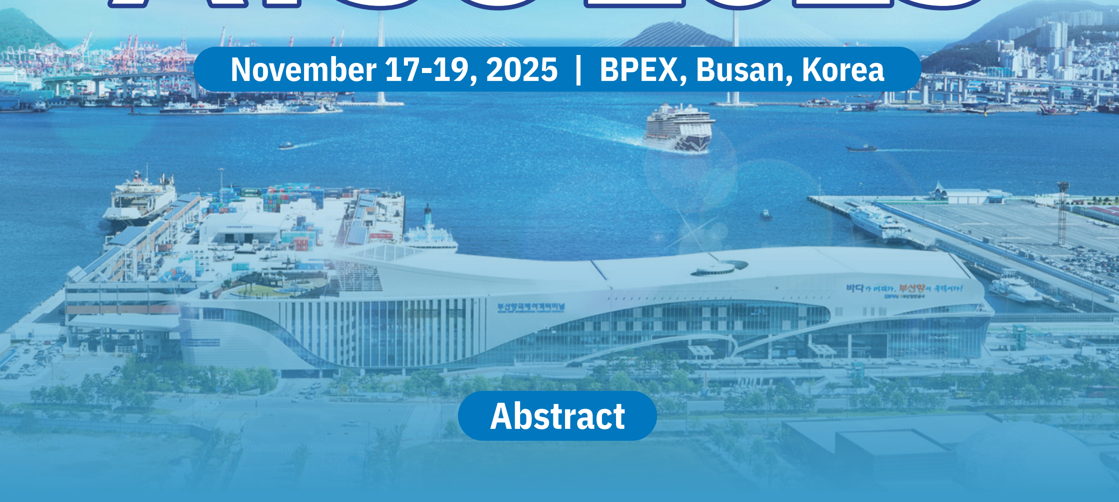
14th Asian Thermal Spray Conference & Expo

ATSC 2025



November 17-19, 2025 | BPEX, Busan, Korea

Abstract

Organized by

KTSA Korea Thermal Spray Association

ATSS Asian Thermal Spray Society

Co-organized by

KIMS Korea Institute of Materials Science

Sponsor/Exhibitor

Chang Sung Corporation CSC

WONIK QnC Quartz & Ceramics

attometal

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Welcome Message

Dear Colleagues, Distinguished Guests, and Friends,

On behalf of the Organizing Committee, it is my great pleasure to welcome you to the 14th Asian Thermal Spray Conference & Exhibition (ATSC 2025), held from November 17 to 19, 2025 at the Busan Port Exhibition & Convention Center (BPEX) in the beautiful coastal city of Busan, Korea.

Under the theme "Be the Next Wave," this year's ATSC aims to explore the next frontiers of thermal spray science and technology from fundamental research to industrial applications, from materials innovation to digital process intelligence.

Our conference brings together researchers, engineers, and industry leaders from around the world to share cutting-edge ideas, foster collaboration, and shape the sustainable future of surface engineering.

We are honored to host an exceptional lineup of Plenary, Keynote, and Invited Speakers, as well as numerous oral and poster presentations that reflect the remarkable diversity and creativity of our global community.

I would also like to express my heartfelt appreciation to all sponsors, exhibitors, and organizing members whose support and dedication have made this event possible.

Busan, with its blend of maritime energy and cultural charm, offers a perfect backdrop for meaningful discussion and friendship. I hope you will enjoy not only the academic program but also the warm hospitality, delicious cuisine, and the spirit of late autumn in Korea.

May ATSC 2025 be a truly inspiring and memorable experience for all of you.

Thank you, and once again, welcome to Busan and to ATSC 2025.

Kee-Ahn Lee
General Chair, ATSC 2025 Committee
Chairman, Korea Thermal Spray Association (KTSA)
Professor, Inha University

Committee

Organizing Society

Organized by: Korea Thermal Spray Association (KTSA)
Co-Organized by: Korea Istitute of Materials Science (KIMS)

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Prof. Shrikant Joshi, University West, Sweden
Dr. Sunghun Lee, Korea Institute of Materials Science, South Korea
Prof. Tatsuya Tokunaga, Kyushu Institute of Technology, Japan
Prof. Yi Liu, Ningbo Inst. Mat. Tech. & Eng., Chinese Academy of Sciences, China

Plenary Lecture

Plenary Lecture 1

Chair: Kee-Ahn Lee (Inha University), Hua Li (NIMTE-CAS)

Chang-Jiu Li (Xi'an Jiaotong University)
Lecture Title: **The Strategy of Microstructure Control towards the Advanced Applications of Thermal Spray Ceramic Coating Based on the Critical Bonding Temperature Concept**
Lecture Time: 09:45–10:25, Monday, November 17, 2025
Lecture Place: Room A, BPEX

Biography

Prof. Chang-Jiu Li received his B. Sc from Mechanical Department of Xi'an Jiaotong University at 1982, Master degree and Ph.D of Engineering from Osaka University (Japan) in 1986 and 1989. From 1989 to 1992, he worked as Research fellow in Kinki Advanced Materials Processing Institute, Japan. Since December 1992 he works as full professor in Xi'an Jiaotong University.

From 1983, he began his career of study on thermal spraying. His research interests include the coating formation mechanisms such as splat formation and lamellar interface bonding, coating microstructure development, coating microstructure design for high performance applications to wear resistant coatings, corrosion-resistant coatings, TBCs, SOFCs, ASSIB (All Solid State Ion Battery). He has published about 800 technical papers, including over 475 papers in the peer-reviewed international journals, 110 papers in Chinese journal and over 230 papers in the conference proceedings. From 2012, he serves as an associate editor of the Journal of Thermal Spray Technology. In 2017, he was selected as ASM Fellow. In 2019, he was inducted to ASM Thermal Spray Fame of Hall.

Plenary Lecture 2

Chair: Kee-Ahn Lee (Inha University), Hua Li (NIMTE-CAS)

Frank Gaertner (Helmut Schmidt University)
Lecture Title: **From Basics on Cold Spraying to Solutions for Additive Manufacturing and Repair**
Lecture Time: 10:25–11:05, Monday, November 17, 2025
Lecture Place: Room A, BPEX

Biography

Frank Gärtner heads the Laboratory of Surface Technology at Helmut-Schmidt-University Hamburg as part of the Institute of Materials Technology. His expertise concerns the formation of metastable phases, as well as mechanisms of coating formation in thermal spray and cold spray techniques. He has pioneered the field of cold – or kinetic spraying since the late 1990ies and holds an internationally well-recognized expertise on exploring the basic mechanisms and on developing applications as well as spray equipment, the latter in close cooperation with industries. Associated research work combines computational fluid dynamics, modelling of deformation and bonding, “in-flight” diagnostics, and various material and surface characterization techniques.

He has published more than 140 journal and about 80 conference papers (about 10000 citations, h-index of 39). Up to present, he was responsible for about 15 publicly funded R&D projects.

Plenary Lecture 3

Chair: Kee-Ahn Lee (Inha University), Hua Li (NIMTE-CAS)

Kentaro Shinoda (AIST)
Lecture Title: **Advanced Thermal and Kinetic Spray Technologies for Addressing Societal Challenges**
Lecture Time: 11:05–11:45, Monday, November 17, 2025
Lecture Place: Room A, BPEX

Biography

Kentaro Shinoda, Ph.D.
Leader, Coatings and Interface Engineering Research Group
Core Manufacturing Technology Research Institute
National Institute of Advanced Industrial Science and Technology (AIST)

Dr. Kentaro Shinoda received his Ph.D. in Engineering from the University of Tokyo in 2006. During his doctoral studies, he conducted research at the Centre for Advanced Coating Technologies, University of Toronto. He subsequently held postdoctoral appointments at the National Institute for Materials Science (NIMS) in Japan and at the Center for Thermal Spray Research, Stony Brook University, USA.

He joined AIST in 2011 and currently leads the Coatings and Interface Engineering Research Group within the Core Manufacturing Technology Research Institute. Dr. Shinoda is the inventor of hybrid aerosol deposition (HAD), a novel ceramic coating technology advancing low-temperature processing for thermal and environmental barrier coatings and remanufacturing toward a circular economy. He has published over 58 peer-reviewed papers and holds 11 granted patents. His contributions have been recognized with multiple awards, including the Best Paper Award at the International Thermal Spray Conference.
He serves as Vice President of the Japan Thermal Spray Society, sits on the Editorial Board of the Journal of Thermal Spray Technology, and is also a Visiting Professor at Shibaura Institute of Technology.

Plenary Lecture 4

Chair: Kazuhiro Ogawa (Tohoku University), Shrikant Joshi (University West)

Shrikant Joshi (University West)
Lecture Title: **Liquid Feedstock Thermal Spraying: Unlocking the Next Frontier?**
Lecture Time: 09:30–10:10, Tuesday, November 18, 2025
Lecture Place: Room A, BPEX

Biography

Prof. Shrikant Joshi is currently a Professor in the Department of Engineering Science at University West in Trollhättan, Sweden. He has over 30 years of experience in areas spanning Surface Engineering, Laser Materials Processing and Additive Manufacturing. He is a Chemical Engineer by academic training, having obtained his M.S. and Ph.D. degrees from the Rensselaer Polytechnic Institute and University of Idaho, respectively, in USA. Prior to moving to Sweden in 2015, he has had long stints at two premier federally funded materials' research laboratories in India. His current areas of research are solution precursor and suspension thermal spraying, powder-liquid 'hybrid' thermal spraying and high velocity air fuel (HVAF) spraying. His work has led to many industrial applications, over a dozen patent submissions and more than 250 publications in peer-reviewed journals. He is a Fellow of ASM International, the Institute of Materials, Minerals & Mining (IoM3) and the Indian National Academy of Engineering. Earlier this year, he was also inducted into the Hall of Fame of the ASM International's Thermal Spray Society.

Plenary Lecture 5

Chair: Kazuhiro Ogawa (Tohoku University), Shrikant Joshi (University West)

Yeon-gil Jung (Changwon National University)
Lecture Title: **TBC and EBC Technologies for Aviation Gas Turbine Engine**
Lecture Time: 10:10–10:50, Tuesday, November 18, 2025
Lecture Place: Room A, BPEX

Biography

Yeon-Gil Jung is a professor of the Department of Advanced Materials Convergence Engineering at Changwon National University since 1999. He received his PhD in inorganic materials science and engineering from Hanyang University. He was a visiting scientist at NIST during 1997—1999 and 2003—2004, and at IUPUI during 2013—2017. From July 2021 to May 2025, He served as the president of the Korea Institute of Ceramic Engineering and Technology. Professor Jung's research interests include the design and manufacturing of ceramic materials, thermal barrier coatings, ceramic-metal composites, layered material design and manufacturing, and material evaluation. He has contributed to over 450 publications, 60 patents, and active participation in various national-level institutional committees.

Plenary Lecture 6

Chair: Eungsun Byon (Korea Institute of Materials Science), Kazuhiro Ogawa (Tohoku University)

Jingyang Wang (IMR-CAS)
Lecture Title: **Advancements of High Temperature Coating for SiCf/SiC Composite**
Lecture Time: 09:30–10:10, Wednesday, November 19, 2025
Lecture Place: Room A, BPEX

Biography

Jingyang Wang is the Vice President of Liaoning Academy of Materials and the director of Institute of Coating Technology for Hydrogen Gas Turbines. He is also a distinguished professor at the Institute of Metal Research, CAS, China. His research interests are focused on fundamental exploration and technological developments of structure ceramics, ceramic-matrix-composites, and high temperature coating for extreme environment applications. He received many prestigious recognitions and awards, represented by Academician of Word Academy of Ceramics, Fellow of The American Ceramic Society, Fellow of ASM International, Fellow of The European Ceramic Society, Acta Materialia Silver Medal Award, ACerS John Jeppson Award, Samuel Geijsbeek PACRIM International Award, ACerS ECD Bridge Building Award, ACerS Global Star Award, and National Leading Talent for Science and Technology Innovation (China), National Leading Talent of Young and Middle-aged Scientists (China), National/Ministry Science and Technology Progress Award (China, 2011/2010) and Liaoning Natural Sciences Award (China).

Plenary Lecture 7

Chair: Eungsun Byon (Korea Institute of Materials Science), Kazuhiro Ogawa (Tohoku University)

Peerawatt Nunthavarawong (King Mongkut's University of Technology North Bangkok)

Lecture Title: **High-Temperature Wear and Thermal Properties of Plasma-Sprayed Mullite-Based Nanocomposite Coatings**

Lecture Time: 10:10–10:50, Wednesday, November 19, 2025

Lecture Place: Room A, BPEX

Biography

Peerawatt Nunthavarawong is a researcher in the field of mechanical and production engineering, specializing in tribology, surface engineering, and materials performance. He received his Ph.D. and Post-Doctoral Certificate in Applied Tribology from the University of the Witwatersrand, Johannesburg, South Africa. He also holds an M.Eng. in Production Engineering and a B.Sc. in Mechanical Engineering (Technical Education Program) from King Mongkut's Institute of Technology North Bangkok (KMUTNB), Thailand. His research focuses on tribology and wear of materials, engineering lubrication, contact mechanics, damage and failure of materials, materials characterization, thermal spraying, and cold spray deposition. His recent work integrates experimental and analytical approaches to understand surface interactions and develop advanced surface engineering solutions for improved reliability and performance.

Keynote Lecture

Keynote Lecture 1

Chair: Frank Gaertner (Helmut Schmidt University), Guang-Rong Li (Xi'an Jiaotong University)

Yuji Ichikawa (Tohoku University)
Lecture Title: **Dynamics of Impact-Induced Bonding: Insights from Single-Particle Impact Experiments and Site-Specific Micromechanical Analysis**
Lecture Time: 13:00–13:30, Monday, November 17, 2025
Lecture Place: Room A, BPEX

Biography

Yuji Ichikawa is an Associate Professor at the Fracture and Reliability Research Institute, Tohoku University, where he studies mechanics of materials, interface fracture, and surface engineering, with emphasis on cold spray and impact-induced bonding. He received his Ph.D. from Tohoku University and has held visiting appointments at Mines Paris and Cornell University. His recent work integrates in situ microparticle impact testing, micromechanics, and electron microscopy to elucidate bonding and strength at metal interfaces. He served as a JST PRESTO researcher (2020–2024) and has received multiple awards from the Japan Thermal Spraying Society and the Society of Materials Science, Japan. He is a board member of the Japan Thermal Spraying Society and contributes to committees of JSME and JSMS.

Keynote Lecture 2

Chair: Chang-Jiu Li (Xi'an Jiaotong Univ.), Yi Liu (NIMTE-CAS)

Hua Li (NIMTE-CAS)
Lecture Title: **Solution Precursor Plasma-Sprayed Ce-Doped Bi_2O_3 Coating with Tuned Bandgap for Enhanced Visible-Light Photocatalytic Activities**
Lecture Time: 13:00–13:30, Monday, November 17, 2025
Lecture Place: Room B, BPEX

Biography

Dr. Hua Li is a professor of Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, China. Dr. Li earned his B.Eng. and M.Eng. from Xi'an Jiaotong University China in 1994 and 1997 respectively. He then joined Nanyang Technological University Singapore for his PhD study on biomedical coatings and got his PhD degree in 2002. Afterwards, Dr. Li continued his research in thermal spray as Research Fellow and later SMF Research Fellow in Nanyang Technological University. In 2006, he joined Brookhaven National Laboratory in New York working on structures of biomolecules. In 2010, Dr. Li returned back China and joined Chinese Academy of Sciences as a full professor to setup his advanced coatings & additive manufacturing laboratory. Dr. Li's laboratory is devoted to deep commitment to both fundamental and applied research on new coating materials, surface chemistry and physics, and design and thermal/cold spray construction of novel functional coatings.

Keynote Lecture 3

Chair: Kazuhiro Ogawa (Tohoku University), Shrikant Joshi (University West)

Guang-Rong Li (Xi'an Jiaotong University)
Lecture Title: **A Bimodal-Structured Coating with Columnar/Lamellar Trans-Scale Features for Strain-Tolerant and Thermal Insulative Performances**
Lecture Time: 11:10–11:40, Monday, November 17, 2025
Lecture Place: Room A, BPEX

Biography

He is an associate professor in Xi'an Jiaotong University. His research focus on structure designs of plasma sprayed thermal protective coatings for long life span and high thermal insulation. Supported by the NSFC and other funds, he has published 40 more papers (including 4 ESI highly cited papers) and held 20 more issued patents. He has gave 10 more invited talks in related high level conferences (including ATSC 2024 et al.). He is a member of the Young Elite Scientists Sponsorship Program by CAST. In 2019, he won the First Prize in Science and Technology of Shaanxi Higher Education Institutions.

Keynote Lecture 4

Chair: Kazuhiro Ogawa (Tohoku University), Shrikant Joshi (University West)

Tatsuya Tokunaga (Kyushu Institute of Technology)
Lecture Title: **Effect of Cooling Rate after Fusing on the Microstructural Evolution of a Ni-Based Self-Fluxing Alloy**
Lecture Time: 11:40–12:10, Tuesday, November 18, 2025
Lecture Place: Room A, BPEX

Biography

Dr. Tatsuya Tokunaga is a professor at Kyushu Institute of Technology, Japan. He received B.S. and M.S. degrees from Nagoya University in Nuclear Engineering and his Ph.D. degree from Kyushu Institute of Technology in Materials Science and Engineering. His main research interests are phase equilibria, phase transformation and computational thermodynamics in alloys based on the CALPHAD method and their applications to engineering materials.

Keynote Lecture 5

Chair: Xiaohua Feng (NIMTE-CAS), Hwasung Yeom (POSTECH)

Sunghun Lee (Korea Institute of Materials Science)
Lecture Title: **Pre-Oxidation Effects on the Thermal-Fatigue Behavior of Thermal Barrier Coatings**
Lecture Time: 13:00–13:30, Tuesday, November 18, 2025
Lecture Place: Room A, BPEX

Biography

Dr. Sunghun Lee, born in 1971 in Gimhae, South Korea, is a Principal Researcher at the Extreme Environment Coating Team of the Extreme Materials Research Institute, Korea Institute of Materials Science (KIMS). After completing his B.S. and M.S. in Materials Engineering at Changwon National University, he began his research career at KIMS in 1996 and earned his Ph.D. in Materials Engineering from Tohoku University in 2009.

With more than 30 years of experience, Dr. Lee specializes in surface engineering for extreme temperature environments. His research focuses on providing advanced coating solutions to enhance the reliability of systems and components operating under high thermal stress. His technical expertise includes high-temperature oxidation behavior, thermo-fluid simulations, and the development of advanced ceramic and metallic coatings.

He has been a driving force behind Korea's self-reliance in aerospace-grade thermal protection technologies, including Thermal Protection Systems (TPS), Thermal Barrier Coatings (TBC), and Thermal Management Coatings (TMC). Notably, he named his surface engineering solution for supersonic environments 'Mach-Shield'. He is also actively involved in developing highly endurable coatings for plasma-resistant and wear-resistant conditions. Dr. Lee is well-versed in PVD, thermal spray, and EB-PVD thick film processing technologies and currently serves as Vice President of the Korea Thermal Spray Association (KTSA). He is also playing a key role in building the Extreme Materials Characterization Research Complex within KIMS.

Keynote Lecture 6

Chair: Tatsuya Tokunaga (Kyushu Institute of Technology), Chunjie Huang (Northwestern Polytechnical University)

Kee-Ahn Lee (Inha University)
Lecture Title: **Fe–Ce–Mo-Based Metamorphic Alloy Coatings with Excellent Wear and Corrosion Resistances Fabricated via Thermal Spray Process**
Lecture Time: 13:00–13:30, Tuesday, November 18, 2025
Lecture Place: Room B, BPEX

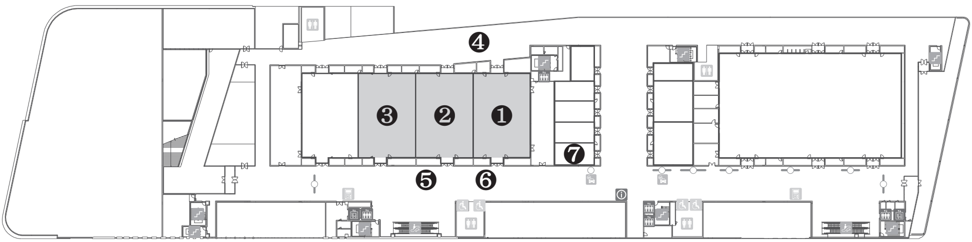
Biography

Education
1993.02: Bachelor, Dep. of Mater. Sci. & Eng., KAIST (Korea Advanced Institute of Sci. and Tech.)
1995.02: Master, Dep. of Mater. Sci. & Eng., POSTECH (Pohang University of Sci. and Tech.)
1999.02: PhD, Dep. of Mater. Sci. & Eng., POSTECH (Pohang University of Sci. and Tech.), Korea

Professional Experience
2024.01– present : President, KTSA (Korean Thermal Spray Association), Korea
2022.01– present : Executive Vice President, KPMI (Korean Powder Metallurgy & Materials Institute), Korea
2025.01– present : Vice President, KIM (Korean Institute of Metals and Materials), Korea
2017.03– present : Professor, Dep. of Materials Science & Engineering, Inha University, Korea
2005.03–2017.02 : Professor, Dep. of Materials Science & Engineering, Andong National University
2009.02–2010.01 : Visiting Professor, UCF (University of Central Florida), USA
2001.01–2005.02 : Senior Researcher, RIST (Research Institute of Industrial Sci. & Tech.), Korea
1999.12–2001.01 : Post Doc. Fellow, MIT (Massachusetts Institute of Technology), USA
* Published papers ~ 340, H-index 40

Venue

BPEX, Busan
Address: 5th floor, 206, Chungjang-daero, Dong-gu, Busan, 48751, Republic of Korea
Tel: +82-51-400-1280



① Event Hall A	Opening, Plenary, Keynote, Scientific Session Room A
② Event Hall B	Keynote, Scientific Session Room B
③ Event Hall C	Welcome Reception, Lunches, Conference Banquet
④ Event Hall Sea Side Lobby	Poster Session, Exhibition
⑤ Event Hall Main Lobby	Registration Desk
⑥ Event Hall Main Lobby	Exhibition
⑦ Meeting Room 6	Special Session, Board Meeting

Detailed Program

	Day 1 (Mon, Nov 17)		Day 2 (Tue, Nov 18)		Day 3 (Tue, Nov 19)
	Room A	Room B	Room A	Room B	Room A
09:30	Opening		Plenary 4 **Shrikant Joshi**	Special Session (Meeting Room 6)	Plenary 6 **Jingyang Wang**
09:40					
09:50	Plenary 1 Chang-Jiu Li				
10:00					
10:10			Plenary 5 **Yeon-gil Jung**		Plenary 7 **Peerawatt Nunthavarawong**
10:20					
10:30	Plenary 2 Frank Gaertner				
10:40					
10:50			Coffee Break		Coffee Break
11:00					
11:10	Plenary 3 Kentaro Shinoda		Keynote 3 **Guang-Rong Li**		Contrib 22 **Peng-Yan Shi**
11:20					
11:30					Closing (Awards & Next ATSC)
11:40			Keynote 4 **Tatsuya Tokunaga**		
11:50	Lunch (Room C)				
11:55					
12:00				-	
12:10			Lunch (Room C)		
12:20					
12:30					
12:40					
12:50					
13:00	Keynote 1 **Yuji Ichikawa**	Keynote 2 **Hua Li**	Keynote 5 **Sunghun Lee**	Keynote 6 **Kee-Ahn Lee**	
13:10					
13:20					
13:30	Invited 1 **Hiroki Saito**	Invited 6 **Xiaohua Feng**	Invited 11 **Kwangyong Park**	Invited 14 **Jirasak Tharajak**	
13:40					
13:50	-	-	Invited 12 **Keekeun Kim**	Contrib 14 **Min-Soo Nam**	
14:00					
14:10	Contrib 1 **Wataru Kai**	Contrib 4 **Yang Rui**	Invited 13 **Hansol Kwon**	-	
14:20					
14:30	Contrib 2 **Gil-Ju Na**	Invited 8 **Mohammed Shahien**	-	-	
14:40					
14:50	Contrib 3 **Luca Klingler**	Contrib 5 **Haruto Oishi**	Coffee Break		
15:00					
15:10	Coffee Break		Contrib 17 **Hyokyeong Kim**	Invited 15 **Sen-Hui Liu**	
15:20	Invited 3 **Hwasung Yeom**	Invited 9 **Shuo Yin**			
15:30			Contrib 18 **Tae-Jun Park**	Contrib 20 **Hyuk Jun Lee**	
15:40	Invited 4 **Chunjie Huang**	Invited 10 **Sung-Gyu Kang**			
15:50			Contrib 19 **Jae-Woo Cho**	Contrib 21 **Xin-Ru Li**	
16:00	Invited 5 **Hyuk Jun Lee**	Contrib 9 **Byeongryun Jeon**			
16:10			-		
16:20	Contrib 6 **Kyung-Un Won**	Contrib 10 **Julio Gutierrez de Frutos**			
16:30			**Poster Session**		
16:40	Contrib 7 **Jim Merlin Manoo Klutta**	Contrib 11 **Byeong-il Min**			
16:50					
17:00	Contrib 8 **Jingze Sun**	Contrib 12 **Byeongryun Jeon**			
17:10					
17:20	-	Contrib 13 **Julio Gutierrez de Frutos**			
17:30					
17:40		-			
17:50					
18:00~20:00	**Welcome Reception (Room C)**		**Conference Banquet (Room C)**		

Oral Session

Monday, November 17

Session I

Room A 09:30~11:45

Chair: Kee-Ahn Lee (Inha Univ.), Hua Li (NIMTE-CAS)

09:30-09:45	Opening Remarks
09:45-10:25	Plenary The Strategy of Microstructure Control towards the Advanced Applications of Thermal Spray Ceramic Coating Based on the Critical Bonding Temperature Concept *Chang-Jiu Li (Xi'an Jiaotong University)*
10:25-11:05	Plenary From Basics on Cold Spraying to Solutions for Additive Manufacturing and Repair *Frank Gaertner (Helmut Schmidt University)*
11:05-11:45	Plenary Advanced Thermal and Kinetic Spray Technologies for Addressing Societal Challenges *Kentaro Shinoda (AIST)*

Session II | Cold Spray / Kinetic Spray I

Room A 13:00~15:10

Chair: Frank Gaertner (Helmut Schmidt University), Guang-Rong Li (Xi'an Jiaotong University)

13:00-13:30	Keynote Dynamics of Impact-Induced Bonding: Insights from Single-Particle Impact Experiments and Site-Specific Micromechanical Analysis *Yuji Ichikawa (Tohoku University)*
13:30-13:50	Invited Cold Spray Metallization of Thermoplastic CFRP for Enhanced Lightning Strike Resistance *Hiroki Saito (Tohoku University)*
13:50-14:10	Invited High Quality Cold Spray Cu Metallization of Ceramics with Widened Deposition Window Enabled via Ti or Cu-Ti Buffer Layer *Xiao-Tao Luo (Xi'an Jiaotong University)*
14:10-14:30	Adhesion and Lightning Strike Resistance of Cold-Sprayed Aluminum Repair Coatings on CFRTP *Wataru Kai (Tohoku University)*

Next Page

14:30-14:50	Dynamic Flattening and Microstructural Changes in Aluminum Particles under High Strain Rates *Gil-Ju Na (Tohoku University)*
14:50-15:10	Improved Al6061 Deposit Performance by In-situ Induction Heating during Cold Gas Spraying *Luca Klingler (Helmut Schmidt University)*

Session III | Solution/Suspension & Hybrid Processes Room B 13:00~15:10

Chair: Shrikant Joshi (University West)

13:00-13:30	Keynote Solution Precursor Plasma-Sprayed Ce-Doped Bi_2O_3 Coating with Tuned Bandgap for Enhanced Visible-Light Photocatalytic Activities *Hua Li (NIMTE-CAS)*
13:30-13:50	Invited Synergistic Feed Rate & Microstructure Design Enables Superior Microwave Absorption in Mechanically Robust Flame-Sprayed $BaFe_{12}O_{19}$/CS/PI Coatings *Xiaohua Feng (NIMTE-CAS)*
14:10-14:30	Fabrication of Visible-Light Active Ce-Doped Bi_2O_3 Coatings via Single-Step Solution Precursor Plasma Spraying *Yang Rui (NIMTE-CAS)*
14:30-14:50	Invited Hybrid Aerosol Deposition from Dense Microstructure to Covalent Bonded Materials *Mohammed Shahien (AIST)*
14:50-15:10	Formation of ZrB_2-based Ultra-high Temperature Ceramics Coatings by Aerosol Deposition *Haruto Oishi (Yokohama National University)*

Session IV | Cold Spray / Kinetic Spray II — Room A 15:20~17:20

Chair: Kentaro Shinoda (AIST), Sunghun Lee (Korea Institute of Materials Science)

15:20-15:40	Invited Cold Spray Technologies for Nuclear Energy Applications *Hwasung Yeom (POSTECH)*
15:40-16:00	Invited Development of Al6061-NiTi Composite via Cold Spray Assisted by Friction Stir Processing *Chunjie Huang (Northwestern Polytechnical University)*
16:00-16:20	Invited Application of Cold Sprayed Coatings in Automotive Industry *Hyuk Jun Lee (Cerectron)*
16:20-16:40	Microstructure and Tribological Property Correlations in Cold-Sprayed Fe-Based Amorphous Alloy Coatings *Kyung Un Won (Inha University)*
16:40-17:00	Influence of Laser Surface Heat Treatments on Mechanical Changes of Deformed Al6061 Bulk Material and Cold Spray Deposits *Jim Merlin Manoo Klutta (Helmut Schmidt University)*
17:00-17:20	Bond Coat Material for Cold Sprayed Polymer Film Formation *Jingze Sun (Tohoku University)*

Session V | Process Diagnostics and Modeling — Room B 15:20~17:40

Chair: Mohammed Shahien (AIST), Yang Rui (NIMTE-CAS)

15:20-15:40	Invited Real-time High-Velocity Visualization of Ceramic Particle Impact on Metal Substrate in Cold Spray *Shuo Yin (Trinity College Dublin)*
15:40-16:00	Invited Evaluation of Mechanical Properties of APS Y_2O_3 Coatings via Micropillar Compression Test *Sung-Gyu Kang (Gyeongsang National University)*
16:00-16:20	CFD Study and Performance Evaluation of a New Cascaded Plasma Spray Torch *Byeongryun Jeon (Korea Institute of Materials Science)*
16:20-16:40	Study of Nozzle Influence on Aerosol Deposition (AD) by using 3D CFD Simulations *Julio Gutierrez De Frutos (Helmut Schmidt University)*

Next Page ⇨

16:40-17:00	Numerical and Experimental Study of In-flight $MgAl_2O_4$ Particles in Atmospheric Plasma Spraying under Arc Current Variation *Byeong-il Min (Korea Institute of Materials Science)*
17:00-17:20	Automated Porosity Evaluation of Thermal Barrier Coatings via CNN-Based Semantic Segmentation *Byeongryun Jeon (Korea Institute of Materials Science)*
17:20-17:40	3D CFD Simulation of Substrate Angle Influence on Bow Shock Effects in Cold Spray (CS) *Julio Gutierrez De Frutos (Helmut Schmidt University)*

Tuesday, November 18

Special Session Meeting Room 6 09:00-11:00

Chair: Kyun Tak Kim (Cosmos Metallizing Co., Ltd)

09:00-09:15	Selecting Candidates in Rare Earth Co-Doped Zirconia Systems for Thermal Barrier Coating Application *Seongwon Kim (Korea Institute of Ceramic Engineering and Technology)*
09:15-09:30	Computational Screening of Rare-Earth-Doped Zirconia for Thermal Barrier Coatings *Inseong Bae (Soongsil University)*
09:30-09:45	Analysis of the Degradation Behavior of 8YSZ in a High-Temperature Hydrogen Environment *Tae Mon Ko (Kyonggi University)*
09:45-10:00	Thermal Spray Coating Powder Technology *Heungsoo Moon (Sewon--Hardfacing)*
10:00-10:15	Isothermal Oxidation Behavior and Thermal Cycle Lifetime of Thermal Barrier Coatings as a Function of Bond Coat Process and Composition *Hansol Kwon (Korea Institute of Materials Science)*
10:15-10:30	Kinetic Modeling of Oxidation/Diffusion Behavior Throughout Thermal Barrier Coating in High Temperature Condition *Dae Eon Hwang (Seoul National University)*
10:30-10:45	Finite-Element Analysis of Thermal Stresses Driven by Internal Temperature Fields in Thermal Barrier Coating *EunGkyu Ahn (Seoul National University)*

Session VI

Room A 09:30~12:10

Chair: Kazuhiro Ogawa (Tohoku University), Chang-Jiu Li (Xi'an Jiaotong University)

09:30-10:10	Plenary Liquid Feedstock Thermal Spraying: Unlocking the Next Frontier? *Shrikant Joshi (University West)*
10:10-10:50	Plenary TBC and EBC Technologies for Aviation Gas Turbine Engine *Yeon-Gil Jung (Changwon National University)*
11:10-11:40	Keynote A Bimodal-Structured Coating with Columnar/Lamellar Trans-Scale Features for Strain-Tolerant and Thermal Insulative Performances *Guang-Rong Li (Xi'an Jiaotong University)*
11:40-12:10	Keynote Effect of Cooling Rate after Fusing on the Microstructural Evolution of a Ni-based Self-fluxing Alloy *Tatsuya Tokunaga (Kyushu Institute of Technology)*

Session VII | TBCs & High-Temp Coatings I

Room A 13:00~14:30

Chair: Xiaohua Feng (NIMTE-CAS), Hwasung Yeom (POSTECH)

13:00-13:30	Keynote Pre-Oxidation Effects on the Thermal-Fatigue Behavior of Thermal Barrier Coatings *Sunghun Lee (Korea Institute of Materials Science)*
13:30-13:50	Invited Doosan Enerbility's Thermal Barrier Coating Technologies for Advanced Next-Generation Gas Turbines *Kwangyong Park (Doosan Enerbility)*
13:50-14:10	Invited High-Temp Coating Systems for Aero Engines *Keekeun Kim (Agency for Defense Development)*
14:10-14:30	Invited Effect of Hf, Si, Ta, Re Additions to NiCoCrAlY Bond Coats on Oxidation Behavior up to 15,000 Hours at 1,000°C *Hansol Kwon (Korea Institute of Materials Science)*
14:30-14:50	Composition-Dependent Tetragonality and Mechanical Behavior of High Entropy Oxides *Janghyeok Pyeon (Changwon National University)*

Session VIII | Wear/Corrosion — Room B 13:00~14:50

Chair: Tatsuya Tokunaga (Kyushu Institute of Technology),
Chunjie Huang (Northwestern Polytechnical University)

13:00-13:30	Keynote Fe–Ce–Mo-Based Metamorphic Alloy Coatings with Excellent Wear and Corrosion Resistances Fabricated via Thermal Spray Process *Kee-Ahn Lee (Inha University)*
13:30-13:50	Invited Damage-Tolerant Surface Protection for Biomass Boiler Tubes via FeAl Intermetallic Layers Formed by Cold-Sprayed Al on Fe Substrate *Jirasak Tharajak (Rajamangala University of Technology Phra Nakhon)*
13:50-14:10	Slag Corrosion Resistance of Yb-silicate Materials for IGCC Protective Coatings *Min-Soo Nam (Korea Institute of Ceramic Engineering and Technology)*
14:10-14:30	Improving the Corrosion Resistance of Cold Spraying 7075 Al Repair Deposits by Pulsed Laser Heat Treatment *Jihao Shen (Xi'an Jiaotong University)*

Session IX | TBCs & High-Temp Coatings II — Room A 15:10~16:10

Chair: Sung-Gyu Kang (Gyeongsang National University),
Shuo Yin (Trinity College Dublin)

15:10-15:30	MAX Phase as Bond Coats in Thermal Barrier Coating System *Hyokyeong Kim (Soongsil University)*
15:30-15:50	Phase Transformation Behavior and High-Temperature Durability of Rare Earth Oxide Co-Stabilized ZrO_2 *Tae-Jun Park (Korea University)*
15:50-16:10	Research on Oxidation Behavior of Ni-Al Coatings Fabricated by Twin Wire Arc Spray *Jae Woo Cho (Korea Institute of Materials Science)*

Session X | Functional Coatings

Room B 15:10~16:10

Chair: Jingyang Wang (IMR-CAS), Hiroki Saito (Tohoku University)

15:10-15:30	Invited Multiphase Flows and Deposition Mechanisms in a LPPS (50–200 Pa) and an Atmospheric Long Laminar Plasma Spraying (ALPS) *Sen-Hui Liu (Xi'an Jiaotong University)*
15:30-15:50	Cold Spray Coating for Biomedical Applications *Hyuk Jun Lee (Cerectron)*
15:50-16:10	Examination into Intersplat Bonding of Atmospheric Plasma-sprayed NiCrCuMoB High Entropy Alloy Coating *Xin-Ru Li (Xi'an Jiaotong University)*

Wednesday, November 19

Session XI Room A 09:30~10:50, 11:10~11:50

Chair: Eungsun Byon(Korea Institute of Materials Science), Kazuhiro Ogawa (Tohoku University)

09:30-10:10	Plenary Advancements of High Temperature Coating for SiCf/SiC Composite *Jingyang Wang (IMR-CAS)*
10:10-10:50	Plenary High-Temperature Wear and Thermal Properties of Plasma-Sprayed Mullite-Based Nanocomposite Coatings *Peerawatt Nunthavarawong (King Mongkut's University of Technology North Bangkok)*
11:10-11:30	Toughening of Plasma-Sprayed Ceramic Coatings via Carbon Nanotube Reinforcement and Controlled Inter-Splat Bonding *Peng-Yan Shi (Xi'an Jiaotong University)*
	Closing (Awards & Next ATSC)

Poster Session

P1	Hierarchical Microstructure–Mechanical Property Correlations in Superior Strength 5 wt% Cr Cold-Work Tool Steel Manufactured by Direct Energy Deposition *Kyung Un Won (Inha University)*
P2	Optimizing Electrostatic Chuck Performance through ZrO_2/Al_2O_3 ratio and Doping Components (SiO_2 and Y_2O_3) *Seungho Baek (Electro Static Technology, Inc.)*
P3	Fabrication, Microstructure, and Mechanical Properties of Fe-16Mn-10Al-5Ni-0.86C (wt.%) Lightweight Steel Manufactured by Directed Energy Deposition *Soobin Kim (Inha University)*
P4	Influence of Wire Arc Additive Manufacturing Induced Microstructure on Elevated-Temperature Compression of Ti-6Al-4V *Soobin Kim (Inha University)*
P5	Deposition Behavior and Microstructural Characterization of Ti-6Al-4V/Al_2O_3 Functionally Graded Materials using Directed Energy Deposition(DED) *Tae-Hyeon Kim (Kyungnam University)*
P6	Development of a High-Performance Abradable Coating with Thermal and Structural Stability *Lee Youngseo (SHINHWA METAL CO., LTD.)*
P7	Development of Oxidation-Resistant Silicide and Aluminide Diffusion Coatings for Aerospace and Power Generation Components *Yoon Sangin (SHINHWA METAL CO., LTD.)*
P8	Spheroidization of Titanium Powders by using a Reverse-polarity Plasma Torch with an Exit Nozzle *Jun-Ho Seo (Jeonbuk National University)*
P9	Gradient Cooling Approach in Vacuum Plasma Spray Coating Process for Crack Formation Control in ZrC Coating Layers on Carbon-carbon Composite *Ho Seok Kim (Jeonbuk National University)*
P10	Enthalpy Probe Measurement and Numerical Analysis on the Thermal Plasma Jets Generated by a Reverse-polarity Plasma Torch with an Exit Nozzle *Jun-Ho Seo (Jeonbuk National University)*

P11	Machine-Learning Interatomic Potential for Temperature-Dependent Properties of Nb_2AlC MAX Phase as a Bond Coat *Hayoung Son (Soongsil University)*
P12	Effect of APS Process Parameter Control on the Microstructure and Thermal Fatigue Characteristics of Thermal Barrier Coatings *Hongbin Cheng (Changwon National University)*
P13	Enhanced Oxidation Resistance of ZrC through Multi-Layer Coatings: Ab Initio Calculation of Oxygen Diffusion Pathways *Jaewon Choi (Soongsil University)*
P14	Mixed Oxide Formation in NiCoCrAlY Powders and Thermal-Sprayed Coatings: Influence of Heat Exposure during Processing *Sang-In Kim (Kyungnam University)*
P15	Study on Bond Materials for Protective UHTC Layers on Graphite by Air Plasma Spraying *Sik Chol Kwon (BST)*
P16	Influence of Ammonia Combustion Atmosphere on the Durability of Metallic Bond Coat in Thermal Barrier Coating *Sohee Baek (Changwon National University)*
P17	Life Assessment of 8% Yttria-Stabilized Zirconia (YSZ) Thermal Barrier Coating (TBC) Through Isothermal and Thermal Cycling Tests *Somi Lee (Seoul National University of Science and Technology)*
P18	CFD Analysis of Particle Heating in VPS of MCrAlY under Ar–H2 Mixed Plasmas *Byeongryun Jeon (Korea Institute of Materials Science)*
P19	Analysis of Oxidation Behavior According to the Addition of Ta or Hf/Si in Thermal Barrier Coating Bond Coat Powder *Su-Han Bae (Kyungnam University)*
P20	Granular Manufacturing Technology and APS Coating and Evaluation Study for Yb-Disilicate Spray Coating for Environmental Barrier Coating *Jiyoo Kim (Sewon-Hardfacing)*

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14th Asian Thermal Spray Conference & Expo

ATSC 2025

November 17-19, 2025 | BPEX, Busan, Korea

Abstract

Session I

Session Chair: Kee-Ahn Lee (Inha Univ.), Hua Li (NIMTE-CAS)

November 17th (Monday) Room A 09:30~11:45

09:45-10:25	Plenary The Strategy of Microstructure Control towards the Advanced Applications of Thermal Spray Ceramic Coating Based on the Critical Bonding Temperature Concept *Chang-Jiu Li (Xi'an Jiaotong University)*
10:25-11:05	Plenary From Basics on Cold Spraying to Solutions for Additive Manufacturing and Repair *Frank Gaertner (Helmut Schmidt University)*
11:05-11:45	Plenary Advanced Thermal and Kinetic Spray Technologies for Addressing Societal Challenges *Kentaro Shinoda (AIST)*

Plenary Lecture

Title	Prof.	First Name	Chang-Jiu	Last Name	Li
Affiliation			Xi'an Jiaotong University		
Presentation Title			**The strategy of microstructure control towards the advanced applications of thermal spray ceramic coating based on the critical bonding temperature concept**		
Abstract			Plasma spraying has been well developed for variety of industrial applications. It is well known that thermal spray ceramic coatings present a lamellar structure with limited lamellar interface bonding, which degrades the mechanical and physical performances of the coatings significantly and consequently limits the development of coating materials potential. In this present, the intrinsic critical bonding temperature for spreading ceramic droplet to form a bonding with previous splats will be presented, which is defined as the glass transition temperature of ceramic coating material. Accordingly, a critical deposition temperature for splat to form a bonding at the interface in terms of the critical bonding temperature is proposed. When the deposition temperature exceeds the critical bonding temperature a thermal spray ceramic coating with sufficiently bonded splats chemically is achieved, otherwise the coatings of conventional lamellar structure are deposited instead. It will be shown that based on the concept of the critical bonding temperature, the ceramic coatings with different microstructures from a fully dense one to porous ones with different pore geometries can be created to fulfill different service requirements for advanced applications such as for wear-resistant coatings, highly durable thermal barrier coatings, energy storage device and high performance SOFC manufacturing. It will be also shown that with the ceramic materials of a melting point lower than about 1500°C the coatings of fully dense microstructure can be deposited at ambient temperature which allows the possibility to extend ceramic coatings to further wider functional applications in different fields.		

Plenary Lecture

<table>
<tr><th>Title</th><th>Dr.</th><th>First Name</th><th>Frank</th><th>Last Name</th><th>Gaertner</th></tr>
<tr><td colspan="3">Affiliation</td><td colspan="3">Helmut Schmidt University - University of the Federal Armed Forces Hamburg</td></tr>
<tr><td colspan="3">Presentation Title</td><td colspan="3">From Basics on Cold Spraying to Solutions for Additive Manufacturing and Repair</td></tr>
<tr><td colspan="3">Abstract</td><td colspan="3">The presentation describes the journey from exploring basic principles in cold spraying and arising obstacles to demands in structural applications and solutions to enable applications in repair and additive manufacturing. As a powder spray technique dealing with solid impacts, cold spraying results in coatings of high purity and unique properties, not attainable by other spray methods. When impact conditions exceed critical velocities, bonding of solid particles is enabled by high strain rate deformation and associated heating, which in consequence by thermal softening then leads to localized adiabatic shear instabilities at particle interfaces. As shown by modelling and experiments, properties of the deposit improve with increasing the ratio between individual particle impact velocity and critical velocity at attained impact temperature. By well-tuned impact conditions, electrical and thermal conductivities as well as mechanical strengths similar to those of respective bulk material could be achieved, enabling applications in serial production.

However, new applications of structural parts by cold spray additive manufacturing and repair demand for further developments. Cold sprayed deposits are highly work hardened and still contain non-bonded interfaces as microcracks, both contributing to rather limited ductility and possibly reduced strength. Apart from that, deposit quality decreases with deviation from orthogonal impact angle. These challenges are tackled by well-tuned powder properties, primary spray parameter sets and secondary parameters that govern the surface temperature by direct heating or adjusted robotics, as well as by post treatments. Optimized path planning then enables the transfer to 3D geometries in part repair. The presented concept demonstrates how to include all that into one common digital, automized environment to enable structural part repair and additive manufacturing. By all-inclusive control, cold spraying should get ready for new applications.</td></tr>
</table>

Plenary Lecture

Title	Dr.	First Name	Kentaro	Last Name	Shinoda
Affiliation			**National Institute of Advanced Industrial Science and Technology (AIST)**		
Presentation Title			**Advanced Thermal and Kinetic Spray Technologies for Addressing Societal Challenges**		
Abstract			Coating technologies—particularly thermal spray and solid-state kinetic spray deposition—are gaining greater importance as global challenges become more complex in an increasingly uncertain and volatile world. Even as the COVID-19 pandemic has subsided, Japan now faces emerging issues including energy and environmental constraints, limited natural resources, a rapidly aging and shrinking population, and the need for resilient infrastructure. In parallel, competition in advanced manufacturing—such as semiconductor equipment and battery technologies—is intensifying as nations reinforce economic security. In this context, coating technologies are positioned to play a pivotal role in enabling robust, efficient, and sustainable industrial systems. This keynote will highlight three examples illustrating how thermal and kinetic spray technologies can contribute to these societal demands. First, ammonia-fueled gas turbine technology will be discussed. As hydrogen and ammonia attract attention as carbon-free energy carriers, ammonia combustion environments pose unique challenges—most notably, nitridation-driven materials degradation under reducing conditions. Understanding degradation mechanisms and exploring protective coating strategies are essential to realizing practical ammonia energy systems. Second, recent progress in solid-state kinetic spray deposition—for low-temperature repair and remanufacturing—will be presented. Processes such as aerosol deposition and cold spray offer pathways to resource-efficient, circular manufacturing by enabling structural restoration without high thermal loads.		

	Finally, advances in next-generation hybrid aerosol deposition (HAD) will be introduced. By integrating localized energy input, including laser-assisted super-temperature fields, HAD opens new opportunities for tailored microstructures and novel processing windows beyond conventional plasma-assisted approaches. Together, these developments underscore how coating science and technology can help build a more sustainable, resilient, and low-carbon society.

Session II | Cold Spray / Kinetic Spray I

Session Chair: Frank Gaertner (Helmut Schmidt University), Guang-Rong Li (Xi'an Jiaotong University)

November 17th (Monday) Room A 13:00~15:10

13:00-13:30	Keynote Dynamics of Impact-Induced Bonding: Insights from Single-Particle Impact Experiments and Site-Specific Micromechanical Analysis *Yuji Ichikawa (Tohoku University)*
13:30-13:50	Invited Cold Spray Metallization of Thermoplastic CFRP for Enhanced Lightning Strike Resistance *Hiroki Saito (Tohoku University)*
13:50-14:10	Invited High Quality Cold Spray Cu Metallization of Ceramics with Widened Deposition Window Enabled via Ti or Cu-Ti Buffer Layer *Xiao-Tao Luo (Xi'an Jiaotong University)*
14:10-14:30	Adhesion and Lightning Strike Resistance of Cold-Sprayed Aluminum Repair Coatings on CFRTP *Wataru Kai (Tohoku University)*
14:30-14:50	Dynamic Flattening and Microstructural Changes in Aluminum Particles under High Strain Rates *Gil-Ju Na (Tohoku University)*
14:50-15:10	Improved Al6061 Deposit Performance by In-situ Induction Heating during Cold Gas Spraying *Luca Klingler (Helmut Schmidt University)*

Keynote Lecture

Title	Dr.	First Name	Yuji	Last Name	Ichikawa
Affiliation			Tohoku University		
Presentation Title			Dynamics of Impact-Induced Bonding: Insights from Single-Particle Impact Experiments and Site Specific Micromechanical Analysis		
Abstract			The deposition mechanism in cold spray (CS) relies on high-velocity impact, where intense plastic deformation fractures and removes the native oxide film, exposing nascent metallic surfaces that subsequently bond. However, the extent of plastic and shear deformation is highly non-uniform, producing regions near the interface where adhesion is hindered. To address the challenges associated with such non-uniform bonding, this presentation introduces advanced mechanical approaches, including the exploration of bonding conditions through single-particle impact experiments and the nano- to micro-scale mechanical evaluation of adhesion strength. In situ microparticle impact experiments, combined with site-specific micromechanical testing, reveal the detailed micromechanics of the bonding process. Our findings demonstrate a pronounced gradient of bond strength across the interface, with the maximum occurring near the periphery. This gradient is linked to localized surface opening during the early stages of impact. Transmission electron microscopy (TEM) observations further show that stronger bonding correlates with the transformation of the native oxide structure from continuous layers into fragmented debris. Metallurgical bonding is thus found to require both sufficient surface exposure through lateral expansion and high local contact pressures to achieve atomic proximity. We present a predictive framework in which bond strength is proportional to the effective pressure and degree of surface exposure, validated by finite element simulations demonstrating that increasing impact velocity enhances bond strength. This research provides critical insights for optimizing cold spray processes.		

Invited Lecture

Title	Dr.	First Name	Hiroki	Last Name	Saito
Affiliation			Tohoku University		
Presentation Title			Cold Spray Metallization of Thermoplastic CFRP for Enhanced Lightning Strike Resistance		
Abstract			Carbon fiber reinforced polymer (CFRP) has been increasingly adopted in modern aircraft and wind turbine blades due to its high specific strength and low weight. However, the inherently high electrical resistivity of the polymer matrix makes CFRP highly susceptible to lightning strike damage. Surface metallization has been recognized as an effective approach to enhance the lightning strike protection (LSP) performance of CFRP, and several coating techniques—such as physical vapor deposition, chemical vapor deposition, thermal spraying, and electroplating—have been explored, yet none have provided a robust and industrially viable solution. Recently, the cold spray process has emerged as a promising solid-state technique for CFRP metallization, offering advantages such as rapid coating formation, low thermal load on substrates, and the potential for in-situ repair. This presentation highlights recent progress in developing LSP coatings on thermoplastic CFRP (CFRTP) substrates using low-pressure cold spray. Through a combined experimental and numerical approach, particle impact energy and substrate temperature have been identified as key parameters governing continuous coating formation while minimizing substrate erosion. Lightning strike tests were conducted on specimens with varying coating thicknesses and deposition patterns, and high-speed imaging was employed to visualize the transient damage process during discharge. Post-strike evaluations revealed multiple damage modes in CFRTP, including polymer ablation, carbon fiber fracture, internal cracking, and interlaminar delamination. It was found that coatings fabricated by the cold spray process effectively mitigated these damage modes, demonstrating their potential to significantly improve the overall lightning strike resistance of CFRTP. Based on these findings, we propose a coating design strategy aimed at realizing a lightweight, lightning-resistant, and easily repairable metallization system for next-generation CFRP structures.		

High quality Cu metallization of ceramics via cold spray enabled by Ti or Cu-Ti buffer layer

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Abstract: Cold spray has garnered significant attention for ceramic metallization due to its high material deposition rate and no hazard emission feature. Although many efforts, such as optimizing the spraying parameters and introducing Al softer buffer layer, have been made, it is still challenging to deposit continuous and dense Cu coating on ceramic substrates with uniform thickness. To address this issue, in this study, Ti powder and mechanically mixed Cu-Ti powder are cold sprayed on Al2O3 substrate as buffer layers for Cu coating. Effect of the buffer layer type on deposition behavior, thermal shock resistance and spraying parameter window of the cold sprayed Cu coating is examined. Results show that Ti particles can be much easier to be deposited on Al2O3 substrate than Cu and Al particles. The porous microstructure endows the Ti buffer layers with low stiffness which could be plastically deformed rather than spall-off from the substrate during Cu particle deposition leading to uniform coating thickness without Cu particle impact erosion induced inter-track grooves. Although both the conventional Al buffer layer, and the Ti and Cu-Ti buffer layers proposed in this work help to get continuous Cu coating with homogenous thickness, the thermal shock lifetimes of coatings with Ti and Cu-Ti buffer layers reach 1.5 times and twice those of Al-buffer-layered Cu coating due to their superior adhesion and moderate thermal expansion coefficients between Cu coating and the Al2O3 substrate. Furthermore, by using Cu-Ti composite buffer layer, the deposition window for Cu coatings is greatly broadened by which Cu coating with higher deposition efficiency and lower porosity to 0.4% is achieved. These findings provide critical insights into the design and optimization of cold spray processes for ceramic metallization, offering significant implications for industrial applications.

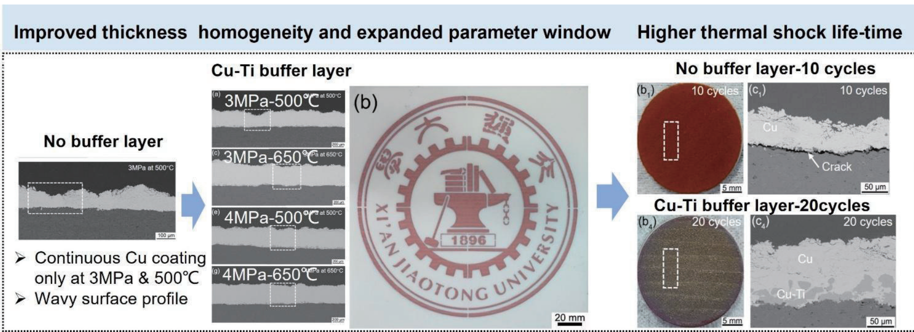

Fig. 1. A comparison of the deposition behavior and thermal shock resistance of cold sprayed Cu coatings on Al_2O_3 with and without the buffer layer

Acknowledgment: This work is supported by National Key R&D program of China (2024YFB4609600) and National Natural Science Foundation of China (52375379).

Keywords: Ceramic metallization, Cold spray, Ti-Cu Buffer layer, Thickness uniformity, Thermal shock resistance

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Adhesion and Lightning Strike Resistance of Cold-Sprayed Aluminum Repair Coatings on CFRTP

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Polymer-based composite aircraft are electrically insulating and thus vulnerable to thermal damage from Joule heating during lightning strikes. Conventional conductive treatments involve complex manufacturing and repair processes, often leading to extended aircraft downtime. Cold spray (CS), a solid-state coating method, has emerged as a promising solution for rapid deposition and on-site application. Previous studies showed copper CS coatings on thermoplastics CFRP (CFRTP) are effective for lightning strike protection, but repair after lightning damage remains unreported. Effective repair requires full electrical restoration, since incomplete repair increases damage extent and reduces residual strength [2]. This study investigates CS-applied aluminum coatings on CFRTP substrates, followed by lightning strike testing. After damage, repair coatings were deposited by CS. Coating quality was assessed by thickness and resistivity measurements, while lightning resistance was evaluated through melted area analysis and ultrasonic flaw detection for both initial and repaired specimens.

The deposition conditions for each specimen are summarized in Table 1. To induce greater damage after the first lightning strike, specimen A was fabricated with a thinner coating. After the first lightning strike, this specimen was subjected to repair deposition. For comparison, specimen B was prepared under the same deposition conditions as the repaired specimen, to evaluate the coating quality and lightning resistance of the coating formed by the initial deposition.

Table 1. Spray conditions of each lightning strike test specimen

Specimen	Gas pressure [MPa]	Gas temperature [°C]	Nozzle traverse speed [mm/s]
A–As-sprayed	0.5	375	60
A–Repaired	0.5	375	30
B–As-sprayed	0.5	375	30

Fig. 1 shows (a) the surface appearance of specimen A after the lightning strike, (b) its surface appearance after repair, (c) the surface appearance after the subsequent lightning strike on the repaired specimen A, and (d) the surface appearance of specimen B after the lightning strike.

Table 2 compares the coating thickness and electrical resistivity between the A-Repaired specimen and the B-As-sprayed specimen. These results show that the coating quality is comparable to that of the initial CS deposition. Table 3 presents the melting area measured with a digital microscope and coating delamination area ratio obtained from ultrasonic testing. The results indicate that even when significant coating delamination occurred during the first strike, repair deposition by CS restored the lightning resistance to a level comparable to the initial deposition.

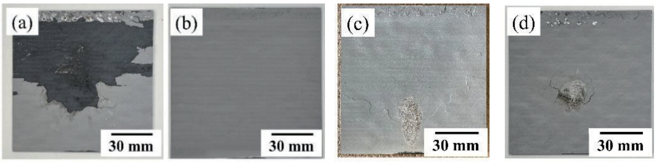

Fig. 1. Surface appearance of each specimen: (a) A-As-sprayed after lightning strike, (b) A-Repaired, (c) A-Repaired after lightning, (d) B-As-sprayed after lightning

Table 2. Comparison of coating quality between the first coating and the repaired coating

	A-Repaired	B-As-sprayed
Coating thickness [μm]	266	219
Electrical resistivity [μΩ·m]	3.66	3.86

Table 3. Comparison of lightning resistance between the initial deposited specimen and the repaired specimen

	A-Repaired	B-As-sprayed
Melting area [mm^2]	374	298
Delamination area ratio [%]	4.86	13.69

Acknowledgment: This work was supported by JKA and its promotion funds from KEIRIN RACE.

Keywords: Cold Spray, CFRTP, Aluminum, Adhesion, Lightning Strike Protection, Repair Coating

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Dynamic Flattening and Microstructural Changes in Aluminum Particles under High Strain Rates

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[2]Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY 14853, USA
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Cold spray (CS) is one of the thermal spray techniques that allows deposition of metallic, polymer, and ceramic powders in a solid state. This aspect gives cold spray the potential to be widely employed across industries, as it can be performed at relatively low temperatures. Therefore, it is important to establish a good understanding of adhesion mechanisms in cold spray. As most studies agree that particle deformation behavior is a key factor in the adhesion mechanism of cold spray, there have been studies employing single-particle impact tests to observe microstructure evolution and analyze the mechanism of the dynamic recrystallization after high-speed deformation[1]. Nevertheless, mechanical properties such as plastic flow stress of the particles during the high-rate deformation, which is one of the decisive factors in cold spray processing, remain unexplored.
In this study, we employed nanoindentation, which has significantly advanced in recent years, allowing step-load impact tests, in other words, a high-strain-rate tests. We have compressed pure aluminum particles against a sapphire substrate using a flat-punch tip of the nanoindentation to interrogate their mechanical properties under different strain rates. Subsequently, we compared the data from the nanoindentation with the results obtained by finite element analysis (FEA) to investigate the differences in actual deformation and simulations using the isotropic constitutive equation. The experimental quasi-static results and FEA showed a good match except for the high initial stress during the experiment which is likely caused by the oxide layer. Meanwhile, load fluctuations observed during the step-load impact test were not present in the corresponding FEA as shown in **Fig. 1 (c)**. This indicates that the fluctuations of the flow load are caused by either microstructural evolution or load measurement technique of the nanoindentation during the step-load impact test.

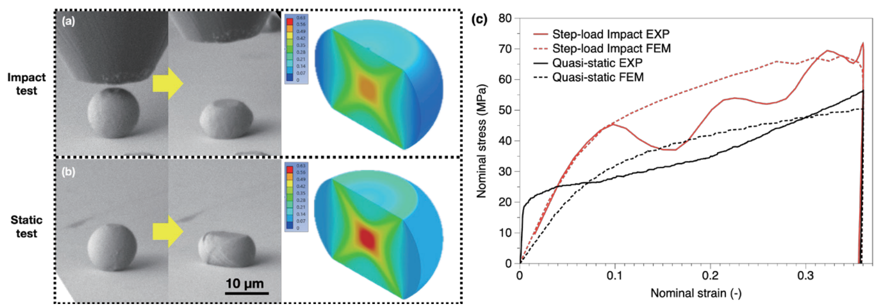

Fig. 1. SEM image of in-situ particle compression test and FEA result of (a) step-load impact test and (b) quasi-static test and (c) the nominal strain-stress curve of experimental result and FEA result.

Additionally, we used a focused ion beam (FIB) to fabricate cross-sectional lamellae perpendicular to the slip lines of the compressed particles for TEM observation as shown in **Fig. 2 (a)** and **(d)**. The observation revealed the formation of subgrains near the corner of the compressed particle, particularly near the terminations of the slip lines formed as shown in **Fig. 2 (b)**. Furthermore, **Fig.2 (c)** and **(f)** shows that coffee bean-like contrast features were observed inside the diamond-shaped grain of the center for both step-load impact test and quasi-static test.–These coffee-bean-like contrasts are indicative of dense dislocation structures[3], possibly associated with dislocation interactions such as the formation of small loops or cells. Nevertheless, we have not yet found significant differences between the microstructures of post-impact test and static test particles.

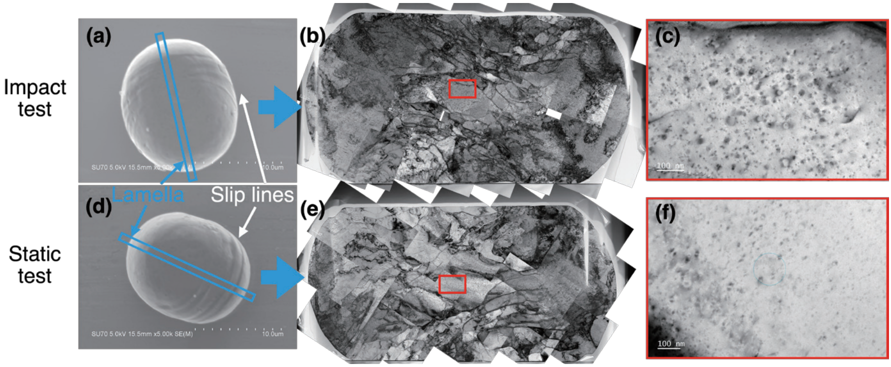

Fig. 2. SEM and TEM images of particles after compression tests. (a), (d) surface morphology of particles, (b), (e) TEM images of the cross-section, and (c), (f) TEM images of the center of particles under higher magnification after impact test and static test respectively.

Acknowledgment: The authors gratefully acknowledge the funding received from JSPS KAKENHI (Grant Number 23H01721), and National Science Foundation CAREER Award (CMMI-2145326)

Keywords: Cold spray, particle compression test, flow stress, microstructure development.

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Improved Al6061 deposit performance by in-situ induction heating during Cold Gas Spraying

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Abstract: Systematic studies investigating influences of cold spray parameters on coating properties mainly concern the so-called primary parameters, such as process gas pressure and temperature [1,2], to shape particle impact conditions [3]. However, previous studies of the authors revealed that secondary parameters governing the surface temperature can also be used for quality optimization of cold spray deposits [4]. In order to obtain a better understanding of surface deformation under particle impact, this study investigates the influence of the substrate temperature on interface phenomena and deposit build-up. To achieve this goal, the substrate temperatures were kept constant during spraying by using an in-situ induction heater. The experiments were carried out using a commercially available cold spray system of type 5/11 by Impact Innovation (Rattenkirchen, Germany), with Al6061 as both feedstock powder and substrate material. Details regarding the various spray parameters and the applied values are specified in Tab. 1.

Tab. 1. Spray parameters and applied values

Parameter	Values/Range
powder size	26 – 49 µm
T_{gas}	500 °C
p_{gas}	5 MPa
nozzle	OUT 1
layers	40
carrier gas flow	4 m^3/h
stand-off distance	40 mm
spray velocity	500 mm/s
line spacing	2 mm
feed rate	16.04 g/min
injection distance	30 mm
substrate pre-heating temperatures	100 °C, 150 °C, 200 °C, 250 °C, 300 °C

Results showed that increasing the substrate temperature leads to more possible deformation of the substrate and the already built-up deposit, resulting in higher thickness/ deposition efficiency, reduced porosity, and increased electrical conductivity. Fig. 1 shows the deposit thickness and porosity as functions of the substrate temperature set by the in-situ induction heating.

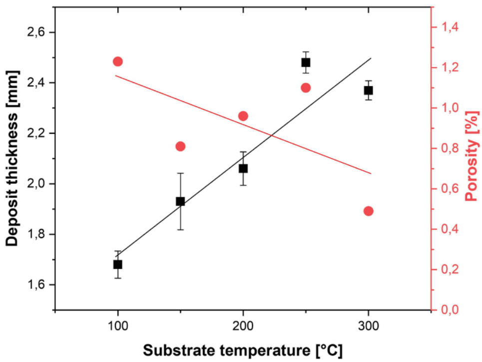

Fig. 1. Deposit thickness and porosity as functions of the substrate temperature

As illustrated in Fig. 1, the deposit thickness increases with rising substrate temperatures. A slight reduction in porosity is also observed with increasing surface temperatures, although this trend is less pronounced. When the substrate temperature is increased from 150 °C to 250 °C, the porosity even slightly rises. This effect could be attributed to the adhesion of particles that would otherwise remain unbonded - a similar trend reported by Rech et al. [5]. Overall, the porosity of the produced coatings remains very low, at around 1 %, with the lowest value obtained at the highest substrate temperature of 300 °C. Within this context, the study reveals the potential of a targeted thermal control during cold spraying to tailor coating properties and thus contributes to a better understanding of thermal effects in cold spraying. Gained results support the development of optimization strategies for 3D additive manufacturing as well as repair applications by combining appropriate sets of primary and secondary cold spray parameters.

Acknowledgment: The authors acknowledge the financial support within the frame work of the project "CORE – Computer-based Refurbishment" by dtec.bw – Digitalization and Technology Research Center of the Bundeswehr. Dtec.bw is funded by the European Union – NextGenerationEU. The authors also like to thank Marion Kollmeier, Matthias Schulze, Bastian Oswald and Matthias Hartmann for technical support.

Keywords: Cold Spray, Al6061, Substrate Temperature, Deposit Performance

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Session III | Solution/Suspension & Hybrid Processes

Session Chair: Chang-Jiu Li (Xi'an Jiaotong University)

November 17th (Monday) Room B 13:00~15:10

13:00-13:30	Keynote Solution Precursor Plasma-Sprayed Ce-Doped Bi_2O_3 Coating with Tuned Bandgap for Enhanced Visible-Light Photocatalytic Activities *Hua Li (NIMTE-CAS)*
13:30-13:50	Invited Synergistic Feed Rate & Microstructure Design Enables Superior Microwave Absorption in Mechanically Robust Flame-Sprayed $BaFe_{12}O_{19}$/CS/PI Coatings *Xiaohua Feng (NIMTE-CAS)*
14:10-14:30	Fabrication of Visible-Light Active Ce-Doped Bi_2O_3 Coatings via Single-Step Solution Precursor Plasma Spraying *Yang Rui (NIMTE-CAS)*
14:30-14:50	Invited Hybrid Aerosol Deposition from Dense Microstructure to Covalent Bonded Materials *Mohammed Shahien (AIST)*
14:50-15:10	Formation of ZrB_2-based Ultra-high Temperature Ceramics Coatings by Aerosol Deposition *Haruto Oishi (Yokohama National University)*

Keynote Lecture

Title	Professor	First Name	Hua	Last Name	Li
Affiliation			Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences		
Presentation Title			**Solution precursor plasma sprayed Ce-doped Bi2O3 coating with tuned bandgap for enhanced visible-light photocatalytic activities**		
Abstract			Thermal spray has shown great promises in fabricating photocatalytic nanostructured coatings for a variety of functional applications. Developing novel photocatalytic materials and appropriate coating techniques for tunable nanostructures yet remains challenging. This presentation will briefly introduce our efforts made in recent years on thermal sprayed photocatalytic coatings. In particular, solution precursor plasma sprayed (SPPS) Ce-doped Bi_2O_3 coatings will be addressed. Bi_2O_3 is a promising yet limited photocatalyst due to its narrow light-response range and rapid charge carrier recombination. Precursor solutions with varying Ce/Bi ratios were deposited onto 316L stainless steel substrates using an atmospheric plasma spray system with a solution feeder. Comprehensive characterization evidenced successful Ce incorporation into Bi_2O_3 lattice, reducing the bandgap and extending light absorption into the visible region. The coating with 3% Ce/Bi ratio exhibited exceptional performance, achieving 91.82% methyl orange degradation after 6 hours of visible light irradiation. This enhancement is attributed to effective bandgap narrowing and oxygen vacancy regulation via Ce doping, which significantly improved visible light absorption and charge carrier separation/transport. The one-step SPPS processing route would shed light on developing high-performance visible-light-driven photocatalytic coatings for environmental purification, biomedical and life health applications.		

Synergistic Feed Rate & Microstructure Design Enables Superior Microwave Absorption in Mechanically Robust Flame-Sprayed $BaFe_{12}O_{19}$/CS/PI Coatings

[1]Pengyu Li, [1]Xiaohua Feng*, [1]Hua Li*

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Abstract: Developing efficient microwave-absorbing coatings via thermal spraying is hindered by the thermal demagnetization and oxidation of fillers. Herein, a low-temperature flame spraying strategy is employed to fabricate Nd-doped $BaFe_{12}O_{19}$/nano-carbon spheres (CS)/polyimide (PI) coatings. By systematically controlling the feed rate, we precisely modulate filler dispersion and coating microstructure evolution, thereby inducing significant transitions in the dominant microwave attenuation mechanisms. At high feed rates, limited CS addition promotes localized surface plasmon resonance (LSPR) and metallization effects within the surface-dense layer, while excessive CS loading induces an overconnected network and prominent skin effect, impairing microwave absorption (MA) in both cases. Conversely, under low feed rates, favorable thermodynamic and kinetic conditions enable the formation of PI-encapsulated spherical filler structures in the surface region. This unique structure effectively suppresses LSPR and the skin effect, enhances polarization losses, prevents excessive conductivity rise (mitigating impedance mismatch), and thus optimizes over MA. Consequently, the high feed rate coating delivers a minimum reflection loss (RL_{min}) of -39.1 dB and an effective absorption bandwidth (*EAB*) of 3.7 GHz at a thickness of 4.3 mm. In stark contrast, the low feed rate coating achieves a superior RLmin of -52.3 dB and a wider *EAB* of 6.1 GHz at 2.1 mm. Furthermore, the coatings demonstrate outstanding adhesion, achieving Class 0 in the cross-cut testing. Scratch testing demonstrated excellent cohesion and interfacial robustness without catastrophic delamination. This study provides critical mechanistic insight and establishes a scalable route for engineering flame-sprayed microwave absorbers with simultaneously enhanced structure-function integration and long-lasting mechanical performance.

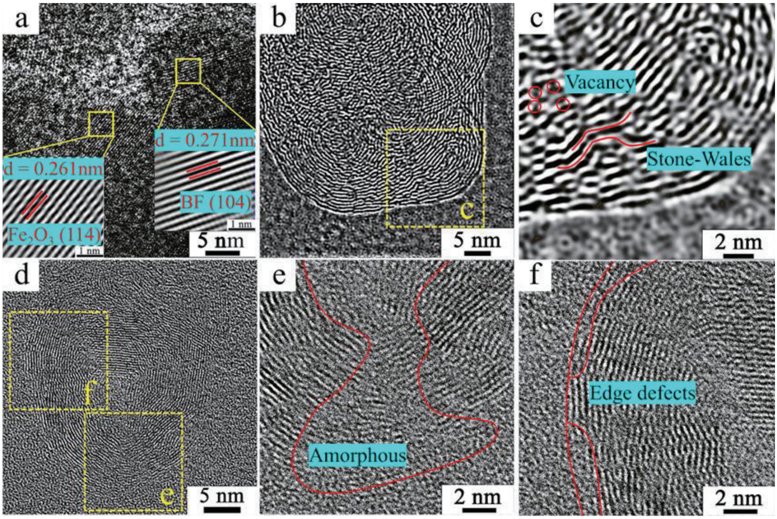

Fig. 1. HRTEM images: (a) BF and α-Fe_2O_3 region in FS-8CS-L coating, (b, c) pristine CS with (c) corresponding to magnified views of the areas in (b), (d-f) CS regions in FS-8CS-L coating with (e) and (f) corresponding to magnified views of the areas in (d).

Acknowledgment:
This work was supported by the Key Research and Development Program of Ningbo, China (Grant # 2024Z198, # 2023Z195), the open Fund of State Key Laboratory of Infrared Physics (Grant No. SITP-NLIST-YB-2024-06), the Young Science and Technology Innovation Leading Talents of Ningbo (Grant # 2024QL019), and the 14th Five-Year Civil Space Pre-Research Project (No. D020502).
Keywords: microwave absorbing coating, flame spraying, microstructure evolution, adhesion performance.

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Enhanced Photocatalytic Performance and Weather Resistance of TiO_2/Phosphate Composite Coatings Fabricated through Suspension Flame Spraying

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Abstract: This study employed suspension flame spraying technology to fabricate an inorganic composite coating with aluminum dihydrogen phosphate as the bonding phase and titanium dioxide (TiO_2) as the photocatalyst, aiming to develop a photocatalytic coating with superior weather resistance. XRD analysis confirmed that TiO_2 in the coating maintained its anatase phase without transformation to the rutile phase. The surface microstructure of the coating was examined via SEM, while its weather resistance and stability impact on photocatalytic performance were evaluated through water immersion tests. Photocatalytic activity was characterized by the degradation rate of methylene blue dye in aqueous media. The results demonstrated that the photocatalytic efficiency of the coating significantly improved with increasing TiO_2 content, achieving methylene blue degradation rates ranging from 77.02% to 97.74%. After weathering treatment, the coating retained excellent photocatalytic efficiency, with performance markedly enhanced at higher TiO_2 concentrations, indicating its stable application potential in aqueous environments.

Keywords: Titanium dioxide, Phosphate composite coating, Photochemical catalysis, Suspension flame spraying

Hybrid Aerosol Deposition from Dense Microstructure to Covalent Bonded Materials

Mohammed Shahien and Kentaro Shinoda

National Institute of Advanced Industrial Science and Technology, AIST, Japan

Hybrid Aerosol Deposition (HAD) is an emerging non-melt ceramic coating technique that combines plasma assistance, room-temperature impact consolidation (RTIC), and advanced three-dimensional deposition capabilities. By bridging the gap between traditional plasma spraying and aerosol deposition, HAD overcomes their respective limitations and opens new opportunities for sustainable coating applications. Its versatility not only improves the performance of ceramic coatings in established fields but also enables the deposition of materials previously inaccessible by conventional methods, with potential benefits for environmental protection and advanced engineering systems. Among such challenging materials is silicon carbide (SiC), which decomposes before melting and is difficult to process using thermal spray techniques, while conventional chemical vapor deposition (CVD) suffers from slow growth rates (<1 μm/h) and thickness limitations. This study explores the potential of HAD for dense Al_2O_3 ceramic coating deposition for environmental protections as well as the potential of HAD SiC deposition, despite its strong covalent bonding structure. The results provide fundamental insights into HAD processing of SiC and lay the groundwork for future advancements in SiC coatings and nanoscale material science.

Formation of ZrB_2-based ultra-high temperature ceramics coatings by aerosol deposition

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Abstract: ZrB_2 is a type of ultra-high temperature ceramics (UHTC), which has attracted attention as a material with a high melting point, relatively low density, and good oxidation resistance. It is also known that adding SiC to ZrB_2 can improve oxidation resistance[1)]. The application of joining UHTC to ceramic matrix composites (CMC) requires extremely high temperatures to produce joints, which degrade the CMC substrate. The aerosol deposition (AD) method can form dense and crystalline coatings at room temperature through particle collisions with the substrate[2)], indicating no degradation of the CMC substrate. The objectives of this study are to verify the formability of ZrB_2 and ZrB_2-SiC coatings by the AD method and to examine their microstructures. ZrB_2 and ZrB_2-SiC coatings were deposited on glass and Mo substrates by the AD method. ZrB_2-SiC powder, used for ZrB_2-SiC coatings, was prepared by mixing ZrB_2 powder and SiC powder. Phase identification of formed coatings was performed by using XRD. The surface and cross-section of the coatings were observed by FE-SEM and EDS. Dense and crystalline ZrB_2 and ZrB_2-SiC coatings were formed by the AD method. SiC powders were dispersed within the coating layer in the case of ZrB_2-SiC coatings.

Acknowledgment: This research was supported by a grant-in-aid for scientific research (B) (18H01745) and (C) (24K08095) from the Japan Society of the Promotion of Science. The authors greatly appreciate the grants.

Keywords: aerosol deposition, ultra-high temperature ceramics, zirconium diboride, silicon carbide, room temperature impact consolidation

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Session IV | Cold Spray / Kinetic Spray II

Session Chair: Kentaro Shinoda (AIST), Sunghun Lee (Korea Institute of Materials Science)

November 17th (Monday) Room B 13:00~15:10

15:20-15:40	Invited Cold Spray Technologies for Nuclear Energy Applications *Hwasung Yeom (POSTECH)*
15:40-16:00	Invited Development of Al6061-NiTi Composite via Cold Spray Assisted by Friction Stir Processing *Chunjie Huang (Northwestern Polytechnical University)*
16:00-16:20	Invited Application of Cold Sprayed Coatings in Automotive Industry *Hyuk Jun Lee (Cerectron)*
16:20-16:40	Microstructure and Tribological Property Correlations in Cold-Sprayed Fe-Based Amorphous Alloy Coatings *Kyung Un Won (Inha University)*
16:40-17:00	Influence of Laser Surface Heat Treatments on Mechanical Changes of Deformed Al6061 Bulk Material and Cold Spray Deposits *Jim Merlin Manoo Klutta (Helmut Schmidt University)*
17:00-17:20	Bond Coat Material for Cold Sprayed Polymer Film Formation *Jingze Sun (Tohoku University)*

Cold Spray Technologies for Nuclear Energy Applications

Hwasung Yeom
Pohang University of Science and Technology

Kumar Sridharan
University of Wisconsin, Madison

Cold Spray Additive Manufacturing (CSAM) is emerging as a key technology in the nuclear energy sector, enabling the deposition of dense metallic or metal–ceramic composite coatings at high rates with minimal heat input to substrates. This presentation will first outline CSAM fundamentals—including spray system configuration, deposition mechanisms, and resulting material properties—before highlighting three nuclear-specific applications:

1. Coating deposition: Chromium coatings applied via CSAM significantly enhance corrosion and oxidation resistance in zirconium-alloy cladding used in light-water reactor fuel assemblies.
2. Near-net shape manufacturing: Fabrication of free-standing oxide dispersion strengthened (ODS) steel cladding tubes for fast reactors, offering superior high-temperature strength and radiation tolerance compared to conventional ferritic/martensitic steels.
3. Defect repair: CSAM is the leading approach for repairing and mitigating stress corrosion cracking in spent fuel storage canisters in the USA and Republic of Korea.

These case studies demonstrate CSAM's versatility for improving performance, enabling advanced manufacturing, and extending the service life of critical nuclear components.

Development of Al6061-NiTi composite via cold spray assisted by friction stir processing

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Abstract

Bulk nickel titanium or nickel titanium – composite parts are employed in many mechanical applications. However, due to the reactivity and the super-elastic behavior of NiTi, possible process routes for casting, sintering, as well as shaping and machining are difficult to apply and quite costly. Thus, new techniques for additive manufacturing of respective parts are needed for paving the way to widespread applications. Using NiTi-Al6061 composites as model system, the present study suggests a new process route by combining cold spraying and friction stir processing for building up layers or parts.

Al-alloys can be processed to coatings by cold spraying. In contrast, super-elastic NiTi can in be build up with a rather lower deposition efficiency. Thus, due to the difference in mechanical strength and the thermal softening behavior, bonding during cold spraying of respective blends is solely caused by the deformation of the Al-alloy powder particles, the strength of internal interfaces between the two constituents being far below optimum. Friction stir processing is applied to reduce the amount of microstructural defects as porosity and non-bonded internal interfaces for Al matrix, and thus improving the mechanical performance of cold sprayed parts. The composites manufactured by using cold spraying followed by friction stir processing have a homogenous NiTi distribution and well bonded NiTi/Al6061 interfaces. By individual parameter optimization, the formation of undesired intermetallic phases can be avoided. The results on microstructures and strengths of as deposited and additionally friction stir processed composites are discussed with respect to the deposition mechanism and the microstructural evolution during post-processing, as well as needed interface qualities to serve as high performance composite material.

Keywords: cold spray, friction stir processing, Al6061/NiTi composite, deposition mechanism, properties

Application of cold sprayed coatings in automotive industry

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The cold spray is a solid state process with mechanical bonding for the coatings. These cold sprayed coatings offer protection against wear, corrosion for improving vehicle reliability and longevity. For this reason, the cold spray coatings are widely used in the automotive industry to enhance the performance and durability of various components. This paper delves into the various applications of cold spray coatings in the automotive components.

Microstructure and Tribological Property Correlations in Cold-Sprayed Fe-Based Amorphous Alloy Coatings

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Abstract: Amorphous alloys possess a densely packed atomic structure based on short-range order. The absence of grain boundaries and dislocations mitigates local stress concentration, thereby suppressing crack initiation and propagation [1]. Furthermore, their high elastic limit and hardness lead to shallow and uniform surface deformation during contact, resulting in lower coefficients of friction (COF) and wear rate than crystalline alloys. This behavior is also advantageous for the rapid formation and maintenance of a continuous and stable protective tribofilm during sliding processes [2]. Cold spray (CS) is a solid-state, supersonic deposition process with particle bonding driven by severe plastic deformation and adiabatic shear under minimal thermal exposure [3]. As a result, melt-related oxidation and phase transformations are avoided. Consequently, CS is well suited for fabricating amorphous coatings. The low process temperature and limited thermal exposure preserve the amorphous fraction and suppress crystallization and oxidation during deposition [4]. Recent studies report that these benefits are maintained because cold spray proceeds as a solid-state deposition without melting.

In this study, amorphous coatings were fabricated under three conditions (CS1, CS2, and CS3) by varying the gas temperature of the cold spray process. XRD and DSC analyses confirmed that the amorphous phase was retained on a coating scale for all three conditions. Cross-sectional and surface observations (Fig. 1) revealed the coexistence of strongly bonded regions with weakly bonded areas, micropores, and microcracks, with limited oxygen signals observed near the particle boundaries. Pin-on-disk tests (counterbody : Al_2O_3 pin) yielded wear rates (Fig 2. (b)) of 1.27×10^{-5}, 2.02×10^{-5}, and 2.07×10^{-5} mm^3/mN for CS1, CS2, and CS3, respectively. These values demonstrate 2–4 times superior wear resistance compared with the same material deposited by HVOF in a previous study. The COF (Fig 2. (c)) stabilized most rapidly for CS1, while CS2 and CS3 were accompanied by initial fluctuations and a gradual increase. Analysis of the worn surfaces and cross-sections commonly showed abrasive grooves and oxide films. Delamination craters and crack propagation originating at interparticle boundaries were more frequent in CS2 and CS3. The tribological performance was found to be more significantly governed by the continuity and integrity of interparticle bonding than by hardness alone. For CS1, the small interfacial gaps and the continuous network of strong bonds resulted in shallow and uniform contact deformation This enabled early formation and stable retention of a protective tribofilm and led to the lowest wear rate (1.27×10^{-5} mm^3/mN) with a stable COF. In contrast, the interconnected network of weak bonds, pores, and cracks in CS2 and CS3 induced a cycle of local stress concentration, delamination, and subsequent tribofilm re-formation, resulting in increased wear rates of 2.02×10^{-5} and 2.07×10^{-5} mm^3/mN. In summary, it was confirmed that preserving the amorphous fraction while ensuring the continuity of strong interparticle bonding are the key design factors determining the stability of the tribofilm and the suppression of wear.

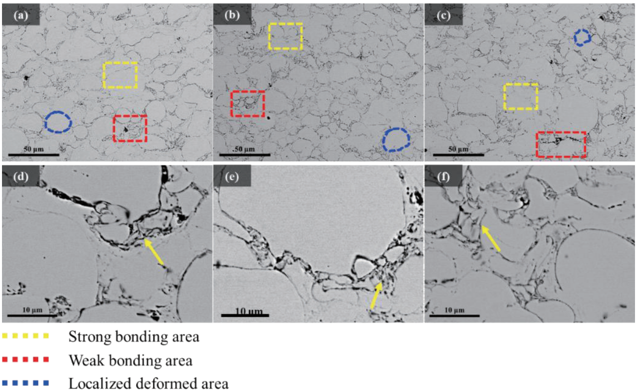

Fig. 1. Cross-sectional microstructure observation photographs of cold spray coating layers.
(a, d) CS1, (b, e) CS2, (c, e) CS3

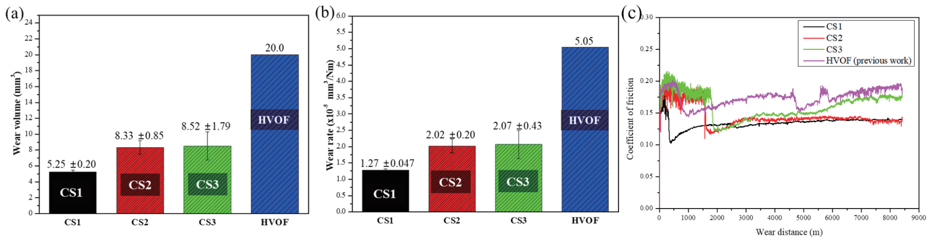

Fig. 2. Wear behavior of cold sprayed amorphous coating layers
(a) wear volume, (b) wear rate (c) coefficient of friction

Keywords: Cold spray, Amorphous alloy, Microstructure, Wear properties, Tribology

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Influence of Laser surface heat treatments on microstructural changes of deformed Al6061 bulk material and cold spray deposits

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Abstract: Heat treatment of high-performance aerospace parts of Al 6061 alloys in T6 temper condition is a delicate matter, as it already undergoes specific and standardized treatments. Cold Spraying could offer possible solutions for part repair, but so far only reaches the needed properties regarding strength, ductility and adhesion, if rare and costly helium is used as process gas. In order to reach the thresholds for repair application by using resource friendly nitrogen as process gas, Laser Assisted Cold Spray could offer needed solutions by improving deposit properties without changing part properties.

This study systematically investigates influences under altered Laser settings, traverse velocities and substrate dimensions and correlates that to changes in strength, ductility and hardness. The mechanical properties were investigated by tensile tests, hardness tests. The correlations aim to find appropriate combination of maximum improvement of deposit properties and minimum alteration of substrate properties. While laser settings were successfully determined, additionally, the results show distinct settings for optimizing deposit ductility or the substrate/deposit interaction. In summary, this study allows to derive parameter selections of needed surface morphology, laser settings and traverse velocities as guideline for part repair by laser assisted cold spray.

Acknowledgment: dtec.bw, NextGenerationEU

Keywords: Laser, Assisted, Post, Processing, Cold, Spray, Repair, AA6061

Bond Coat Material for Cold Sprayed Polymer Film Formation

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Abstract: Cold spray deposition of fluoropolymer coatings such as perfluoroalkoxy alkane (PFA) remains highly challenging due to inherently low deposition efficiency and poor adhesion on metallic substrates. Most PFA particles rebound upon impact, resulting in thin, weakly bonded coatings (typically <20% polymer deposition per pass) that greatly restrict practical applications. Conventional approaches—such as surface pretreatments by grit blasting or laser texturing and the use of particle additives—can enhance polymer deposition [1], but they increase process complexity and equipment requirements. In this work, we discovered that introducing a cold-sprayed metallic bond coat provides a simpler yet more effective alternative: compared to laser-treated substrates, the bond coat method not only simplifies the process but also achieves even higher deposition efficiency and more stable film formation. For instance, a titanium (Ti) bond coat on the substrate markedly improved PFA deposition efficiency and enabled the formation of a continuous, well-adhered PFA layer.

To systematically identify the factors governing PFA film formation, a comparative study was performed using various metallic bond coats including titanium (Ti), zinc (Zn), copper (Cu), and aluminum (Al), along with laser-textured (LT) substrates. As illustrated in Figure 1, when the bond coats exhibited similar surface roughness values, the resulting PFA deposition efficiencies were similar across different metals, indicating that chemical composition plays a minor role in adhesion. Instead, surface morphology was found to be the dominant factor. When the bond coats were fabricated using fine particle feedstocks or mechanically polished to achieve smoother finishes, a dramatic decrease in deposition efficiency was observed, often preventing continuous film formation. Interestingly, while the LT surfaces achieved surface roughness comparable to that of cold-sprayed coatings, their PFA deposition performance was notably lower. The variations in surface roughness among the LT samples shown in Figure 1 were caused by differences in laser output power and scan interval. However, altering these parameters did not significantly affect the deposition efficiency, suggesting that roughness alone is insufficient to improve PFA adhesion on LT surfaces. This difference can be explained by examining the microstructural and thermal characteristics of the bond coats. As shown in Figure 2, cold-sprayed coatings possess a porous microstructure that reduces effective thermal conductivity. Figures 2(a) and 2(b) correspond respectively to the LT sample with the second-highest roughness and to the Ti bond coat sample in Figure 1. This thermal insulation effect promotes local interfacial temperature rise during particle impact, leading to enhanced polymer softening and improved interlocking. In contrast, LT surfaces, despite being rough, lack this thermal advantage due to their dense, bulk-like structure. These findings suggest that the bond coat's effectiveness arises not only from its surface topography but also from its capacity to create favorable thermal conditions for PFA adhesion.

In summary, the cold-sprayed metallic bond coat offers a simpler and more effective route for fluoropolymer film formation than laser texturing. This method enhances deposition efficiency and coating integrity by combining a rough, porous surface with reduced thermal conductivity, which facilitates polymer softening and anchoring. The findings establish bond-coat engineering as a practical strategy for achieving continuous, well-adhered PFA coatings, providing a new framework for extending cold spray technology to fluoropolymer applications.

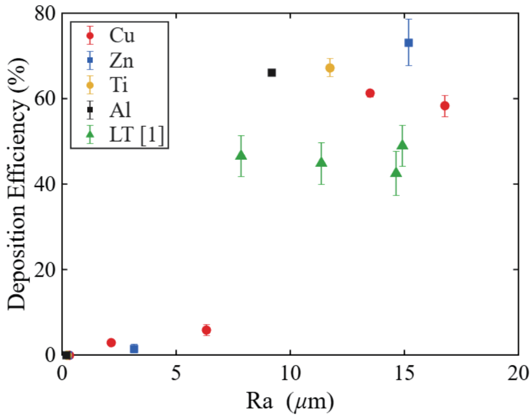

Fig. 1. Effect of Bond Coat Roughness on PFA Deposition Efficiency

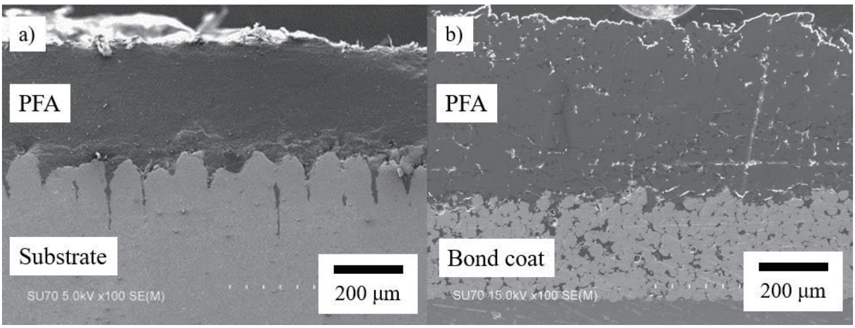

Fig. 2. Cross-sectional SEM images of (a) laser-treated substrate [2] and (b) Ti bond coat with PFA deposited

Keywords: Cold spray, Fluoropolymer coatings, Bond coat, Surface roughness

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Session V | Process Diagnostics and Modeling

Session Chair: Mohammed Shahien (AIST), Yang Rui (NIMTE-CAS)

November 17th (Monday) Room B 15:20~17:40

15:20-15:40	Invited Real-time High-Velocity Visualization of Ceramic Particle Impact on Metal Substrate in Cold Spray *Shuo Yin (Trinity College Dublin)*
15:40-16:00	Invited Evaluation of Mechanical Properties of APS Y_2O_3 Coatings via Micropillar Compression Test *Sung-Gyu Kang (Gyeongsang National University)*
16:00-16:20	CFD Study and Performance Evaluation of a New Cascaded Plasma Spray Torch *Byeongryun Jeon (Korea Institute of Materials Science)*
16:20-16:40	Study of Nozzle Influence on Aerosol Deposition (AD) by using 3D CFD Simulations *Julio Gutierrez De Frutos (Helmut Schmidt University)*
16:40-17:00	Numerical and Experimental Study of In-flight $MgAl_2O_4$ Particles in Atmospheric Plasma Spraying under Arc Current Variation *Byeong-il Min (Korea Institute of Materials Science)*
17:00-17:20	Automated Porosity Evaluation of Thermal Barrier Coatings via CNN-Based Semantic Segmentation *Byeongryun Jeon (Korea Institute of Materials Science)*
17:20-17:40	3D CFD Simulation of Substrate Angle Influence on Bow Shock Effects in Cold Spray (CS) *Julio Gutierrez De Frutos (Helmut Schmidt University)*

Abstract (ATSC 2025)

Metal matrix composites (MMCs) are an important branch of materials capable of being manufactured using cold spray. These coatings comprise of metal powders mixed with a low weight percentage of ceramic powders which act as a reinforcement for the metallic coating, which in turn improve its mechanical properties [2-4]. Previous research has shown a higher retention of smaller, fragmented ceramic particles in the coating lead to better material properties, but an inhomogeneous material distribution at the substrate-coating interface [5]. Numerical studies have also been proposed to better understand the ceramic-substrate interaction, but these studies have been restricted to spherical powder morphologies which are less common in MMCs [1]. In this work, Laser Ablation, Particle Acceleration and Observation (LAPAO) is utilized to study the fragmentation and embedment velocities of ceramic particles as they impact metallic substrates to better understand how the coating-substrate interface can be improved. Through varying particle morphology, velocity and substrate surface roughness a better understanding of the primary mechanism behind ceramic particle embedment is gained, concluding that spherical ceramic particles fragmentation and embedment are independent of velocity, but primarily dependent on irregularities formed during the powder fabrication process. Additionally, angular ceramic particles fragment and embed at much lower velocities making them much more suitable for MMCs being made with the intention of increasing material hardness.

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Evaluation of Mechanical Properties of APS Y_2O_3 Coatings via Micropillar Compression Test

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Abstract: Yttrium oxide (Y_2O_3) is widely used as a plasma etching-resistant material in semiconductor manufacturing industry due to its excellent resistance to halogen-based plasma etching processes. As the aspect ratio of semiconductor devices increases and higher etching power is required, the mechanical properties of Y_2O_3 coatings become critical in determining their durability and effectiveness. Evaluating the mechanical properties of thermal spray coatings has traditionally relied on methods such as Vickers hardness and nanoindentation test. However, these methods offer limited insight into the effect of internal defects in coatings on mechanical performance. In this study, micropillar compression test was applied to assess the mechanical properties of thermal spray coatings, considering the influence of coating microstructures and defects. Micropillar compression tests were conducted on Y_2O_3 coatings under various spraying parameters. The microstructure of Y_2O_3 coatings were observed by scanning electron microscopy (SEM) and the correlation between the microstructure and mechanical properties were investigated.

Acknowledgment:

Keywords: Micropillar compression test; Mechanical properties; Atmospheric plasma spraying; Yttrium oxide; Microstructure

References

CFD Study and Performance Evaluation of a New Cascaded Plasma Spray Torch

[1, 2]Byeongryun Jeon, [1]Byeong-il Min, [1]Do Hyun Kim, [1]Youngjin Park, [1]Yong-jin Kang, [1]Hunkwan Park*

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Abstract: In plasma spraying, an electrically generated, ultra-high-temperature (≈10^4 K) ionized gas jet melts and accelerates fine powder particles toward a substrate. The arc-driven jet provides high thermal capacity and independently tunable enthalpy and momentum via discharge current and plasma-gas composition, enabling melting of refractory ceramics while tightly controlling heat input. It is widely used in aerospace, power generation, and manufacturing to deposit thermal barrier coatings and wear- and corrosion-resistant overlays on critical parts [1]. Conventional atmospheric plasma spray (APS) torches typically demand high-rating power supplies (≈80 kW). To lower electrical demand while maintaining jet stability for coating processes, we designed a cascaded-anode plasma spray torch for stable, low-power operation (≈30 kW).
Performance was evaluated via computational fluid dynamics under the LTE assumption, implemented in OpenFOAM [2]. The multi-physics framework solves the coupled electromagnetic, flow, and energy equations with Joule heating and radiative losses. Temperature- and pressure-dependent thermodynamic and transport properties are employed for an Ar-N_2 plasma-forming gas mixture [3].
Performance is assessed by analyzing (i) arc behavior (e.g., voltage characteristics and arc column shape), (ii) the internal flow field within the torch body (pressure, temperature, velocity, etc.), and (iii) the outlet jet (temperature and velocity profiles). Parametric scans over discharge current, total flow rate, and Ar-N_2 mixing ratio are conducted to map stability limits and identify operating windows that meet low-power targets. In future work, downstream particle injection will be incorporated to verify that the predicted exit enthalpy and momentum are sufficient for effective spraying.

Keywords: Numerical Simulation, OpenFoam, LTE Assumption, Plasma Spraying Torch, Cascaded Plasma Torch.

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Study of nozzle influence on aerosol deposition (AD) by using 3D CFD simulations

Julio Gutierrez, Andreas Elsenberg, Luca Bachnick, Frank Gärtner, Thomas Klassen

Helmut Schmidt University - University of the Federal Armed Forces

Abstract:

In aerosol deposition, fine ceramic powders in sizes of less than typically 5 µm are deposited as a coating at room temperature. Aerosol deposition must be performed under a vacuum to apply such fine powders and avoid bow shock effects. According to experimental results, coating formation by aerosol deposition only occurs if particle velocities exceed a material-specific threshold velocity. Thus, knowledge of attained particle velocities over acceleration in the nozzle and under the expansion into a vacuum is essential for deriving conditions for successful deposition. In the present study, 3D CFD simulations were used to investigate the key geometric variables in particle acceleration. Three different nozzle geometries were investigated: a converging nozzle, a converging-diverging nozzle, and a converging nozzle followed by a constant cross-section toward the exit. In addition, these three nozzle geometries were optimized to maximize the particle impact velocity. The results show that the converging-diverging nozzle supplies the highest particle velocities within this comparison. By the design optimization, the particle velocities can be improved for all the geometry types. The most promising geometry from the CFD optimization was manufactured and compared to the original one, providing a gain in particle velocity of 26%.

Note

I am submitting a second abstract for ATSC2025; however, I would like the abstract titled "3D CFD simulation of substrate angle influence on bow shock effects in cold spray (CS)" to be given priority for consideration, if only one presentation may be accepted. In that event, if feasible, I would be pleased to present the second topic as a poster.

Numerical and Experimental Study of In-flight $MgAl_2O_4$ Particles in Atmospheric Plasma Spraying under Arc Current Variation

[1]Byeong-Il Min, [1]Byeongryun Jeon, [1]Hansol Kwon, [1]Yeonwoo Yoo, [1]Do Hyun Kim, [1]Youngjin Park, [1]Yong-Jin Kang and [1]Hunkwan Park*

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Abstract: Atmospheric plasma spraying (APS) forms coatings by injecting particles into a thermally expanded plasma jet (on the order of 10^4 K and up to several $km \cdot s^{-1}$) and impinging the molten particles onto a substrate [1]. Plasma-jet temperature and velocity are governed primarily by gas composition (transport coefficients and thermodynamic properties), arc-current, and torch geometry [2]. In-flight particle temperature, velocity, and trajectory depend on the plasma-jet temperature and velocity as well as on particle thermophysical properties (e.g., heat capacity and density). Direct measurement of plasma-jet–particle interactions under such extreme conditions is limited, so APS optimization has largely relied on ex-situ coating characterization, which becomes time- and cost-intensive when new powders or operating conditions are introduced. Therefore, we develop a numerical method to quantify the effect of arc-current variation on in-flight $MgAl_2O_4$ particles, and we compare the numerical results with measurements of particle temperature and velocity [3]. The validated numerical method provides quantitative guidance, reduces trial and error, and offers a practical route to accelerate APS process optimization for $MgAl_2O_4$ and other ceramic powders.

Acknowledgment: This work was supported by the Korea Evaluation Institute of Industrial Technology (KEIT) grant funded by the Ministry of Trade, Industry and Energy (MOTIE, Republic of Korea) under Project No. RS-2024-00422158, "Development of high heat-resistant and corrosion-resistant ceramic coating materials, processes, and reliability evaluation technologies for hydrogen-fueled gas turbines." The authors also acknowledge the support of the Korea Institute of Materials Science (KIMS) through the Fundamental Research Program (No. PNKA430).

Keywords: Numerical Analysis, Thermal Plasma, Atmospheric Plasma Spraying (APS), In-Flight Particle, $MgAl_2O_4$, Magnesium Aluminate Spinel (MAS)

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Automated Porosity Evaluation of Thermal Barrier Coatings via CNN-Based Semantic Segmentation

[1, 2]Byeongryun Jeon, [1]Byeong-il Min, [1]Hansol Kwon, [1]Yeon Woo Yoo, [1]Sunghun Lee, [1]Hunkwan Park*

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Abstract: Thermal spraying propels molten feedstock onto component surfaces, enabling deposition of thermal barrier coatings (TBCs) and wear- or corrosion-resistant overlays on mission-critical hardware in aerospace, power, and manufacturing [1]. In particular, TBCs defend components at high temperatures by reducing effective thermal conductivity via pores distributed within the coating. However, porosity evaluation remains predominantly manual, time-consuming, and prone to operator subjectivity and inconsistent criteria.

This study conducts automated analysis of TBC microstructure images using CNN-based semantic segmentation to precisely delineate the topcoat and pores and to derive consistent porosity measurements. We constructed training and validation datasets by pixel-wise annotating micrographs into five classes: substrate, bond coat, topcoat, mounting resin, and pores. The encoder underwent staged transfer learning, first pretrained on the general-domain ImageNet corpus and subsequently on the microscopy-focused MicroNet [2], followed by fine-tuning on our task-specific dataset. To handle ultra-high-resolution images within GPU memory constraints, we employed overlapping tiling with weighted stitching to preserve full-field predictions. Robustness to domain shift (e.g., magnification, illumination, and specimen-preparation differences) was improved via data augmentation—brightness/contrast perturbations, noise and blur, rotations, and contrast normalization. Porosity was then computed in a region-of-interest–restricted manner by aggregating pore pixels only within the segmented topcoat mask, thereby excluding mounting resin and other non-relevant regions.

Although this study was trained and evaluated on a single sample, we plan to expand to a dataset comprising multiple samples that span diverse material chemistries, spray processes, and sample preparation/imaging conditions to enhance generalization and external validity. We further aim to establish a generalized, standardized workflow for automated porosity assessment that can be applied consistently across processes and facilities.

Keywords: Semantic Segmentation, Thermal Spraying, Porosity, Image Analysis

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3D CFD simulation of substrate angle influence on bow shock effects in cold spray

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Extended abstract

In cold spray, a high-velocity gas jet is used to transport and accelerate particles towards a substrate [1]. When the gas jet meets the substrate, it is drastically decelerated and deflected. The gas deceleration is associated with an increase in gas pressure, density, and temperature. The corresponding volume of this phenomena is known as the bow shock [2]. As a result of the low gas velocity and the high density, the sprayed particles inside the gas jet are decelerated in this region too, which is detrimental to the deposition efficiency and the coating quality [3]. Thus, reducing the bow shock effect while maintaining the particle velocities is beneficial for improved cold spray process performance.

It is well known that the adhesion of the deposited material highly depends on the particle velocities upon impact. More precisely, particle impact velocities need to be above the material depended critical velocities to achieve a 50% deposition efficiency [4]. However, the component of the particle impact velocity vector referred to here, is the one in the direction normal to the substrate [5], which is defined as the effective velocity. Thus, the effective velocity is always less than or equal to the particle impact velocity. In this study, 3D CFD simulations were performed to identify optimal spray angles at which the reduction of bow shock effects compensates for the decrease in effective particle impact velocities.

For the simulations, the process gas was set to nitrogen, with a pressure of 5 MPa and a temperature of 500 °C. Nitrogen was also used as carrier gas, at a temperature of 20 °C in combination with a mass flow rate corresponding to 5% of that of the process gas. The outlet was set to 0.1 MPa and 20 °C. The simulated powder was Al6061 with a homogeneous particle diameter of 47 µm. For the simulations, the substrate surface orientation was rotated between 0° and 30° about the Y and Z axes, as shown in Fig. 1, with 0° representing the angle at which the substrate's normal vector is parallel to the nozzle centerline.

Fig. 1 illustrates the variation in powder impact velocity and the volume of the bow shock under different spray angles. Both subfigures in Fig. 1 show similarities: the particle impact velocity and bow shock volume present maximum values at minimum axis rotations. Moreover, both show local minima at the maximum simulated angles. This results suggest that the reduction of the bow shock volume does not compensate for the decrease in effective particle velocity. In addition, the powder impact velocity exhibits a dependence on the substrate's rotation axis, a behavior not observed in the bow shock. This difference arises because impact velocity is a powder-related property, while the bow shock volume is a gas-related property. As a result, the gas shows axis-related symmetry, whereas the powder does not. The asymmetry occurs because the powder enters the system radially, as shown in Fig. 2. Finally, a local maximum in powder impact velocity is observed at a substrate rotation of approximately 4° about the Z-axis (Fig. 1a), indicating an optimum spray angle for the investigated conditions.

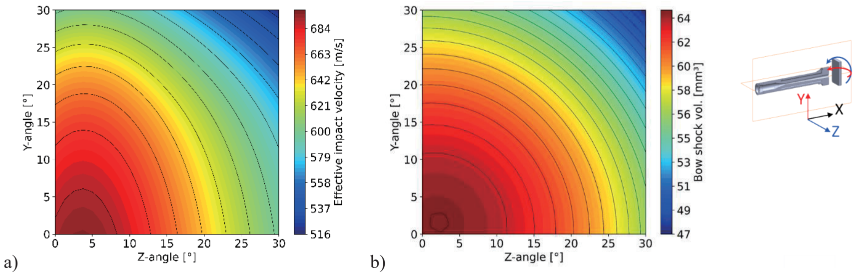

Fig. 1. Particle impact velocity (a) and bow shock volume (b) when rotating the substrate.

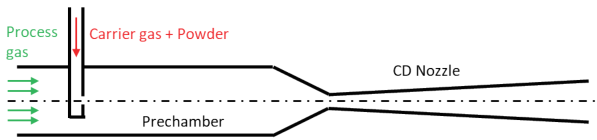

Fig. 2. Schematics of the powder injection geometry upstream of the prechamber.

Acknowledgment: This research in the frame of the project ‘‘CORE – Computerized Refurbishment’’ and the used computational resources (HPC cluster HSUper) are both funded by dtec.bw – Digitalization and Technology Research Center of the Bundeswehr, which we gratefully acknowledge. dtec.bw is funded by the European Union – NextGenerationEU.

Keywords: Cold Spray, Modeling, 3D CFD, Particle velocity.

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Session VI

Session Chair: Kazuhiro Ogawa (Tohoku University), Shrikant Joshi (University West)

November 18th (Tuesday) Room A 09:00-12:10

09:30-10:10	Plenary Liquid Feedstock Thermal Spraying: Unlocking the Next Frontier? *Shrikant Joshi (University West)*
10:10-10:50	Plenary TBC and EBC Technologies for Aviation Gas Turbine Engine *Yeon-Gil Jung (Changwon National University)*
11:10-11:40	Keynote A Bimodal-Structured Coating with Columnar/Lamellar Trans-Scale Features for Strain-Tolerant and Thermal Insulative Performances *Guang-Rong Li (Xi'an Jiaotong University)*
11:40-12:10	Keynote Effect of Cooling Rate after Fusing on the Microstructural Evolution of a Ni-based Self-fluxing Alloy *Tatsuya Tokunaga (Kyushu Institute of Technology)*

Plenary Lecture

Title	Prof.	First Name	Shrikant	Last Name	Joshi
Affiliation			University West		
Presentation Title			Liquid feedstock thermal spraying: Unlocking the Next Frontier?		
Abstract			While thermal spraying has long served as an industrial mainstay for protective and functional coatings, the reliance on powder feedstocks has imposed inherent limits on microstructural refinement and compositional flexibility. Liquid feedstock thermal spraying, mainly encompassing *suspension plasma spraying (SPS)* and *solution precursor plasma spraying (SPPS)*, is redefining these boundaries by respectively enabling either delivery of submicron or nano-sized powders into a plasma jet or their synthesis in flight. These approaches bypass challenges in feeding ultrafine powders while offering unprecedented control over coating architecture and chemistry. Recent advances in axial feed capable plasma torches appear well-placed to accelerate interest in the above approaches by ensuring efficient heat transfer, higher throughputs, and reproducible coating quality, positioning liquid feedstock spraying closer to industrial viability. Moreover, hybrid powder–liquid strategies now allow layered, composite, and functionally graded coatings that combine the robustness of powders with the versatility of liquid feedstock routes. This talk will highlight how liquid feedstock spraying can bring together chemistry, plasma physics, and process innovation to unlock the next frontier in advanced coatings. Recent examples from our group will be presented to Illustrate the promise of suspensions and solution precursors to reshape the landscape of thermal spray science.		

Plenary Lecture

Title	Prof./Dr.	First Name	Yeon-Gil	Last Name	Jung
Affiliation			Changwon National University		
Presentation Title			TBC and EBC Technologies for Gas Turbine		
Abstract			Currently, Ceramic Matrix Composites (CMCs) are employed in hot-section components of gas turbines including turbine shroud and vane, blade, blisk, nozzle flap/seal where they provide enhanced durability at elevated temperatures. Their application is expected to expand in both commercial and military engines, highlighting the need for a better understanding of damage mechanisms, failure modes, and predictive tools to ensure safe and reliable operation. Nevertheless, prolonged exposure to harsh environments such as high-temperature steam, molten salts, and oxidative atmospheres can lead to surface oxidation, volatilization, and internal degradation in CMCs. To mitigate these issues, Environmental Barrier Coatings (EBCs) are essential. In particular, rare-earth silicate-based EBCs offer chemical stability and thermal expansion compatibility with CMC substrates. Recent researches have focused on Thermal-Environmental Barrier Coatings (T-EBCs), which integrate the thermal insulation of conventional Thermal Barrier Coatings (TBCs) with environmental protection. These multifunctional coatings improve both thermal and structural stability, enabling long-term performance of CMCs under extreme conditions. In today's presentation, the key properties of TBCs and EBCs including T-EBCs are reviewed, and the strategic directions for the design of reliable coating systems for ultra-high-temperature structural applications are discussed and proposed.		

Keynote Lecture

<table>
<tr><td>Title</td><td>Associate Professor</td><td>First Name</td><td>Guang-Rong</td><td>Last Name</td><td>Li</td></tr>
<tr><td colspan="3">Affiliation</td><td colspan="3">Xi’an Jiaotong University</td></tr>
<tr><td colspan="3">Presentation Title</td><td colspan="3">Structure designs for durable thermal barrier coatings in multi-scales</td></tr>
<tr><td colspan="3">Abstract</td><td colspan="3">Long life span is a basic support for thermal insulation function of thermal barrier coatings (TBCs). However, it is difficult to simultaneously achieve these two performances in conventional lamellar or columnar TBCs, which often have to sacrifice one performance due to limit of the mono-featured structure. In this work, a bimodal-structured coating with columnar/lamellar trans-scale features was designed to meet multiple requirements. The micro-lamellar structure was deposited to effectively prevent heat flux, and the macro-columnar structure was tailored to tolerate strain. Firstly, a method to prepare and tailor the bimodal-structured coating was proposed. From the view of thermal insulation, thermal conductivity of the bimodal-structured coating was comparable to the typical lamellar structure. From the view of durability, thermal cyclic life span of the bimodal-structured coating can be extended significantly compared to the typical lamellar structure. Subsequently, the macro-columnar structures were optimized based on tailoring the distance between neighboring vertical cracks, L, and coating thickness, h, and a finite element model was developed to investigate the optimization of the geometry of such coatings. Overall, the bimodal-structured coating is expected to co-enhance thermal insulation and thermal cyclic performances, which represents a fundamental step toward the development of advanced TBCs for future applications.</td></tr>
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Invited Lecture

Title	Professor	First Name	Tatsuya	Last Name	Tokunaga
Affiliation			Kyushu Institute of Technology		
Presentation Title			Effect of cooling rate after fusing on the microstructural evolution of a Ni-based self-fluxing alloy		
Abstract			The effect of cooling rate after fusing treatment on microstructural evolution and hardness of a nickel-based self-fluxing alloy has been investigated to obtain fundamental knowledge for optimizing of fusing condition. The simulated thermal spraying and fusing specimens with cooling rates ranging from 10 to 300 °C/min were prepared using differential thermal analysis (DTA) apparatus. Microstructure observations were performed using optical microscopy, electron probe microanalysis (EPMA), X-ray diffraction (XRD) measurements, and electron back-scattered diffraction pattern (EBSP) analysis. Phase identification revealed existence of (Ni), Ni_3B, Ni_5Si_2, MB, M_7C_3 and M_6C in all specimens. Therefore, it was found that within the range of cooling conditions adopted in this study, the cooling rate after fusing process did not affect phases formed. On the other hand, the cooling rate was found to influence the microstructural morphology, and increasing cooling rate promoted the grain refinement of ((Ni)+Ni_3B) eutectic structure and the formation of ((Ni)+Ni_3B+Ni_5Si_2) eutectic structure. The hardness of the region composed of the ((Ni)+Ni_3B) and ((Ni)+Ni_3B+Ni_5Si_2) eutectic structures increased with increasing cooling rate due to grain refining of ((Ni)+Ni_3B) eutectic structure and the increase in the ((Ni)+Ni_3B+Ni_5Si_2) eutectic structure region. The continuous cooling transformation (CCT) diagram during the cooling process after fusing process of the nickel-based self-fluxing alloy was estimated from DTA cooling curves. The obtained CCT diagram and hardness data would be useful to optimize fusing condition and hardness of nickel-based self-fluxing alloy coating.		

Session VII | TBCs & High-Temp Coatings I

Session Chair: Xiaohua Feng (NIMTE-CAS), Hwasung Yeom (POSTECH)

November 18th (Tuesday) Room B 13:00~14:30

13:00-13:30	Keynote Pre-Oxidation Effects on the Thermal-Fatigue Behavior of Thermal Barrier Coatings *Sunghun Lee (Korea Institute of Materials Science)*
13:30-13:50	Invited Doosan Enerbility's Thermal Barrier Coating Technologies for Advanced Next-Generation Gas Turbines *Kwangyong Park (Doosan Enerbility)*
13:50-14:10	Invited High-Temp Coating Systems for Aero Engines *Keekeun Kim (Agency for Defense Development)*
14:10-14:30	Invited Effect of Hf, Si, Ta, Re Additions to NiCoCrAlY Bond Coats on Oxidation Behavior up to 15,000 Hours at 1,000°C *Hansol Kwon (Korea Institute of Materials Science)*
14:30-14:50	Composition-Dependent Tetragonality and Mechanical Behavior of High Entropy Oxides *Janghyeok Pyeon (Changwon National University)*

Pre-oxidation Effects into the Thermal-Fatigue Behavior of Thermal Barrier Coatings

Sunghun Lee*, Young-Jin Park, Yong-Jin Kang, Hansol Kwon, Yeon-Woo Yu, Do-Hyun Kim, Hun-Kwan Park, Eungsun Byon

Extreme Materials Research Institute, Korea Institute of Materials Science, South Korea
*Corresponding author's Email: shlee@kims.re.kr

Abstract: This keynote will synthesize the state of the art on pre-oxidation for thermal barrier coatings (TBCs) and then introduce our recent EB-PVD studies that map processing–microstructure–lifetime links. From literature, pre-forming a thin, dense α-Al_2O_3 thermally grown oxide (TGO) can suppress transient θ/γ-Al_2O_3, reduce growth-stress and rumpling, and extend cyclic life—provided temperature–time–oxygen partial pressure are judiciously tuned. Building on this, we engineered TGO pre-growth on MCrAlY bond coats prior to 7–8 wt% YSZ top coats and quantified sensitivities: TGO thickness increases systematically with temperature (950→1100 °C) and pressure (0.5→3 mTorr), while a short pre-oxidation hold without oxygen has negligible effect. Under a standard furnace cyclic test (1100 °C, 50 min hot/10 min cool), benchmark EB-PVD TBCs spalled at ~700 cycles, whereas optimized pre-growth (e.g., 120 min, ≥1000 °C) yielded ≥800–925 cycles without spallation; pressure was comparatively less influential than temperature/time. Cross-sections reveal thicker, continuous α-Al_2O_3 (and late-stage spinel) with reduced interfacial cracking; an Al_2O_3 interlayer concept further tightened the TGO and curtailed crack initiation. We will conclude with a practical process map (T–t–pO_2) and design rules that couple pre-oxidation with graded/columnar architectures to target a sub-critical TGO thickness/roughness window for aero-engine duty, and outline open problems for modeling-assisted lifetime prediction.

Keywords: Thermal barrier coating (TBC), pre-oxidation, thermally grown oxide (TGO), EB-PVD, furnace cyclic test

Invited Lecture

Title	Senior Engineer	First Name	Kwangyong	Last Name	Park
Affiliation			Doosan Enerbility		
Presentation Title			**Doosan Enerbility's Thermal Barrier Coating Technologies for Advanced Next-Generation Gas Turbine**		
Abstract			In the face of global climate goals, high-efficiency gas turbines are vital for complementing renewable energy and ensuring a stable power supply. Doosan Enerbility is leading this energy transition by applying its proprietary H-class gas turbine technology to develop next-generation, low-carbon power solutions. This presentation details Doosan's comprehensive roadmap for hydrogen and ammonia turbines, a strategy fortified by breakthroughs in advanced materials, specifically Thermal Barrier Coatings (TBC). Doosan's development plan is ambitious and multifaceted. For hydrogen, the company aims to complete a 400MW full-hydrogen turbine by 2027, a timeline positioned to outpace major global competitors by approximately three years. Additionally, a 90MW medium-sized full-hydrogen turbine, developed in partnership with Korea Western Power, is slated for completion in 2028. For existing infrastructure, Doosan is pioneering ammonia co-firing technology. The company has already successfully achieved a 30% co-firing rate with superior NOx emission control, demonstrating a pragmatic, short-term path to decarbonization. Central to these advancements is Doosan's expertise in high-temperature component technologies, including TBCs. These ceramic coatings are applied to gas turbine parts to protect them from extreme temperatures exceeding 1,500°C. This protection reduces thermal stress, prevents oxidation, and improves overall turbine efficiency and durability. Doosan's R&D has yielded a TBC system with a remarkably low thermal conductivity, a significant improvement over the conventional thermal conductivity of existing technologies. This is achieved through a multi-scale porous microstructure engineered for enhanced high-temperature performance. In conclusion, Doosan Enerbility's integrated roadmap, which merges a diversified turbine portfolio with cutting-edge material science, positions it as a global leader in the clean energy transition. By addressing critical technical challenges and forging strategic partnerships, Doosan is not only contributing to a sustainable future but also shaping the next generation of power generation technology.		

Invited Lecture

Title	Dr.	First Name	Keekeun	Last Name	Kim
Affiliation			**Agency for Defense Development**		
Presentation Title			**Toward Technological Independence: Development Status of High-Temperature Coating Systems for Aero Engines**		
Abstract			Recent successes in the export of domestically developed defense systems have accelerated interest in the indigenous development of advanced aerospace propulsion technologies. Along with the achievements of the KF-21 fighter jet and the medium-altitude unmanned aerial vehicle (MUAV), expectations for local aerospace capabilities have risen considerably. However, the aero-engines that power these systems remain entirely dependent on foreign technology. To achieve genuine technological independence, it is essential to establish high-temperature component technologies, particularly thermal barrier coating (TBC) technologies, which are indispensable for high-performance engines. Because the core TBC processes especially electron-beam physical vapor deposition (EB-PVD) and atmospheric plasma spray (APS) coatings are subject to strict export controls, domestic development has become both critical and urgent. This talk introduces ongoing research to design, manufacture, and demonstrate domestic coating facilities and processes for these technologies. The newly developed EB-PVD and APS systems were successfully operated, and effective coatings were formed on test specimens through process optimization. In-house furnace thermal tests confirmed that the coatings achieved durability performance meeting internal qualification standards. Based on these results, prototype engine components have been coated using the developed equipment, and engine-level testing is scheduled to verify performance under actual operating conditions. This research marks Korea's first successful localization of EB-PVD coating equipment under strict international technology restrictions and demonstrates the technical feasibility and readiness of domestic high-temperature coating production. Moving forward, to realize mass production of reliable coatings and support the future export of indigenous engines, close collaboration among industry, academia, and research institutes, together with continued investment in core materials technology, will be essential. Acknowledgements: This research was financially supported by the Institute of Civil Military Technology Cooperation funded by the Defense Acquisition Program Administration and Ministry of Trade, Industry and Energy of Trade of Korean government under grant No. UM24308RD3		

Effect of Hf, Si, Ta, Re additions to NiCoCrAlY bond coats on oxidation behavior up to 15,000 hours at 1,000℃

[1]Hansol Kwon, [1]Yong-Jin Kang, [1]Yeon Woo Yoo, [1]Do Hyun Kim, [1]Eungsun Byon*

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Abstract: Thermal barrier coatings (TBCs) are widely applied to protect high-temperature components in gas turbines from thermal and oxidative degradation. Among these, NiCoCrAlY bond coats are used to improve long-term oxidation resistance by forming a stable thermally grown oxide (TGO) layer. In this study, the long-term oxidation behavior of commercial NiCoCrAlY bond coat alloys containing Hf, Si, Ta, and Re was investigated after exposure for up to 15,000 h at 1,000 °C. The TGO thickness was measured at selected time intervals, and the oxidation kinetics were quantified by calculating the parabolic rate constant (Kp) from the growth data. The results revealed that the basic NiCoCrAlY composition exhibited the lowest Kp value, indicating the slowest oxidation rate. The addition of Hf and Si led to the highest Kp value, signifying accelerated oxidation. In contrast, when all four elements (Hf, Si, Ta, and Re) were incorporated, the Kp value decreased compared to the Hf–Si-containing alloy. These findings suggest that while Hf and Si promote faster oxide growth, the presence of Ta and Re mitigates this effect by retarding the interdiffusion of bond coat constituents, thereby suppressing oxidation. This study presents direct experimental results from long-term (15,000 h) oxidation testing, accompanied by detailed microstructural observations. Notably, it reports for the first time a comprehensive microstructural analysis of NiCoCrAlY bond coats containing Hf, Si, Ta, and Re, providing valuable insights for the design of next-generation TBC systems with improved durability under prolonged high-temperature service.

Acknowledgment: This work was supported by the Korea Evaluation Institute of Industrial Technology (KEIT) grant funded by the Ministry of Trade, Industry and Energy (MOTIE, Republic of Korea) through the project titled "Development of high heat-resistant and corrosion-resistant ceramic coating materials, processes, and reliability evaluation technologies for hydrogen-fueled gas turbines" (Project No. RS-2024-00422158).

Keywords: Thermal barrier coating (TBC); Bond coat; Isothermal oxidation; Microstructure

Session VIII | Wear/Corrosion

Session Chair: Tatsuya Tokunaga (Kyushu Institute of Technology),
Chunjie Huang (Northwestern Polytechnical University)

November 18th (Tuesday) Room A 13:00~14:50

13:00-13:30	Keynote Fe-Ce-Mo-Based Metamorphic Alloy Coatings with Excellent Wear and Corrosion Resistances Fabricated via Thermal Spray Process *Kee-Ahn Lee (Inha University)*
13:30-13:50	Invited Damage-Tolerant Surface Protection for Biomass Boiler Tubes via FeAl Intermetallic Layers Formed by Cold-Sprayed Al on Fe Substrate *Jirasak Tharajak (Rajamangala University of Technology Phra Nakhon)*
13:50-14:10	Slag Corrosion Resistance of Yb-silicate Materials for IGCC Protective Coatings *Min-Soo Nam (Korea Institute of Ceramic Engineering and Technology)*
14:10-14:30	Improving the Corrosion Resistance of Cold Spraying 7075 Al Repair Deposits by Pulsed Laser Heat Treatment *Jihao Shen (Xi'an Jiaotong University)*

Fe-Ce-Mo based metamorphic alloy coatings with excellent wear and corrosion resistances fabricated via thermal spray processe

[1]Kee-Ahn Lee, [1]Yong-Hoon Cho, [1]Kyung-Un Won, [1]Yu-Jin Hwang. [2]Gi-Su Ham, [2]Choongnyun Paul Kim, [3]Geun-Sang Cho,

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A cost-effective Fe-Cr-Mo based metamorphic alloys were newly designed and fabricated as coating material using the high-velocity oxygen fuel (HVOF) and atmospheric plasma spray (APS) thermal spray processes, and its microstructure, wear resistance, corrosion resistance were investigated in comparison with a conventional HVOF WC-12Co coating. The metamorphic coating material consisted of a splat area and un-melted powder area. The splat area contained metallic glass, $(Cr,Fe)_2B$, Cr_2B, and minor Fe-based BCC phases, and the un-melted powder area was composed of Fe-based BCC, $(Cr,Fe)_2B$, and Cr_2B phases. Room-temperature wear tests revealed that HVOF metamorphic coating material exhibited wear resistance comparable to HVOF WC-12Co coating and even superior performance at high-stress wear conditions. The corrosion resistance of APS metamorphic coating material significantly improved by addition of Mo and Nb elements. This superior wear behavior of metamorphic coating material was mainly attributed to the minimal hardness difference between the metallic glass and boride, the plasticity of the metallic glass, and the formation of a lubricating tribofilm. Based on the above results, the wear and corrosion mechanisms of Fe–Cr–B based metamorphic alloy coating layers were also discussed.

Damage-Tolerant Surface Protection for Biomass Boiler Tubes via FeAl Intermetallic Layers Formed by Cold-Sprayed Al on Fe Substrate

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Abstract: Biomass boiler superheater tubes are susceptible to failure from high-temperature hot corrosion and solid-particle erosion, driven by molten alkali-salt deposits ($KCl–K_2SO_4$) near 700 °C. To overcome these challenges, FeAl diffusion layer was developed to mitigate this degradation. The process involves cold-spraying ~200 µm of aluminum onto steel, followed by 800 °C interdiffusion to form a continuous FeAl layer. This method is benchmarked against conventional pack aluminizing (900 °C anneal). The protection concept leverages selective Al oxidation to create a slow-growing, highly adherent Al_2O_3 scale, which resists oxygen/halide ingress and spallation. Microstructural integrity was characterized by XRD and cross-sectional SEM/EDS. Performance was evaluated at 700 °C through oxidation, hot corrosion, and solid-particle erosion tests. The cold-spray route yielded a dense, continuous FeAl layer with superior erosion resistance compared to the pack aluminizing reference. This method is practical, manufacturable, and field-repairable, providing a viable solution for extending the service life of critical boiler components.

Keywords: FeAl intermetallic, Cold spray, Aluminizing, Biomass boiler, Hot corrosion

Slag Corrosion Resistance of Yb-silicate Materials for IGCC Protective Coatings

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Abstract: In coal-based power generation, Integrated Gasification Combined Cycle (IGCC) technology is gaining attention as a promising solution that has high efficiency and low environmental impact. However, the extreme conditions inside the gasifier, particularly the high temperatures and corrosive interactions with molten slag, pose significant challenges to the durability and performance of critical components such as burner muffles. This study investigates the corrosion behavior of Yb_2SiO_5 and its composites containing 5 wt.% and 10 wt.% Al_2O_3 under IGCC slag environments. Yb_2SiO_5 is known for its relatively high coefficient of thermal expansion (CTE) compared to other environmental barrier coating (EBC) materials. Moreover, the addition of Al_2O_3 aims to form garnet phases with higher CTE to prevent the mismatch with the substrate, thereby enhancing the overall CTE of the compositions. Bulk samples of Yb_2SiO_5 and its Al_2O_3 composites were exposed to molten slag. Subsequently, microstructural changes, phase transformations, and slag reaction layers were analyzed, and their schematic diagrams are shown in Fig. 1. Furthermore, the thermal expansion coefficients, thermal conductivity, and slag resistance of each composition were evaluated and compared. The results indicate that Yb_2SiO_5 demonstrates high thermal stability and forms a dense reaction layer that effectively prevented slag infiltration. Additionally, composites containing 5wt.% and 10wt.% Al_2O_3, showed improved thermal compatibility with the carbon steel substrate, increasing their CTE to 8.99×10^{-6} K^{-1} and 9.81×10^{-6} K^{-1}, respectively. The formation of the $Yb_2Si_2O_7$ phase further contributed to slag consumption during the reaction, suggesting its potential as a coating material.

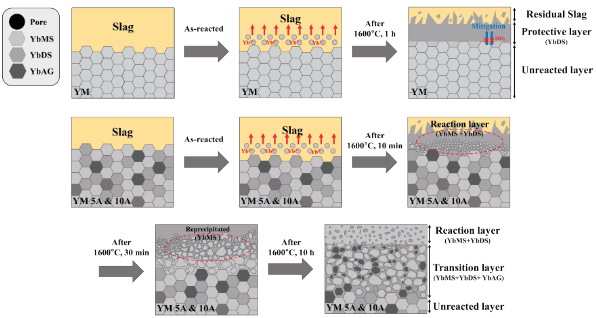

Fig. 1. Schematic diagrams of slag reaction mechanism for the different reaction times.

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Acknowledgment: This study was supported by the Public Trust Research and Development Program funded by Korea Western Power Co., Ltd. under the project titled "Development of Environmental Barrier Coating Technology for Improving Anti-Erosion Properties of IGCC Gasifier Components".

Keywords: Molten slag, Yb_2SiO_5, $Yb_2Si_2O_7$, $Yb_3Al_5O_{12}$, Corrosion resistance.

Improving the Corrosion Resistance of Cold Spraying 7075 Al Repair Deposits by Pulsed Laser Heat treatment

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Abstract: Cold spray has been demonstrated as a highly promising technique for the in-situ repair of high-strength aluminum alloy components. However, the unique work hardened microstructure of cold-sprayed Al deposits typically leads to significantly reduced corrosion resistance. Although heat treatment can improve the corrosion resistance of the deposits, conventional bulk heat treatment inevitably degrades the mechanical properties of the substrate. In this study, AA7075 aluminum alloy was selected as an example, and a novel pulsed laser heat treatment process was developed to locally modify the microstructure and enhance the corrosion resistance of cold-sprayed 7075 Al repair deposits. Under optimized conditions, this treatment effectively improved the corrosion resistance of the deposits, resulting in a uniform corrosion morphology with pit size reduced from 50–100 μm to 1–5 μm after immersion tests, while maintaining a narrow heat-affected zone (≤ 2 mm). Meanwhile, multiple microstructural and electrochemical analyses revealed the microstructural evolution (Fig. 1) and the mechanism of corrosion resistance enhancement (Fig. 2). The initial network-like structure, composed of solute segregations (Mg, Zn, Cu), amorphous phases, and minor η phase ($MgZn_2$), was dissolved and transformed into dispersed η precipitates after pulsed laser heat treatment. This transformation blocked the continuous penetration pathways for corrosive media, effectively confining corrosion to the surface. Additionally, pulsed laser heat treatment promoted recrystallization and reduced dislocation density, thereby suppressing galvanic corrosion between the deposit and the substrate. The results confirm that pulsed laser heat treatment is a highly effective localized post-processing method for enhancing the corrosion resistance of cold-sprayed high-strength aluminum alloy repairs.

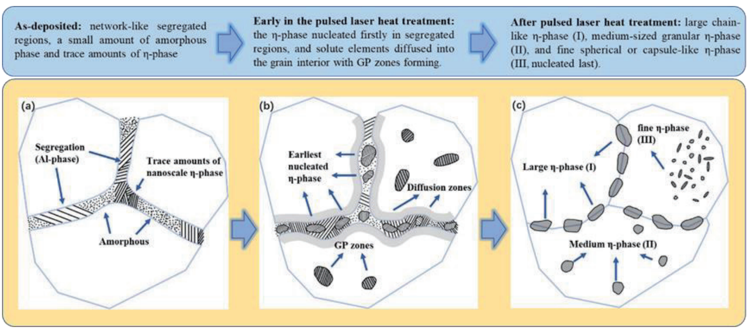

Fig. 1. A schematic diagram of repair deposit microstructure transformation mechanism during pulsed laser heat treatment; (a) the network-like solute element segregation within the repair deposit; (b) the nucleation of η phase and GP zones during pulsed laser heat treatment; (c) the dispersed granular

precipitates within the repair deposit surface after pulsed laser heat treatment, including three types of η phases.

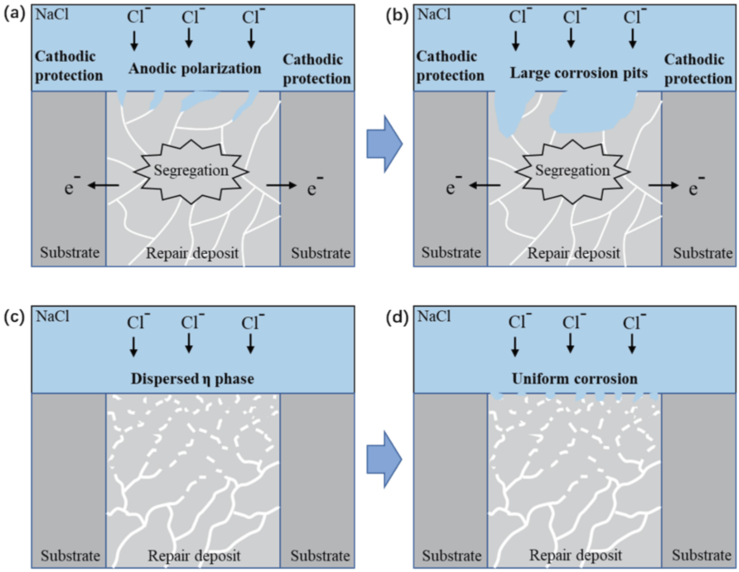

Fig. 2. A schematic diagram of the corrosion behaviour of the as-deposited and 120 T pulsed laser heat treated samples in the immersion test; (a) the anodic polarization behaviour and corrosion pits initiation on as-deposited repair deposit surface; (b) the large corrosion pits on the as-deposited repair deposit surface; (c) the dispersed η phase on the 120 T pulsed laser heat treated repair deposit surface; (d) the dispersed small corrosion pits on the 120 T pulsed laser heat treated repair deposit surface.

Acknowledgment: This work is supported by National Key R&D program of China (2024YFB4609600) and National Natural Science Foundation of China (52375379).

Keywords: Cold spray, pulsed laser, 7075 aluminum alloy, corrosion resistance, microstructural evolution.

Session IX | TBCs & High-Temp Coatings II

Session Chair: Sung-Gyu Kang (Gyeongsang National University), Shuo Yin (Trinity College Dublin)

November 18th (Tuesday)

Room A 15:10~16:10

15:10-15:30	MAX Phase as Bond Coats in Thermal Barrier Coating System *Hyokyeong Kim (Soongsil University)*
15:30-15:50	Phase Transformation Behavior and High-Temperature Durability of Rare Earth Oxide Co-Stabilized ZrO_2 *Tae-Jun Park (Korea University)*
15:50-16:10	Research on Oxidation Behavior of Ni-Al Coatings Fabricated by Twin Wire Arc Spray *Jae Woo Cho (Korea Institute of Materials Science)*

MAX phase as bond coats in thermal barrier coating system

[1]Hyokyeong Kim and [1,2]Jiwoong Kim *

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Abstract: Thermal barrier coatings (TBCs) are subjected to significant thermal and residual stresses, especially at high temperatures. They typically consist of a ceramic top coat (TC), a metallic bond coat (BC), and a superalloy substrate. Conventional metallic BCs require a minimal mismatch in the coefficient of thermal expansion (CTE) between the TC and the substrate to avoid stress-related failures. To address this limitation, BCs capable of mitigating thermal stresses more effectively are needed. MAX phases, which exhibit relatively high CTEs compared to other ceramics and can form dense protective oxides such as Al_2O_3, present a promising alternative. This study designs novel MAX phase BCs to enhance thermal shock and crack resistance, employing multi-scale simulations. We model various MAX phases with Al at the A-site and C or N at the X-site. Ab initio calculations are used to investigate the temperature dependence of the Young's modulus and CTE of these MAX phases. A small CTE mismatch between the MAX phase and the thermally grown oxides (TGOs) or substrate can effectively reduce thermal stresses. Furthermore, MAX phases exhibiting the highest high-temperature flexural strength demonstrate the highest crack resistance. These results provide valuable insights into the design of MAX phase bond coats for next-generation gas turbines and engine applications.

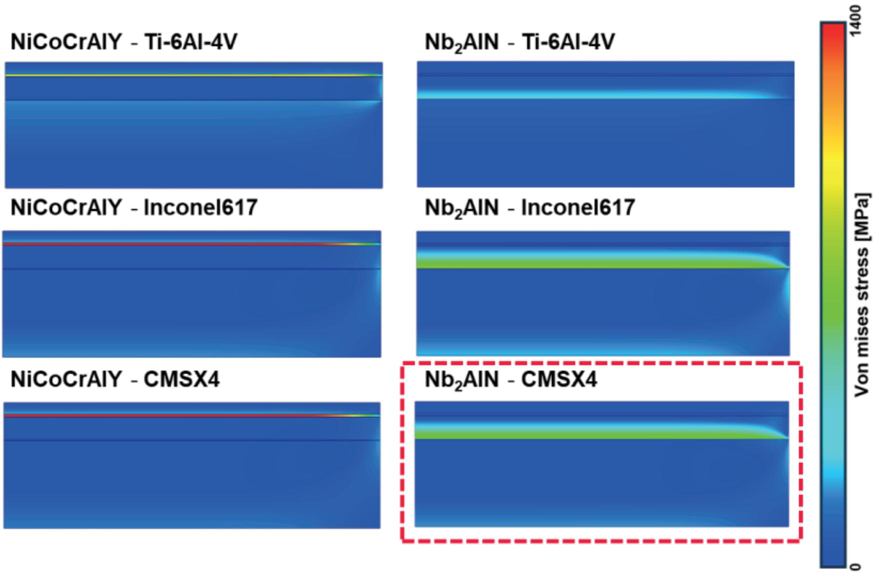

Fig. 1. Thermal stress distribution in the TBC system, comparing MAX phases with NiCoCrAlY

Acknowledgment: This work was supported by Korea Research Institute for defense Technology planning and advancement(KRIT) grant funded by the Korea government(DAPA(Defense Acquisition Program Administration)) (No. KRIT-CT-23-039, Development of multi-component Ultra-High Temperature Ceramic Coating Technology).

Keywords: MAX phase, Thermal barrier coating, Bond coat, Multi-scale simulation, Ab initio calculation

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Phase Transformation Behavior and High-Temperature Durability of Rare Earth Oxide Co-Stabilized Zirconia

[1,2]Tae-Jun Park, [1,2]Gye-Won Lee, [1] Jong-Il Kim, [2] Sahn Nahm, [1]Yoon-Suk Oh*

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Abstract: Thermal Barrier Coatings (TBCs) are protective systems designed to shield gas turbine components from heat in high-temperature combustion environments. They use Yttria-Stabilized Zirconia (YSZ), which has low thermal conductivity and excellent mechanical properties, as the top coat material for thermal barrier coatings. However, in response to climate change and following carbon neutrality policies, a transition from traditional fossil fuel-based combustion environments to hydrogen-based combustion environments is required. Hydrogen-based combustion environments are known to burn faster than fossil fuels and create high-temperature combustion conditions exceeding 1200°C. These combustion conditions exceed the maximum operating temperature of YSZ, necessitating research into materials that can be used in hydrogen combustion environments above 1200°C.

In this study, we aimed to develop compositions with low thermal conductivity and phase stability for use in high-temperature hydrogen combustion environments above 1200°C. First, various rare earth oxides were individually doped into zirconia to evaluate their effects on thermal conductivity and phase stability.

Bulk specimens were fabricated using pressureless sintering based on the designed compositions. X-ray diffraction (XRD) analysis was performed to analyze the monoclinic phase transformation behavior, and thermal conductivity was measured using Laser Flash Analysis (LFA) (Fig. 1).

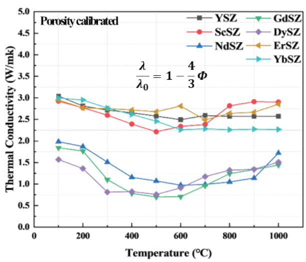

Fig. 1. Thermal conductivity of rare earth-doped zirconia ceramics

Keywords: thermal barrier coating, rare-earth-stabilized zirconia, phase stability, thermal conductivity

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Research on Oxidation Behavior of Ni-Al coatings Fabricated by Twin Wire Arc Spray

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Abstract: Ni-Al based coatings are commonly used under high-temperature and corrosive conditions, such as boiler tubes in thermal power plants. Twin-wire arc spray (TWAS) is one of the most widely used types of thermal spraying technologies, offering low cost, high deposition rate, and excellent field usability. In this study, Ni, Ni-5Al, and Ni-20Al coatings were deposited onto High Strength Low Alloy (HSLA) steel substrates using the TWAS process to investigate their protective effects under high-temperature conditions. Oxidation tests were carried out on coated and bare samples in air at 900°C. The effect of Al content on the Ni-Al coating was examined through microstructural analysis depending on high-temperature exposure time. As a result of the oxidation tests, the oxidation resistance of all coated samples was improved. The presence of Al in the coating suppressed internal oxide formation and decreased the thickness of the interdiffusion zone between the Ni–Al coating and the substrate. Among all the coatings, the Ni-20Al coating exhibited the highest oxidation resistance, which was attributed to the formation of a protective oxide scale.

Keywords: Twin wire arc spray, HSLA, Ni-Al coatings, Microstructure, High temperature oxidation

Session XI

Session Chair: Eungsun Byon(Korea Institute of Materials Science),
Kazuhiro Ogawa (Tohoku University)

November 19th (Wednesday) Room A 09:30~10:50, 11:10~11:50

09:30-10:10	Plenary Advancements of High Temperature Coating for SiCf/SiC Composite *Jingyang Wang (IMR-CAS)*
10:10-10:50	Plenary High-Temperature Wear and Thermal Properties of Plasma-Sprayed Mullite-Based Nanocomposite Coatings *Peerawatt Nunthavarawong (King Mongkut's University of Technology North Bangkok)*
11:10-11:30	Toughening of Plasma-Sprayed Ceramic Coatings via Carbon Nanotube Reinforcement and Controlled Inter-Splat Bonding *Peng-Yan Shi (Xi'an Jiaotong University)*

Advancements of high temperature coating for SiC_f/SiC composite

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[2]Liaoning Academy of Materials, China
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Abstract: SiC_f/SiC composite is disruptive material for the hot-section components in new generation aviation engine. High temperature coatings, including thermal barrier coating, environmental barrier coating, as well as abradable coating, can protect various SiC_f/SiC components against harsh thermal and chemical attacks in combustion environment. The request for service temperature of coatings has been critically increased up to 1350 to 1500°C, regarding the various combustion environments. The key technology depends on the whole chain advancement of intelligent design, feedstock production, coating fabrication, and coating evaluations. This talk presents the recent progresses of high temperature coating technologies for SiC_f/SiC components in aviation engine. The developments support the explorations and applications of SiC_f/SiC composite in high-thrust aeroengine.

Keywords: High temperature coating, Thermal spray, Ceramic matrix composite, Evaluation.

High-Temperature Wear and Thermal Properties of Plasma-Sprayed Mullite-based Nano Composite Coatings

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Abstract: In this study, three plasma-sprayed coatings, M100 (100% mullite), M95 (95% mullite – 5%MCrAlY), and M90 (90% mullite - 5%MCrAlY - 5%nano-fly ash) were deposited on AISI 410 substrates. The objective was to assess the role of MCrAlY and nano-fly ash in improving coating performance. Notably, fly ash, an industrial by-product, was incorporated as a sustainable feedstock, aligning with cost-effectiveness and environmental considerations. According to the coefficient of thermal expansion (CTE) from room temperature to 900 °C, it was found that M90 (8.6×10^{-6} °C^{-1}) values are closer to the substrate (12.4×10^{-6} °C^{-1}) than M100 (5.8×10^{-6} °C^{-1}). This indicates that the addition of MCrAlY and nano-fly ash reduces thermal mismatch between the coating and substrate during heating. Thermal shock tests at 650 °C demonstrated that M90 (8×10^{-3} mg) showed intermediate mass loss, indicating balanced resistance under cyclic conditions, while high-temperature wear tests showed that M90 (4.72×10^{-4} mg/m) had the lowest wear rate compared with M100 (5.66×10^{-4} mg/m) and M95 (7.11×10^{-4} mg/m). Nano-indentation tests revealed that M90 achieved the highest hardness (8.71 GPa) and Young's modulus (138 GPa), confirming improved mechanical properties. These results highlight that combining MCrAlY with nano-fly ash in mullite-based coatings enhances both performance and sustainability.

Acknowledgment: This work was financially supported by King Mongkut's University of Technology North Bangkok (KMUTNB), Thailand, and the Electricity Generating Authority of Thailand with Contract No. 64-N201000-11-IO.SS03N3008589.

Keywords: mullite, nano-fly ash, thermal barrier coatings, plasma spray

Toughening of Plasma-Sprayed Ceramic Coatings via Carbon Nanotube Reinforcement and Controlled Inter-Splat Bonding

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Abstract: Plasma-sprayed ceramic coatings have been widely applied to industrial fields to protect metals from wear, corrosion and high temperature. However, the intra-splat microcracking due to quenching stress and inter-splat unbonded interfaces in the coatings degrade the coating performance. While the latter can be effectively addressed based on the critical bonding temperature theory, intra-splat cracking it has been regarded as intrinsic feature of the ceramic spraying process. Facing the challenge to suppress the intra-splat microcracking, in this study toughening of splats by introducing multi-walled carbon nanotubes (MWCNTs) as reinforcing agents into agglomerated Al_2O_3-TiO_2 feedstock powders is attempted. The splats and coatings were deposited by plasma spraying. The distribution and orientation of MWCNTs within the splats were analyzed, and the microstructure and fracture toughness of the coatings were evaluated. Results show that MWCNTs are well aligned following the flattening direction upon droplet impact. The significant improvement in fracture toughness is observed that is attributed to the effects of MWCNT reinforcement and controlled substrate temperature.

Session X | Functional Coatings

Chair: Jingyang Wang (IMR-CAS), Hiroki Saito (Tohoku University)

November 19th (Wednesday) Room B 15:10~16:10

15:10-15:30	Invited Multiphase Flows and Deposition Mechanisms in a LPPS (50–200 Pa) and an Atmospheric Long Laminar Plasma Spraying (ALPS) *Sen-Hui Liu (Xi'an Jiaotong University)*
15:30-15:50	Cold Spray Coating for Biomedical Applications *Hyuk Jun Lee (Cerectron)*
15:50-16:10	Examination into Intersplat Bonding of Atmospheric Plasma-sprayed NiCrCuMoB High Entropy Alloy Coating *Xin-Ru Li (Xi'an Jiaotong University)*

Multiphase flows and deposition mechanisms in a LPPS (50-200 Pa) processing and an atmospheric long laminar plasma spraying(ALPS)

<u>Sen-Hui Liu</u>[1,], Juan. P. Trelles[2] , Anthony B. Murphy[3]， Cheng-Xin Li[1*],Chang-Jiu Li[1],

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2. Department of Mechanical Engineering, University of Massachusetts Lowell, Massachusetts 01854, USA；

3. CSIRO Manufacturing, Lindfield NSW 2070, Australia)

Abstract: Progresses in an novel long laminar plasma spraying(ALPS), low-pressure supersonic plasma-induced physical vapor deposition of quasi-columnar ceramic coatings is presented. The shadowing effect, flash vaporization, breakup, and atomization of in-flight droplets at a chamber pressure of 200 Pa, and maximum distance of 2200 mm were clarified.The heating history, motion, and phase transformation of the powder in the LPPS and ALPS have been studied. The maximum substrate temperature ranges from 1100 ◦C to 1250 ◦C when the plasma plume impinges perpendicularly on the substrate at the distance from 800 mm to 1500 mm. It is also found that the Mach number of the LPPS plasma flow is 3.4. The numerical simulation predicts the maximum velocity and temperature of the plasma plume are 6474.8 m/s and 12823.7 K, respectively. Furthermore, the hybrid growth model of the vapor and droplet co-deposited coating is clarified in this paper.

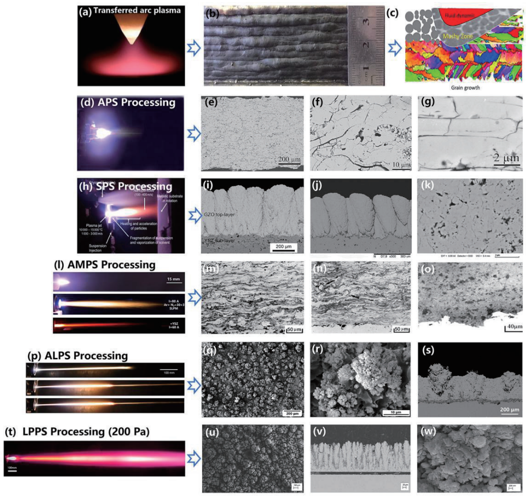

Fig. 1 (a) Transferred arc plasma processing [1]; (b) top surface view of alloys produced through arc-additive manufacturing [2]; (c) powder-bed additive manufacturing process [3]; (d) conventional atmospheric plasma spray processing (APS) [4] and (e-g) typical microstructures of /metallic ceramic coatings produced through APS [5],[6]; (h) atmospheric suspension plasma spray processing (SPS) [7] and (i-k) typical microstructures of the coatings synthesized through atmospheric SPS [8],[9]; (l) novel atmospheric micro plasma spray (AMPS) and (m-o) typical microstructures of AMPS-produced coatings; (p) atmospheric laminar plasma spray processing (ALPS) [10] and (q-s) typical microstructures of YSZ coatings produced through ALPS [11]; (t) low-pressure plasma spray (LPPS) processing and (u-w) typical microstructures of coatings [13] (Reproduced with permission © Springer Nature, IOP Publishing Ltd., & Elsevier B.V.)

Acknowledgment: The authors acknowledge the Massachusetts Green High-Performance Computing Center (MGH - PCC). This work was supported by the National Natural Science Foundation of China (Grant No. 52001017) and the National Science and Technology Major Project (No. 2017-V I -0010-0081, 2017-V I -0002-0072).

Keywords: Plasma Spray; Laminar Plasma Spray; Modelling simulation; TBCs; PS-PVD

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Cold spray coating for biomedical applications

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This paper demonstrates that the cold sprayed Hydroxy Apatite (HA) coating on the PEEK materials increased biocompatibility in vitro and promoted osteointegration in vivo, which suggests that the Hydroxy Apatite (HA) coating could improve the biofunctionality of various medical devices used in clinical applications.

Microstructure and Tribological Property Correlations in Cold-Sprayed Fe-Based Amorphous Alloy Coatings

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Abstract: Amorphous alloys possess a densely packed atomic structure based on short-range order. The absence of grain boundaries and dislocations mitigates local stress concentration, thereby suppressing crack initiation and propagation [1]. Furthermore, their high elastic limit and hardness lead to shallow and uniform surface deformation during contact, resulting in lower coefficients of friction (COF) and wear rate than crystalline alloys. This behavior is also advantageous for the rapid formation and maintenance of a continuous and stable protective tribofilm during sliding processes [2]. Cold spray (CS) is a solid-state, supersonic deposition process with particle bonding driven by severe plastic deformation and adiabatic shear under minimal thermal exposure [3]. As a result, melt-related oxidation and phase transformations are avoided. Consequently, CS is well suited for fabricating amorphous coatings. The low process temperature and limited thermal exposure preserve the amorphous fraction and suppress crystallization and oxidation during deposition [4]. Recent studies report that these benefits are maintained because cold spray proceeds as a solid-state deposition without melting.

In this study, amorphous coatings were fabricated under three conditions (CS1, CS2, and CS3) by varying the gas temperature of the cold spray process. XRD and DSC analyses confirmed that the amorphous phase was retained on a coating scale for all three conditions. Cross-sectional and surface observations (Fig. 1) revealed the coexistence of strongly bonded regions with weakly bonded areas, micropores, and microcracks, with limited oxygen signals observed near the particle boundaries. Pin-on-disk tests (counterbody : Al_2O_3 pin) yielded wear rates (Fig 2. (b)) of 1.27×10^{-5}, 2.02×10^{-5}, and 2.07×10^{-5} mm^3/mN for CS1, CS2, and CS3, respectively. These values demonstrate 2–4 times superior wear resistance compared with the same material deposited by HVOF in a previous study. The COF (Fig 2. (c)) stabilized most rapidly for CS1, while CS2 and CS3 were accompanied by initial fluctuations and a gradual increase. Analysis of the worn surfaces and cross-sections commonly showed abrasive grooves and oxide films. Delamination craters and crack propagation originating at interparticle boundaries were more frequent in CS2 and CS3. The tribological performance was found to be more significantly governed by the continuity and integrity of interparticle bonding than by hardness alone. For CS1, the small interfacial gaps and the continuous network of strong bonds resulted in shallow and uniform contact deformation This enabled early formation and stable retention of a protective tribofilm and led to the lowest wear rate (1.27×10^{-5} mm^3/mN) with a stable COF. In contrast, the interconnected network of weak bonds, pores, and cracks in CS2 and CS3 induced a cycle of local stress concentration, delamination, and subsequent tribofilm re-formation, resulting in increased wear rates of 2.02×10^{-5} and 2.07×10^{-5} mm^3/mN. In summary, it was confirmed that preserving the amorphous fraction while ensuring the continuity of strong interparticle bonding are the key design factors determining the stability of the tribofilm and the suppression of wear.

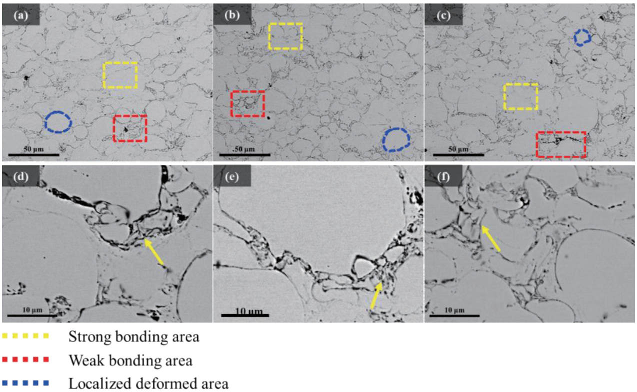

Fig. 1. Cross-sectional microstructure observation photographs of cold spray coating layers.
(a, d) CS1, (b, e) CS2, (c, e) CS3

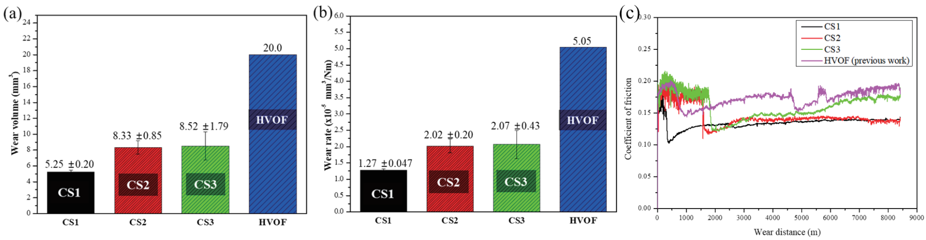

Fig. 2. Wear behavior of cold sprayed amorphous coating layers
(a) wear volume, (b) wear rate (c) coefficient of friction

Keywords: Cold spray, Amorphous alloy, Microstructure, Wear properties, Tribology

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Session XI

Chair: Eungsun Byon(Korea Institute of Materials Science),
Kazuhiro Ogawa (Tohoku University)

November 19th (Wednesday) Room A 09:30~10:50, 11:10~11:50

09:30-10:10	Plenary Advancements of High Temperature Coating for SiCf/SiC Composite *Jingyang Wang (IMR-CAS)*
10:10-10:50	Plenary High-Temperature Wear and Thermal Properties of Plasma-Sprayed Mullite-Based Nanocomposite Coatings *Peerawatt Nunthavarawong (King Mongkut's University of Technology North Bangkok)*
11:10-11:30	Toughening of Plasma-Sprayed Ceramic Coatings via Carbon Nanotube Reinforcement and Controlled Inter-Splat Bonding *Peng-Yan Shi (Xi'an Jiaotong University)*

Advancements of high temperature coating for SiC_f/SiC composite

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[2]Liaoning Academy of Materials, China
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Abstract: SiC_f/SiC composite is disruptive material for the hot-section components in new generation aviation engine. High temperature coatings, including thermal barrier coating, environmental barrier coating, as well as abradable coating, can protect various SiC_f/SiC components against harsh thermal and chemical attacks in combustion environment. The request for service temperature of coatings has been critically increased up to 1350 to 1500ºC, regarding the various combustion environments. The key technology depends on the whole chain advancement of intelligent design, feedstock production, coating fabrication, and coating evaluations. This talk presents the recent progresses of high temperature coating technologies for SiC_f/SiC components in aviation engine. The developments support the explorations and applications of SiC_f/SiC composite in high-thrust aeroengine.

Keywords: High temperature coating, Thermal spray, Ceramic matrix composite, Evaluation.

High-Temperature Wear and Thermal Properties of Plasma-Sprayed Mullite-based Nano Composite Coatings

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Abstract: In this study, three plasma-sprayed coatings, M100 (100% mullite), M95 (95% mullite – 5%MCrAlY), and M90 (90% mullite - 5%MCrAlY - 5%nano-fly ash) were deposited on AISI 410 substrates. The objective was to assess the role of MCrAlY and nano-fly ash in improving coating performance. Notably, fly ash, an industrial by-product, was incorporated as a sustainable feedstock, aligning with cost-effectiveness and environmental considerations. According to the coefficient of thermal expansion (CTE) from room temperature to 900 °C, it was found that M90 (8.6×10^{-6} °C^{-1}) values are closer to the substrate (12.4×10^{-6} °C^{-1}) than M100 (5.8×10^{-6} °C^{-1}). This indicates that the addition of MCrAlY and nano-fly ash reduces thermal mismatch between the coating and substrate during heating. Thermal shock tests at 650 °C demonstrated that M90 (8×10^{-3} mg) showed intermediate mass loss, indicating balanced resistance under cyclic conditions, while high-temperature wear tests showed that M90 (4.72×10^{-4} mg/m) had the lowest wear rate compared with M100 (5.66×10^{-4} mg/m) and M95 (7.11×10^{-4} mg/m). Nano-indentation tests revealed that M90 achieved the highest hardness (8.71 GPa) and Young's modulus (138 GPa), confirming improved mechanical properties. These results highlight that combining MCrAlY with nano-fly ash in mullite-based coatings enhances both performance and sustainability.

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Keywords: mullite, nano-fly ash, thermal barrier coatings, plasma spray

Toughening of Plasma-Sprayed Ceramic Coatings via Carbon Nanotube Reinforcement and Controlled Inter-Splat Bonding

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Abstract: Plasma-sprayed ceramic coatings have been widely applied to industrial fields to protect metals from wear, corrosion and high temperature. However, the intra-splat microcracking due to quenching stress and inter-splat unbonded interfaces in the coatings degrade the coating performance. While the latter can be effectively addressed based on the critical bonding temperature theory, intra-splat cracking it has been regarded as intrinsic feature of the ceramic spraying process. Facing the challenge to suppress the intra-splat microcracking, in this study toughening of splats by introducing multi-walled carbon nanotubes (MWCNTs) as reinforcing agents into agglomerated Al_2O_3-TiO_2 feedstock powders is attempted. The splats and coatings were deposited by plasma spraying. The distribution and orientation of MWCNTs within the splats were analyzed, and the microstructure and fracture toughness of the coatings were evaluated. Results show that MWCNTs are well aligned following the flattening direction upon droplet impact. The significant improvement in fracture toughness is observed that is attributed to the effects of MWCNT reinforcement and controlled substrate temperature.

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P20	Granular Manufacturing Technology and APS Coating and Evaluation Study for Yb-Disilicate Spray Coating for Environmental Barrier Coating *Jiyoo Kim (Sewon-Hardfacing)*

Hierarchical Microstructure–Mechanical Property Correlations In Superior Strength 5 wt% Cr Cold-Work Tool Steel Manufactured by Direct Energy Deposition

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Abstract: Metal additive manufacturing process technology holds great potential for a wide range of industries because it enables the immediate manufacture of optimized part geometries. Among the various metal additive manufacturing (AM) methods, direct energy deposition (DED), which is based on laser cladding engineering, uses an energy source to precisely deposit the feedstock onto a substrate. This method has the advantage of rapid manufacturing of parts with fewer size limitations [1]. Therefore, DED has shown promise in tool and die industries, where these advantages are most needed. The DED process enables rapid deposition and repair, providing an efficient approach to producing durable tool steel components. Cold-work tool steels offer excellent hardness, toughness, strength, and wear resistance, rendering them suitable for a wide range of industrial applications. Among these, 5 wt% Cr cold-work tool steel (Uddeholm Caldie) is known for its exceptional resistance to chipping and cracking as well as its high strength, making it ideal for use in cold-work parts, such as blanking dies, machine knives, rolling dies, and cold forging and trimming operations [2]. Compared with other high-carbon, high-chromium tool steels, Caldie materials have reduced carbon (0.7–0.8 wt%) and chromium (4.5–5.0 wt%) contents to mitigate the adverse effects of coarse carbides. Conversely, the molybdenum and vanadium contents are increased to precipitate various small carbides during heat treatment, forming uniform and fine-tempered martensite to improve the dimensional stability. Caldie steel offers excellent mechanical properties, availability, accessibility, and competitive pricing. This could provide attractive guidelines for its application in the high carbon tool steel sector, if successfully manufactured using the DED process. In addition, the microstructure and properties of tool steel parts manufactured by DED can be presented more objectively than those of conventional materials under the same conditions. However, to date, no studies have reported on the properties of 5 wt% Cr cold-work tool steel manufactured using the DED process. In this study, Caldie tool steel was fabricated via DED for the first time, and the effects of post-heat treatment on its hierarchical microstructure and mechanical properties were investigated and compared with those of wrought (reference) material. The as-built sample exhibited a mixed microstructure comprising lath martensite, retained austenite, polygonal ferrite, and carbide networks, which transformed into full martensite with fine carbides after heat treatment (DED-HT). The tensile strength of the DED Caldie material increased from 1340 MPa to 1949 MPa after heat treatment, demonstrating superior strength compared to other heat-treated, DED processed high-carbon tool steels. Compared to DED-HT, the wrought material exhibited finer martensite, a more uniform Bain group distribution, and finer carbides, resulting in higher strength. This study provides insights into the effects of heat treatment on the hierarchical microstructure and mechanical behavior of Caldie tool steel manufactured by DED.

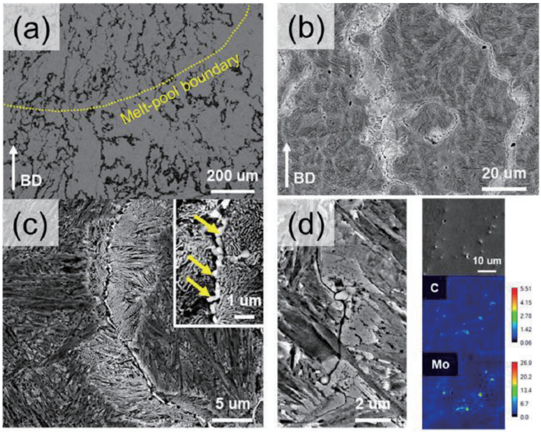

Fig. 1. (a) Low magnification OM image of layer-wise microstructure. (b) SEM image showing initial microstructures of the DED-built sample after etching. (c) Precipitate network formed along the build direction, (d) Prior austenite grain boundary region with C and Mo microsegregation.

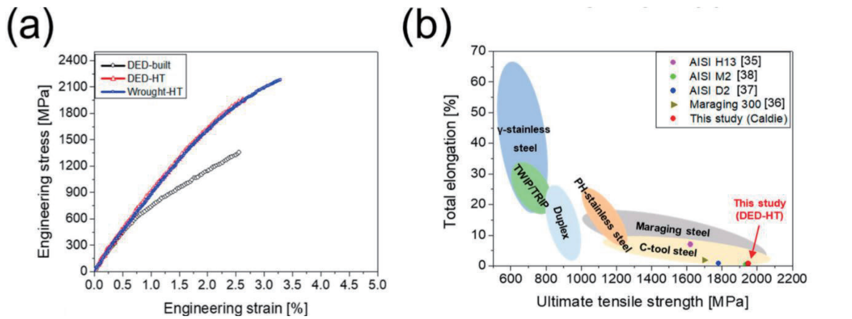

Fig. 2. Room-temperature mechanical properties of DED-built, DED-HT, and Wrought-HT 5 wt% cold-work tool steels: (a) tensile stress–strain curves (b) comparison of tensile properties between the DED-HT material and other high-strength steels fabricated by DED followed by post-heat treatment.

Keywords: direct energy deposition, 5 wt% Cr cold work tool steel, post-heat treatment, mechanical property

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Optimizing Electrostatic Chuck Performance through ZrO_2/Al_2O_3 ratio and Doping Components (SiO_2 and Y_2O_3)

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Abstract: Electrostatic chucks (ESCs) are essential components in semiconductor and display processing equipment. Recent research has explored the doping of Al_2O_3 with TiO_2 to enhance ESC performance by facilitating the transition to the Johnsen-Rahbek (J-R) mode. While this approach effectively improves clamping force, the lowered resistivity can compromise the electrical stability of the ESC, affecting its reliability during operation. In this study, we present the enhancement of ESC performance through ZrO_2/Al_2O_3 composites, with additional doping of Y_2O_3 and SiO_2. The composites were deposited by Atmospheric Plasma Spraying(APS). Fig. 1 shows electrical properties of APS-coated films as a function of ZrO_2-Al_2O_3 ratios. Notably, the mixed powder with the highest ZrO_2 content achieved a relative dielectric constant of about 22 with a volume resistivity of ~1.0×10^{14} Ω·cm. The increased dielectric constant and reduced resistivity induced J-R mode, leading to a clamping force of 25gf/cm^2 on glass substrate, exceeding the industrial requirement of 10~15gf/cm^2. Additionally, It demonstrated a breakdown voltage of approximately 4.2kV and a dielectric strength of about 17V/μm, indicating better voltage stability compared to traditional TiO_2-doped Al_2O_3. Our results demonstrate that ZrO_2-Al_2O_3 coatings, along with Y_2O_3 and SiO_2 doping, have potential as a promising alternative to TiO_2-doped Al_2O_3 chucks in advanced manufacturing applications.

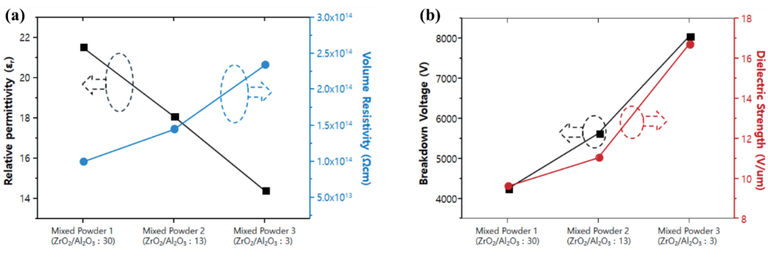

Fig. 1. Electrical properties of APS-coated films as a function of ZrO_2/Al_2O_3 ratios : (a) Relative dielectric constant and Volume resistivity; (b) Breakdown voltage and Dielectric strength

Keywords: Electrostatic chuck, Atmospheric plasma spraying, Johnsen-Rahbek effect, Dielectric strength

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Fabrication, microstructure, and mechanical properties of Fe-16Mn-10Al-5Ni-0.86C (wt.%) lightweight steel manufactured by directed energy deposition

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Abstract: Laser Directed Energy Deposition (L-DED), as an advanced Additive Manufacturing (AM) technology, provides an efficient approach for fabricating complex lightweight steel components [1,2]. However, due to a lower cooling rate compared to Laser Powder Bed Fusion (L-PBF), the microstructure of L-DED-fabricated materials is relatively coarse, limiting their mechanical properties [3,4]. Additionally, lightweight steels strengthened by κ-carbide tend to undergo microstructural coarsening during heat treatment, further weakening their strengthening effect. Therefore, developing suitable strengthening mechanisms for the L-DED process is crucial for optimizing material properties. In this study, B2-phase-strengthened Fe-16Mn-10Al-5Ni-0.86C (wt.%) lightweight steel was fabricated using the L-DED process, and the effects of heat treatment on its microstructure and mechanical properties were systematically investigated. Microstructural analysis revealed that the as-deposited sample consists of an FCC matrix phase and a BCC/B2 phase, with minor DO_3 precipitates, exhibiting columnar and dendritic structures. After heat treatment at 900°C for 1 hour, dislocation nucleation facilitated the precipitation of fine B2 phases, which were uniformly distributed within austenite grains and along grain boundaries, with an average size of 4.58 μm, accompanied by a small amount of fine κ-carbide. The dispersed distribution of precipitates significantly enhanced the lightweight steel's strengthening effect, optimizing the balance between strength and ductility. After heat treatment, the yield strength increased to 1058.4 MPa, the ultimate tensile strength reached 1423.5 MPa, and the elongation significantly improved to 16.3%, closely approaching the properties of the same composition lightweight alloy in the cold-rolled and tempered condition. This study demonstrates that the L-DED process, combined with appropriate heat treatment, effectively improves the mechanical properties of lightweight steel and provides theoretical guidance and process insights for microstructural control and performance optimization in L-DED-fabricated lightweight steels.

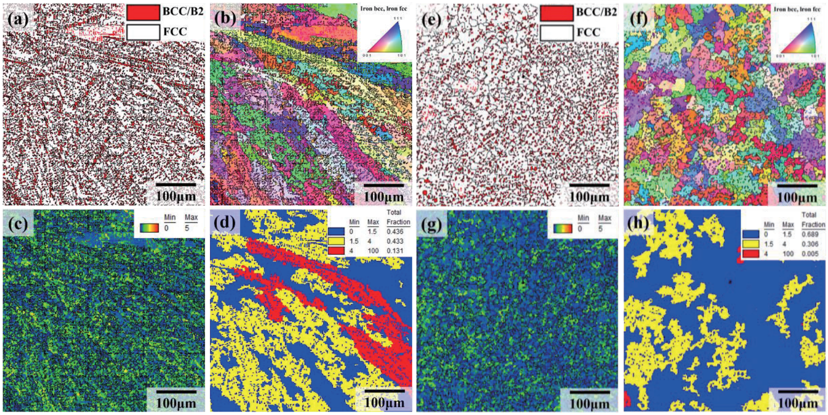

Fig. 1. EBSD results for as-built (a, b, c, d) and HT-DED (e, f, g, h) Fe-16Mn-10Al-5Ni-0.86C lightweight steel specimens: Phase maps (a and e), ND-IPF (b and f), KAM (c and g) and GOS (d and h) maps.

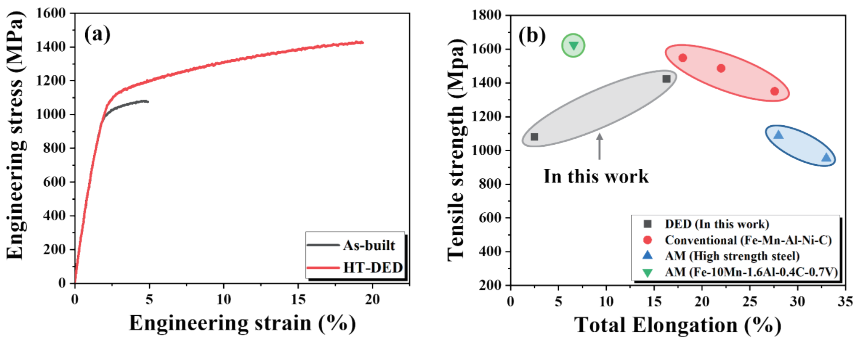

Fig. 2. (a) Engineering stress-strain curves and (b) comparison with conventional LWS [5], advanced high strength steel-AM [6] and AM-Fe-10Mn-1.6Al-0.4C-0.7V [7].

Keywords: Fe-16Mn-10Al-5Ni-0.86C lightweight steel; Directed energy deposition; Microstructure; Heat treatment; Microstructure; Microstructure; Mechanical Properties

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Influence of Wire Arc Additive Manufacturing Induced Microstructure on Elevated-Temperature Compression of Ti-6Al-4V

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Abstract: Ti-6Al-4V is a key material for aerospace and biomedical applications owing to its high specific strength, corrosion resistance, thermal stability, and biocompatibility [1-3]. Wire-arc additive manufacturing (WAAM) offers high deposition efficiency and rapid fabrication of near-net-shape components, thereby reducing material waste and production costs for Ti-6Al-4V [4,5]. Due to its layer-wise thermal history, WAAM-fabricated Ti-6Al-4V develops a distinctive microstructure that strongly influences mechanical behavior at elevated temperatures. This study investigates the effect of WAAM-induced microstructure on high-temperature deformation by comparative analysis with wrought Ti-6Al-4V. Compression tests were performed from room temperature to 700°C at a true strain rate of 1×10^{-3} s^{-1}. The initial microstructures of both alloys were observed using SEM, as shown in Fig. 1. The WAAM sample exhibited columnar prior-β grains elongated along the build direction and a complex intragranular α-lath morphology (Fig. 1(a_1, a_2)), whereas the wrought sample displayed an equiaxed α-grain structure (Fig. 1(b)). EBSD analysis indicated an α-phase dominance of 99.8% and a high-angle grain boundary fraction 80.8% in the WAAM condition. In compression, WAAM Ti-6Al-4V exhibited compressive yield strengths of 1034.1 MPa (RT), 679.1 MPa (300 °C), 646.2 MPa (500 °C), and 318.1 MPa (700 °C), whereas the wrought material showed 998.8 MPa, 619.9 MPa, 530.7 MPa, and 224.6 MPa, respectively. Fig. 2 presents the high-temperature compression response: (a) stress-strain curves at each test temperature and (b) a plot of compressive yield strength as a function of temperature. The superior high-temperature mechanical stability of the WAAM material is attributed to its columnar prior-β topology, dense α-lath network, and elevated high-angle boundary fraction, which collectively impede dislocation motion and retard thermally activated softening. These results establish processing-structure-property correlations and highlight the potential of WAAM Ti-6Al-4V for elevated-temperature structural applications.

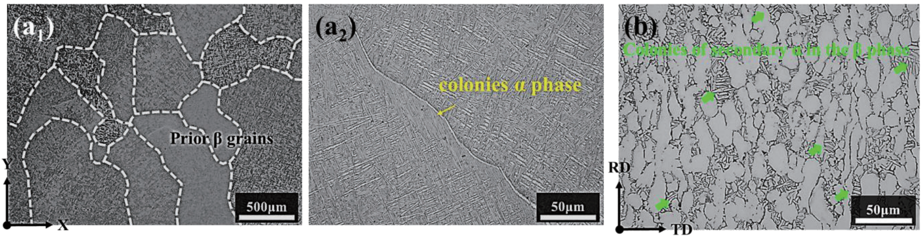

Fig. 1. Initial SEM microstructures of Ti-6Al-4V alloys (a_1, a_2) WAAM sample (b) Wrought sample

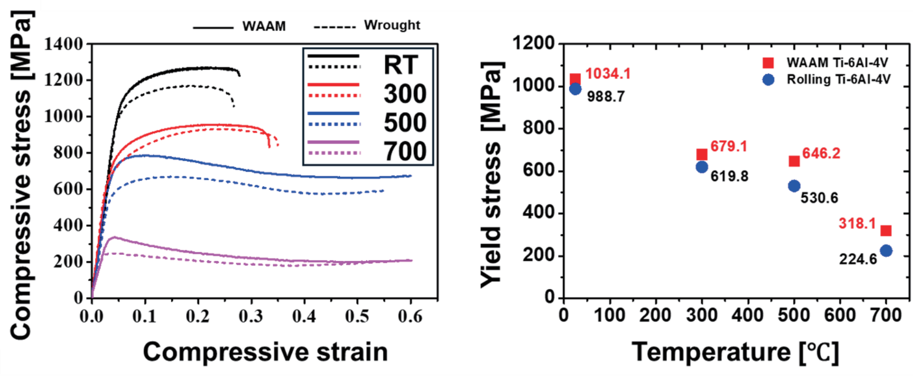

Fig. 2. High-temperature compressive behaviour of WAAM and wrought Ti-6Al-4V alloys (a) stress-strain curves (b) Compressive yield strength as a function of temperature

Keywords: Wire arc additive manufacturing, Ti-6Al-4V, High-temperature compression, Microstructure

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Analysis of the deposition behavior and microstructure of Ti-6Al-4V/Al_2O_3 functionally graded materials manufactured by the DED (Directed Energy Deposition) process

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Abstract:

Ti-6Al-4V (Ti64) alloy forms a protective TiO_2 layer on its surface under high-temperature oxidation environments. However, as this layer grows, internal stresses accumulate due to the mismatch in the coefficient of thermal expansion (CTE) between the Ti64 substrate and the TiO_2 oxide scale, leading to cracking and spallation of the oxide layer. To address this issue, ceramic-based surface treatment and coating technologies have been proposed, and additive manufacturing (AM) has attracted particular attention owing to its capability for localized repair of damaged regions and deposition of new coating layers. In this study, functionally graded materials (FGMs) composed of Ti64 and Al_2O_3 were fabricated on a Ti64 substrate using the directed energy deposition (DED) process with Al_2O_3 powders as feedstock. By varying three major process parameters—laser power, scanning speed, and powder feed rate—1D, 2D, and 3D deposition experiments were conducted to determine the optimal processing conditions. In the 1D single-bead deposition, bead width was measured using polarized optical microscopy (OM), and in the 2D plane deposition, layer thickness was evaluated. Subsequently, the cross-sectional microstructure and compositional distribution of the 3D cube were analyzed using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS). Through these experiments, the deposition behavior and microstructural characteristics of Ti64/Al_2O_3 FGMs were investigated, and the mechanisms of metal–ceramic bonding were proposed.

Acknowledgment:

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Keywords: Ti-6Al-4V(Ti64), Al_2O_3, additive manufacturing(AM), directed energy deposition (DED), fuctionally graded materials(FGMs)

Development of a High-Performance Abradable Coating with Thermal and Structural Stability

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Abstract: The increasing demand for higher efficiency and reliability in aviation and power generation has emphasized the critical role of abradable seal coatings in minimizing blade-tip clearances and enhancing thermal stability in gas turbines. The studies have shown that conventional abradable coatings often suffer from densification, susceptibility to erosion, and limited thermal shock resistance under prolonged service conditions. To address these limitations, Shinhwa Metal has developed an advanced abradable coating system specifically engineered for severe turbine environments, with the aim of improving clearance management and extending service life.

The coating is characterized by a low elastic modulus, high resistance to sintering, and a controlled defect–macroporous microstructure. This compliant, low-stiffness architecture effectively mitigates thermal shock damage and maintains structural stability under cyclic thermal loading, consistent with recent reports highlighting the importance of microstructural design in abradable systems. Abradability testing, conducted in accordance with Oerlikon Metco standard procedures, replicated realistic blade-incursion conditions and enabled a rigorous assessment of coating performance.

Examination of wear plate specimens, combined with detailed microstructural characterization, revealed uniform cutting behavior and robust structural integrity. Wear maps established correlations between pore architecture and rub response, providing valuable insights into performance optimization. The coating developed by Shinhwa Metal not only achieves superior abradability, oxidation resistance, and erosion resistance, but also provides a reliable solution in abradable coating technology for next-generation gas turbine applications.

Acknowledgment:

Keywords: Abradable coating, Gas turbines, Thermal stability, Microstructure

References

Development of Oxidation-Resistant Silicide and Aluminide Diffusion Coatings for Aerospace and Power Generation Components

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Abstract: The development of advanced oxidation-resistant coatings is essential for aerospace and power generation applications, where metallic components are exposed to severe thermal and oxidative stresses at elevated temperatures. In this work, both silicide and aluminide diffusion coatings were developed using proprietary slurry- and vapor-based diffusion coating processes engineered by Shinhwa Metal, enabling systematic control of coating growth kinetics, microstructural evolution, and phase formation. The silicide coatings, specifically tailored for niobium-based alloys in rocket launch vehicle components, effectively mitigated catastrophic oxidation by forming continuous, protective silicide scales. In parallel, aluminide coatings applied to turbine blades facilitated the formation of dense and adherent alumina scales that act as robust diffusion barriers against oxygen ingress. Comprehensive microstructural characterization revealed uniform thickness distribution, strong interfacial adhesion, and well-defined phase assemblages. High-temperature isothermal and cyclic oxidation tests further confirmed excellent scale adherence, thermal stability, and long-term durability. These results demonstrate the technological capability of Shinhwa Metal's proprietary diffusion processes and underscore their potential for deployment in next-generation aerospace propulsion and energy conversion systems.

Acknowledgment:

Keyword: Aluminide coating, Silicide coating, Microstructure, Oxidation

Spheroidization of titanium powders by using a reverse-polarity plasma torch with an exit nozzle

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In this paper, a reverse-polarity plasma torch with an exit nozzle was proposed as a cost-effective heat source to make the irregularly shaped Ti powders spherical. In our previous work, we have reported that when electrically connecting the rear electrode and front electrode in reverse polarity, hollow electrode plasma torches can produce a laminar-like plasma jet with high enthalpy but relatively low velocities less than 100 m/s at torch exit. In addition, the proposed type of torch can generate plasma flames with relatively large volume due to the nozzle diameter larger than 10 mm. Taking advantage of these unique features of a reverse-polarity plasma torch, a 15 kW class plasma torch system for spheroidization process was designed and titanium powders (75–150 μm), prepared from scrap via high-energy ball milling, were injected at the position 10 mm from the nozzle exit. From the FE-SEM images for the as-treated powders, it was confirmed that most of the injected powders were spheroidized. These results indicate that although axial injection is impossible, a high enthalpy plasma jet with low velocities and diameters larger than 10 mm can provide the injected powders with many trajectories to be melted and spheroidized during their flight of plasma jet. However, the XRD data showed that small amount of TiO2 was present in the as-spheroidized powders, requiring for the oxygen control in the proposed process.

Gradient cooling approach in vacuum plasma spray coating process for crack formation control in ZrC coating layers on carbon-carbon composite

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Abstract: Ultra-high temperature ceramics (UHTCs) are gaining attention as thermal barrier layers for protecting structural materials in extreme environments. Zirconium carbide (ZrC), one of UHTCs, is a promising candidate for aerospace and energy applications due to its high melting point, oxidation resistance, and thermal stability. ZrC coatings are typically fabricated by thermal spray methods such as vacuum plasma spray (VPS), to produce dense coatings under vacuum conditions. However, ZrC coatings often suffer from crack formation caused by steep thermal gradients during rapid cooling. These cracks lower mechanical strength and accelerate oxidation, necessitating effective crack-control strategies.

In this study, a gradient cooling stage was introduced through a post-heating process to mitigate crack formation in ZrC coatings on carbon–carbon composites. Unlike conventional rapid cooling (4.20 °C/s), gradient cooling reduced the cooling rate to approaximately1.34 °C/s over 100 s after the coating process, decreasing crack density from 0.9 to 0.5 cracks/mm. Through the microstructural characterization, the benefits of gradient cooling approach were confirmed. For example, adhesion strength tests showed no reduction in interfacial bonding due to post-heating. On the other hand, the cross-sectional micro-Vickers hardness increased by 13.2%, while porosity decreased by 10.8% compared to conventional cooling case. XRD analysis further indicated that gradient cooling did not cause ZrC phase transformation or affect interfacial stability.

From the results, the introduction of post-heating with gradient cooling provides a practical method to reduce crack formation with improved coating reliability and durability in UHTC coatings fabricated by VPS for advanced aerospace and energy applications.

Acknowledgment: This research was supported by Korea Basic Science Institute (National research Facilities and Equipment Center) grant funded by the Ministry of Education.(2021R1A6C101B383)

Keywords: Zirconium carbide (ZrC), Vacuum plasma spray (VPS), Crack control, Gradient cooling

Enthalpy probe measurement and numerical investigation on the thermal plasma jets generated by a reverse-polarity plasma torch with an exit nozzle

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In this paper, enthalpy probe measurements and numerical analyses were conducted to disclose the information on enthalpies, temperatures and velocities of thermal plasma jets generated by a hollow electrode plasma torch with reverse polarity discharge structure. The experimental and numerical setup featured a hollow electrode plasma torch with a cylindrical exit nozzle, which was added coaxially to the cylindrical front electrode with a 1.5 mm gap. With the help of an additional gas injected through the gap between the front electrode and the exit nozzle, this type of plasma torch can produce stable plasma jets at high thermal efficiency. The results revealed that when electrically connected in reverse polarity, hollow electrode plasma torch can be operated at low current-high voltage conditions, resulting in high thermal efficiency and high enthalpy plasma jet. During the measurement experiments, for example, relatively high arc voltages of ~300 V were maintained stably at the arc current of 40 A and the N2 gas flow rate of 40 lpm. For the plasma jets generated at this operation condition, an enthalpy probe with outer and inner diameters of 4.8 mm and 1.0 mm, respectively, was inserted to provide radial profiles of enthalpies, temperatures and velocities of the thermal plasma jets at various positions along jet axis, and the measured results were validated by comparing them with numerical results. Detailed comparison results will be discussed in ATSC 2025.

Machine-Learning Interatomic Potential for Temperature-Dependent Properties of Nb_2AlC MAX Phase as a Bond Coat

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Abstract: Nb_2AlC MAX phase combines metallic ductility with ceramic high-temperature stability, making it a promising candidate for bond coat materials in next-generation thermal barrier coating (TBC) systems. However, despite their critical importance under the extreme thermal and mechanical conditions experienced in service, reliable data on its temperature-dependent mechanical properties and thermal expansion behavior remains limited. While ab initio molecular dynamics can provide accurate predictions, the computational cost becomes prohibitively high for large supercells and wide temperature ranges. In this study, we developed a machine learning–based moment tensor potential (MTP) specifically for the Nb_2AlC system and applied it to molecular dynamics simulations. The constructed potential accurately reproduced elastic constants at room temperature and elevated temperatures (E_z = 247.8 GPa), showing good agreement with reported experimental and ab initio calculation results (E_z = 242 GPa). Furthermore, the thermal expansion coefficient of Nb_2AlC (8.9×10^{-6} K^{-1}), a key indicator of compatibility in bond coat applications, was captured with high accuracy compared to literature values (8.7×10^{-6} K^{-1}). These results demonstrate that the developed potential efficiently and accurately quantifies the mechanical stability and thermal suitability of Nb_2AlC at the atomic scale. Furthermore, it can serve as a fundamental resource for evaluating the applicability of Nb_2AlC as a bond coat material in TBC systems.

Acknowledgment: This work was supported by Korea Research Institute for defense Technology planning and advancement(KRIT) grant funded by the Korea government(DAPA(Defense Acquisition Program Administration)) (No. KRIT-CT-23-039, Development of multi-component Ultra-High Temperature Ceramic Coating Technology).

Keywords: MAX phase, Molecular dynamics simulation, Bond coat, Machine learning

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Effect of APS Process Parameter Control on the Microstructure and Thermal Fatigue Characteristics of Thermal Barrier Coatings

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Abstract: Thermal barrier coatings (TBCs) are commonly used to protect the metal substrates of gas turbines operating at high temperatures. Yttria-stabilized zirconia (YSZ), typically containing 7-8 wt% yttria, is a widely used topcoat due to its low thermal conductivity and excellent thermal stability. It is primarily deposited using the atmospheric plasma spraying (APS) technique. Coating properties, including porosity, thickness, crack morphology, adhesion, and thermal durability, are significantly influenced by process variables, ultimately determining coating quality and service life. Therefore, optimizing the APS process is essential for improving the reliability and service life of turbine components. In this study, various TBC specimens were fabricated using APS by controlling the spray distance, powder feed rate, and deposition rate. The microstructure of the coatings was systematically analyzed and structural differences under various conditions were compared. Furthermore, thermal fatigue tests were performed to evaluate the thermal durability of the coatings. This study led to the identification of optimal deposition parameters for each process condition.

Acknowledgment: This work was supported by the Korea Planning & Evaluation Institute of Industrial Technology (KEIT) grant funded by the Korea government(MOTIE) (RS-2024-00422159, Reliability assessment of thermal barrier coatings under hydrogen combustion and substantiation assessment by a demand company).

Keywords: Gas turbine, Atmospheric plasma spray, Thermal barrier coating, Process parameters, Optimization

Enhanced Oxidation Resistance of ZrC through Multi-Layer Coatings: Ab Initio Calculation of Oxygen Diffusion Pathways

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Abstract: Zirconium carbide (ZrC) is a promising candidate for structural applications in extreme environments due to its high melting point, mechanical strength, and thermal stability. However, its rapid oxidation at elevated temperatures limits long-term durability. In this study, ab initio calculation combined with the nudged elastic band (NEB) method were employed to investigate oxygen diffusion behavior in ZrC coatings with varying layer structures. The results reveal that multi-layer ZrC exhibits significantly enhanced oxidation resistance compared to single-layer ZrC. In the ZrC(100)/(100) interface, while bulk-to-surface and surface-to-surface diffusion paths showed higher energy barriers, oxygen preferentially migrated through interfacial regions, leading to reduced overall diffusion. Furthermore, the protective ZrO_2 film formed on the surface provided an additional diffusion barrier, synergistically hindering oxygen penetration. These findings highlight the importance of interface engineering and oxide stabilization in delaying oxidation. This work provides fundamental insights into the design of multi-layer carbide coatings for extreme temperature environments and offers guidance for developing oxidation-resistant protective coatings in advanced energy and aerospace systems.

Acknowledgment: This work was supported by Korea Research Institute for defense Technology planning and advancement(KRIT) grant funded by the Korea government(DAPA(Defense Acquisition Program Administration)) (No. KRIT-CT-23-039, Development of multi-component Ultra-High Temperature Ceramic Coating Technology).

Keywords: ZrC, multi-layer coating, oxidation resistance, oxygen diffusion, ab initio calculation

Mixed Oxide formation in NiCoCrAlY powders and Thermal-Sprayed Coatings: Influence of heat exposure during processing

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Abstract

This study investigates the formation behavior of mixed oxides (MOs) that shorten the service life of thermal barrier coatings (TBCs). Thermally grown oxides (TGOs) can form not only as Al_2O_3 but also as MOs such as Cr_2O_3, NiO, CoO, and spinel, which exhibit higher defect densities and faster growth kinetics than α-Al_2O_3. The formation of MOs accelerates TGO thickening and induces local stress concentration, thereby promoting top coat (TC) delamination. Thus, understanding MO behavior is crucial for ensuring the durability of TBCs. In this study, the oxidation behaviors of NiCoCrAlY (Amdry365-4, ©Metco) powder, thermally spray-coated specimens (High Velocity Oxygen Fuel and Vacuum Plasma Spray), and powders exposed to the heat source during spraying without deposition on the substrate were compared in air at 1000°C. MOs were observed to form earlier in heat-exposed powders and coatings than in the as-received powders, and a schematic of the oxidation behavior was established accordingly. These findings clarify the impact of high-temperature exposure during thermal spraying on MO formation behavior and provide fundamental insights for suppressing abnormal MO formation in future TBC systems.

This study was supported by the Korea Institute of Energy Technology Evaluation and Planning's Energy Human Resources Development Project (RS-2024-KP002514) and the Korea Institute of Industrial Technology Planning and Evaluation's Automotive Industry Technology Development Project (RS-2025-02317513) and Space-K BIG Project Program(RS-2025-16063273) funded by the Korea AeroSpace Administration(KASA).

Keywords
TBC(Thermal Barrier Coating), TGO(Thermally Grown Oxide), MO(Mixed Oxides), Thermal-Spray Coating, MCrAlY(M=Ni, Co)

Study on Bond Materials for Protective UHTC Layers on Graphite by Air Plasma Spraying

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Abstract: Graphite has long been recognized as an essential material for high-temperature engineering applications, including heat treatment, brazing, sintering, and advanced metallurgical processes. Despite its excellent thermal and mechanical properties, graphite suffers from rapid oxidation above 500 °C in oxygen-containing environments, which significantly limits its long-term performance. To overcome this limitation, a protective multi-layer coating was developed by air plasma spraying (APS) as a preliminary step toward Ultra High Temperature Coatings (UHTCs).

In this study, bond materials of tungsten (W) and molybdenum (Mo) were deposited on graphite substrates, followed by a graded ceramic topcoat of Al_2O_3–YSZ designed to reduce thermal expansion mismatch. The microstructure and phase composition were examined by SEM and XRD, while hardness and adhesion testing provided insight into mechanical integrity. In addition, thermal cycling experiments were conducted at 1450 °C under controlled vacuum conditions to evaluate high-temperature durability.

The results showed that the Mo bond layer exhibited significantly improved coating quality compared with W. Mo produced denser deposits with lower porosity and stronger adhesion, attributed to favorable wetting on the graphite substrate and the formation of interfacial Mo_2C carbides. In contrast, W layers demonstrated higher porosity, limited carbide formation, and spalling under thermal shock conditions. These findings indicate that the choice of bond material plays a critical role in the stability and performance of protective coatings for graphite.

Overall, this work demonstrates that Mo-based bond layers are more effective than W for improving oxidation resistance of graphite and enhancing coating adhesion. Importantly, the present results establish a scientific foundation and technical pathway for the future design of UHTCs capable of withstanding extreme thermal and oxidative environments, relevant to aerospace, nuclear, and advanced energy applications.

Keywords: Graphite oxidation protection; Bond materials (Mo, W); Ultra High Temperature Coatings (UHTCs)

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Influence of Ammonia Combustion Atmosphere on the Durability of Metallic Bond Coat in Thermal Barrier Coating

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Abstract: Ammonia (NH_3) has attracted attention as a promising carbon-free fuel for next-generation gas turbine due to its high volumetric energy density, simple storage, and ease of transport. However, the unburned ammonia, increased water vapor, and corrosive combustion products may have detrimental effects on the turbine components. In particular, the reactive nitrogen species and hydrogen radicals generated during ammonia combustion can severely compromise the durability of metallic bond coat, which is critical to the performance of thermal barrier coating system.

In this study, the thermal behavior of metallic bond coat was systematically investigated under various high-temperature ammonia/nitrogen mixed-gas conditions. The microstructural evolution and chemical stability of metallic bond coats with different compositions were evaluated, focusing on the nitride and oxide formation, elemental diffusion, and coating integrity. The results revealed a unique degradation mechanism of the bond coat in ammonia combustion environments, thereby providing fundamental insights for the development of coating system in carbon-neutral gas turbine.

Acknowledgment: This work was supported by the "Development of Core Technologies for Ammonia-Fueled Gas Turbine Combustors for Power Generation" of KETEP from MOTIE, Republic of Korea [grant number RS-2024-00455846].

Keywords: Gas turbine, Ammonia combustion, Thermal barrier coating, Metallic bond coating

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Life Assessment of 8% Yttria-Stabilized Zirconia (YSZ) Thermal Barrier Coating (TBC) Through Isothermal and Thermal Cycling Tests

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Abstract: In the rapidly advancing field of energy technology, raising the turbine inlet temperature (TIT) of gas turbines is essential for improving efficiency and power output to meet the growing global demand. However, higher operating temperatures accelerate the degradation of thermal barrier coatings (TBCs), which are critical for protecting turbine components from severe thermal stresses. Therefore, understanding and predicting the lifetime of TBCs under such conditions is vital for ensuring safe and reliable turbine operation. In this study, the durability of 8% yttria-stabilized zirconia (8YSZ) TBCs was assessed at 1100 °C using two test methods. The isothermal test was conducted in a chamber furnace for up to 1400 h to evaluate oxidation and continuous degradation behavior, while the thermal cycling test, consisting of 10 min heating, 40 min dwelling at 1100 °C, and 10 min air cooling, was repeated up to 1000 cycles to simulate service conditions with thermal shocks. Both tests revealed steady growth of thermally grown oxide (TGO), accompanied by cracking and densification of the top coat. The Al-rich phases in the bond coat were completely depleted before reaching 200 h, marking the stage of internal crack propagation caused by brittle mixed oxides. Under isothermal exposure, degradation progressed gradually without spallation, while thermal cycling accelerated damage, leading to top-coat spallation after 520 cycles. These results highlight differences in TGO growth and spallation behavior, providing important insights for TBC reliability assessment.

Acknowledgment:
This research was supported by KEPCO KPS.

Keywords: Thermal Barrier Coatings (TBC), Thermal Cycling, Isothermal Test, Thermally Grown Oxide (TGO)

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CFD Analysis of Particle Heating in VPS of MCrAlY under Ar–H_2 Mixed Plasmas

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Abstract: Vacuum plasma spraying (VPS) offers a controlled, low-oxygen environment to consolidate MCrAlY coatings for oxidation- and corrosion-resistant applications. Yet, how Ar–H_2 plasma composition governs the thermal and kinematic history of injected particles—and thereby porosity and oxide formation in the deposit—remains quantitatively underexplored.

We establish a coupled thermal-plasma/Discrete Phase Model framework to predict arc-jet fields and Lagrangian particle trajectories in a 3D torch-to-substrate domain [1]. We further implement the threshold restrike model coupled to the thermal-plasma solver [2]. Thermodynamic and transport properties are evaluated for Ar/H_2 mixtures assuming LTE, and radiative as well as Joule heating effects are accounted for [2]. Parametric sweeps over argon flow (30–50 $L \cdot min^{-1}$) and hydrogen addition (9–14 $L \cdot min^{-1}$) reveal counteracting trends: increasing Ar raises jet momentum and particle impact velocity while moderating particle temperature, which correlates with reduced in-flight oxidation and lower pore content; conversely, additional H_2 elevates particle enthalpy but diminishes acceleration, intensifying oxide formation at splat interfaces. These predictions are consistent with ex-situ compositional mapping that indicates greater intersplat oxide fraction at higher H_2 settings. The analysis highlights hydrogen flow rate as the most sensitive knob for suppressing oxidation without sacrificing particle melting, and delineates operating windows that balance temperature–velocity trade-offs for dense, low-oxide MCrAlY coatings.

Keywords: Numerical Simulation, OpenFoam, LTE Assumption, Vacuum Plasma Spraying, Restrike Model.

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Analysis of oxidation behavior according to addition of Ta or Hf/Si in Thermal barrier coating Bond Coat powder

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Abstract: This study aimed to analyze the high-temperature oxidation behavior when Ta and Hf/Si were added to the NiCoCrAlY powder, which is a commercial powder for the Bond Coat layer of the TBC (Thermal Barrier Coatings) system. In the TBC system, the Thermally Grown Oxide (TGO) can be formed not only from α-Al_2O_3 but also from mixed oxides (Mixed Oxides, MO) such as Cr_2O_3, NiO, and Spinel. The formation of mixed oxides accelerates the thickness of the TGO and promotes its peeling from the TC (Top Coat) layer, so understanding the formation and growth behavior of mixed oxides is crucial for securing the TBC life. The experiment was conducted on NiCoCrAlY-Ta (Amdry997, ©Metco) and NiCoCrAlY-Hf,Si (Amdry386-2.5, ©Metco) powders and compared with the oxidation behavior of existing commercial powders by conducting isothermal oxidation tests in air at 1000℃ and 1100℃. The oxidation behavior was analyzed by field emission scanning electron microscopy (FE-SEM), energy dispersive spectrometry (SEM-EDS), and X-ray diffraction (XRD). The experimental results showed that α-Al_2O_3 was the main oxide at the beginning (50 h), and local Ta-rich and Hf-rich oxides were observed at the interface between α-Al_2O_3 and the powder and near the grain boundaries. In addition, we aimed to analyze the formation of a PEG structure that was not observed in existing commercial powders but appeared due to the addition of Ta and Hf. The results of the TGO thickness measurement after the 1000℃ oxidation test were compared with the results of a previous study measuring the thickness of existing commercial powders, and the effects of Al content and PEG structure formation were analyzed.

Acknowledgment: This study was supported by the Korea Institute of Energy Technology Evaluation and Planning's Energy Human Resources Development Project (RS-2024-KP002514) and the Korea Institute of Industrial Technology Planning and Evaluation's Automotive Industry Technology Development Project (RS-2025-02317513) and Space-K BIG Project Program(RS-2025-16063273) funded by the Korea AeroSpace Administration(KASA).

Keywords: TBC(Thermal Barrier Coatings), Bond Coat, TGO(Thermally Grown Oxide), NiCoCrAlY-Ta, NiCoCrAlY-Hf,Si

Granular Manufacturing Technology and APS Coating and Evaluation Study for Yb-Disilicate Spray Coating for Environmental Barrier Coating.

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Abstract: This study introduces a technology for manufacturing Ytterbium-disilicate($Yb_2Si_2O_7$) for environmental barrier coating as granules for thermal spray coating. In addition, through this granule, a coating layer is formed by the APS coating method, and high temperature characteristics(Burner rig test) are evaluated with the formed coating layer to discuss the results.

Keywords: Ytterbium-disilicate($Yb_2Si_2O_7$), Environmental barrier coating, APS, Burner rig test.

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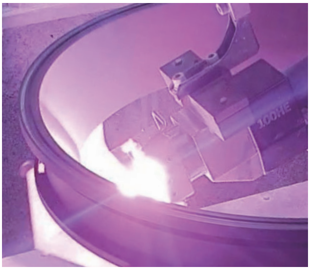

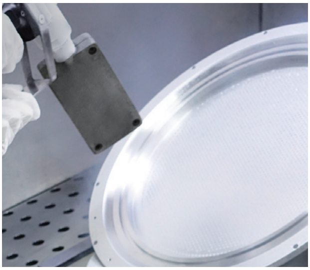

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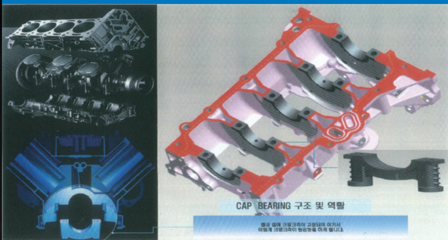

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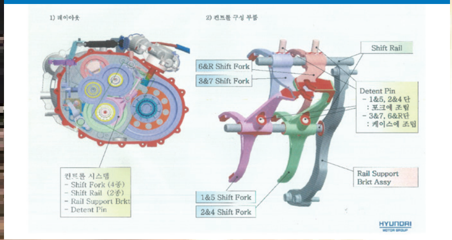

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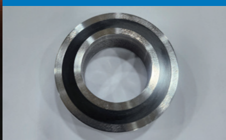

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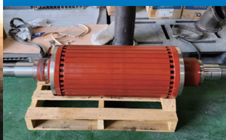

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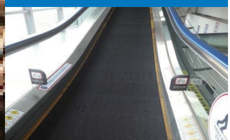

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