Under Extreme Thermo-Mechanical Conditions

Sung-Gyu Kang (*Gyeongsang National University*)

Type: Poster

Understanding the mechanical behavior of liquids at the nanoscale—particularly under hydrostatic stress across a wide range of strain rates and extreme temperatures—holds significant potential for advancing microfluidic, biomedical, and energy systems. However, experimental investigations in this regime remain limited due to the challenges of stably encapsulating liquids at the micro/nanoscale and precisely applying and measuring stress within confined spaces. Here, we present a novel single-step fabrication method that enables liquid encapsulation at the microscale and subsequent in situ micromechanical testing under extreme dynamic thermo-mechanical conditions. Through localized electrodeposition within liquid environments, hollow copper microstructures containing picoliter volumes of liquid were directly formed. The presence of the encapsulated liquid was verified through structural characterization at both cryogenic and elevated temperatures. Compression experiments were conducted to examine the mechanical role of the confined liquid. At room temperature, the incompressibility of the encapsulated liquid was confirmed, providing structural reinforcement. At $-160\text{ }^{\circ}\text{C}$, the confined liquid underwent a phase transition to solid ice, resulting in enhanced load-bearing capacity. These results suggest that the size-dependent strength enhancement of confined ice contributes to improved energy dissipation. Furthermore, the tensile behavior of the copper–ice composite was evaluated at $-160\text{ }^{\circ}\text{C}$ using microfabricated push-to-pull structures. This work introduces a novel approach for liquid encapsulation within metallic microstructures, broadening potential applications in microelectronics, pharmaceuticals, and energy storage systems.

34. Mechanical Properties of Low Temperature CuAg Metal-to-Metal Bonding through Nano-Multilayer Alloy Films

Dong Jin Seon (*Tech University of Korea*), Byoung-Joon Kim (*Tech University of Korea*)

Type: Poster

Cu-based metal-to-metal direct bonding generally requires high processing temperatures above $300\text{ }^{\circ}\text{C}$ to promote atomic diffusion and achieve sufficient interfacial bonding. However, such high temperatures impose a considerable thermal burden on semiconductor devices and packaging materials. Therefore, reducing the bonding temperature while maintaining sufficient bonding integrity is essential for advanced semiconductor packaging. Various approaches, including Cu(111) preferred orientation, plasma treatment, and passivation layers, have been investigated for low-temperature Cu bonding. However, some of these approaches require additional processes or have limited compatibility with chemical mechanical polishing. In this study, CuAg alloy films were introduced for low-temperature bonding. Ag was selected because of its low electrical resistivity, and a metastable CuAg alloy structure was designed to promote atomic redistribution and interfacial bonding

at reduced temperatures. CuAg alloy films were deposited by co-sputtering, and nano-multilayer structures were formed by controlling the substrate rotation speed. TEM-EDS analysis confirmed periodic Cu-rich and Ag-rich compositional modulation, with the modulation period decreasing as the rotation speed increased. The 10 RPM film exhibited an electrical resistivity of $4.12 \mu\Omega\text{-cm}$, representing a 21.4% reduction compared with $5.24 \mu\Omega\text{-cm}$ for the 0 RPM film. Bonding was performed at 200°C under 5 MPa for 1 h. Double cantilever beam testing showed that the interfacial fracture energy increased from 1.27 J/m^2 for the 0 RPM film to 3.46 J/m^2 for the 10 RPM film. The fracture behavior also changed from predominantly interfacial failure to mixed fracture. These results demonstrate that substrate-rotation-induced nano-multilayer structures simultaneously reduce electrical resistivity and improve the mechanical properties of CuAg bonded interfaces. This approach provides a practical strategy for low-temperature metal-to-metal bonding in advanced semiconductor packaging.

35. Modeling of Laser Beam Welding in an IN792 alloy: Experimental Validation of the Predicted Stress-strain Field against Rate-derived Nano-Hardness Measurements.

Giovanni Maizza (Politecnico di Torino), *Peihong Cheng* (University of Rome "Tor Vergata"), *Alessandra Varone* (University of Rome "Tor Vergata"), *Roberto Montanari* (University of Rome "Tor Vergata")

Type: Poster

Multiphysics simulation of laser beam welding (LBW) of IN 792 DS alloy is an essential means to analyze the intricate effects determined by rapid thermal cycling and steep thermal gradients. Both factors determine the final mechanical performance, distortions and residual stresses of welded joints. As LBW models must guarantee realistic predictions, appropriate non-linear materials properties across the whole working temperature range, realistic boundary conditions and robust a-posteriori verification of the predicted fields are paramount. Typically, among the multiple fields involved, the experimental validation of the stress-strain field is rather challenging. The elastoplastic response of welded joints is commonly probed by micro- and nano-indentation tests. However, the measured hardness field is seldom used to validate the predicted stress-strain field as it intrinsically: a) cannot discern the presence of long-range residual stresses from microstructure hardness, b) depends on the applied load (i.e., ISE dependent), c) samples a surface typically prepared by multiple slicing of the original welded joint. The latter factor is of special concern here as it is responsible of a dramatic change in the original (i.e. LBW-induced) residual stress state thereby making the validation of the predicted stress-strain field less straightforward. This research aims at developing a laser welding process which has been applied to an IN 792 DS alloy in two sequential steps: a) first the LBW process has been simulated giving a predicted post-LBW stress-strain field, b) the actual sample surface preparation (for nanoindentation testing) has been simulated via a sequence of multiple slicing operations and inherent redistribution and relaxation of the original stress-strain field. The latter residual stress-strain field has been used to experimentally validate the computed stress-strain field against the experimental nanoindentations by taking advantage of a new ISE-free parameter. The results are provided in terms of stress field after sample preparation.

36. Experimental Considerations for High-Temperature Instrumented Micro-Indentation of Superalloys

Hoseung Kang (Department of Materials Science and Engineering, Seoul National University), Eunsu Lee (Department of Materials Science and Engineering, Seoul National University), In-Suk Choi (Department of Materials Science and Engineering, Seoul National University)

Type: Poster

Ni- and Co-based superalloys are widely used in gas turbines, aerospace engines, and other extreme environments where mechanical performance at elevated temperatures governs component reliability and service lifetime. Accurate characterization of hardness, elastic modulus, deformation resistance, and time-dependent deformation behavior under service conditions is therefore essential. While conventional high-temperature tensile and compression tests provide reliable bulk mechanical properties, they require relatively large specimens and complex experimental procedures. High-temperature nanoindentation offers localized mechanical characterization but is often sensitive to surface preparation, oxidation, and microstructural heterogeneity because of its limited penetration depth. High-temperature instrumented micro-indentation provides an attractive intermediate approach by combining relatively small specimen requirements with larger indentation depths than nanoindentation, thereby reducing surface-related effects while maintaining localized property evaluation. However, reliable measurements remain challenging because several experimental factors become increasingly significant at elevated temperatures. These include machine compliance, thermal drift, thermal expansion, oxidation, indenter deformation, and unstable indenter-specimen contact, all of which may influence displacement measurement and consequently affect the calculated contact depth, hardness, and elastic modulus. In this work, we discuss the major experimental challenges encountered during high-temperature instrumented micro-indentation testing and present practical approaches for improving measurement reliability. Particular attention is given to machine compliance calibration under high-temperature testing conditions, thermal drift correction, and verification using reference materials. The influence of pile-up on contact area estimation is also examined by comparing indentation impressions measured using optical microscopy with contact areas predicted from indentation analysis. Preliminary results demonstrate the importance of appropriate experimental calibration and data interpretation for obtaining reliable high-temperature indentation properties. This study provides practical guidance toward establishing a robust high-temperature micro-indentation testing protocol for evaluating structural materials under elevated-temperature service conditions.

37. Spatially-distributed impact testing – a micro-mechanical test method for simulating solid particle erosion

Dr Ben Beake (Micro Materials Ltd.), Dr Luis Isern (Cranfield University, UK), Prof John Nicholls (Cranfield University, UK), Dr Hannah Zhang (National Physical Laboratory, UK), Prof Mark Gee (National Physical Laboratory, UK)

Type: Poster

A novel micro-mechanical high strain rate test method has been developed to replicate the spatial distribution of multiple impacts that occur when a material is subjected to solid particle erosion. The test method has been

developed from the nano-impact test which has proved effective in the study of impact resistance at high strain rate and small scale. A strong correlation has been shown between coating performance in the cyclic impact test and erosion resistance and metal cutting applications such as end milling and interrupted turning that involve repetitive contact. In a cyclic impact test repetitive contact occurs at the same point on the surface which does not closely replicate how erosion wear proceeds. A novel alternative approach is to perform multiple controlled impacts at different locations on the sample surface to better understand microstructural and crack morphological influences on damage propagation at the single-impact level. In this spatially-distributed impact test, a specified number of individual impacts occur with defined energy and chosen statistical distribution within a set area. Results on thermal barrier coatings (TBCs) showed that the test could reproduce the main damage mechanisms and surface morphology in solid particle erosion. Densification below impact craters and sub-surface cracking between the dense layer and the un-densified columns were revealed by focussed ion beam milling. Differences between the TBCs were consistent with their difference in erosion resistance. The test capability was validated at elevated temperature. In tests on bulk ceramics PSZ performed slightly better than alumina with sapphire being significantly worse consistent with reported differences in erosion rate. Experiments with controlled spacing between impacts showed greater radial cracking on sapphire and a smaller interaction spacing at which crack systems coalesce resulting in lateral fracture and material removal. This is considered an important factor limiting its erosion resistance.

38. Mechanical and Thermal Performance of AlSi10Mg/316L SS/OLC Tri-layer Composite Structures for Advanced Heat Dissipation

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Type: Poster

This study evaluates the feasibility of an AlSi10Mg/316L stainless steel/onion-like carbon (OLC) tri-layer composite structure as a promising candidate material for high-efficiency heat dissipation modules. AlSi10Mg substrates were first fabricated via selective laser melting (SLM) and subsequently annealed at 300°C to stabilize the microstructure and relieve manufacturing-induced residual stresses. To construct the hetero-structured architectures, 316L intermediate layers with varying thicknesses (300, 400, and 500 nm) were deposited via DC sputtering, followed by the deposition of OLC surface layers (50 and 100 nm) via E-gun evaporation. Interfacial configurations and carbon structural were characterized using SEM, HRTEM, XRD and Raman spectroscopy. The film exhibits a distinct, densely packed columnar grain structure with a well-defined boundary, where the thickness was measured at approximately 397.2 nm. Tensile testing demonstrated that the 316L intermediate layer improved the mechanical properties of the composite structures. SE09 (400 nm 316L/100 nm OLC) exhibited the highest tensile strength, with an ultimate tensile strength of 373.58 MPa and a yield strength of

286.93 MPa. For thermal performance, dynamic thermal responses were systematically analyzed using dimensionless temperature, mid-stage heating slope, and characteristic time ($t_{63\%}$). SE08 exhibited the fastest thermal response and the highest heating efficiency. Crucially, the reinforcement and thermal dissipation efficiencies did not follow a monotonic trend with thickness; excessive thicknesses (500 nm 316L or 100 nm OLC) led to residual stress accumulation and localized boundary defects, thereby deteriorating the thermal behavior due to increased interfacial thermal resistance. Overall, considering its comparable tensile properties to SE09 and its superior dynamic thermal response, the 400 nm 316L/50 nm OLC configuration of SE08 was identified as the optimal design for heat-dissipation applications. To further elucidate the atomic-scale interfacial structures via HRTEM, site-specific TEM lamellae were prepared using a focused ion beam system.

39. Creep Behavior at 630°C of Ferritic/Martensitic Heat-Resistant Steel with Cu Addition

Du-Hyun Kim (Department of Hydrogen Energy Materials Research Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea), *Byeong-Hyeon Lee* (Department of Advanced Analysis Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea), *Seong Hoon Kim* (Department of Steels, Korea Institute of Materials Science, Changwon 51508, Republic of Korea), *Woo-Sang Jung* (Department of Hydrogen Energy Materials Research Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea), *Dong-Ik Kim* (Department of Hydrogen Energy Materials Research Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea), *Gyeong Ho Kim* (Department of Advanced Analysis Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea), *Tae-Ho Lee* (Department of Steels, Korea Institute of Materials Science, Changwon 51508, Republic of Korea), *Jong-Ho Shin* (Corporate Research and Development Institute, Doosan Enerbility Co., Ltd., 22 Doosanvolvo-Ro, Changwon 51711, Republic of Korea), *Jin-Yoo Suh* (Department of Hydrogen Energy Materials Research Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea), *Seok Su Sohn* (Department of Materials Science and Engineering, Korea University, Seoul 02841, Republic of Korea)

Type: Poster

This study investigates the effect of Cu addition on the creep resistance of 10% Cr ferritic/martensitic steel used in steam turbine rotors and blades. An alloy was developed by replacing Co with Cu to improve high-temperature stability at lower cost. Creep tests were performed for Cu-free and Cu-containing steels at 630°C under various stresses. The Cu-added steel exhibited superior creep life under low-stress conditions, particularly at 145 MPa, where the lifetime increased to 12,733 hours, showing a 14% improvement over the reference steel. Microstructural analyses revealed that Cu addition effectively stabilized the microstructure during long-term creep. EBSD results showed stable prior austenite grain size and improved retention of martensite lath structures. TEM and APT confirmed the formation of Cu-rich precipitates along grain boundaries and inside grains, which suppressed grain coarsening and delayed recovery. XRD-based Modified Williamson-Hall and Modified Warren-Averbach analyses further indicated that dislocation density decreased by 81% in the Cu-free steel, whereas the Cu-added steel exhibited only a 66% decrease after creep exposure at 145 MPa. These results demonstrate that Cu is an effective substitute for Co in enhancing creep resistance and microstructural stability of turbine steel under prolonged low-stress conditions.

40. Effect of heat treatment on the fatigue behavior of STS304J1 stainless steel corrugated pipes under different loading conditions

Jae Hyun Park (Pusan National University), Yoon Suk Choi (Pusan National University)

Type: Poster

The effect of heat treatment on the rotating-bending fatigue behavior of STS304J1 stainless steel corrugated pipes was investigated under different applied loads. Continuous annealing was performed at a peak temperature of 1000–1100 °C for holding times of 16 and 38 min. Electron backscatter diffraction, Vickers hardness testing, rotating bending fatigue test, and fractographic analysis were conducted to characterize the microstructural changes, mechanical properties, and crack initiation behavior associated with corrugation forming and subsequent heat treatment. Before heat treatment, the corrugated region exhibited the highest martensite fraction and hardness. Heat treatment reduced the martensite fraction and hardness while promoting an increase in the austenite fraction, recrystallization, and grain growth. The fatigue life exhibited a distinct load-dependent trend. Under a high load condition, the as-received specimens exhibited the longest fatigue life, whereas the heat-treated specimens showed shorter fatigue lives because of their reduced strength. In contrast, under a low load condition, the fatigue life increased with increasing heat-treatment time. Fractographic analysis revealed that fatigue cracks predominantly initiated at the inner surface and that the ratchet-mark density decreased with increasing heat-treatment time, indicating a lower crack initiation frequency. These results suggest that the fatigue behavior of STS304J1 corrugated pipes is governed by the competing effects of strength reduction and microstructure-dependent crack initiation, with their relative contributions depending on the applied load.

Poster Presentation

2026-11-04 12:30 ~ 14:00

1. Rebound Hardness Test of Glass by Using Hammer with Vickers Indenter

Lu Chen (Kyushu Institute of Technology), Shuta Okajima (Kyushu Institute of Technology), Kenji Matsuda (Kyushu Institute of Technology)

Type: Poster

Rebound hardness tests—which define hardness values based on the ratio of velocities before and after impact or the ratio of rebound height to impact height—can be said to evaluate the degree of hammer energy dissipation caused by the impact. For metallic materials in which energy is primarily consumed by plastic deformation, the hardness value represents the material's resistance to plastic deformation. On the other hand, if a hammer impact causes fracture in a brittle material and the hammer's energy is consumed in that process, it is expected that the material's resistance to fracture can also be evaluated through a rebound hardness test. In this study, a cemented carbide hammer tipped with a Vickers indenter was dropped onto a glass surface from various heights to investigate the hammer's rebound behavior and the damage occurring at the point of impact. As a result, a tendency for the coefficient of restitution to decrease slightly with increasing drop height was observed within the drop height range of approximately 0.2 to 4 mm. It was also confirmed that the cracks occurring along the diagonal directions of the indentation increased as the drop height increased. Furthermore, there existed results where the coefficients of restitution were clearly lower than in other cases despite the same drop heights, and the formation of larger cracks was observed in the specimen that exhibited their lower coefficients. Observation of the acceleration waveform at the top of the hammer revealed that oscillation were superimposed midway through the loading process. The causes of the rapid increase in hammer vibration during the loading process were investigated using two types of numerical analysis methods. The results revealed that a sudden drop in impact load associated with glass fracture is one of the factors contributing to this phenomenon.

2. Nanoindentation Evaluation of Hydrogen Embrittlement in CoCrNi-Based MEAs with Composition-Dependent SFE

Ji-Hyeon Kim (School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeongbuk National University), Tae-Yeon Park (School of Materials Science and Engineering, Kumoh National Institute of Technology), In-Chul Choi (School of Materials Science and Engineering, Kumoh National Institute of Technology), Young-Cheon Kim (School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeongbuk National University)

Type: Poster

CoCrNi-based medium-entropy alloys (MEAs) are widely recognized for their excellent combination of strength, ductility, and fracture toughness, while maintaining superior mechanical properties even under cryogenic conditions. Owing to these characteristics, they have attracted considerable attention as structural materials for next-generation hydrogen energy systems, including liquid hydrogen storage and transportation systems.

However, hydrogen uptake in materials exposed to hydrogen environments can alter local plastic deformation, crack initiation, and fracture behavior, which may lead to the degradation of mechanical reliability in structural materials. Meanwhile, the mechanical behavior of CoCrNi-based MEAs is strongly influenced by stacking fault energy (SFE), which is closely associated with the activation of major deformation mechanisms such as dislocation glide, stacking fault formation, and deformation twinning. Therefore, to understand changes in local deformation behavior induced by hydrogen ingress, it is necessary to consider differences in SFE controlled by compositional variation. In this study, electrochemical hydrogen charging was conducted on CoCrNi-based MEAs with different Co/Ni compositions, and changes in local mechanical properties induced by hydrogen ingress were evaluated using nanoindentation tests. By comparing Co₄₃Cr₃₄Ni₂₃(Co-rich), Co₂₃Cr₃₄Ni₄₃(Ni-rich), and CoCrNi(equiatomic) compositions, this study aimed to examine the effect of composition-controlled SFE on the local mechanical response under hydrogen environments. For this purpose, load–depth curves, hardness, elastic modulus, and indentation deformation responses before and after hydrogen charging were analyzed. Based on these results, changes in deformation resistance and differences in hydrogen embrittlement susceptibility among the different compositions were investigated. This study was supported by a grant from the Korea Institute for Advancement of Technology (KIAT), funded by the Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea (Project No. RS-2024-00409639, Industrial Innovation Talent Growth Support Program, 2024).

3. Effect of TiB Particle on Hydrogen Embrittlement behavior of α -Ti

*Hyun Jeong (Chungnam National University), Yakai Zhao (A*STAR Future Energy Acceleration & Translation (FEAT)), Keun Hyung Lee (Chungnam National University), Soo Yeol Lee (Chungnam National University), Dong-Hyun Lee (Chungnam National University)*

Type: Poster

Titanium (Ti) and its alloys have been widely used in aerospace, marine, nuclear, and chemical industries owing to their high specific strength, excellent corrosion resistance, and oxidation resistance. They are also promising structural materials for hydrogen energy infrastructure. However, exposure to hydrogen can induce δ -hydride formation in Ti, leading to localized embrittlement, crack initiation, and degradation of ductility, strength, and fatigue resistance. Therefore, understanding hydrogen trapping, hydride formation, and hydrogen-induced crack propagation is essential for designing Ti-based materials for hydrogen environments. In this study, Ti–TiB titanium matrix composites with different TiB fractions were fabricated by ball milling commercially pure Ti and AlB₂ powders followed by reaction sintering. The specimens were classified as C0, C1, and C4 according to the TiB fraction. The total TiB fraction and the distribution of TiB particles at grain boundaries and within grains were quantitatively analyzed using optical microscopy and ImageJ. Grain morphology, crystallographic orientation, and phase evolution after hydrogen charging were examined by EBSD. Hydrogen embrittlement behavior was evaluated by room-temperature tensile tests under electrochemical hydrogen charging, and the fracture surfaces and crack tips were analyzed using SEM and EBSD. Ag decoration was further performed to visualize hydrogen trapping sites at TiB/Ti interfaces, grain boundaries, and the α -Ti matrix. In addition, nanoindentation was used to quantify local hardness changes before and after hydrogen charging by distinguishing hydride regions from the α -Ti matrix. This study aims to clarify how TiB fraction, TiB distribution,

TiB/Ti interfaces, hydride formation, and local mechanical property changes affect hydrogen-induced crack formation in Ti–TiB alloys.

4. Correlation between Single-Particle Fracture Strength and Cycle Life of Li-Rich Layered Oxide Cathodes Measured by Micro-Compression Testing

Hyungcheoul Shim (University of Ulsan)

Type: Poster

Long-term cycling stability is a primary requirement for lithium-ion battery cathodes. One factor limiting cycle life is mechanical degradation of the active material: repeated lattice expansion and contraction during cycling generates stress within particles, leading to crack formation and impedance growth. In Li-rich layered oxide (over-lithiated oxide, OLO) cathodes, transmission electron microscopy of cycled particles reveals extensive intragranular cracking, suggesting that the mechanical strength of individual particles is linked to their electrochemical lifetime. Direct experimental evidence for this relationship, however, remains limited. In this work, the compressive fracture strength of individual OLO secondary particles was measured by micro-compression testing (MCT), in which a flat indenter loads a single particle to failure and the strength is evaluated from the failure load and particle diameter. Two sample sets were examined: particles surface-coated with different materials (AlF_3 , ZnO , and Al_2O_3) and particles calcined at different temperatures (700, 750, and 800 °C). Coin half cells fabricated from the same powders were cycled at 1C/1C to obtain capacity retention. Surface coating increased particle strength, with wet-coated AlF_3 showing a 173% improvement over the pristine material (257.5 versus 94.1 MPa), and the coated cathode exhibited higher capacity retention (94% versus 90% after 41 cycles). Among the coatings, Al_2O_3 gave the highest strength (304.1 MPa). Calcination temperature showed a monotonic relationship with both properties: fracture strength increased from 308.5 to 4468.2 MPa and capacity retention from 85.5% to 92.6% as the temperature increased from 700 to 800 °C, which is attributed to enhanced crystallinity. These results demonstrate a consistent correlation between single-particle fracture strength and cycle life in Li-rich layered oxide cathodes. Particle-level strength measured by MCT can serve as a screening parameter for cathode durability, and particle-reinforcing strategies such as oxide coating and optimized calcination provide a route toward long-lived cathodes.

5. Indentation-Depth Criterion for Hardness Evaluation of Ion-Irradiated Reduced-Activation Ferritic/Martensitic Steel: Extended Nix–Gao Analysis and Residual-Imprint Morphology

Sumin Lee (Tohoku University), Diancheng Geng (Tohoku University), Minha Park (Tohoku University), Sosuke Kondo (Tohoku University), Ryuta Kasada (Tohoku University)

Type: Poster

Reduced-activation ferritic/martensitic steels are leading candidate structural materials for fusion reactor blanket systems, where reliable evaluation of irradiation hardening is essential. Ion irradiation enables accelerated screening and mechanistic studies, but produces only a shallow damaged layer, making quantitative mechanical characterization difficult. Nanoindentation is therefore widely used; however, the measured

hardness is influenced by the indentation size effect and by the unirradiated substrate when the plastic zone extends beyond the damaged region. A physically based criterion for identifying the depth range representative of the irradiated layer is still lacking. In this study, continuous stiffness measurement nanoindentation was performed to maximum indentation depths of 400 and 2000 nm on F82H steel irradiated with 10.5 MeV Fe³⁺ ions at 270 °C to doses of 5, 20, and 62 dpa. The irradiation produced an approximately 2-μm-thick damaged region. Residual indent morphologies were examined by scanning electron microscopy and confocal laser microscopy. The conventional Nix–Gao framework (Kasada, 2011) was extended by introducing a substrate-transition depth separating an irradiated-layer-dominated regime from a substrate-affected regime (Geng, 2024). The apparent hardness increased with irradiation dose but also depended strongly on indentation depth. The substrate-transition depth varied with irradiation condition, showing that a single universal depth criterion is not appropriate. These results show that hardness measured at a fixed indentation depth can contain an irradiation-condition-dependent substrate contribution, even when the indentation depth is smaller than the nominal damage-layer thickness. Combining depth-resolved Nix–Gao analysis with residual-imprint morphology provides a more reliable basis for evaluating ion-irradiation hardening and supports the development and assessment of fusion structural materials.

6. Microindentation Based Evaluation of Hydrogen Induced Fracture Toughness Degradation in Advanced High Strength Steels

Ehsan Norouzi (Korea Institute of Science and Technology (KIST)), *Reza Miresmaeili* (Tarbiat Modares University), *Laura Vergani* (Politecnico di Milano)

Type: Poster

Hydrogen embrittlement is one of the major challenges limiting the safe application of advanced high strength steels (AHSSs) in hydrogen related industries. Therefore, reliable evaluation of fracture resistance under hydrogen exposure is essential for the development of hydrogen tolerant structural materials. In this study, the fracture behavior of newly developed FeCrNiBSi advanced high-strength steels together with metastable austenitic stainless steels was investigated using a microindentation-based fracture toughness approach. Hydrogen was introduced by in-situ electrochemical charging, and the influence of hydrogen on fracture resistance was evaluated through load–displacement analysis obtained from microindentation tests. The results were correlated with tensile properties, electron backscatter diffraction (EBSD) observations, and thermal desorption spectroscopy (TDS) analyses to clarify the underlying deformation and embrittlement mechanisms. The microindentation results demonstrated a clear reduction in fracture toughness after hydrogen charging for all investigated steels, which was consistent with the degradation observed in tensile ductility and strength. Among the investigated materials, the metastable stainless steel exhibited the largest deterioration in fracture toughness, whereas the newly developed carbon-containing AHSS showed the highest resistance to hydrogen-assisted degradation. Microstructural characterization revealed that hydrogen promoted localized deformation, increased dislocation density, and facilitated crack initiation and propagation through phase transformation or heterogeneous microstructural features, depending on the alloy composition. Furthermore, irreversible hydrogen trapping by boride precipitates and retained austenite contributed to the variation in embrittlement behavior among the investigated steels. The results demonstrate that microindentation provides a rapid,

reliable, and minimally destructive technique for evaluating hydrogen-induced degradation of fracture toughness. This method offers an efficient alternative for characterizing fracture resistance in advanced steels and provides valuable insights for the design and development of high strength materials for future hydrogen energy applications.

7. Characterization of Mechanical Behavior in Ion-Irradiated Tungsten for Fusion Divertor Applications

Sun-Young Park (Korea Atomic Energy Research Institute), Suk-Hoon Kang (Korea Atomic Energy Research Institute), Hyung-Ha Jin (Korea Atomic Energy Research Institute), Sangyeob Lim (Korea Atomic Energy Research Institute), Seunghyun Lee (Korea Atomic Energy Research Institute), Dong won Lee (Korea Atomic Energy Research Institute)

Type: Poster

Divertor components in future fusion reactors are expected to operate under severe heat and particle fluxes throughout their service time. Tungsten remains the leading candidate for these plasma-facing surfaces owing to its excellent thermal conductivity, high melting temperature, and low sputtering yield. However, continuous bombardment by particle fluxes generates lattice defects that build up over operating time and progressively alter the deformation response of materials. Therefore, it is necessary to understand the relationship between irradiation-induced microstructure and the resulting mechanical response of tungsten under fusion-relevant conditions. This work establishes that the effect of ion irradiation on the mechanical behavior of tungsten was investigated through Fe-ion irradiation. Irradiation experiments were conducted over a damage range of 1–20 displacements per atom (dpa) to represent different levels of irradiation damage at the KEARI Heavy Ion Irradiation Facility. Since ion irradiation typically produces a near-surface damaged layer with a limited penetration depth, microscale tensile specimens were fabricated. Dog-bone shaped micro-tensile specimens were prepared using focused ion beam (FIB) milling from within approximately 4 μm beneath the irradiated surface. Mechanical characterization was performed using in-situ micro-tensile testing inside a scanning electron microscope (SEM). In addition, microstructural characterization was carried out for each irradiation condition to investigate the evolution of irradiation-induced defects. The evolution of irradiation-induced defect structures was analyzed and correlated with the measured mechanical response, providing insight into the relationship between defect evolution and the deformation behavior of ion-irradiated tungsten.

8. In-situ Electromechanical Characterization of Damage in Hydrogen-Charged Crystalline/Amorphous Nanolaminates

Jeongbin Park (Korea Advanced Institute of Science and Technology), JungHun Park (Korea Advanced Institute of Science and Technology), Zion Lee (Korea Advanced Institute of Science and Technology), Woosuk Seo (Samsung Display), Tae-Ho Lee (Samsung Display), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Poster

Nanolaminate thin films have attracted attention as protective coatings and structural components in hydrogen environments, owing to their combination of high mechanical strength and hydrogen barrier properties. Such films can serve as hydrogen permeation barriers (HPB) in components such as hydrogen storage vessels and

fuel cells, which are subjected to long-term cyclic loading. Quantitative evaluation of the onset of functional failure in HPB coatings under such loading conditions remains a practical challenge, as conventional methods typically assess only the final failure behavior, without capturing the progression of deformation that precedes it. This is critical for HPB applications, where a single crack can create a leak path well before macroscopic failure occurs. We report an integrated in-situ micro-mechanical testing and electrical resistance measurement approach for evaluating the performance of HPB. Monotonic tensile and cyclic fatigue tests were performed on nanolaminate specimens while electrical resistance was continuously monitored. Nanolaminate specimens (alternating crystalline Aluminum/amorphous Al-Y-Ni-Co alloy layers) with total thickness $< 1\mu\text{m}$ were deposited by magnetron sputtering and electrochemically hydrogen-charged for 0, 0.5, 1, and 2 h prior to testing. The tensile tests revealed a resistance-strain correlation for each charging condition, which was used as a basis for interpreting the fatigue response. The critical number of cycles to the onset of an abrupt increase in electrical resistance (N_{init}) decreased with hydrogen charging and varied with charging duration, indicating that pre-charged hydrogen accelerates damage onset in the nanolaminates. This behavior may correspond to the point at which the nanolaminate's HPB performance begins to degrade. These results show that electrical resistance measurements can track deformation and enable early-stage detection of damage before fracture in hydrogen-charged nanolaminates.

9. Effect of Electrolyte on the Local Mechanical Properties of STS304 during Electrochemical Hydrogen Charging

Sang-Min Park (Materials Research Center for Energy and Clean Technology, Gyeongbuk National University), Sang-yeob Lee (Materials Research Center for Energy and Clean Technology, Gyeongbuk National University), Young-Cheon Kim (Materials Research Center for Energy and Clean Technology, Gyeongbuk National University)

Type: Poster

Enter description here. Austenitic stainless steel STS304 is widely used in marine, chemical, and hydrogen energy-related industries owing to its excellent corrosion resistance and mechanical properties. However, hydrogen generated under electrochemical environments can enter the material and affect its mechanical behavior, and hydrogen evolution and uptake are strongly influenced by electrolyte conditions. In this study, electrochemical hydrogen charging was performed using H_2SO_4 and NaCl solutions, and the mechanical properties of STS304 were evaluated by Micro-Vickers hardness testing as a function of electrolyte concentration, post-charging exposure time, and indentation load. The hardness of hydrogen-charged STS304 generally increased compared with the uncharged condition, with the extent of increase depending on electrolyte type and concentration. A relatively pronounced hardness increase was observed in the acidic electrolyte, while hardness gradually decreased with increasing post-charging exposure time. The hardness change also varied with indentation load, suggesting a more pronounced hydrogen-charging effect in the near-surface region. In addition, optical microscopy was used to examine surface corrosion and corrosion products after hydrogen charging, and their relationship with the time-dependent changes in hardness was evaluated. This research was conducted with funding from the government (Ministry of Trade, Industry and Energy) in 2024 and support from the Korea Institute for Advancement of Technology (RS-2024-00409639, 2024 Industrial Innovation Talent Development Support Program).

10. Analysis of Hydrogen Embrittlement and Corrosion Behavior of STS304 Strain-Induced Martensite in a Seawater Environment

Sang-Yeob Lee (Gyeongbuk National University), Sang Min Park (Gyeongbuk National University), Young-Cheon Kim (Gyeongbuk National University)

Type: Poster

In austenitic stainless steel (STS304), a strain-induced phase transformation occurs under low-temperature and deformation conditions, in which austenite transforms into martensite; this transformation alters hydrogen diffusion and trapping behavior, thereby having a decisive impact on hydrogen embrittlement sensitivity. In particular, in chloride environments such as seawater, combined degradation where hydrogen ingress and pitting corrosion occur simultaneously threatens structural integrity. In this study, the mechanical behavior and electrochemical properties of STS304 according to the strain-induced martensite fraction were investigated in a seawater-simulating environment. Electrochemical hydrogen loading was performed on specimens with controlled martensite fractions in a 3.5 wt.% NaCl + 3 g/L NH₄SCN electrolyte. Nanoindentation and tensile tests were conducted to evaluate the local and macroscopic mechanical behavior, respectively. In addition, isopotential polarization tests were conducted to observe changes in corrosion resistance in a chloride environment. The experimental results revealed a correlation whereby, as the martensite fraction increased, hardness rose due to changes in the density of hydrogen trap sites, while elongation and corrosion resistance decreased significantly. This research was conducted with funding from the government (Ministry of Trade, Industry and Energy) in 2024 and support from the Korea Institute for Advancement of Technology (RS-2024-00409639, 2024 Industrial Innovation Talent Development Support Program).

11. Reduced hardness difference between V and Cu-rich Phases for enhanced malleability of V-Cu-Ni-Al hydrogen separation membranes

Jung Hun Han (Korea University), Sang Yoon Song (Korea University), Ju-Hyun Baek (Korea Institute of Science and Technology), Gunjick Lee (Korea Institute of Science and Technology), Jin-Yoo Suh (Korea Institute of Science and Technology), Seok Su Sohn (Korea University)

Type: Poster

Vanadium-based alloys offer excellent hydrogen permeability but suffer from hydrogen embrittlement and poor malleability, limiting their industrial application. In this study, two alloys, V76Cu15Ni7Al₂ (7Ni2Al) and V76Cu15Ni2Al₇ (2Ni7Al), were designed to improve mechanical stability by tailoring the microstructure through preferential partitioning of Ni to the V matrix and Al to the Cu-rich phase. Microstructural analyses revealed that 7Ni2Al formed a sigma phase and exhibited an inhomogeneous Cu-rich phase distribution, whereas 2Ni7Al developed a continuous Cu-rich network and suppressed sigma phase formation. Nano indentation measurements further showed that the hardness difference between the V matrix and Cu-rich phase decreased from 1.94 GPa in 7Ni2Al to 0.49 GPa in 2Ni7Al due to the preferential partitioning of Ni and Al. This reduction in hardness difference contributed to more uniform deformation and improved mechanical stability, resulting in significantly improved malleability. After 80% cold rolling, 2Ni7Al exhibited far fewer and shorter edge cracks

than 7Ni2Al. Both alloys demonstrated high hydrogen permeability of approximately 2.0×10^{-8} mol H₂·m⁻¹·Pa^{-1/2}·s⁻¹ at 673 K, exceeding that of pure Pd membranes. Furthermore, neither alloy exhibited hydrogen blistering nor embrittlement during cooling, confirming stable permeability under non-steady-state conditions. These findings highlight that optimizing the Cu-rich phase distribution, Ni/Al ratio, and hardness difference between constituent phases is a promising strategy for designing hydrogen separation membranes with superior malleability and resistance to hydrogen embrittlement.

12. Mechanical Characterization of Irradiated Tungsten Diboride

Ellen Yoo (Imperial College London), Sam Humphry-Baker (Imperial College London), Oriol Gavalda-Díaz (Imperial College London)

Type: Poster

Tungsten diboride (WB₂) is a leading candidate material for inboard shielding in tokamak fusion reactors due to its exceptional neutron attenuation and thermal properties. However, its mechanical property evolution under radiation damage remains poorly understood. This is challenging given the typically thin degradation layers in ion-irradiated materials, coupled with the anisotropic nature of WB₂ and its exceptionally high hardness. The aim of this presentation is to uncover recent progress using nanoindentation coupled with FIB microscopy and electron back-scattered diffraction (EBSD) to address these challenges. We first report the properties of unirradiated materials with respect to the basal and prismatic planes, which are not yet reported in the literature for this material. Second, we report the properties of materials irradiated at various temperatures in the range of 300-700 degC. Higher temperature increased irradiation-induced defect annealing, and mitigated the observed changes in mechanical properties. Finally, FIB Slice-and-View reveals cracking morphology in the subsurface, which was induced in the peak damage area of the irradiation. These observations are discussed together with the mechanical data in Part 2. The results of this work will help in understanding the damage pathways in this material and may inform the engineering of more radiation-resilient shielding.

13. Effect of Reverted Austenite on the Hydrogen Embrittlement Resistance of Maraging Steel Produced by L-PBF

Jin Mo Park (Pukyong National University), Min Ho Lee (Pukyong National University), Junghoon Lee (Research Institute of Industrial Science & Technology (RIST)), Seungyeon Lee (Korea Institute of Materials Science (KIMS)), Park Jeong-min (Korea Institute of Materials Science (KIMS)), Jae Wung Bae (Pukyong National University)

Type: Poster

Maraging steel produced by laser powder bed fusion (L-PBF) exhibits excellent mechanical properties but can be susceptible to hydrogen embrittlement (HE) due to its martensitic matrix and heterogeneous microstructure. This study investigated the effects of different heat-treatment routes on the microstructure, mechanical properties, and HE behavior of L-PBF maraging steel. Microstructures and phase distributions were characterized using electron backscatter diffraction (EBSD) and X-ray diffraction (XRD), and HE susceptibility was evaluated by slow strain rate tests of hydrogen-charged and uncharged specimens. In the solution and

aging treatment (SAT) condition, the cellular structure and microsegregation formed during L-PBF were largely eliminated during solution treatment, and a small amount of reverted austenite was observed at grain boundaries. In contrast, the direct aging treatment (DAT) condition exhibited a higher fraction of reverted austenite, mainly near retained cell boundaries. Both heat treatments increased strength relative to the as-built condition due to precipitation strengthening. The total elongations of the DAT and SAT specimens were 25.0% and 11.8%, respectively, and decreased to 14.2% and 2.8% after hydrogen charging. The corresponding relative losses in total elongation were 43.2% for DAT and 76.3% for SAT, indicating higher HE resistance in the DAT condition. Changes in the reverted austenite fraction before and after hydrogen charging and deformation were evaluated by XRD, and hydrogen desorption behavior was also analyzed by thermal desorption spectroscopy. These results suggest that differences in reverted austenite fraction and microstructure between DAT and SAT conditions affect the HE behavior of L-PBF maraging steel.

14. Indentation-Based Comparison of Mechanical Property Changes with Hydrogen Content in Different Metallic Materials

Huicheol Shin (Korea Institute of Materials Science, Yeungnam University), *Gyubeom Kim* (Korea Institute of Materials Science), *Doo-won Kim* (Korea Institute of Materials Science), *Siwhan Lee* (Korea Institute of Materials Science), *Nokeun Park* (Yeungnam University), *Seung-gun Lee* (Korea Institute of Materials Science)

Type: Poster

The development of reliable structural materials for hydrogen transport and storage systems is essential for the widespread utilization of hydrogen energy. Metallic materials used in hydrogen storage vessels and pipelines are exposed to various hydrogen environments, where hydrogen uptake can alter their mechanical properties. The extent of these hydrogen-induced changes is strongly influenced by material characteristics, including crystal structure and hydrogen transport behavior. In this study, the effect of retained hydrogen content on the instrumented indentation response of metallic materials with different crystal structures was investigated. Hydrogen was introduced into the specimens by high-pressure gaseous hydrogen charging. After charging, the specimens were stored in liquid nitrogen for different durations, and the retained hydrogen content was quantitatively determined using thermal desorption spectroscopy (TDS). Instrumented indentation tests were conducted to evaluate hydrogen-induced changes in local mechanical response. Particular attention was paid to the indentation impressions and pile-up morphology to characterize localized plastic deformation and material-dependent responses to hydrogen. The indentation response was subsequently compared with bulk tensile properties obtained from conventional tensile tests to examine the relationship between local mechanical response and macroscopic mechanical behavior. The correlations among retained hydrogen content, indentation characteristics, and tensile properties were examined for the different materials. Based on these correlations, material-dependent mechanical responses to hydrogen were discussed, and the applicability of instrumented indentation as a rapid screening method for structural metallic materials used in hydrogen transport and storage systems was assessed.

15. Evaluation of IASCC Initiation Susceptibility of Proton-Irradiated Austenitic Stainless Steel Welds

Ji-Yun Kim (Korea Atomic Energy Research Institute), WonJoon Na (Korea Atomic Energy Research Institute), Min-Jae Choi (Korea Atomic Energy Research Institute)

Type: Poster

Irradiation-assisted stress corrosion cracking (IASCC) is one of the major degradation mechanisms affecting the structural integrity of austenitic stainless steel components in reactor vessel internals (RVIs) of nuclear power plants. Studies on IASCC initiation mechanisms have primarily focused on Cr depletion at grain boundaries by radiation-induced segregation (RIS) as a cause of intergranular cracking of materials in primary water environments. IASCC initiation has also been investigated from a mechanical perspective, focusing on localized deformation and stress concentration by the interaction of dislocation channels with grain boundaries. In addition, IASCC initiation in welded regions of RVIs has become an important issue, while the applicability of the initiation mechanisms identified in base metals to welds remains uncertain. In this study, the effects of welding on IASCC initiation susceptibility were evaluated by conducting slow strain rate tensile tests on proton-irradiated Type 304 and 316 stainless steel welds and base metals in a simulated primary water environment. The welds were fabricated by GTAW, SSRT tests were conducted up to 10% strain, and IASCC initiation susceptibility was quantified by measuring the total length of intergranular cracks on the irradiated surfaces. After the SSRT tests, nano tensile specimens were fabricated on the grain boundary and in the grain near intergranular crack from the welded regions using FIB milling. In-situ nano tensile tests were performed in SEM using a nanoindenter with a push-to-pull device to evaluate the mechanical properties of grain boundaries associated with IASCC initiation. It was found that IASCC initiation susceptibility in the welds was dependent on the relative orientation between the tensile direction and the columnar grain growth direction.

16. In-Situ Detection of Machining Mode During Micro-Hole Drilling of Single-Crystal Silicon Using Acoustic Emission Sensor and Dynamometer

Hwa-Sub Lee (Korea Institute of Machinery and Materials (KIMM), University of science and technology (UST)), Dong-hyun Seo (Korea Institute of Machinery and Materials (KIMM), University of science and technology (UST)), Doo-Sun Choi (Korea Institute of Machinery and Materials (KIMM)), Jun Sae Han (Korea Institute of Machinery and Materials (KIMM), University of science and technology (UST)), Eun-Ji Gwak (Korea Institute of Machinery and Materials (KIMM), University of science and technology (UST))

Type: Poster

Hard and brittle materials, including single-crystal silicon, are increasingly demanded in precision semiconductor and micro-electromechanical systems (MEMS) applications. Although material removal is achievable in both ductile and brittle regimes, machining in the brittle regime induces subsurface cracking and poor surface finish, rendering it unsuitable for precision components. High-quality cutting therefore requires operating within the ductile regime, governed by the critical depth of cut (critical depth) — the maximum undeformed chip thickness below which plastic deformation dominates over fracture. Scratch testing is widely used to determine critical depth; however, its test speed and deformation mode differ substantially from actual

machining conditions, limiting the direct applicability of scratch-derived values to real cutting processes. This study presents an in-situ methodology for identifying the machining mode during micro-hole drilling of single-crystal silicon. Drilling experiments were conducted across multiple discrete feed rate conditions, each corresponding to a different effective depth of cut per revolution. Cutting force signals were acquired via a piezoelectric dynamometer, and elastic waves were simultaneously captured by an acoustic emission (AE) sensor — known to be highly sensitive to crack initiation in brittle materials. By comparing AE and force signals under ductile, brittle, and ductile-to-brittle transition (DBT) conditions, characteristic signals were identified for each regime. The results demonstrate that AE frequency signals and cutting force profiles exhibit distinctly different patterns depending on the prevailing material removal mode, enabling reliable, real-time discrimination of ductile, brittle, and DBT states without post-process surface inspection. The proposed dual-sensor approach offers a practical pathway toward process-integrated monitoring in precision micro-machining of brittle semiconductors, where conventional scratch test conditions are not applicable. This work was supported by the Materials & Components Technology Development Program funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea) (No. RS-2026-25536427).

17. Investigating the Residual Stresses in the Cross-section of an L-PBF 316L Alloy using Instrumented Indentation Tests and X-Ray Diffraction

Ahmad Atef Abdullatef Hamed (University of Rome ~~WWW"Tor VergataWWW"~~), Giovanni Maizza (Politecnico di Torino), Maria Josè Marques (University of Porto), Antonio Castanhola Batista (University of Coimbra), Maria Richetta (University of Rome ~~WWW"Tor VergataWWW"~~), Roberto Montanari (University of Rome ~~WWW"Tor VergataWWW"~~)

Type: Poster

Residual stresses are intrinsic to materials produced by laser powder bed fusion (L-PBF) due to the occurrence of rapid thermal cycles and steep thermal gradients. The characterization of these stresses using instrumented indentation tests (IIT) faces several challenges including: i) difficulty in defining a stress-free reference material state, ii) difficulty in correlating the IIT results with other residual stress measuring techniques, which also suffer from their own limitations, and iii) alteration of the initial residual stress state during sample preparation. The objective of this study is to investigate these three aspects by comparing IIT and X-ray diffraction (XRD) techniques and attempt a correlation by means of the rate-derived hardness, HR. Nanoindentations were carried out at several points in the cross-section of an L-PBF 316L alloy where XRD measurements were done. The results show that the mean value of HR (in the range 2.32 GPa – 2.62 GPa) at each analyzed point is linearly decreasing with the long-range normal residual stresses measured by XRD (in the range -123 MPa – 128 MPa). The standard deviation of HR at each point was attributed to the variations of short-range residual stresses. The alteration of the residual stresses in the longitudinal direction was also studied using XRD measurements before and after sample slicing using electrical discharge machining (EDM). After slicing, a release of tensile residual stresses was observed which must be considered when correlating the IIT parameters to the mechanical effects induced by the L-PBF process.

18. Grain Boundary Effects on Slip Transmission and Dislocation Avalanches during Nanoindentation

CHANJAE SHIN (*Department of Materials Science and Engineering, Seoul National University*), Ill Ryu (*Department of Materials Science and Engineering, Seoul National University*)

Type: Poster

The size-dependent plasticity of polycrystalline metallic micro-components is widely attributed to local strain gradients arising from the evolution of geometrically necessary dislocations (GNDs). In regions of highly localized deformation, such as beneath a nanoindenter, inhomogeneous dislocation accumulation produces additional hardening beyond conventional forest hardening. When the indentation-induced plastic zone reaches a nearby grain boundary, the competition between dislocation pile-up at the boundary and slip transmission across it can further modify the indentation response. While nanoindentation offers a unique opportunity to probe mechanical properties at small length scales, directly resolving the underlying deformation mechanisms associated with defect microstructure remains challenging because of high dislocation densities, severe entanglement, and limited experimental access to subsurface microstructural evolution. To overcome these limitations, we have developed a mesoscopic defect dynamics model that directly couples the Finite Element Method (FEM) with Discrete Dislocation Dynamics (DDD). The framework captures complex loading and boundary conditions in realistic geometries while explicitly resolving atomistically informed dislocation-grain boundary (GB) interactions. Dislocation nucleation at stress concentrators (e.g., nanoindentation tips, GBs, and defects) is also incorporated via a kinetic Monte Carlo approach. We utilize this framework to investigate the nanoindentation response of polycrystalline metals under varying spatial confinement, modulated by the indenter-to-GB distance. The simulations reveal how confinement alters geometrically necessary dislocation (GND) accumulation, slip transmission, and surface-nucleation avalanches. Critically, we identify a transition from transmission-dominated to nucleation-dominated plasticity under severe spatial constraints. This work elucidates the mechanistic origins of indentation size effects by establishing a direct link between variations in indentation hardness and discrete defect dynamics.

19. Noise-Robust FEA-ANN Inverse Analysis for Tensile Property Prediction Using Instrumented Indentation Testing

Im-Deok Kim (*Seoul National University*), Si Hyun Park (*Pukyong National University*), Joost J. Vlassak (*Harvard University*), Jong-Hyoung Kim (*Pukyong National University*), Seung-Kyun Kang (*Seoul National University*)

Type: Poster

Instrumented indentation testing (IIT) has attracted considerable attention as a non-destructive alternative to conventional tensile testing for evaluating mechanical properties, particularly in small-scale regions where standard specimen extraction is difficult. When combined with inverse analysis based on finite element analysis (FEA) and artificial neural networks (ANNs), IIT enables tensile properties to be estimated from load-displacement responses. However, conventional FEA-ANN inverse frameworks are typically trained using idealized simulation data and often fail to account for measurement uncertainty inevitably present in real indentation experiments. As a result, their predictive performance can deteriorate when applied to experimental

data. In this study, a noise-robust ANN framework is proposed to improve the reliability of tensile property prediction from instrumented indentation data. Experimental variability observed in repeated indentation measurements was statistically characterized and incorporated into FEA-generated training data through noise-based data augmentation. By learning from both ideal and perturbed indentation responses, the proposed model was designed to better accommodate realistic experimental uncertainty and reduce sensitivity to measurement noise. The developed framework was validated using various metallic specimens to evaluate its applicability under practical testing conditions. The results demonstrated that experimentally informed noise augmentation improved the consistency of ANN-based inverse analysis when applied to experimental indentation responses. These findings suggest that the noise-robust FEA-ANN inverse analysis framework can serve as a practical and reliable tool for indentation-based mechanical property characterization. The proposed method is expected to broaden the applicability of IIT in practical applications where conventional tensile testing is limited or infeasible.

20. ANN-Based Substrate Effect Correction for the Accurate Evaluation of Intrinsic Film Properties

Hyun-Wook Cho (Pukyong National University), Si Hyun Park (Pukyong National University), Tae Hyeon Park (Pukyong National University), Woo-jin Lee (Seoul National University), Gyeong-Seok Hwang (Harvard University), Ji-Hyeon Jo (UNIST (Ulsan National Institute of Science and Technology)), Ju-Young Kim (UNIST (Ulsan National Institute of Science and Technology)), Seung-Kyun Kang (Seoul National University), Jong-hyoung Kim (Pukyong National University)

Type: Poster

As the semiconductor industry scales down to the nanometer level, heterogeneous device architectures create intricate internal stresses, often leading to catastrophic failures like cracking and delamination. While FEA maps these stress fields, its predictive accuracy depends heavily on precise input data, particularly the local elastic modulus. Although conventional tensile testing is standard at the macroscale, downscaling it to the nanometer level remains inherently difficult due to specimen preparation, handling, and experimental complexities. As a result, nanoindentation has become a practical alternative due to its ease of use, being widely employed to assess local mechanical attributes, including the thin film's elastic modulus and hardness. In order to obtain intrinsic film properties, nanoindentation depth is generally limited to 10% of the film thickness to avoid substrate effects. However, as films become ultra-thin, satisfying this rule requires extremely shallow depths, leading to significant data scattering due to the instrument's noise floor. To circumvent this issue, deeper indentation is inevitable, which inherently distorts the load-displacement response with substrate properties. Consequently, a robust substrate effect correction is indispensable to extract the intrinsic properties of the film. In this study, an artificial neural network (ANN)-based model was developed to correct substrate effects using only data from a single sharp indentation test. Going beyond the conventionally recommended 10% depth limit, the model effectively estimates intrinsic film properties at relatively deep indentation depths (25–50% of the film thickness), provided the substrate's elastic modulus is known. The model was experimentally validated across various film-substrate combinations exhibiting a wide range of mechanical contrasts, confirming its robust applicability. Furthermore, the data-driven ANN framework inherently facilitates straightforward adaptation to alternative indenter geometries and the mitigation of simulation-experiment

discrepancies via transfer learning. Ultimately, this study establishes a universal substrate effect correction framework for the precise evaluation of ultra-thin film mechanical properties.

21. Revealing Cryo-loading Induced Twinning and its Impact on Titanium via Correlative Data-driven Mechanomicroscopy

Xiao Liang (School of Materials Science and Engineering, Beihang University, Beijing, 100191, China)

Type: Poster

Twinning plays a pivotal role in strengthening titanium and its alloys, particularly at cryogenic temperatures, yet the hardening mechanism of twins is largely elusive, involving intricate twin types and orientations. Conventional macroscopic mechanical testing fails to characterize the twin-associated microscale hardening behavior. To tackle this problem, we employed the state-of-the-art FT-104 nanoindenter to acquire approximately 30,000 nanoindentation points within twinned regions. Nanoindentations were performed in a regular array pattern with 0.8 μm spacing between adjacent indents and a maximum depth of 75 nm. For CSM (continuous stiffness measurement), the oscillation frequency was set at 150 Hz with an amplitude of 2 nm. Each nanoindentation hardness map was spatially registered with its corresponding EBSD maps, enabling the correlation between local hardness and microstructures. Combined nanoindentation-EBSD characterizations yield hardness-orientation curves for both twins and the matrix, and demonstrate that twins exhibit markedly higher hardness than the matrix under identical crystallographic orientations. Machine learning analysis of these datasets establishes a hardness hierarchy: secondary {11-22} twins (1000-1200 MPa) > primary {11-22} twins (700-1000 MPa) > {10-12} twins (400-600 MPa) > most matrix (~0 MPa). These conclusions provide solid experimental support for strengthening pure titanium via introducing high-density twins, and clearly justify the adoption of high latent hardening for slip induced by twinning in crystal plasticity simulations.

22. Deep Learning-Assisted Spherical Indentation for Simultaneous Characterization of Plastic Flow and Non-Equibiaxial Residual Stress

Deunbom Chung (Seoul National University), Minwoo Park (Seoul National University), Wanchuck Woo (Korea Atomic Energy Research Institute), Kyeongjae Jeong (Sungkyunkwan University), Heung Nam Han (Seoul National University)

Type: Poster

Residual stress and plastic flow jointly affect the structural performance of metallic components, but separating their contributions through conventional testing remains challenging, particularly under non-equibiaxial stress states. This study introduces an inverse characterization framework that integrates finite element (FE) spherical-indentation simulations with a convolutional neural network (CNN) to simultaneously determine plastic hardening behavior and two orthogonal in-plane residual-stress components. A comprehensive numerical database was generated by systematically varying Swift hardening parameters and residual-stress conditions. Selected load values from the indentation curve and surface-height profiles measured along three directions were employed as CNN inputs, allowing the model to capture both global contact behavior and directional pile-up patterns. Sensitivity analyses were conducted for several indenter radii and normalized penetration depths to identify conditions that improve parameter identifiability. The results showed that residual-stress

sensitivity depends on indenter size. This behavior was associated with changes in the cumulative volume of equivalent plastic strain surrounding the indentation imprint. Within the investigated material range, a penetration ratio of 15% produced the most informative response and the best overall prediction performance. The trained CNN accurately predicted the plastic parameters and residual stresses with an average error below 5% of the investigated stress range. Experiments on OFHC copper subjected to controlled biaxial loading verified the framework for homogeneous stress fields. Additional testing on additively manufactured stainless steel demonstrated good agreement with neutron-diffraction measurements under spatially heterogeneous conditions. The proposed method therefore enables localized, direction-sensitive, and non-destructive characterization without requiring a stress-free reference specimen.

23. Atomistic investigation into the tilting of coherent twin boundaries in Cu under tribological loading

Dong-Hyun Kim (Department of Materials Science and Engineering, Korea University), Won-Seok Ko (Department of Materials Science and Engineering, Korea University)

Type: Poster

Molecular dynamics simulations are performed to investigate the tilting behavior of a $\Sigma 3$ coherent twin boundary (TB) in Cu under tribological loading, i.e., nanoindentation and subsequent scratching. Our simulations reveal that the dislocations generated during the indentation and scratching processes are not transmitted across the TB. When the tilting of the TB is pronounced, band-shaped dislocations glide along the indentation direction on planes parallel to the TB and accumulate in the underlying region. Because these band-shaped dislocations possess Burgers vectors of an identical direction, their accumulation induces a rotation of the entire lattice in accordance with the Frank equation. Notably, the same lattice rotation is also observed in the cell without the TB, which indicates that the TB does not directly contribute to the rotation but rather acts as a marker that clearly reveals the tilting of the lattice. The present findings provide an atomic-scale basis for understanding and tailoring the tribological behavior of twinned metallic materials.

24. Molecular dynamics study of shape-memory property control in LPBF-processed Ni–Al alloys

Jong-Hoon Park (Korea University), Won-Seok Ko (Korea University)

Type: Poster

Ni–Al based shape-memory alloys are attractive candidates for high-temperature applications owing to their elevated transformation temperatures and oxidation resistance. Their inherent room-temperature brittleness, however, has long impeded conventional thermomechanical processing and confined component geometries to simple shapes. Additive manufacturing, especially laser powder bed fusion (LPBF), offers a viable alternative by enabling the fabrication of complex parts directly from powder feedstock, accompanied by rapid solidification and non-equilibrium thermal cycles that produce heterogeneous microstructures. The atomic-scale connection between LPBF processing parameters, the resulting microstructural heterogeneity, and the macroscopic shape-memory response, however, remains poorly understood — particularly because the relevant

ordering kinetics and defect-formation events occur on length and time scales beyond the reach of both experimental observation and continuum modeling. To address this gap, large-scale molecular dynamics simulations of the LPBF process were performed for Ni₆₀Al₃₃ shape-memory alloys, with laser power and scan speed varied across a representative parameter space. The influence of these variables on chemical ordering and defect populations was tracked, and the resulting microstructures were subsequently subjected to thermal cycling and uniaxial loading to characterize martensitic transformation behavior and superelastic response. A distinctly non-linear correlation between volumetric energy density and shape-memory properties emerges, with scan speed independently governing ordering kinetics while laser power dictates the overall defect fraction — together demarcating the processing window for optimal shape-memory performance. The findings offer atomistic-scale guidance for selecting LPBF parameters in the manufacturing of ordered intermetallic shape-memory alloys. **Keywords :** Atomistic simulation, Ni-Al shape-memory alloy, Additive manufacturing

25. Atomistic simulation study of tramp element effects on liquid metal penetration in Fe–Cu–X systems

Jong-Hoon Park (Korea University), Hye-Ji Jo (Korea University), Hye-Hyun Ahn (Inha University), Dong-Hwi Kim (Hyundai Motor Company), Minwoo Kang (Hyundai Motor Company), Youngjae Kim (Hyundai Motor Company, Seoul National University), Won-Seok Ko (Korea University)

Type: Poster

Liquid metal embrittlement during hot rolling of recycled steels, caused by tramp elements accumulated through repeated scrap recycling, represents a critical challenge for sustainable steel production. Here we develop interatomic potentials for Fe–Cu–X (X = Sn, Sb, As, Pb, and Bi) ternary systems and employ molecular dynamics simulations to elucidate atomistic mechanisms governing grain boundary penetration of liquid metals. Systematic investigation of binary Fe–X and Cu–X systems establishes that penetration is controlled by wetting thermodynamics depending on both the mixing enthalpy and the solute concentration dissolved in the liquid phase. Extension to ternary systems reveals three distinct penetration regimes determined by the disparity in mixing enthalpies between binary pairs relative to entropic stabilization: (i) Sn and Sb promote cooperative penetration where tramp elements lead Cu into grain boundaries, with penetration efficiency increasing systematically with tramp element concentration in the liquid; (ii) Pb and Bi suppress penetration as their unfavorable Fe interactions exclude them from the solid–liquid interface, maintaining baseline Fe–Cu behavior; and (iii) As exhibits decoupled penetration where its extreme Fe affinity induces liquid phase separation, suppressing Cu penetration despite independent As infiltration. These findings establish a thermodynamic framework based on the difference between binary mixing enthalpies that enables prediction of tramp element effects on grain boundary penetration and provides guidance for prioritization of elements for industrial control.

26. Classification of Duplex Stainless Steel Microstructures Using Nanoindentation Testing and Machine Learning

Jun-Hi Im (Materials Research Center for Energy and Clean Technology, Gyeongbuk National University), Woo-ram Noh (Materials Research Center for Energy and Clean Technology, Gyeongbuk National University), Young-Cheon Kim (Materials Research Center for Energy and Clean Technology, Gyeongbuk National University)

Type: Poster

To identify phases within the microstructure of metallic materials, microstructural and crystallographic analysis techniques such as optical microscopy (OM), scanning electron microscopy (SEM), and EBSD are generally employed. Since the austenite and ferrite phases that constitute duplex stainless steel can exhibit differences not only in their crystallographic properties but also in their local mechanical responses, the load–displacement curves obtained from nanoindentation tests can be used as analytical factors reflecting phase-specific mechanical behavior. Therefore, in this study, we evaluated the feasibility of classifying the austenite and ferrite phases in 2205 duplex stainless steel (2205 DSS) by combining curve-based features extracted from nanoindentation load–displacement curves with machine learning. Following nanoindentation, the indentation locations were labeled as Austenite, Ferrite, and Boundary regions through optical microscopy (OM) and scanning electron microscopy (SEM) observations, and a Random Forest-based binary classification model was constructed using Austenite and Ferrite data. Feature importance analysis, PeaYoung-cheon Kimrson correlation, and feature removal were performed on the initial features extracted from the loading and unloading intervals to select the final feature set. The final model achieved an accuracy of 0.8644 and a ROC-AUC of 0.9071 on an independent test set. Additionally, to examine the phase-specific load response and the local mechanical response in the phase boundary region, we performed cumulative frequency analysis and boundary response analysis using the ferrite-likeness score. These results demonstrate that it is possible to evaluate the classification of the austenite and ferrite phases in 2205 DSS by combining curve-based features extracted from nanoindentation load–displacement curves with machine learning. This research was conducted with funding from the government (Ministry of Trade, Industry and Energy) in 2024 and support from the Korea Institute for Advancement of Technology (RS-2024-00409639, 2024 Industrial Innovation Talent Development Support Program). Keywords: 2205 DSS, Nanoindentation, Machinelearning, Randomforest, Microstructural Classification

27. Transfer Learning-Based Tensile Property Prediction Compensating for Indenter Tip Geometric Imperfection in Instrumented Indentation

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Type: Poster

The mechanical properties of materials are key information for structural design and reliabilityassessment, and are generally evaluated through tensile testing. However, it is difficult to extractstandard tensile specimens from actual structures, weldments, heat-affected zones, and micro-scale regions, and there are also limitations in evaluating local property variations depending on location. As an alternative, instrumented indentation testing, which can evaluate local mechanical behavior while minimizing specimen damage, has been utilized, and recently, inverse analysis studies combining finite element analysis (FEA) and artificial neural networks

(ANN) have been actively conducted to estimate tensile properties from indentation load-displacement responses. FEA-based ANN has the advantage of being able to learn the complex nonlinear relationship between indentation response and tensile properties under various material conditions. However, such models tend to overfit to the specific indenter shape or testing machine used for training, so when small differences in indenter shape or properties occur in actual experiments, prediction accuracy deteriorates significantly. In this study, transfer learning was introduced to overcome this limitation. First, a general-purpose ANN "mother model" was constructed based on spherical indentation data, and then a small amount of indentation data obtained under actual non-ideal shapes or different property conditions was additionally trained to implement a model optimized for the equipment and indenter conditions. As a result of generating indentation curves under various conditions through finite element analysis (FEA) for validation, the mean absolute percentage error (MAPE) in predicting key properties such as elastic modulus, yield strength, and work-hardening exponent was significantly reduced compared to the existing ANN. This study presents a method for compensating for experimental error factors such as indenter shape imperfection.

28. Evaluation of Intrinsic Material Properties of Multilayer Thin-Film Structures via Artificial Neural Network-Based Nanoindentation

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Type: Poster

The continued advancement of semiconductor technologies has increased the importance of multilayer thin-film structures composed of materials with distinct mechanical properties. Accurate characterization of individual layers is essential for understanding their mechanical behavior and ensuring reliable structural design and finite element analysis (FEA). However, conventional mechanical testing is difficult to apply to nanometer-scale thin films, while nanoindentation inherently reflects the combined response of multiple layers and the underlying substrate, making it challenging to isolate individual layer properties. In multilayer thin-film systems, the relative contribution of each layer to the indentation response changes with indentation depth as the deformation field progressively extends into the underlying layers and substrate. Thus, depth-dependent indentation responses contain information associated with the mechanical properties and thicknesses of individual layers, providing a basis for their determination through inverse analysis. In this study, we propose an artificial neural network (ANN)-based inverse analysis method to simultaneously determine the elastic moduli and thicknesses of individual layers from a single nanoindentation test in continuous stiffness measurement (CSM) mode. Depth-resolved stiffness obtained using a Berkovich indenter, load-displacement features, and total film thickness were used as ANN inputs. FEA simulations with multiple unloading sequences were performed to approximate CSM stiffness responses and construct a training dataset covering various combinations of layer properties and thicknesses. Unlike conventional approaches relying primarily on responses at specific indentation depths or final unloading stiffness, the proposed method utilizes the evolution of stiffness throughout indentation to distinguish the contributions of individual layers. This fra

mework demonstrates the feasibility of simultaneously determining layer-specific elastic moduli and thicknesses from a single CSM indentation response, providing a promising approach for localized mechanical characterization of nanometer-scale multilayer thin-film systems.

29. LLM-assisted learning for plastic flow prediction from spherical indentation

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Type: Poster

Accurate characterization of plastic flow behavior is essential for evaluating the mechanical performance and formability of metallic materials. While conventional uniaxial tensile testing is inherently destructive and requires substantial specimen preparation, instrumented indentation testing offers a minimally destructive alternative for evaluating local mechanical properties. Previous studies have employed empirical correlations, finite element inverse analysis, and more recently, deep learning to infer plastic properties from indentation load–depth responses. However, these approaches often require extensive experimental datasets or computationally expensive simulations, while valuable indentation data reported in the literature remain underutilized due to variations in testing conditions. This study proposes a data-driven framework for predicting the plastic flow behavior of steels from spherical indentation responses. A large language model (LLM) was employed to facilitate the extraction and organization of published indentation data, which were systematically categorized by testing conditions and steel grades. The collected load–depth curves were normalized into a unified representation to account for variations in experimental conditions. To expand the range of plastic hardening behaviors represented in the training dataset, literature-derived data were supplemented with numerically generated indentation responses. An artificial neural network trained on the integrated dataset demonstrated improved predictive accuracy compared with a model trained solely on literature data when evaluated using previously unseen indentation responses. The proposed framework enables plastic flow curve prediction from a single spherical indentation test and demonstrates the potential of combining LLM-assisted literature mining with simulation-augmented learning for data-efficient mechanical property characterization. Keywords: Spherical indentation, Plastic flow, Neural network, Large language model, Data mining

30. Nanomechanical Characterization of Organic Molecular Semiconductors Using Atomic Force Microscopy

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Type: Poster

The mechanical reliability of organic molecular semiconductors (OMSs) is becoming increasingly important as these materials are integrated into flexible and wearable electronic devices. Although their electronic properties have been extensively studied, quantitative investigations of their nanoscale mechanical behavior remain

relatively limited. A deeper understanding of these properties is essential for improving the durability and long-term performance of organic electronic devices. In this work, we systematically investigated the nanomechanical characteristics of a series of OMS materials using atomic force microscopy (AFM). Quasi-static techniques, including PinPoint mode and Quantitative Imaging (QI) mode, were employed to measure local stiffness and Young's modulus, while Intermodulation AFM (ImAFM) was used to examine the dynamic mechanical response. The combination of these complementary methods enabled reliable mechanical characterization over different measurement regimes and provided a comprehensive assessment of the materials' local mechanical properties. The results revealed distinct variations in stiffness and elastic modulus among the OMS samples, reflecting differences in their molecular structures and nanoscale morphologies. Furthermore, the comparative analysis demonstrated that integrating static and dynamic AFM techniques improves the sensitivity and reliability of nanomechanical measurements beyond what can be achieved using a single method. This study provides valuable insights into the relationship between molecular architecture and mechanical performance in organic molecular semiconductors. The findings contribute to the development of design strategies for mechanically robust organic semiconductor materials, supporting their application in next-generation flexible and wearable electronic devices.

31. Micromechanical Softening of Constituent Phases Governing the Hot Deformation of La–Fe–Co–Si Alloys

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Type: Poster

La–Fe–Co–Si alloys are attractive magnetocaloric materials for near-room-temperature solid-state cooling; however, their multiphase microstructure and intrinsic brittleness make plastic shaping difficult. In this study, phase-resolved high-temperature nanoindentation was used to clarify the local deformation behavior of an as-cast $\text{La}_{1.0}\text{Fe}_{11.2}\text{Co}_{0.7}\text{Si}_{1.3}$ alloy and to establish a micromechanical basis for selecting suitable hot-rolling conditions. The as-cast microstructure consisted primarily of α -Fe dendrites surrounded by a brittle La(Fe,Co)Si-type 1:1:1 intermetallic phase. Nanoindentation measurements were performed from room temperature to 800 °C using a peak load of 5 mN, and the resulting hardness, indentation modulus, penetration depth, and elastic recovery were evaluated for each phase. At room temperature, the 1:1:1 phase exhibited a substantially higher hardness than α -Fe, with values of approximately 10.90 and 6.95 GPa, respectively. With increasing temperature, both phases progressively softened. At 800 °C, the hardness decreased to approximately 3.40 GPa for the 1:1:1 phase and 1.40 GPa for α -Fe, corresponding to reductions of about 69% and 80% relative to their room-temperature values. The marked loss of hardness and elastic recovery in the 1:1:1 phase between 600 and 800 °C indicates the onset of thermally activated plastic accommodation in the otherwise brittle intermetallic constituent. Complementary hot-compression testing showed a pronounced reduction in macroscopic flow stress with temperature, supporting 800 °C as an effective processing window. Based on these results, the alloy was successfully hot rolled to a thickness reduction of 67% using a stainless-steel protective jacket, without macroscopic surface cracking. The findings demonstrate that phase-specific

nanoindentation provides a direct means of linking local mechanical softening to bulk hot workability and offers a practical framework for optimizing the thermomechanical processing of brittle magnetocaloric alloys.

32. Correlation of Phase-Specific Nanomechanical Properties with Single-Particle Strength and Electrochemical Performance of Si Alloy Anode Powders

Myungje Lee (Myongji University), Taeyun Kwon (Myongji University), Chansun Shin (Myongji University)

Type: Poster

Silicon alloy anodes are promising candidates for next-generation lithium-ion batteries because of their high theoretical capacity. However, the large volume changes during lithiation and delithiation frequently induce particle fracture, leading to rapid capacity degradation. Although nanoindentation has been widely employed to characterize local mechanical properties, the relationship between phase-specific nanomechanical properties, particle-scale mechanical integrity, and electrochemical performance remains poorly understood. In this study, water-atomized Si alloy powders with an average particle size of approximately 3 μm were investigated. Powders with different degrees of matrix crystallinity were prepared to examine the influence of microstructure on mechanical behavior. Cross-sectional nanoindentation mapping was performed to measure the hardness and elastic modulus of Si-rich and matrix regions. Representative particle mechanical properties were estimated from the phase-specific properties and their volume fractions. Single-particle compression tests were subsequently conducted to evaluate the fracture strength of individual particles. SEM and TEM analyses were performed to characterize the microstructures, while electrochemical half-cell tests were used to evaluate cycling performance. The representative mechanical properties derived from nanoindentation showed a strong correlation with the fracture strength measured by single-particle compression tests, demonstrating that local nanomechanical properties effectively reflect the overall mechanical integrity of individual particles. Furthermore, powders exhibiting higher particle strength consistently showed improved capacity retention during electrochemical cycling, indicating a close correlation between mechanical robustness and cycling stability. These results demonstrate that nanoindentation, when combined with microstructural information, provides an effective approach for linking local mechanical properties to particle-scale strength and battery performance. This study establishes an indentation-based framework for evaluating and optimizing mechanically robust Si alloy anode materials.

33. Effect of Mechanical Properties on Thermo-Warpage and Stress Analysis of Stretchable Anisotropic Conductive Films (SACFs) for Large-Area Electronic Packaging

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Type: Poster

Flexible and large-area electronic packaging requires interconnection materials with high electrical stability and mechanical reliability under deformation. In this study, the thermomechanical behaviors of stretchable anisotropic conductive film (SACF) and conventional anisotropic conductive film (ACF) were systematically compared using finite element method (FEM) analysis. In ACF-based display interconnections, warpage is an

important reliability factor because it can disturb conductive-particle contact uniformity and contribute to optical non-uniformity, such as the Mura effect, in display panels. Therefore, the effects of film thickness, large-area bonding conditions, and material properties on warpage and equivalent stress were investigated as key reliability indicators. The results showed that the low elastic modulus and compliant structure of SACF effectively reduced internal stress concentration and promoted a more uniform deformation distribution than conventional ACF. To validate the simulation results, digital image correlation (DIC) was employed to directly measure the actual warpage behavior of SACF and ACF bonded structures, and the experimentally observed warpage trends were compared with the FEM predictions. In addition, the influences of elastic modulus, Poisson's ratio, coefficient of thermal expansion, and film thickness on stress and warpage were quantitatively analyzed. Based on these results, thickness and bonding design guidelines are proposed to improve the thermomechanical reliability of SACF for next-generation flexible and high-density electronic packaging systems.

34. Precipitation behavior and local mechanical properties near grain boundaries in Al-Mg-Si alloy

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Type: Poster

Al-Mg-Si alloys are widely used for automotive body panels due to their excellent formability, corrosion resistance, and age-hardening response. During aging, Mg-Si-based precipitates evolve through clusters, GP zones, β'' , β' , and the stable β phase. While β'' precipitates within grain interiors (GIs) are the primary strengthening phase, the behavior of precipitates near grain boundaries (GBs) remains poorly understood despite its importance for local deformation and damage initiation. This study uses nanoindentation combined with transmission electron microscopy to investigate the influence of GBs on precipitation behavior and local mechanical properties. Directionally solidified Al-0.9Mg-0.4Si alloys were prepared using the vertical Bridgman method. The alloys were then homogenized, solution-treated, water-quenched, and aged at 180°C for 1 hour (under-aged) or 15 hours (peak-aged). EBSD was used to select a low-angle grain boundary (LAGB, 8°) and a high-angle grain boundary (HAGB, 51°). Nanoindentation was performed across the GBs using a Berkovich indenter. The average hardness of GIs increased from 1.4 GPa in the under-aged state to 1.7 GPa in the peak-aged state. In the under-aged state, the hardness near both GBs exceeded that of the GIs. For the LAGB, hardness increased continuously toward the GB. For the HAGB, however, hardness decreased within approximately ± 500 nm of the GB due to the formation of a wider precipitation-free zone (PFZ). This wider PFZ is attributed to the stronger vacancy sink effect of the HAGB. In the peak-aged state, the hardness of the GIs increased, resulting in lower hardness near the GBs. The softened region extended approximately ± 500 nm from the LAGB and ± 1 μ m from the HAGB. These results demonstrate that the precipitation behavior and local mechanical properties near GBs depend on the misorientation angle. This highlights the important role of GB structure in governing the local age-hardening behavior of Al-Mg-Si alloys.

35. Micromechanical behavior and the role of a compositionally graded zone in an additively manufactured multilayer medium-entropy alloy

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Type: Poster

This study explores the micromechanical behavior of an LPBF-fabricated multilayer CoCrNi–CoCrNi₂ medium-entropy alloy at macro- and micro-scales. Although the constituent layers shared a single-phase face-centered cubic structure and similar grain morphology, chemical and hardness mapping revealed the formation of an intrinsic compositionally graded zone (CGZ) between the alternating layers. Under iso-strain tensile loading, the multilayer alloy exhibited enhanced ductility with intermediate strength compared with the monolithic constituents. Micro-DIC analysis showed that plastic strain was preferentially accommodated in the CGZ and gradually transferred to adjacent layers. Finite element simulations further revealed smoother stress transfer and less interfacial stress concentration in CGZ-containing case than those in a sharp interface case. Finally, a novel approach combining nanoindentation testing and micro-DIC analysis was suggested to simultaneously evaluate local strength and deformation fields in the multilayer structure. The results confirmed that the suggested approach can provide a useful local experimental framework for linking spatially resolved mechanical properties with deformation accommodation in heterogeneous structure.

36. Morphological analysis on hierarchical nanoporous gold

Hansol Jeon (Keimyung University)

Type: Poster

Nanoporous gold (NPG), a bicontinuous structure composed of nanoscale gold ligaments and pores, has attracted considerable attention for applications requiring high surface reactivity, such as catalysts, sensors, and actuators, owing to its high specific surface area and chemical stability. Recently, hierarchical nanoporous gold (HNPG), in which additional pores are formed within the ligament framework, has been developed. HNPG possesses an additional porous architecture compared with conventional NPG, resulting in a higher specific surface area and faster surface reactivity. However, in-depth studies on the mechanical properties of HNPG remain limited, and its hierarchical morphology has not yet been systematically analyzed. In this study, we investigated the mechanical properties and morphology of HNPG and NPG with the same relative density. HNPG and NPG samples were fabricated from the same Ag–Au master alloy by controlling the dealloying conditions. Compression pillar specimens were then prepared using focused ion beam (FIB) milling, and

microscale compression tests were conducted in an electrochemical environment. The geometric and morphological characteristics of the porous structures were analyzed and discussed using three-dimensional reconstruction, focusing on ligament size distribution, interfacial normal distribution (IND), and connectivity.

37. Deformation and Fracture Behavior of APS Y_2O_3 Coatings Investigated by Micropillar Compression

Inseop Baek (Gyeongsang National University), *Jun-Ha Kim* (Korea Institute of Materials Science (KIMS)), *Yeon-Woo Yoo* (Korea Institute of Materials Science (KIMS)), *Sung-Gyu Kang* (Gyeongsang National University)

Type: Poster

Y_2O_3 coatings are widely used as protective materials for plasma etching equipment due to their excellent plasma resistance and chemical stability. However, coatings fabricated by atmospheric plasma spraying (APS) contain heterogeneous microstructures—including pores, splat boundaries, and microcracks—that can significantly affect mechanical reliability and fracture behavior. While previous simulation-based studies have shown that porosity strongly influences the effective elastic modulus, direct experimental evaluation of thin APS layers remains challenging. Conventional techniques such as Vickers hardness and nanoindentation are limited by substrate effects or insufficient sampling volume, making micropillar compression an effective alternative for probing local mechanical behavior inclusive of real microstructural defects. In this study, micropillar compression tests were performed on sintered and plasma-sprayed Y_2O_3 specimens. Porosity, pore size, and pore distribution were quantified from cross-sectional SEM images, while EBSD and XRD analyses provided crystallographic orientation, KAM values, and residual stress information. FIB-fabricated micropillars were compressed in situ, and stress–strain response, elastic modulus, compressive strength, and fracture morphology were evaluated. Elastic modulus and compressive strength were closely correlated with pore structure. Dense coatings exhibited superior mechanical properties, whereas pore-rich regions promoted earlier crack initiation and reduced load-bearing capacity. In APS micropillars, compression led to initial elastic deformation followed by axial crack formation and subsequent intergranular fracture. This fracture behavior is attributed to tensile stress fields developing around pores during compressive loading, which promote crack initiation and propagation along grain boundaries. These findings demonstrate that micropillar compression is an effective experimental approach for assessing local mechanical reliability of APS Y_2O_3 coatings and for experimentally validating porosity-dependent behavior predicted by simulations.

38. Effect of Interface Architecture on the Uniaxial Tensile Behavior of Cu–Nb Nanolaminates

Krittichok Rattanakodsakun (Korea Advanced Institute of Science & Technology), *Haechan Jo* (Korea Advanced Institute of Science & Technology), *Gi-Dong Sim* (Korea Advanced Institute of Science & Technology)

Type: Poster

Cu–Nb nanolaminates have attracted considerable interest as high-strength metallic systems because their nanoscale layer architecture and high density of heterogeneous interfaces can effectively impede dislocation motion. Previous studies have demonstrated exceptional strength in Cu–Nb multilayers through

nanindentation and small-scale compression. However, their intrinsic uniaxial tensile behavior remains comparatively less explored, particularly when the interface is extended from a sharp two-dimensional boundary into a finite-thickness or compositionally graded region. Understanding how such interface architectures affect tensile deformation is therefore essential for developing nanolaminates that combine high strength with improved deformability. In this study, Cu–Nb nanolaminates with three distinct interface architectures are investigated to determine how interface structure influences their tensile deformation behavior. Conventional nanolaminates consist of alternating 20 nm Cu and 20 nm Nb layers with relatively sharp interfaces. A second architecture incorporates an approximately 10 nm-thick intermixed Cu–Nb interface region between the Cu and Nb layers. A fully graded architecture is also fabricated in which the composition continuously varies between Cu-rich and Nb-rich regions without discrete pure layers. The total film thickness is maintained at approximately 1 μm for all architectures. Freestanding microscale tensile specimens are fabricated from the sputtered films using MEMS-based processes and subjected to uniaxial tensile testing to directly evaluate their strength, ductility, and fracture response. The tensile responses are correlated with nanoscale microstructural characteristics to identify how interface thickness and compositional grading modify deformation mechanisms relative to conventional sharp-interface nanolaminates. This study aims to clarify how extending and grading Cu–Nb interfaces modify deformation under uniaxial loading. The results are expected to provide experimental insight into interface-engineering strategies for simultaneously controlling strength and deformability in nanoscale metallic multilayers.

39. Geometric Tailoring of Nitinol Thin Film and Sheet for Improved Elastocaloric Cooling

Juyoung Lee (Korea Advanced Institute of Science and Technology), Hyemin Ryu (Korea Advanced Institute of Science and Technology), Jae-Hoon Choi (Jeonbuk National University), Gi-Dong Sim (Korea Advanced Institute of Science and Technology)

Type: Poster

Shape memory alloys (SMAs) are recognized as representative materials exhibiting elastocaloric behavior. This material property can be exploited in the design of solid-state refrigerants, offering advantages over conventional vapor-compression refrigeration systems in terms of scalability and coefficient of performance (COP)—defined as the ratio of heat absorption to input work. The COP of an SMA-based elastocaloric system can be improved by reducing work dissipation induced by microscopic friction during martensitic transformation, as reflected by a narrower hysteresis loop observed in the cyclic stress-strain response. In this study, we aim to reduce the hysteresis area observed in the cyclic responses of freestanding Nitinol SMA thin films ($\sim 1\mu\text{m}$) under tension by incorporating hourglass-shaped and porous geometry specimen designs. Furthermore, thicker Nitinol sheets ($\sim 100\mu\text{m}$) are similarly machined and evaluated to demonstrate the scalability of this geometric tailoring approach. Finite element analysis (FEA) was also conducted to examine the phase transformation process throughout the deformation of the geometrically tailored films. Consequently, there was significant narrowing of the load-displacement hysteresis. While this hysteresis narrowing was evident at both the thin-film and bulk-sheet scales, the specimens exhibited distinct shape in load-displacement curve in similar geometries attributed to differences in their inherent mechanical properties. These findings suggest

geometric optimization as a viable route for developing high-efficiency micro-scale elastocaloric cooling devices, by reducing the work dissipation.

40. Coupled Effects of Grain and Ligament Sizes on the Mechanical Behavior of Nanoporous Gold

minwoo Bang (Department of Advanced Materials Engineering, Keimyung University), Hansol Jeon (Department of Advanced Materials Engineering, Keimyung University)

Type: Poster

The mechanical response of nanoporous gold (NPG) depends on relative density, ligament dimensions, and the microstructure of the solid network. Grain size and ligament size introduce distinct length scales, but their combined influence on deformation and fracture remain to be clarified. This study aims to examine their coupled effects using NPG specimens with a target relative density of 30% and different combinations of grain and ligament sizes. The ligament-to-grain size ratio is defined as, where and denote the characteristic ligament diameter and grain size, respectively. Compressive tests will be performed to compare strength, deformation, and fracture behavior across the selected microstructures. Scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD) will be used to characterize ligament morphology and grain structure and to examine deformation and fracture features. Both the size ratio and the absolute grain and ligament sizes will be considered when interpreting the mechanical response. The study will identify whether the relative dimensions of grains and ligaments provide a useful descriptor of strengthening and deformation behavior in NPG.

41. Tensile Behavior of Hierarchical Nanoporous Gold Fabricated by 3D Printing and Dealloying

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Type: Poster

Combining three-dimensional (3D) printing with dealloying offers a route to hierarchical nanoporous gold (HNPG) in which a printed upper-level architecture contains a nanoscale ligament-pore network. Understanding how this architecture responds to tensile loading is important for the mechanical design of low-density porous metals. This study aims to investigate the tensile behavior of HNPG with different upper-level strut thicknesses and the associated variations in relative density. A 3D-printing-based fabrication route will be used to prepare Ag-Au precursor structures with the same nominal composition but different upper-level strut thicknesses. Subsequent heat treatment and dealloying will be used to form the hierarchical structure, with the lower-level nanoporous network generated within the struts by selective dissolution. Dog-bone specimens will be tested in tension to evaluate the relationship between the resulting structures and tensile strength. Because changes in strut thickness also alter relative density, these variables will be considered together when interpreting the mechanical response. The study is intended to clarify how the geometry of the printed structure influences the tensile performance of hierarchical porous gold.

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