NANOJOINING&MICROJOINING ASSOCIATION

6TH INTERNATIONAL CONFERENCE ON NANOJOININIG AND MICROJOINING

NMJ 2025

TECHNICAL PROGRAM

YEONGJU, KOREA

17TH-21ST NOVEMBER

Welcome Address

On behalf the Conference Chairs and the International Steering Committee (ISC) of the Association for Nanojoining and Microjoining (NMJ), we cordially welcome you to 6th NMJ conference from 17th – 21th of November 2025 in Yeongju, Korea.

Joining, whether at the macro-, micro-, or nano-scale has long been recognized as a key-enabling manufacturing technology in a broad range of fields, such as microelectronics, energy conversion, robotics, aerospace, medical implants, automation and sensing. While micro-joining has already become one of the most critical technical prerequisites in the manufacturing of micro-devices and micro-systems, further technological advancements are still needed to allow faster, cost-effective, more reliable and sustainable fabrication routes, while keeping the pace of continuing miniaturization and diversification. The field of nano-joining is also evolving rapidly and is expected to become a key technology for the large-scale manufacturing and commercial application of nano-devices and nano-systems in the coming decades.

The NMJ conference series provides a dedicated forum for scientific and technical presentations, discussions and personal exchanges in the field of nano-/micro-joining. We encourage all attendees to share their newest research findings and practical experiences in the field and hope you will have the opportunity to be engaged in insightful presentations, interactive discussions with leading experts, to network and to start fruitful scientific and professional collaborations. Thank you for joining us in this journey of discovery and exploration. We cordially invite all of you to foster progress in the field by contributing your expertise to what promises to be a very exciting meeting.

We would like to thank all the local conference chairs and their organizing committees, the speakers, the participants, and all sponsors for their participation and support.

Please enjoy the time spent with the NMJ community in the wonderful scenery offered and get acquainted with Korean hospitality, culture and habits.

Wishing you a rewarding NMJ conference!

Lars P.H. Jeurgens

President of the NMJ Association

Welcome Address

Distinguished scholars and industry leaders from home and abroad, Honored guests,

It is my great pleasure, as the Acting Mayor of Yeongju City, to welcome you all to the 2025 International Conference on Nano & Micro Joining (NMJ 2025) here in Yeongju.

First of all, I would like to express my sincere gratitude to the organizing committee and all those who have devoted their time and effort to make this conference a success.

Nano and micro joining technologies form the very foundation of cutting-edge industries around the world such as semiconductors, precision machinery, electronic devices, energy systems, and future mobility.

It is therefore deeply meaningful that this prestigious conference, standing at the forefront of technological innovation, is being held here in Yeongju, Republic of Korea.

Yeongju City is currently preparing for the future of Korea's precision machinery industry through the establishment of the Advanced Bearing National Industrial Complex.

Bearings are the "heart" of all rotating machinery and represent the culmination of advanced joining and precision processing technologies.

By integrating nano and micro joining technologies with the advanced bearing industry, Yeongju aims to build a new ecosystem of manufacturing innovation enhancing industrial sophistication and strengthening global competitiveness.

I sincerely hope that this conference will serve as a vital platform for the exchange of cutting-edge technologies and ideas, where experts from around the world can share the latest research achievements in nano and micro joining,

and explore new opportunities for collaboration in line with Yeongju city's vision for advanced industries.

Lastly,

I wholeheartedly congratulate everyone on the successful opening of NMJ 2025,

and I hope that all participants will experience Yeongju's warm hospitality, beautiful natural surroundings,

and our city's vision to become a leading hub of future industries.

Thank you.

Jeong-geun Yu

The Acting Mayor of Yeongju City

NMJ2025

Welcome Address

It is my great honor to extend a warm welcome to all distinguished speakers, esteemed researchers, and colleagues from around the world. On behalf of the organizing committee, I am truly delighted to welcome you to the International Conference on Nanojoining & Microjoining (NMJ 2025) at the Sunbeechon Convention Center in Yeongju City, Republic of Korea.

We are privileged to host NMJ 2025 in Yeongju, a UNESCO Heritage Zone known for its stunning Sobaek Mountain, Naeseongcheon Stream, and cultural treasures like Buseoksa Temple and Sosu Seowon. We hope this inspiring setting enhances your experience.

This is the sixth NMJ, a landmark event since it has started at Tsinghua University in 2012, and the first time it's held in Korea. NMJ 2025 focuses recent breakthroughs in nano- and micro-joining technologies that play a crucial role in advancing industries such as semiconductors, batteries, and mobility. The conference program includes 125 presentations - 90 orals and 35 posters - covering various topics from semiconductor packaging and laser joining to 3D integration, battery systems, and joining reliability.

Our distinguished keynote, invited, and contributing presenters will inspire insightful and transformative discussions over the next three days. NMJ 2025 serves as a platform for collaboration and innovation, and I encourage all of you to actively participate in the sessions and networking events.

I would like to express my sincere gratitude to Gyeongbuk Province, Yeongju City, our sponsors, organizers, volunteers, and all partners whose strong support has made this event possible. Now, let us begin this exciting journey of discovery together.

Thank you once again, and let's make NMJ 2025 a great success!

Jae Pil Jung, Professor

Conference chair of the NMJ 2025

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Program at Glance

Conference Day 1 (Mon. Nov 17)

Time		Lobby	Convention Hall A	Convention Hall B	Outside
12:00	14:00	Registration			Steering committee Lunch (near Sunbee village)
14:00	17:00		Steering committee meeting		
17:00	18:00	Break			
18:00	20:00				Welcome Reception (Galbiman restaurant)

Conference Day 2 (Tue. Nov 18)

Time		Lobby	Convention Hall A	Convention Hall B	Outside
8:00	8:30	Registration & Industrial Exhibition			
8:30	8:50		Opening Ceremony		
9:00	9:30		Keynote 1 (Yongfeng Lu)		
9:30	9:50		Advanced Semiconductor and Display Packaging	Laser joining (1)	
9:50	10:10				
10:10	10:30		Coffee Break (Lobby)		
10:30	10:50		Advanced Semi-conductor and Display Packaging	Laser joining (1)	
10:50	11:10				
11:10	11:30				
11:30	11:50				
11:50	12:10				
12:10	13:10	Poster Installation	Lunch (Sunbee Soban)		
13:10	13:40	Registration & Industrial Exhibition & Poster Exhibition	Keynote 2 (Sayoon Kang)		
13:40	14:10		Keynote 3 (Pawel J. Kulesza)		
14:10	15:10		Advanced Semiconductor Packaging	Laser joining (2) & Power Devices	
15:10	15:30		Coffee Break (Lobby)		
15:30	15:50		Advanced Semiconductor Packaging	Laser joining (2) & Power Devices	
15:50	16:10				
16:10	16:30				
16:30	16:50				
16:50	17:10				
17:10	17:30				
17:30					
17:50	18:00	Break			
18:00	20:00				

Conference Day 3 (Wed. Nov 19)

Time		Lobby	Convention Hall A	Convention Hall B	Outside
8:30	9:00	Registration & Industrial Exhibition & Poster Exhibition			
9:00	9:30		Keynote 4 (Eiji Higurashi)		
9:30	9:50		Micro- and Nano-joining (1)	Battery & Power Devices (1)	
9:50	10:10				
10:10	10:30		Coffee Break (Lobby)		
10:30	10:50		Micro- and Nano-joining (1)	Battery & Power Devices (1)	
10:50	11:10				
11:10	11:30				
11:30	11:50				
11:50	12:10				
12:10	13:10		Lunch (Sunbee Soban)		
13:10	13:40		Keynote 5 (Ehrenfried Zschech)		
13:40	14:00		Micro- and Nano-Joining (2)	Battery & Power Devices (2)	
14:00	14:20				
14:20	14:40				
14:40	15:00		Coffee Break (Lobby)		
15:00	15:20		Micro- and Nano-Joining (2)	Battery & Power Devices (2)	
15:20	15:40				
15:40	16:00		Banquet Setting		
16:00	16:20	Poster Presentation			
16:20	16:40				
16:40	17:00				
17:00	18:00	Break			
18:00	20:00		Banquet (Convention B+C room)		

Conference Day 4 (Thur. Nov 20)					
Time		Lobby	Convention Hall A	Convention Hall B	Outside
8:30	9:00	Registration & Industrial Exhibtion			
9:00	9:30		Keynote 6 (Jaesik Lee)		
9:30	10:00		Keynote 7 (Zhi-Quan Liu)		
10:00	10:20		Advanced Joining and Welding	Thin film interface and Reliability	
10:20	10:40		Coffee Break (Lobby)		
10:40	11:00		Advanced Joining and Welding	Thin film interface and Reliability	
11:00	11:20				
11:20	11:40				
11:40	12:00				
12:00	12:20				
12:20	13:20		Lunch (Sunbee Soban)		
13:20	13:40		3D Semiconductor Packaging and Hybrid bonding	Specialized Joining	
13:40	14:00				
14:00	14:20				
14:20	14:40				
14:40	15:00				
15:00	15:30		Awarding & Closing Ceremony		

Conference Day 5 (Fri. Nov 21)					
Time		Lobby	Convention Hall A	Convention Hall B	Outside
9:00	16:00	Social Program (Light Materials Research Centre & Culture Visit)			

* Welcome Reception(Galbiman restaurant)

246, Daehak-ro, Yeongju-si, Gyeongsangbuk-do, Republic of Korea

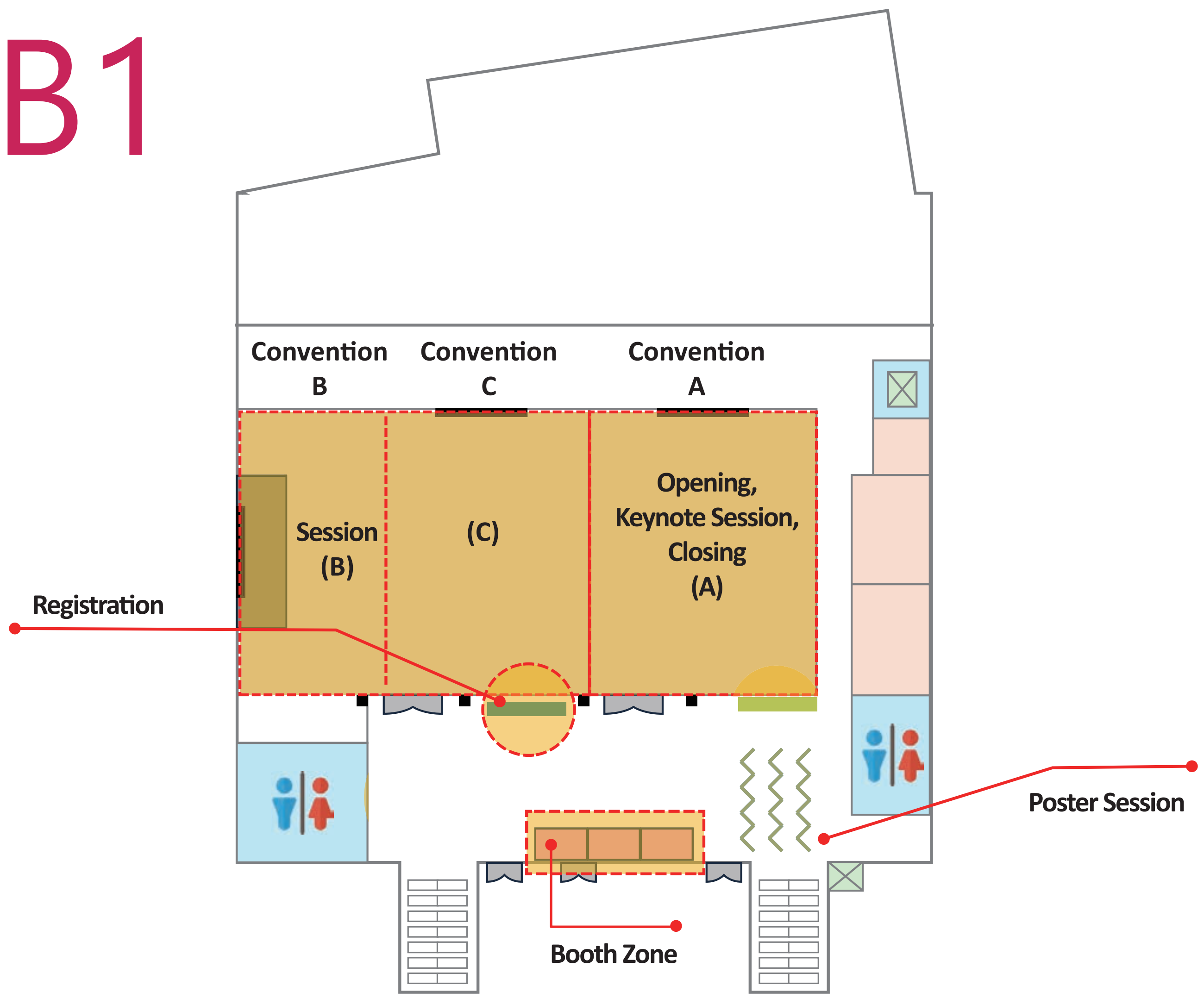
* Banquet

Convention B+C room

* Lunch

Sunbee Soban

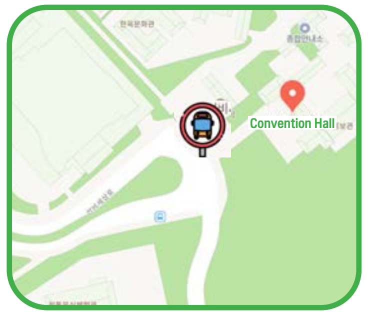
Floor Map



* Lunch Location(Sunbee Soban)

Shuttle bus schedule & Shuttle bus Station

Sunbee World



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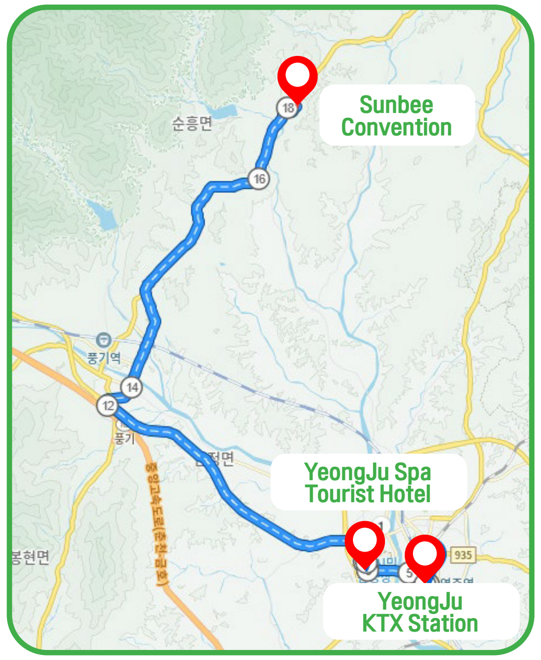
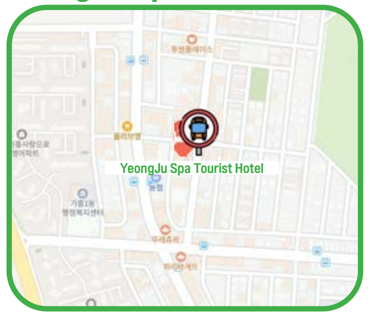
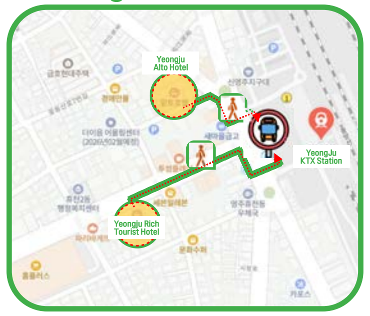


YeongJu Spa Tourist Hotel



YeongJu KTX Station



Conference (Nov. 18) Hotel → Convention			
Bus No	YeongJu Station	YeongJu Spa Tourist Hotel	Sunbee Convention
No1	7:10	7:25	8:00
No2	7:20	7:35	8:05
No3	7:30	7:45	8:30
No1	9:30	9:45	10:15
No2	10:00	10:15	10:55
No3	11:00	11:15	12:00
No1	13:00	13:15	14:00
No2	14:00	14:15	15:00
No3	15:00	15:15	16:00

Conference (Nov. 18) Convention → Hotel			
Bus No	Sunbee Convention	YeongJu Spa Tourist Hotel	YeongJu Station
No1	18:10	18:50	19:00
No2	18:20	19:10	19:20
No3	18:30	19:20	19:30

Conference (Nov. 19) Hotel → Convention			
Bus No	YeongJu Station	YeongJu Spa Tourist Hotel	Sunbee Convention
No1	7:10	7:25	8:00
No2	7:20	7:35	8:05
No3	7:30	7:45	8:30
No1	9:30	9:45	10:15
No2	10:00	10:15	11:00
	*Convention via Intercity Bus Terminal (10:30 AM)		
No3	11:00	11:15	12:10
No1	13:00	13:15	14:00
No2	14:00	14:15	15:00
No3	15:00	15:15	16:00

Conference (Nov. 19) Convention → Hotel			
Bus No	Sunbee Convention	YeongJu Spa Tourist Hotel	YeongJu KTX Station
No1	20:10	20:50	21:00
No2	20:20	21:10	21:20
No3	20:30	21:20	21:30

Conference (Nov. 20) Hotel → Convention			
Bus No	YeongJu KTX Station	YeongJu Spa Tourist Hotel	Sunbee Convention
No1	7:10	7:25	8:00
No2	7:20	7:35	8:05
No3	7:30	7:45	8:30
No1	9:30	9:45	10:20
No2	10:00	10:15	11:00
	*Convention via Intercity Bus Terminal (10:30 AM)		
No3	11:00	11:15	12:10

Conference (Nov. 20) Convention → Hotel			
Bus No	Sunbee Convention	YeongJu Spa Tourist Hotel	YeongJu KTX Station
No1	16:10	16:50	17:00
No2	16:20	17:00	17:15
No3	16:30	17:10	18:00

Technical Program NMJ 2025

Time	Convention Hall A
	Conference Day 2 (Tue. Nov 18)
8:00-8:30	
8:30-8:50	Opening Ceremony (Hyun-Sik Kim)
9:00-9:30	**Keynote 1** **Micro/nano joining of carbon structures in 1D, 2D and 3D** Yongfeng LU[*,1], Xi HUANG[1], Haoyu DONG[1], Peizi LI[1], Qiuchi Zhu[1], Bai CUI[2], and Jean-Francois SILVAIN[3] *[1]Department of Electrical and Computer Engineering, University of Nebraska, Lincoln, NE 68588-0511, USA.* *[2]Department of Mechanical and Materials Engineering, University of Nebraska, Lincoln,NE 68588-0526, USA.* *3CNRS, University of Bordeaux; Bordeaux I.N.P., ICMCB, UMR 5026, F-33608 Pessac, France.*
	Session: Advanced Semiconductor and Display Packaging, (chair: Lars P.H. Jeurgens, Ah-Young Park)
9:30-9:50	**[Invited] Process Innovations in Fluidic Self-Assembly for High-Throughput MicroLED Integration** Daewon Lee *Hanyang University, Korea*
9:50-10:10	**[Invited] Development of Cd-Free Quantum Dots for Industrial Applications** Nayoun Won, Taekhoon Kim, Deukseok Chung, Jonghoon Won, Sanghyeon Park, Tae-Gon Kim and Shinae Jun *Materials Research Center, Samsung Advanced Institute of Tetchnology, Gyeonggi, Suwon 16678, Korea*
	10:10-10:30 Coffee Break (Lobby)
10:30-10:50	**[Invited] Emerging Trends and Technological Challenges in Advanced Semicon-ductor Packaging: A Focus on Chiplet Integration and Micro-LED Applications** Kwang-Seong Choi, Jiho Joo, Gwang-Mun Choi, Jungho Shin, Chanmi Lee, Ki-Seok Jang, Jin-Hyuk Oh, Ho-Gyeong Yun, Seok Hwan Moon, Gaeun Lee, Seong Cheol Kim, Yong-Sung Eom *Low-Carbon Integration Tech. Creative Research Section, Electronics and Telecommunications Research Institute, Daejeon, Korea*
10:50-11:10	**[Invited] Ultrafast, Reworkable Glass Interposer Interconnection via Photo-Induced Reversible Polymer Crosslinking** R. Lee[1], C.H. Song[2], J.W. Kim[1] *[1] Department of Semiconductor Convergence Engineering, Sungkyunkwan University, Suwon 16419, Korea* *[2] Department of Electrical Engineering, Korea University, Seoul 02841, Korea*
11:10-11:30	**Enhanced Low-Temperature Sinter Bonding by Hybridization of Cu Micro-particles and Self-Reducible CuxO Nanoparticles** T. Yonezawa[1], T. Aso[1], and T. Tsukamoto[1] *[1] Division of Materials Science and Engineering, Faculty of Engineering, Hokkaido University, Kita 13 Nishi 8, Kita-ku, Sapporo, Hokkaido 060-8628 Japan*
11:30-11:50	**Exploration of Low-Melting Nano-Solders and Their Effects on Structure and Properties of E-Textile Gas Sensors** Daniel Chuqing Liu[1, a], Ileas Harb[1], Edward Fratto[1] and Zhiyong Gu[1, b] *[1] Department of Chemical Engineering, University of Massachusetts Lowell,1 University Ave, Lowell, MA,01854, USA.*
11:50-12:10	**Cu-Mo nanocomposites as an interlayer for joining in thermal management systems** D. Pałgan[1], S. H. Rajendran[2], B. Rheingans[2], J. Janczak-Rusch[2] and M. Lewandowska[1] *[1] Warsaw University of Technology, Faculty of Materials Science and Engineering, Woloska 141, 02-507 Warsaw, Poland* *[2] Laboratory for Joining Technologies and Corrosion, Empa - Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, Dübendorf, CH-8600 Switzerland*

	12:10-13:10 Lunch (Sunbi Soban)
13:10-13:40	**Keynote 2** **The Role of semiconductor Packaging toward New AI Era** Sayoon Kang *Professor of Manufacturing Innovation School. Inha University*
13:40-14:10	**Keynote 3** **Fuel cell research: integration of metal-oxide-additives with carbon-supported low-Pt-content-catalysts for oxygen reduction** Pawel J. Kulesza, Aldona Kostuch, Anna Chmielnicka, Iwona A. Rutkowska *Faculty of Chemistry, University of Warsaw, Pasteura 1, 02-093 Warsaw, Poland*
	Session: Advanced Semiconductor Packaging, (chair: Jolanta Janczak-Rusch, Young-Bae Park)
14:10-14:30	**[Invited] Reliability challenges in electronic packaging and development of effective assessment techniques** Choong-Un Kim *University of Texas – Arlington, USA*
14:30-14:50	**[Invited] Low-Temperature Thermo-Compression Bonding of Nanotwinned metals for Advanced Electronic Packaging** Hongjun Ji[1, 2, 3], Dashi Lu[1, 2, 3], Jingyuan Ma[1, 2, 3], and Anping Wang[1, 2, 3] *[1] State Key Laboratory of Precision Welding & Joining of Materials and Structures, Harbin, China* *[2] School of Integrated Circuits, Harbin Institute of Technology, Shenzhen, Shenzhen, China* *[3] School of Materials Science and Engineering, Harbin Institute of Technology, Shenzhen, Shenzhen, China*
14:50-15:10	**[Invited] Conductive paths in electrically conductive adhesives containing spiny silver particles** S. Fukumoto[1], T. Tanaka[1], T. Domae[1], H. Furui[2], A. Fujita[2], N. Kamada[2], and M. Matsushima[1] *[1] Department of Materials Science and Engineering, Seoul National University, Seoul, Korea* *[2] Frontics. Inc., Seoul, Korea*
	15:10-15:30 Coffee Break (Lobby)
15:30-15:50	**[Invited] Interfacial Phenomena in Solid-State Bonding for Electronics Packaging Applications** H. Tatsumi[1, 5]. Nitta[1,2], A. M. Ito[3,4], A. Takayama[3,4], M. Takahashi[1], S. Moon[5], E. Tsushima[5], and H. Nishikawa[1] *[1] Joining and Welding Research Institute, The University of Osaka* *[2] Graduate School of Engineering, The University of Osaka* *[3] National Institute for Fusion Science, National Institutes of Natural Sciences* *[4] Graduate Institute for Advanced Studies, SOKENDAI* *[5] FJ Composite Materials Co., LTD.*
15:50-16:10	**[Invited] AI-Linked Instrumented Indentation for Local Properties, Internal Stress, Fracture Toughness, and Reliability Assessment of Micro/Nano Joints** Dongil Kwon[1], Junghwa Hong[2] *[1] Department of Materials Science and Engineering, Seoul National University, Seoul, Korea* *[2] Frontics. Inc., Seoul, Korea*
16:10-16:30	**Influence of cold rolling induced microstructure on oxidation-free Cu sintering behavior in air at 250 °C** YehRi Kim[1,2] , Byeongkwon Ju[2], and Dongjin Kim[1] *[1] Advanced Packaging Integration Center (APIC), Korea Institute of Industrial Technology (KITECH), Incheon, Republic of Korea* *[2] Department of Electrical Engineering, Graduate School, Korea University, Seoul, Republic of Korea*
16:30-16:50	**Modified Nickel Nanopastes for Pressure-Reduced Nanojoining: Shear Strength and Microstructure of Joints** Benjamin Sattler[1 *], Susann Hausner[1], Guntram Wagner[1] *[1] Group of Composites and Material Compounds, Chemnitz University of Technology, 09125 Chemnitz, Germany*

16:50-17:10	**Cu-oxide + PEG nanopastes for sinter-bonding: Effect of particle size and heating rate** B. Rheingans[1], C. Cancellieri[1], J. Janczak-Rusch[1], L. P. H. Jeurgens[1] *[1] Laboratory for Joining Technologies and Corrosion, Empa - Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, Dübendorf, CH-8600 Switzerland*
17:10-17:30	**The effect of transfer mold-post mold curing process on in-air Cu sintering and porous sheet bonding applications** Byeongchan Kim[1,2], YehRi Kim[1,2], and Dongjin Kim[1,*] *[1] Advanced Packaging Integration Center (APIC), Korea Institute of Industrial Technology (KITECH), Incheon* *[2] Graduate School, Korea university, Seoul, Republic of Korea*
17:30-17:50	**Enhanced Copper-to-copper direct bonding on highly (111)-oriented nanotwinned copper via suface activation** Seongmin An, Seung ju Nam, and Jeoung han Kim *Department of Materials Science & Engineering, Hanbat National University, Daejeon, 34158, Republic of Korea*

NMJ2025

Conference Day 2 (Tue. Nov 18)	
Time	**Convention Hall B**
8:00-8:30	
8:30-8:50	Opening Ceremony (Hyun-Sik Kim)
9:00-9:30	**Keynote 1 (Convention Hall A)** **Micro/nano joining of carbon structures in 1D, 2D and 3D** Yongfeng LU[*,1], Xi HUANG[1], Haoyu DONG[1], Peizi LI[1], Qiuchi Zhu[1], Bai CUI[2], and Jean-Francois SILVAIN[3] *[1]Department of Electrical and Computer Engineering, University of Nebraska, Lincoln, NE 68588-0511, USA.* *[2]Department of Mechanical and Materials Engineering, University of Nebraska, Lincoln, NE 68588-0526, USA.* *[3]CNRS, University of Bordeaux; Bordeaux I.N.P., ICMCB, UMR 5026, F-33608 Pessac, France*
Session: Laser joining (1), (chair: Susann Hausner, Choong-Un Kim)	
9:30-9:50	**[Invited] Femtosecond laser 3D structuring and micro-welding for glass based micro-device fabrication** Jiyeon Choi, Geon Lim, Hyonkee Sohn, and Jeng-O Kim *Department of Laser & Electron Beam Technologies, Korea Institute of Machinery & Materials*
9:50-10:10	**[Invited] Femtosecond laser induced nanojoining for device integration** Lei Liu *Tsinghua University, China*
10:10-10:30 Coffee Break (Lobby)	
10:30-10:50	**[Invited] Mizue Mizoshiri - Femtosecond laser multiple-pulse heating for copper microfabrication** Mizue Mizoshiri[1] *[1] Department of Mechanical Engineering, Nagaoka University of Technology, 1603-1, Kamitomioka, Nagaoka, 940-2188, Japan*
10:50-11:10	**[Invited] Micro-welding of glass by multi-spot beam of picosecond pulsed laser with high repetition rate** Y. Okamoto[1], S. Hiramatsu[2] and A. Okada[2] *[1] Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8527, Japan* *[2] Okayama University, 3-1-1 Tsushima-naka, Kita-ku, Okayama 700-8530, Japan*
11:10-11:30	**[Invited] Fabricating Large-Scale Field Effect Transistor with Laser Nanojoining** Jianlei Cui *Xi'an Jiaotong University, China*
11:30-11:50	**Femtosecond Laser Processing of Ultra-Sensitive SERS Substrate for PFOA Analysis** U. Dewanjee, D. Fieser, J. Liu, A. Hu *Department of Mechanical, Aerospace and Biomedical Engineering, University of Tennessee Knoxville, 1512 Middle Drive, Knoxville, TN37996, USA*
11:50-12:10	**Fabrication of Gold Nanobowl SERS Substrates by Femtosecond Laser for bio-sensing** Mingyang Han[1], Zhaoxu Li [1], Hao Chen[1], and Shi Bai[2] *[1] Hebei Key Laboratory of Materials Near-Net-Forming Technology, School of Material Science and Engineering, Hebei University of Science and Technology, Shijiazhuang 050018, Hebei, China* *[2] Advanced Laser Processing Research Team, RIKEN Center for Advanced Photonics, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan*
12:10-13:10 Lunch (Sunbee Soban)	
13:10-13:40	**Keynote 2 (Convention Hall A)** **The Role of semiconductor Packaging toward New AI Era** Sayoon Kang *Professor of Manufacturing Innovation School. Inha University*
13:40-14:10	**Keynote 3 (Convention Hall A)** **Fuel cell research: integration of metal-oxide-additives with carbon-supported low-Pt-content-catalysts for oxygen reduction** Pawel J. Kulesza, Aldona Kostuch, Anna Chmielnicka, Iwona A. Rutkowska *Faculty of Chemistry, University of Warsaw, Pasteura 1, 02-093 Warsaw, Poland*

Session: Laser joining (2) & Power Devices, (chair: Guisheng Zou, Jiyeon Choi)	
14:10-14:30	**[Invited] Laser-Based Processes and Equipment for Advanced Semiconductor and Display Packaging** Seungman Kim[1,2], Seungheum Han[1], Jaeseung Lim[1,2], Jae Hak Lee[1], Hakyung Jeong[1], Hyunkyu Moon[1,2], Seungjin Oh1, Jun-Yeob Song[1] *[1] Semiconductor Manufacturing Research Center, Korea Institute of Machinery and Materials, Daejeon, Korea* *[2] Department of Robot·Manufacturing Systems, University of Science and Technology, Daejeon, Korea*
14:30-14:50	**[Invited] Laser Joining and Transfer of Nanostructures for Microwave and Optical Devices** Ruo-Zhou Li[1,*], Jing Yan[2], Ke Qu[2] and Ying Yu[1] *[1] College of Integrated Circuit Science and Engineering, Nanjing University of Posts and Telecommunications, Nanjing, 210023, China* *[2] College of Electronic and Optical Engineering, Nanjing University of Posts and Telecommunications, Nanjing 210023, China*
14:50-15:10	**[Invited] Monitoring and Diagnosis of Microcrack Formation in Battery Can-Cap Laser Welding Processes** Minjung Kang[1*], Jeonghun Shin[1] *[1] Korea Institute of Industrial Technology, 156 Gaetbeol-ro, Yeonsu-gu, Incheon*
15:10-15:30 Coffee Break (Lobby)	
15:30-15:50	**[Invited] Microscale Solid-State Printing of Dissimilar Metals Using Laser-Induced Supersonic Impact Printing (LISIP)** Yiliang Liao[1] *[1] Iowa State University, Ames, IA, 50010 USA.*
15:50-16:10	**Liquid Interlayer Assisted Femtosecond Laser Welding of Glasses for Device Packaging** Shi Bai[1], Hao Chen[2], and Koji Sugioka[1] *[1] Advanced Laser Processing Research Team, RIKEN Center for Advanced Photonics* *[2] School of Material Science and Engineering, Hebei University of Science and Technology, China*
16:10-16:30	**Rapid Electromagnetic Heating and Intermetallic Compound Formation in Transient Inductive Chip-Level Bonding Using SnCuSn Foil for Microelectronic Applications** S. Panhale[1*], C. Hofmann[2*], M. Kroll[1], P. Rochala[1], T. Petzold[2], T. Clausmeyer[1] *[1]Institute for Machine Tools and Production Processes (IWP), Professorship Forming Technology, Chemnitz Uni-versity of Technology, 09107 Chemnitz, Germany* *[2]Fraunhofer Institute for Electronic Nano Systems ENAS, Technologie-Campus 3, 09126 Chemnitz, Germany*
16:30-16:50	**Visual Inspection of Solder Joint under the Molten State in Robot Sol-dering System** M.Matsushima, S.Imada, and S.Fukumoto *Graduate School of Engineering, The University of Osaka, 2-1 Yamadaoka, Suita, Osaka, Japan*
16:50-17:10	**Innovative implementation of a direct cooling system for large-area joints in power inverters** Ha-Young Yu[1], Shin-Il Kim[1], and Dongjin Kim[1] *[1] Advanced Packaging Integration Center (APIC), Korea Institute of Industrial Technology (KITECH), 21999, Yeon-su-gu, Incheon, Republic of Korea*
17:10-17:30	**Pressureless Transient Liquid Phase Sintering Based on Cu@Cu6Sn5-based Pre-forms for HighPow-er Device Packaging** Yichen Zhu[1,2], Hongyun Wang[1,2], Jiaqi Zhou[1], Bolong Dong[1,2], Xiangji Li[1], Chuanqi Dong[1,2], Wenbo Zhu[1,*] and Mingyu Li[1,*] *[1] Department of Integrated Circuits, Harbin Institute of Technology (Shenzhen), Shenzhen 518055, China* *[2] Sauvage Laboratory for Smart Materials, Department of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), Shenzhen 518055, China*
17:30-17:50	**Self-Assembled Rosette-Like Porous Silver Microparticles for Power Electronics Packaging** Bolong Dong[1,2], Chuanqi Dong[1,2], Yichen Zhu[1,2], XiangJi Li[1], Wenbo Zhu[1], and Mingyu Li[1] *[1] School of Integrated Circuits, Harbin Institute of Technology (Shenzhen), Shenzhen 518055, China* *[2] Sauvage Laboratory for Smart Materials, School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), Shenzhen 518055, China*

Conference Day 3 (Wed. Nov 19)	
Time	**Convention Hall A**
8:30-9:00	
9:00-9:30	**Keynote 4** **Low-Temperature Bonding Technology for Heterogeneous Integration and Advanc-es in Sensors and Electronic Devices** Eiji Higurashi *Department of Electronic Engineering, Graduate School of Engineering, Tohoku University, 6-6-05, Aramaki Aza Aoba, Aoba-ku, Sendai, 980-8579, Japan*
Session: Micro- and Nano- joining (1), (chair: João Oliveira, Guntram Wagner)	
9:30-9:50	**[Invited] Properties and application possibilities of electroplated CuAg as a new packaging material** Kyu Hwan Lee *Korea Inst. of Materials Sci., Korea*
9:50-10:10	**[Invited] Copper electrodeposition for solder joint applications** Chih-Ming Chen and Jia-Syuan Chang *Department of Chemical Engineering, National Chung Hsing University, Taichung 402202, Taiwan*
10:10-10:30 Coffee Break (Lobby)	
10:30-10:50	**[Invited] Highly active bayberry-like porous silver microparticles for low temperature sintering joining** Mingyu Li *Harbin Inst. of Tech. (Shenzhen), China*
10:50-11:10	**[Invited] Current-assisted sinter joining using ion migration for highly efficient microjoining** T. Matsuda[1], T. Matsuda[1], T. Okamoto[1], M. Kambara[1], and A. Hirose[1] *[1] Division of Materials and Manufacturing Science, Graduate School of Engineering, The University of Osa-ka, 2-1 Yamadaoka, Suita, 565-0871 Osaka, Japan*
11:10-11:30	**[Invited] From Atomic Metrology to Nanobonding with Cs-STEM in Perovskite Oxide Layers and Membranes** D.T.L. Alexander[1] *[1] Electron Spectrometry and Microscopy Laboratory (LSME), Institute of Physics (IPHYS), École Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne, Switzerland*
11:30-11:50	**A High-Performance Nano-Copper Paste with Good Oxidation Resistance** Hongtao Chen[1], Jinghui Zhang[1], and Mingyu Li[1] *[1] School of Integrated Circuits, Harbin Institute of Technology (Shenzhen), Shenzhen 518055, China*
11:50-12:10	**Micro-anchor structures for joining dissimilar metals for multi-material addi-tive manufacturing** W. Lee, Q. Jin *School of Materials Science and Engineering, Pusan National University, 46241 Busan, Republic of Korea*
12:10-13:10 Lunch (Sunbee Soban)	
13:10-13:40	**Keynote 5** **High-resolution X-ray imaging of micro joints for advanced packaging in microelectronics** E. Zschech[1], K. Kutukova[2], B. Lechowski[2], T. Djuric-Rissner[3], and P. Czurratis[3] *[1] Brandenburg University of Technology Cottbus-Senftenberg, Konrad-Zuse-Str. 1, 03046 Cottbus, Germany* *[2] PVA Vision GmbH, Forstst. 1, 01454 Radeberg, Germany* *[3] PVA TePla Analytical Systems GmbH, Deutschordenstr. 38, 73463 Westhausen, Germany*

Session: Micro- and Nano- Joining (2), (chair: Shoichi Nambu, Chih Ming Chen)	
13:40-14:00	**[Invited] Challenges and thoughts on trend to nanojoining** M. Tuerpe[1,2] *[1] TU Dresden, Institute of Manufacturing, D-01062 Dresden, Germany* *[2] WHZ, Institute for Production Engineering, P.O. Box 201037, D-08012 Zwickau, Germany*
14:00-14:20	**[Invited] Resistance microwelding of NiTi and SS wires for biomedical applications** Kaiping Zhang[1], Y. Norman Zhou[1], and Peng Peng[1] *[1] Centre for Advanced Materials Joining (CAMJ), Department of Mechanical and Mechatronics Engineering, Uni-versity of Waterloo, 200 University Avenue West, Waterloo, Ontario, N2L 3G1, Canada.*
14:20-14:40	**[Invited] Designing Nanoparticle Assemblies Driven by Water Molecules** Hiroya Abe *Osaka University Joining and Welding Research Institute, Japan*
14:40-15:00 Coffee Break (Lobby)	
15:00-15:20	**[Invited] Influence of Additional Elements and Rolling Processing on the Super-plasticity of Sn-Bi Based Alloys** A. Yamauchi[1], S. Akashi[2], N. Tamura[2], and M. Kurose[1] *[1] National Institute of Technology, Gunma College* *[2] Department of Mechanical Engineering, National Institute of Technology, Gunma College*
15:20-15:40	**Neuromorphic computing Enabled by heterogeneous integration of 2D Material** Jinpeng Huo [1], Jin Peng [1], Zehua Li [1], Tianming Sun [1], Yu Xiao [1], Sanghoon Chae[2], Lei Liu[*,1], Guisheng Zou[*,1] *[1] State Key Laboratory of Clean and Efficient Turbomachinery Power Equipment, Department of Mechanical En-gineering, Tsinghua University, Beijing 100084, P. R. China.* *[2] School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, 639798, Sin-ga-pore*
15:40-18:00 **Banquet Setting (Table Setting)**	
18:00-20:00 **Banquet**	

Conference Day 3 (Wed. Nov 19)	
Time	Convention Hall B
8:30-9:00	
9:00-9:30	**Keynote 4 (Convention Hall A)** **Low-Temperature Bonding Technology for Heterogeneous Integration and Advanc-es in Sensors and Electronic Devices** Eiji Higurashi *Department of Electronic Engineering, Graduate School of Engineering, Tohoku University, 6-6-05, Aramaki Aza Aoba, Aoba-ku, Sendai, 980-8579, Japan*
Session: Battery & Power Devices (1), (chair: Iwona A Rutkowska, Yongho Ko)	
9:30-9:50	**[Invited] Recent Developments in Resistance Projection Welding for Automotive and Secondary Battery Manufacturing** Yeong-Do Park[1] and B.Savyasachi Nellikode[1] *[1] Dong-Eui University, Dept. of Advanced Materials Engineering, Pusan, South Korea*
9:50-10:10	**[Invited] Perspectives of laser technologies in battery manufacturing** Wilhelm Pfleging *Karlsruhe Inst. of Tech., Germany*
10:10-10:30 Coffee Break (Lobby)	
10:30-10:50	**[Invited] Data-Driven Evaluation of Ultrasonic Welds Quality in Multi-Layer Ul-tra-Thin Copper Foil Stacks Using Process Signals** H.S. Bang[1], B.S. Go[2], J.W. Cho[2] D.W. Choi[2] *[1] Dept. of Welding and Joining Science Engineering, Chosun Univ., Gwangju. 61452, Korea* *[2] Dept. of Welding and Joining Science Engineering, Graduate School, Chosun Univ., Gwangju. 61452, Korea*
10:50-11:10	**Phosphoric Acid-Based Surface Modification for Direct Bonding of Alumi-num and Polypropylene Used in Lithium-Ion Battery Pouch Films** Jin Woong Park[1], Sohee Jeon[1], Byoung Jun Han[1], Emmanuel Appiah[1] Junyun Kim[2], Sungmin Park[2], Jeoung Han Kim[1*] *[1] Department of Materials Science and Engineering, Hanbat National University, Daejeon 34158, Republic of Korea* *[2] Department of Battery Material Development, Lotte Infracell Co., Ltd, Ansan 13385, Republic of Korea*
11:10-11:30	**Investigation of Lamination Bonding Behavior in Ultra-Thin Foil Stacks Using Vaporizing Foil Actua-tor Welding** Jungyu Choi[1], Deepak Kumar[1], Taeseon Lee[1] *[1] Department of Mechanical Engineering, Incheon National*
11:30-11:50	**LIFT for printing and assembly – a study on optimized water-based inks for batteries** U. Rist[1], W. Pfleging[1] *[1] Institute for Applied Materials-Applied Materials Physics (IAM-AWP), Karlsruhe Institute of Technology (KIT), Kaiserstraße 12, 76131 Karlsruhe, Germany*
11:50-12:10	**Advances in advanced power electronics packaging technology** Dongjin Kim[1] *[1] Korea Institute of Industrial Technology (KITECH), 156, Gaetbeol-ro, Yeonsu-gu, Incheon, Republic of Korea*
12:10-13:10 Lunch (Sunbee Soban)	
13:10-13:40	**Keynote 5 (Convention Hall A)** **High-resolution X-ray imaging of micro joints for advanced packaging in microelectronics** E. Zschech[1], K. Kutukova[2], B. Lechowski[2], T. Djuric-Rissner[3], and P. Czurratis[3] *[1] Brandenburg University of Technology Cottbus-Senftenberg, Konrad-Zuse-Str. 1, 03046 Cottbus, Germany* *[2] PVA Vision GmbH, Forstst. 1, 01454 Radeberg, Germany* *[3] PVA TePla Analytical Systems GmbH, Deutschordenstr. 38, 73463 Westhausen, Germany*

Session: Battery & Power Devices (2), (chair: Mingyu Li, Yiliang Leon Liao)	
13:40-14:00	**[Invited] EV System Reliability** Sanghoon Shin *Hanyang University, Korea*
14:00-14:20	**Effect of Palladium Doping in Gold Wire Bonding on Aluminum Pads in High-Temperature** S.Y. Kim[1], H.J. Park[2], J.J. Shin[2], and O.S. Song[1] *[1] Department of Materials Science and Engineering, University of Seoul, 163, Seoulsiripdea-ro, Dong-dae-mum-gu, Seoul 02504, Republic of Korea.* *[2] R & D Center, MK Electron, 405, Geumeo-ro, Pogok-eup, Cheoin-gu, Yongin-si, Gyeonggi-do, 17030, Republic of Korea.*
14:20-14:40	**Targeted Induction Heating of High-Power Device Interconnects on Circuit Boards** Peng Cui[1], Haosong Li[1], Boda Ren[1], Wenbo Zhu[1], and Mingyu Li[1#] *[1] Sauvage Laboratory for Smart Materials, School of Integrated Circuits, Harbin Institute of Technology, Shen-zhen, China*
14:40-15:00 Coffee Break (Lobby)	
15:00-15:20	**[Invited] Low-Temperature Ag-Al Composite Paste Sinter Joining for High-Reli-ability SiC Power Devices** Chuantong Chen *Osaka University, Japan*
15:20-15:40	**[Invited] Uncovering Diffusion Pathways and Phase Segregation in Alloys and Oxides via Atomistic Simulations** Penghao Xiao[1] *[1] Department of Physics and Atmospheric Science, Dalhousie University, Halifax, NS Canada*
15:40-18:00	**Banquet Setting (Table Setting)**
18:00-20:00	**Banquet**

Time	Convention Hall A
Conference Day 4 (Thur. Nov 20)	
8:30-9:00	
9:00-9:30	**Keynote 6** **Advanced Packaging in Artificial Intelligence** Jaesik Lee *SK hynix America, 3101 North First Street, San Jose, CA 95134*
9:30-10:00	**Keynote 7** **The nanojoining and microjoining in hybrid bonding: structure, process and materials** Zhi-Quan Liu *Southern University of Science and Technology, Shenzhen 518055, China*
Session: Advanced Joining and Welding, (chair: Young-Do Park, Lei Liu)	
10:00-10:20	**[Invited] Interlayers in multi-material joining guided by thermodynamic design of high-entropy alloys** Namhyun Kang[1], Yoona Lee[1], Byoungwook Choi[1], Seonghoon Yoo[1], Wookjin Lee[1], and Yoon suk Choi[1] *[1] Department of Materials Science and Engineering, Pusan National University, Korea*
10:20-10:40 Coffee Break (Lobby)	
10:40-11:00	**[Invited] Welding of high entropy alloys** J. P. Oliveira[1] *[1] CENIMAT/I3N, Departamento de Ciências dos Materiais, Faculdade de Ciências e Tecnologia, Univer-sidade Nova de Lisboa, 2829-516, Caparica, Portugal*
11:00-11:20	**[Invited] On the Strength of Welds of Thin Cu Wires Welded by Joule Heat** H. Tohmyoh, T. Sakatoku, and Y. Kimura *Department of Finemechanics, Graduate School of Engineering, Tohoku University, 6-6-01 Aoba, Aramaki, Ao-ba-ku, Sendai 980-8579, Japan*
11:20-11:40	**[Invited] Metal-Polymer Dissimilar Material Joining Technology Using Plasma-As-sisted Hot Press-ing Method** K. Takenaka[1], G. Uchida[2], and Y. Setsuhara[1] *[1] Joining and Welding Research Institute, The University of Osaka, 11-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan* *[2] Faculty of Science and Technology, Meijo University, 1-501 Shiogamaguchi, Tempaku-ku, Nagoya 468-8502, Japan*
11:40-12:00	**HPT processing of Cu-Mo composites for tailoring thermal prop-erties for thermal management** M. Lewandowska[1], D. Pałgan[1], K. Bozek[1], S. H. Rajendran[2], J. Janczak-Rusch[2] *[1] Warsaw University of Technology, Faculty of Materials Science and Engineering, Woloska 141, 02-507 Warsaw, Poland* *[2] Laboratory for Joining Technologies and Corrosion, Empa - Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, Dübendorf, CH-8600 Switzerland*
12:00-12:20	**Cracking Behavior and Laser Direct Energy Deposition of Tungsten** D. Fieser, U. Dewanjee, A. Hu *Department of Mechanical, Aerospace and Biomedical Engineering, University of Tennessee Knoxville, 1512 Middle Drive, Knoxville, TN37996, USA*
12:20-13:20 Lunch (Sunbee Soban)	

Session: 3D Semiconductor Packaging and Hybrid bonding, (chair: Tomo Ogura, Peng Peng)	
13:20-13:40	**[Invited] Multiscale analysis for microstructure and bonding strength at interface of dissimilar metallic materials** Shoichi Nambu *The University of Tokyo, Japan*
13:40-14:00	**[Invited] Experimental and numerical study on the mechanical impact of surface roughness in TGV glass** X. Long[1,*], X.H. Ma[1], B. Yang[2], and C.Q. Cui[2] *[1] School of Mechanics and Transportation Engineering, Northwestern Polytechnical University, Xi'an, 710072, China* *[2] School of Mechanical and Electrical Engineering, Guangdong University of Technology, Guangzhou, 510006, China*
14:00-14:20	**Evaluation and Analysis of the Quantitative Interfacial Adhesion Energy of SiO2-SiO2 Bonding Interfaces** Yeonwoo Jung[1], Sarah Eunkyung Kim[2], and Young-Bae Park[1†] *[1] School of Materials Science and Engineering, Gyeongkuk National University, Andong, Republic of Korea* *[2] Department of Semiconductor Engineering, Seoul National University of Science and Technology, Seoul, Republic of Korea*
14:20-14:40	**Air Exposure Time Effect on the Interfacial Adhesion Energy of the Cu-Cu Bonding Interface after Ar/N2 2-step Plasma Treatment** Seunggyun Lee[1], Yeonwoo Jung[1], Junyoung Choi[2], Sarah Eunkyung Kim[2], Young-Bae Park[1†] *[1] School of Materials Science and Engineering, Gyeongkuk National University, Andong, Republic of Korea* *[2] Department of Semiconductor Engineering, Seoul National University of Science and Technology, Seoul, Republic of Korea*
14:40-15:00	**Cu-to-Cu direct bonding in the air atmosphere without oxidation for advanced 3D packaging in various pressure condition** Ha-Young Yu[1], YehRi Kim[1], and Donjin Kim[1] *[1] Korea Institute of Industrial Technology (KITECH), 156, Gaetbeol-ro, Yeonsu-gu, Incheon, Republic of Korea*
15:00-15:30	Awarding & Closing Ceremony

Conference Day 4 (Thur. Nov 20)	
Time	Convention Hall B
8:30-9:00	
9:00-9:30	**Keynote 6 (Convention Hall A)** **Advanced Packaging in Artificial Intelligence** Jaesik Lee *SK hynix America, 3101 North First Street, San Jose, CA 95134*
9:30-10:00	**Keynote 7 (Convention Hall A)** **The nanojoining and microjoining in hybrid bonding: structure, process and materials** Zhi-Quan Liu *Southern University of Science and Technology, Shenzhen 518055, China*
Session: Thin film interface and Reliability, (chair: Hiroaki Tatsumi, Duncan Alexander)	
10:00-10:20	**[Invited] Mechanical Reliability of Thin Film Materials for Semiconductors, Displays, and More** Taek-Soo Kim *Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST), Korea*
10:20-10:40 Coffee Break (Lobby)	
10:40-11:00	**[Invited] Small-scale Local Residual Stress Measurement Technique: Slitting Method Based on FIB-μDIC** Jong-hyoung Kim[1,2], Hyun-Wook Cho[1], Seo Hyeon Jang[1], Shuming Kang[2] and Joost J. Vlassak[2] *[1] Pukyong National University, Department of Materials Science and Engineering, Busan, Republic of Korea 48513* *[2] Harvard University, John A. Paulson School of Engineering and Applied Science, Cambridge MA, USA 02138*
11:00-11:20	**[Invited] Interfacial adhesion and fracture behavior in BEOL structures** Sumin Kang[1] *[1] Department of Mechanical and Automotive Engineering, Seoul National University of Science and Technology*
11:20-11:40	**[Invited] Effects of carbon nanotubes in enhancing the thermal and mechanical prop-erties of W/Cu-CNTs/CuCrZr alloy joints** Zumin Wang[1], Zhang Liu[1] *[1] State Key Laboratory of High Performance Roll Materials and Composite Forming, School of Materials Science and Engineering, Tianjin University, Tianjin 300350, China*
11:40-12:00	**Effect of Temperature Variation on Residual Stress in Cu/PI Structures for Fan-Out Package** Hyukjin Kwon[1], Hyeyoung Kong[1], Jinyoung Ha[2], Hyun Sue Huh[2], Young-Bae Park[1†] *[1] School of Materials Science and Engineering, Gyeongkuk National University, Andong, Republic of Korea* *[2] nepes Corporation, Republic of Korea*
12:00-12:20	**Evaluation of Fracture Morphology of Al/Cu Joints for Development of Separa-tion Techniques for Joining Dissimilar Matals** T. Ogura[1] and Y. Kiyoto[1] *[1] The University of Osaka, 2-1, Yamadaoka, Suita, Osaka 565-0871, Japan*
12:20-13:20 Lunch (Sunbee Soban)	

Session: Specialized Joining, (chair: Hiroaki Tatsumi, Seungjin Oh)	
13:20-13:40	**[Invited] Development of domestic technology for high-power plasma arc cutting for nuclear power plant decommissioning** Dae-Won Cho *Korea Institute of Machinery & Materials, Korea*
13:40-14:00	**Suppressing Kirkendall voids in solder joints by eliminating sulfur in nt-Cu/Zn metallization** Z. C. Sa[1], W. Shang[1], H. Zhang[2], J. Y. Feng[1], H. Z. Li[1], J. X. Ma[1], X. D. Liu[1], Q. Sun[1] and Y. H. Tian[1*] *[1] State Key Laboratory of Precision Welding & Joining of Materials and Structures, Harbin Institute of Technology, Harbin, China* *[2] Department of Mechanical Engineering, The University of Hong Kong, Hong Kong SAR, China*
14:00-14:20	**Constrained Conformal Soldering Technology for Complex Structure Using Metal Aerogel** Wenbo Zhu[1], Qidong Hu[1], Xiangji Li1 and Mingyu Li[1] *[1] Sauvage Laboratory for Smart Materials, School of Integrated Circuits, Harbin Institute of Technology (Shen-zhen), HIT Campus of University Town, Shenzhen, 518055, China*
14:20-14:40	**Ruthenium-Cultured Bacterial Biofilms as Integrated Systems for Electrochemical and Photoelectrochemical Reduction of Carbon Dioxide** Iwona A. Rutkowska, Ewelina Seta-Wiaderek, Pawel J. Kulesza *Faculty of Chemistry, University of Warsaw, Pasteura 1, 02-093 Warsaw, Poland*
14:40-15:00	**Ultrasonic Evaluation of Thermoplastic Weld Quality under Variable Temperature** Changhyeon Kim[1], Young-Dae Shim[2], Jihun Kim, Jauk Gu and Eun-Ho Lee[3] *[1] Department of Mechanical Engineering, Sungkyunkwan University, Suwon-si, South Korea* *[2] Department of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA* *[3] Facility Team, Samsung Electronics, Hwasung-si, South Korea* *[4] Department of Fabrication Technology, Sungkyunkwan University, Suwon-si, South Korea* *[5] Department of Intelligent Robotics, Sungkyunkwan University, Suwon-si, South Korea*
15:20-15:30	Awarding & Closing Ceremony

Poster Session

1	**Development of Sn-Bi alloys for low-temperature soldering applications** Chih-Hui Yu[1] and Chih-Ming Chen[1,2] *[1] Master Program in Semiconductor and Green Technology, Academy of Circular Economy, National Chung Hsing University, Nantou City, Nantou County 540216, Taiwan* *[2] Department of Chemical Engineering, National Chung Hsing University, Taichung 402202, Taiwan*
2	**Corrosion and inhibition study of copper in electronic packaging** Xin You Ye, Yen Ju Chu, and Chih Ming Chen *Department of Chemical Engineering, National Chung Hsing University, Taichung 402202, Taiwan*
3	**Develop Electroplated Composite Copper Films with Different Grain Sizes for Cu-Cu Bonding** Hsiang-Yu Wei and Chih-Ming Chen *Department of Chemical Engineering, National Chung Hsing University, Taichung 402202, Taiwan*
4	**Thermal Shock and Joining Characteristics of Lotus-Type Porous Copper/Dissimilar Materials Depending on Pore Filling Ratio** Jae-ho Shin[1], A Sum Cho [1], Keun-soo Kim[2] and Soong-keun Hyun[1] *[1] Department of Advanced Materials Processing Engineering, Inha Manufacturing Innovation School, Republic of Korea* *[2] Department of Electronic Materials Engineering, Hoseo University, Republic of Korea*
5	**Study on Bonding of AMB Substrate for Power Semiconductors Using Lotus-type Porous Copper** Seung Min Cho[1], Jeong Yeon Back[1], Keun Soo Kim[2] and Soong Keun Hyun[1] *[1] Department of Advanced Materials Processing Engineering, Inha Manufacturing Innovation School, 36 Gaet-beol-ro, Yeonsu-gu, Incheon 21999, Korea* *[2] Department of Electronic Materials Engineering, Hoseo University, 201 Sandan 7-ro, Seongmun-myeon, Dang-jin-si, Chungcheongnam-do 31702, Korea*
6	**Plasma Interface Engineering for Modulating Robust MoS_2-MoO_3 Neuromorphic Devices** Pan Pan[1], Ruixiao Ou[1], Siyi Wu[1] and Ming Xiao[1] *[1] School of Microelectronics Science and Technology, Sun Yat-sen University, 519082 Zhuhai, China*
7	**Interface-Engineered Nano-joining Between NiCo Nanoparticles and Polyimide-Based Covalent Organic Framework for High-Performance Oxygen Evolution Reaction Catalysis** Ting-Yu Lo[1], Manik Chandra Sil[2], and Chih-Ming Chen[1] *[1] Department of Chemical Engineering, National Chung Hsing University, Taichung 402202, Taiwan* *[2] Department of Chemistry, Rajendra University, Prajna Vihar, Balangir, Odisha-767002, India*
8	**Evaluation of Cu-Sn Transient Liquid Phase Bonding Characteristics with Lotus-Type Porous Copper Interlayer for Power Module Applications** Hong Seok Kim[1], Soo Hyun Lee[1], and Keun Soo Kim[2] Soong Keun Hyun[1*] *[1] Department of Advanced Materials Processing Engineering, Inha Manufacturing Innovation School, Korea* *[2] Department of Materials Science and Engineering, Hoseo University, Korea*
9	**Study on the correlation between microstructure and electromigration characteristics of the solder joints formed by intense pulsed light soldering** Hyeri Go[1], Gahui Kim[2], Young-Bae Park[2] and Yoonchul Sohn[1*] *[1] Department of Welding and Joining Science Engineering, Chosun University, Gwangju 61452, Korea* *[2] School of Materials Science and Engineering, Andong National University, Gyeongdong-ro 1375, Andong-si, Gyeongsangbuk-do 36729, Korea*
10	**Elemental segregation-induced variation of phase stability in additively manufactured Fe-SMA** Dohyung Kim[1], Irene Ferretto[2, 3], Youngkeun Park[4], Christian Leinenbach[2, 3], Wookjin Lee[5] *[1] School of Materials Science and Engineering, Yeungnam University, Gyeongsan, Republic of Korea* *[2] Empa-Swiss Federal Laboratories for Material Science and Technology, Switzerland* *[3] Laboratory for Photonic Materials and Characterization, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland* *[4] Ulsan Division, Korea Institute of Industrial Technology, Ulsan, Republic of Korea Ulsan Division, Korea Institute of Industrial Technology, Ulsan, Republic of Korea* *[5] School of Materials Science and Engineering, Pusan National University, Busan, Republic of Korea*
11	**A Study on the Trend and Competitiveness of Domestic defense Semiconductor Industry** Chang Ho Kim[1,2], Il Ho Jeong[2], Jae Pil Jung[3] and Suk Jae Jeong[1] *[1] Author's Dept. Acquisition Program., University of Kwangwoon, Seoul(01897), Korea* *[2] Author's Defense Acquisiton Program Administration, Government Complex Gwacheon(13809), Korea* *[3] Author's Dept. Materials Sci. and Eng., University of Seoul, Seoul(02504), Korea*

12	**Development of a Low-Silver, Flux-Free Brazing Alloy for Cu-SUS Joint with Heat Treatment-Optimized Properties** Chan Yang Lee[1,2], Il Ho Jeong[2], Jae Pil Jung[3] and Suk Jae Jeong[1] *[1] Author's Dept. Acquisition Program., University of Kwangwoon, Seoul(01897), Korea* *[2] Author's Defense Acquisiton Program Administration, Government Complex Gwacheon(13809), Korea* *[3] Author's Dept. Materials Sci. and Eng., University of Seoul, Seoul(02504), Korea*
13	**Development of a Low-Silver Filler Metal for Brazing Dissimilar Copper and Stainless Steel with Enhanced Joint Properties** Chan Yang Lee[1,2], Min Chul Oh[2], Geon Hong Kim[2] and Byungmin Ahn[1,3] *[1] Department of Materials Science and Engineering, Ajou University* *[2] Mechanical Convergence System Center, Institute for Advanced Engineering* *[3] Department of Energy Systems Research, Ajou University*
14	**Development of a Flexible Technique for RF Welding of Innovative Recyclable Mono-Material Packaging Films** S. Panhale[1], M. Götz[2], A. Fröhlich[1], M. Kroll[1], T. Clausmeyer[1] *[1]Institute for Machine Tools and Production Processes (IWP), Professorship Forming Technology, Chemnitz University of Technology, 09107 Chemnitz, Germany* *[2]Fraunhofer Institute for Process Engineering and Packaging IVV, Heidelberger Straße 20, 01189 Dresden, Germany*
15	**Developing of Bonding Process Technology for MLCB Electronic Components with Various Process Conditions** Jahyeon Kim[1,2], Taeyoon Im[1], Minseo Park[1], Sejeong Hwang[1], Won Bin Im[2] and Yong-Ho Ko[1] *[1] Advanced Packaging Integration Center (APIC), Korea Institute of Industrial Technology (KITECH), Incheon 21999, Korea* *[2] Division of Materials Science & Engineering, Hanyang Univeristy, Seoul 04763, Korea*
16	**Laser Microwelding of Si Die to Cu Lead Frame** Arko Roychoudhury[1], Kaiping Zhang[1], Tetsuya Oyamada[1], Peng Peng[1] *[1] Centre for Advanced Materials Joining, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada*
17	**Machine Learning-Based Prediction of Mechanical Properties of Metal Thin Films via Nanoindentation FEA with Imperfect Indenter Tip Geometry** Ju-been-Ham[1], Si-Hyun Park[2], Hyeon-Wook-Cho[2], Jong-Hyoung Kim[2], Young-Cheon Kim[1†] *[1] School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeongkuk Na-tional University, 1375, Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Republic of Korea* *[2] Pukyong National University, Department of Materials Science and Engineering, Busan Metropolitan City 45 Yongso-ro(E13-915) Nam-gu, Busan 48513, Republic of Korea*
18	**Interlayer Delamination Simulation of Hybrid Bonding Based on Nanoindentation Testing** Seo-Woo Nam[1], Yeon-Woo Jung[1], Y. -B. Park[1], Young-Cheon Kim[†] *[1] School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeongkuk National University, 1375, Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea*
19	**Simulation of friction stir welding process with Lagrangian based finite element method** D. J. Myung[1], Y. J. Jeon[2], J. G. Yoon[2], S.A. Kang[2], and W. Wnoh[2] *[1] Samsung Electronics, Suwong 16677, Republic of Korea* *[2] Department of Advanced Materials Science and Engineering, Gyeongkuk National University, Andong 36729, Republic of Korea*
20	**A Semi-Analytical Approach for Numerical Analysis of Residual Stress in Oxide Scale Grown on Hot-Rolled Steels** SeonA Kang *Gyeongkuk National University*
21	**Fabrication of Wafer-Level RDL Structure for 3D-IC Process Integration** Ye Jin Kim[1], Ha Neul Choi[1], and Sang Jeen Hong[1*] *[1] Department of Semiconductor Engineering, Myongji University, Yongin 17058, Republic of Korea.*
22	**Cu Electroplated Bonding of LED Chips on Ni-Plated Fabric Flexible Substrates for Wearable Devices** Gieop Lee[1], Hyung Gu Kim[2], Sang Hyeon Ahn[1], Jun-beom Park[2], Tak Jeong[2], and Jun-Seok Ha[1,3] *[1] Department of Chemicals Engineering, Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju 61186, Republic of Korea* *[2] Korea Photonics Technology Institute (KOPTI), Cheomdanbencheo-ro 108 Beon-gil 9, Buk-gu, Gwangju, 61007, Republic of Korea* *[3] Energy Convergence Core Facility, Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju 61186, Republic of Korea*

23	**Evaluation and Optimization of Anisotropic Nanoindentation Characteristics on Metal Surfaces Using Digital Image Correlation (DIC) Technique** Ji-Hyeon Kim, Soo-Hyun Kim, and Young-Cheon Kim *School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeo-ngKuk National University, 1375, Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea*
24	**Evaluation of Substrate Influence on the Nano-Hardness of Cu Films Deposited on PI Using Contact Area Calibration** Hee-Chang Seo[1], Ju-Bin Ham[1], Ji-Hyeon Kim[1], Seo-Woo Nam[1], Wooram Noh[1], Young-Cheon Kim[†] *School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeongkuk Na-tional University, 1375, Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea*
25	**Nanoindentation-Induced Fracture Behavior and of Ni-Rich NCM Nanoparticles with Photolithographic Process** Sae-Deok Seo[1], Ji-Hyeon Park[1], Seung-Hoon Nam[2], Youn-Cheon Kim[1†] *[1] School of Materials Science & Engineering, Research Center for Energy and Clean Technology, Gyeongkuk Na-tional University, 1375, Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea* *[2] Department of Advanced Materials Science & Engineering, Myongji University, 116, Myeongji-ro, Cheoin-gu, Yongin-si, Gyeonggi-do, 17058, Korea*
26	**Comparative Analysis of Laser and Conventional Soldering Methods in Multi-Reflow Processes for MLCC Assembly** Taeyoon Im[1], Jahyeon Kim[1], Minseo Park[1], Sejeong Hwang[1] and Yong-Ho Ko[1,*] *[1] Advanced Packaging Integration Center (APIC), Korea Institute of Industrial Technology (KITECH), Incheon 21999, Korea*
27	**A Fundamental Study on the Optimization of the Laser Cleaning for Lubricating Oil Removal on the Surface of Aluminum Heat Exchanger Components** S.H.Kim[1], J.O.Jeon[2], K.S.Kim[2], P.S.Kim[3] and J.D. Kim[4†] *[1] raduate School of Maritime Industries, Korea Maritime&Ocean University 727, Taejong-ro, Yeongdo-gu, Busan, Republic of Korea, 49112* *[2] Graduate school, Korea Maritime & Ocean University* *[3] Hanjo. Co, Ltd.* *[4] Division of Marine System Engineering, Korea Maritime & Ocean University*
28	**Fundamental Study on Energy Density Parameters in Laser Scabbling for Concrete Surface Decontamination** Moo-Keun Song *Korea Research Institute of Decommissioning*
29	**Laser-Direct Fabrication of Graphene Flakes Decorated with Silver Nanoparticles** Yong-Won Ma *Korea Research Institute of Decommissioning*
30	**Tailoring Electromechanical Characteristics of Metal Films for AI-Empowered Electronic Skins: A Leaf-Bioinspired, Micro/Nano Dual Scale Synergistic Regulation Strategy** Tianming Sun, Bin Feng, Jinpeng Huo, Lei Liu*, Guisheng Zou* *Department of Mechanical Engineering, Tsinghua University, Beijing 100084, P. R. China.*
31	**Microstructural Evolution and Reliability of Laser Solder Ball Jetted SAC305/ENIG Joints Subjected to Multiple Reflow Cycles** Seungchan Ga [1], Deborah Bae [1], Junsu Kim [1], Jun-Kyo Seo [1], Ashutosh Sharma [1,2], Gi-Jung Nam [3], Hyun-Sik Kim [1], Jae Pil Jung [1] *[1] Department of Materials Science and Engineering, University of Seoul, Seoul 02504* *[2] Amity Institute of Applied Sciences, Amity University Jharkhand, Ranchi 834002, India.* *[3] DAWON-NEXVIEW Co. Ltd, Ansan, GyeongGi-do, 15616*
32	**Analysis of Al-Cu-Cu Overlap Weldment according to Wobbling Amplitude during Laser Dual Beam Welding** J.O.Jeon[1], H.J.Kim[2], K.S.Kim[1] and J.D. KIM[3†] *[1] Graduate school, Korea Maritime&Ocean University 727, Taejong-ro, Yeongdo-gu, Busan, Republic of Korea, 49112* *[2] Graduate School of Maritime Industries, Korea Maritime&Ocean University* *[3] Division of Marine System Engineering, Korea Maritime&Ocean University*
33	**Effect of Lotus Cu on thermal shock properties in Ag-Sintered joints** Minsu Kim[1,2], Hiroaki Tatsumi[2], Hiroshi Nishikawa[2] and Soong Keun Hyun[1] *[1] Manufacturing Innovation School, Inha University, Incheon, 22212, South Korea* *[2] Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka, 567-0047, Japan*

34	**Effects of Dy_2O_3 Nanoparticle Addition on the Mechanical and Physical Properties of Sn–Bi Based Solder** Junsu Kim [1], JunKyo Seo [1], Ashutosh Sharma [1], Jae Pil Jung [1], Hyun-Sik Kim [1] *[1] Department of Materials Science and Engineering, University of Seoul, Seoul 02504*
35	**Effect of Intense Pulsed Light soldering condition on the Microstructural Evolution and Reliability of SAC 305 Solder Joints in LED Packages** DongGil Kang, JaeJun Yoon, HoKyeong Sung, Seung-Boo Jung* *School of Advanced Materials Science and Engineering, Sungkyunkwan University 2066 Seobu-ro, Jangan-gu Suwon, 16419, South Korea*
36	**Investigation of electrochemical migration behavior of various surface treatment** Ho-Kyeong Seong[1], DongGil Kang[2], Jaejun Yoon[1], Seung-Boo Jung[1,2†] *[1]Department of Semiconductor Convergence Engineering, Sungkyunkwan university, Suwon, Korea* *[2]School of Advanced Materials Science and Engineering, Sungkyunkwan University*
37	**Interfacial Enrichment of Bismuth and Its Impact on the Reliability of Low-Temperature Solder Joints** MinJi Kim[1], HyeRin Jin[2] and Seung-Boo Jung[2†] *[1] School of Chemical Engineering, Sungkyunkwan university, Suwon, Korea* *[2] School of Advanced Materials Science & Engineering, Sungkyunkwan University, Suwon, Korea*
38	**Electroplating of Copper for Through-Glass Via Filling** JunKyo Seo [1], Junsu Kim [1], Chul Hwa Jung [1], Ashutosh Sharma [1], Jae Pil Jung [1], Hyun-Sik Kim [1] *[1] Department of Materials Science and Engineering, University of Seoul, Seoul 02504*
39	**Analysis of Palladium Diffusion from ENEPIG Surface Finish into Solder Joint** Do Ah Kim[1], HyeRin Jin[2] and Seung-Boo Jung[2†] *[1] School of Chemical Engineering, Sungkyunkwan university, Suwon, Korea* *[2]School of Advanced Materials Science & Engineering, Sungkyunkwan University, Suwon, Korea*

Keynote

Keynote 1

09:00-09:30 Tuesday November 18

Micro/Nanojoining of Carbon Structures in 1D, 2D and 3D

Yongfeng Lu

Univ. of Nebraska - Lincoln, USA

Abstract

This talk presents advanced techniques for the precise joining and integration of carbon-based nanomaterials, including 1D single-walled carbon nanotubes (CNTs), 2D graphene, and 3D diamond-based composite materials, to address critical challenges in nanoelectronics and thermal management. A laser-assisted chemical vapor deposition (LCVD) method leverages optical near-field effects from CO_2 laser irradiation on pre-patterned substrates with sharp metallic tip electrodes, acting as optical antennas (Fig. 1). These antennas locally enhance the electric field, generating nanoscale heating to promote selective CNT growth between opposing electrode tips at a substrate temperature of ~500°C. The process ensures precise placement, reliable electrical contacts, and semiconducting properties, enabling scalable fabrication of CNT-based nanoelectronic devices. Additionally, a plasmonic-assisted LCVD approach uses silver nanoantenna arrays to couple laser energy into localized surface plasmon resonances, selectively activating catalyst nanoparticles in sub-100-nm gaps to grow CNT bridges in a single step. The resulting infrared bolometers exhibit high responsivity (~800 V/W) at room temperature due to enhanced optical field-CNT interactions. For 2D graphene, a laser-assisted nanowelding technique reduces graphene-metal contact resistance to 2.57 Ω·μm by creating localized defects at the contact interface, followed by thermal annealing to form strong covalent bonds, yielding a fourfold increase in photocurrent in photodetectors (Fig. 2). For 3D structures, a hybrid copper/carbon (Cu/C) metal matrix composite with carbide interphases (TiC or ZrC), enhances interfacial bonding and thermal conductivity for advanced thermal management in microelectronics. Microstructural and thermal characterizations confirm high-quality interfaces and superior performance, offering a versatile platform for next generation electronic and optoelectronic devices.

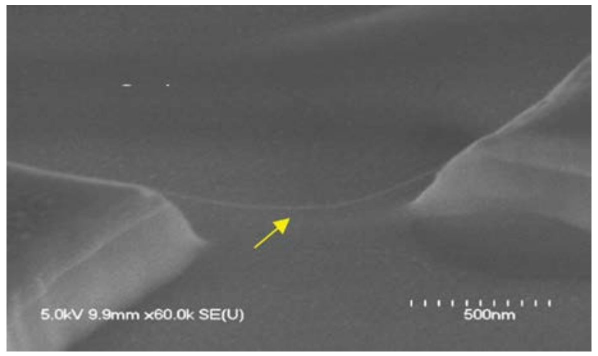


Fig. 1. Schematic diagram of Au surface smoothing by thin film transfer process based on template stripping and surface activated bonding

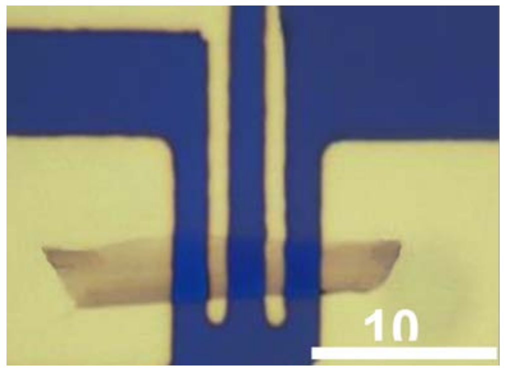


Fig. 2. Cross sectional scanning electron microscopy (SEM) images of the Au plating before and after smoothing.

Keynote 2

13:10-13:40 Tuesday November 18

The Role of Semiconductor Packaging Toward New AI Era

Sayoon Kang

Professor of Manufacturing Innovation School. Inha University

Abstract

Over the past decade, the proliferation of mobile devices—symbolizing the era of mobility—has been a major driver of IT innovation. This mobility revolution reshaped the semiconductor industry, demanding breakthroughs in ultra-low power consumption, miniaturization, and thermal management. To meet these requirements, semiconductor companies advanced IC design methodologies and pursued aggressive technology scaling, which has remained a cornerstone of progress.

Today, however, artificial intelligence (AI) has emerged as the defining force of the next era. Together with 5G communications and high-performance computing (HPC), AI is driving unprecedented demand for computing density, memory bandwidth, and system-level integration. Unlike the mobility era, where efficiency and portability were paramount, the AI era requires heterogeneous integration of diverse functions—logic, memory, sensors, and accelerators—within a single package. This necessitates advanced packaging technologies such as 2.5D/3D integration, chiplet-based architectures, through-silicon vias (TSVs), fine-pitch redistribution layers (RDLs), and high-density interconnects.

At the same time, the challenges of power delivery, signal integrity, and thermal management are becoming more severe as AI workloads scale. Traditional transistor scaling alone cannot address these bottlenecks, especially given the escalating cost and complexity of advanced process nodes. In this context, packaging is no longer a supporting technology but a strategic enabler—the key to achieving higher performance-per-watt, reduced latency, and cost-effective system integration.

This keynote will explore a central question: How should the semiconductor packaging industry innovate in heterogeneous integration, advanced interconnects, and thermal/power solutions to seize the unprecedented opportunities of the AI and 5G era, and position itself as the cornerstone of the Fourth Industrial Revolution?

Keynote 3

13:40-14:10 Tuesday November 18

Fuel cell research: Integration of Metal-oxide-additives with Carbon-supported low-Pt-Content-Catalysts for Oxygen Reduction

Pawel J. Kulesza

Faculty of Chemistry, University of Warsaw, Pasteura 1, 02-093 Warsaw, Poland

Abstract

The proton-exchange membrane fuel cell (PEMFC) technology is one of the most promising approaches for energy conversion in automotive applications. The progress in this subject is greatly hindered by the high cost and scarcity of the state-of-the-art platinum-based materials which are regarded as the most effective cathode catalysts. Therefore, most of the current research studies have been devoted to the optimization of active centers and maximization of their utilization, which should allow the lowering of the cathode Pt loadings without loss of performance and durability. Unfortunately, the problem of electrochemical stability and the danger of generation of higher quantities of the undesirable hydrogen peroxide intermediate may become even more serious in the case of systems utilizing lower amounts of the Pt catalyst.

Among important strategies is the integration, nano-joining, activation, and stabilization of carbon-supported Pt catalysts by functionalization through admixing with certain nanostructured and typically substoichiometric metal oxides. Special attention is paid to application of the bi- or multi-metallic Pt-based alloys in their various forms and structures. Among other important issues are such features as porosity, hydrophilicity, and degree of graphitization of carbon components, in addition to the existence of metal–support interactions, high electrochemical active surface area, electronic structure of interfacial Pt, and the feasibility of adsorptive or activating interactions with oxygen molecules. Hybrid supports, which utilize metal oxides (e.g., CeO_2, WO_3, or ZrO_2) have been demonstrated to stabilize Pt and carbon nanostructures and diminish their corrosion while exhibiting high activity toward the four-electron (most efficient) reduction of oxygen.

The rotating ring-disk electrode methodology, are typically applied to diagnose mechanisms and dynamics of oxygen reduction reaction. A tempting alternative for recording the electrochemical responses is to integrate the current and to report charge passed as a function of time. Chronocoulometry offers important advantages for the systems' characterization including good signal-to-noise ratio because the act of integration smooths random noise on the current transients. Furthermore, by integrating the responses, it is possible to separate surface phenomena (e.g. interfacial oxidation of carbon or platinum) more readily from bulk electrochemical responses. The results of electrochemical and XPS experiments imply the existence of strong mutual interactions between the mixed-valent metal oxides (cocatalysts), platinum (catalytic centers), and carbon (carriers) components.

Keynote 4

09:00-09:30 Wednesay November 19

Low-Temperature Bonding Technology for Heterogeneous Integration and Advances in Sensors and Electronic Devices

Eiji Higurashi

Department of Electronic Engineering, Graduate School of Engineering, Tohoku University, 6-6-05, Aramaki Aza Aoba, Aoba-ku, Sendai, 980-8579, Japan

Abstract

In recent years, bonding technology has attracted considerable attention and has become increasingly important for realizing high-performance multifunctional semiconductor devices with small size, low power consumption, high thermal dissipation, and high output power requirements. Low-temperature bonding technology with advanced features, such as low thermal damage and low residual stress, is becoming important for heterogeneous integration, which is key to the continued growth of the semiconductor industry.

In this presentation, I will focus on low-temperature bonding technology [1] and introduce recent research topics related to electronic devices. Surface-activated bonding is a method of bonding activated solid surfaces using adhesive forces between surface atoms. It requires extremely smooth bonding surfaces (root-mean-square roughness: 1 nm or less), and there is a major issue of difficulty in bonding when ultra-precision polishing processing cannot be applied. For example, the chemical mechanical polishing (CMP) process is not applicable to 3-D structured substrate surfaces, such as the bottom surfaces of etched cavities for MEMS-based sensing devices. In response, we developed a multiple thin-film transfer method based on template stripping for the simple fabrication of smooth Au surfaces, as shown in Figs. 1 and 2. The multiple thin-film transfer method consists of template stripping, which mechanically peels off Au thin films prepared by sputter deposition on a smooth template, and a simultaneous low-temperature direct transfer process to target rough surfaces multiple times. This technique significantly expands the range of bonding targets [2-4].

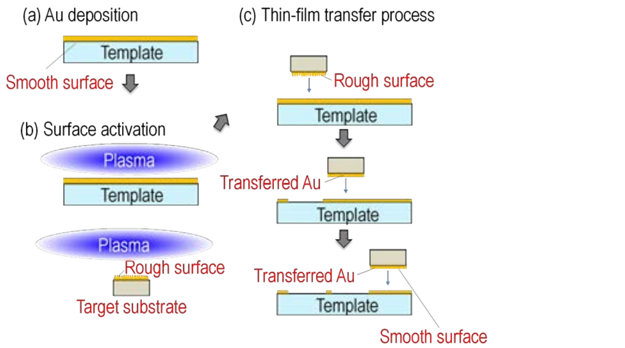


Fig. 1. Schematic diagram of Au surface smoothing by thin film transfer process based on template stripping and surface activated bonding

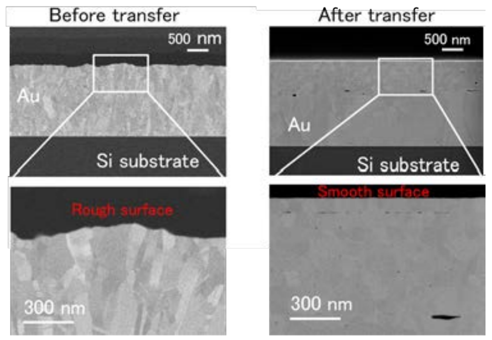


Fig. 2. Cross sectional scanning electron microscopy (SEM) images of the Au plating before and after smoothing.

[1] E. Higurashi, Heterogeneous integration based on low-temperature bonding for advanced optoelectronic devices, Japanese Journal of Applied Physics, vol. 57, no. 4S, 04FA02 (2018).
[2] E. Higurashi, M. Yamamoto, R. Nishimura, T. Matsumae, Y. Kurashima, H. Takagi, T. Suga, and T. Itoh, Formation of smooth Au surfaces produced by multiple thin-film transfer process based on template stripping for low-temperature bonding, The 2020 IEEE 70th Electronic Components and Technology Conference (ECTC), pp. 223-228 (2020).
[3] S. Goto, S. Koseki, K. Takeuchi, and E. Higurashi, Surface smoothing based on Au thin film transfer on rough-surface AlN ceramic substrates for low-temperature bonding, 2025 IEEE 75th Electronic Components and Technology Conference (ECTC), pp. 1791-1794 (2025).
[4] K. Takeuchi, S. Koseki, L. H. H. Thu, T. Matsumae, H. Takagi, Y. Kurashima, T. Tsuda, T. Tokuhisa, T. Shimizu, E. Higurashi, Room Temperature Bonding of Au Plating through Surface Smoothing using Polyimide Template Stripping, Sensors and Actuators: A. Physical, vol. 383, 116211 (2025).

Keynote 5

13:10-13:40 Wednesay November 19

Scanning Acoustic Microscopy and High-Resolution X-Ray Imaging for Industrial Process Control and Failure Analysisin Microelectronics

Ehrenfried Zschech

1 Brandenburg University of Technology Cottbus-Senftenberg, Konrad-Zuse-Str. 1, 03046 Cottbus, Germany

Abstarct

The rapid evolution of advanced semiconductor technologies, including heterogeneous 3D integration of ICs and chiplet architectures, causes increasing challenges for metrology, defect inspection, and physical failure analysis (PFA). To address these challenges, innovation in microscopy techniques and related workflows is required. With respect to nondestructive imaging, acquisition speed (throughput) and achievable resolution have to be balanced [1]. Scanning acoustic microscopy (SAM) continues to be the tool of choice for inspecting interfacial integrity (e.g. delamination), and detecting defects (e.g. voids, cracks) in 3D-stacked dies and wafers [2]. Transmission X-ray microscopy (TXM) and nano X-ray computed tomography (XCT) are reliable nondestructive techniques for overlay metrology, defect inspection, and fault isolation; however, they have low throughput [3]. The time for image acquisition and analysis must be reduced significantly without sacrificing the resolution of the X-ray images. Ways for a drastic acquisition speed increase are new high-brilliance laboratory X-ray sources, the application of AI algorithms for new image acquisition protocols, and high-speed data processing.

In [4], typical applications of high-resolution XCT were categorized into 3 groups: 1) Creation of 3D digital images of the complete interior structure of an opaque object (typically for fundamental research), 2) Monitoring industrial processes and defect inspection (e.g., in the semiconductor industry), and 3) Observing kinetic processes in objects, such as materials ageing and product degradation, important for industrial quality control and reliability engineering. These different categories of applications have different requirements for the accuracy of the 3D reconstruction and for the time-to-data. Time for image acquisition and analysis is essential for group 2).

A seamless workflow for advanced package FA and defect inspection, that combines acoustic and X-ray techniques, will improve throughput and defect detectability [5]. Kinetic studies, e.g., of reliability-limiting degradation processes in microchips, provide the opportunity to establish appropriate risk mitigation strategies to avoid catastrophic failure. The nano-XCT imaging of the microcrack evolution points out possible directions to ensure the requested mechanical robustness of microchips and of heterogeneously integrated chiplets [6].

[1] EDFAS Electronic Device Failure Analysis Technology Roadmap, ASM International (2023)
[2] S. Brand, S. Tismer, S. T. Moe, K. Schjølberg-Henriksen, "Non-destructive wafer-level bond defect identification by scanning acoustic microscopy", Microsystem Technologies 21, 1385–1394 (2015)
[3] E Zschech, "Nano NDE with X-rays", Handbook of Nondestructive Evaluation 4.0, 1377 (2025)
[4] E. Zschech, M. V. Chukalina, K. B. Bulatov, "High-resolution X-ray imaging for industrial process monitoring and quality control", Computer Optics, accepted (2025)
[5] E. Zschech, K. Kutukova, B. Lechowski, P. Czurratis, T. Djuric-Rissner, "Combining Acoustic Microscopy and X-Ray Microscopy for Metrology, Inspection and Failure Analysis in Advanced Packaging", ISMP IRSP Busan, Korea (2024)

Keynote 6

09:00-09:30 Thursday November 20

Advanced Packaging in Artificial Intelligence

Jaesik Lee

SK hynix America, 3101 North First Street, San Jose, CA 95134

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Rapid advancements of Generative Artificial Intelligence and Large Language model (LLM), such as ChatGPT and Bard followed by Agent AI and Physical AI, have significantly dominated the technological landscape recently, which has escalated the demand for ever increased computational performances. Those increase demands for high performance computing drives high density, power efficient and high speed interconnect in data transfer between logic, memory, and chiplets, where a variety of 2.5D and 3D advanced packaging technologies with concurrent integration of logic and memory such as xPU and high bandwidth memory (HBM) has become crucial components in AI systems. In this presentation, 2.5D and 3D advanced packaging architecture innovations along with High bandwidth memory (HBM) architectures and their challenges associated with stacking technologies, power delivery, and thermal in the package and system levels will be discussed.

Keynote 7

09:30-10:00 Thursday November 20

The Nanojoining and Microjoining in Hybrid Bonding: Structure, Process and Materials

Prof. Zhi-Quan Liu

Southern University of Science and Technology, Shenzhen 518055, China

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In the era of heterogeneous integration and three-dimensional (3D) packaging in IC industry, nano/micro-joining techniques are critical for achieving high-density electronic interconnects. Hybrid bonding, distinguished by simultaneous metal-metal and dielectric interface formation, represents a major advancement beyond traditional solder-based methods. Central to this evolution is the integrated development of structural design, optimized bonding processes, and advanced material innovations. Structurally, hybrid bonding technology uses through silicon vias (TSVs) as vertical interconnects between stacked chips and supports ultra-fine interconnect pitches of only a few microns, significantly increasing I/O density. Therefore, by reconstructing the chip architecture in three-dimensional space, multiple chips can be bonded into a single 3D system-level package, achieving a performance leap. From a processing standpoint, advancements in surface planarization and novel surface activation approach effectively mitigate oxide formation and minimize interfacial defects, ensuring near-void-free interfaces. Concurrently, material innovations engineered Cu with nanotwins or nanograin boundaries, facilitating diffusion paths and enhancing low-temperature bonding (typically below 200 ℃). The application of ultra-thin diffusion barriers and nanoscale passivation layers further ensures interfacial stability under stress. Future research will focus on addressing key challenges associated with multi-material integration, including thermal expansion mismatches at multiple interfaces and complexity of interconnections. This work outlines recent progress, current challenges, and prospects for hybrid bonding, emphasizing how structural tuning, process optimization, and materials innovation collectively enhance interconnect performance, reliability, and scalability for next-generation heterogeneous electronic systems.

Abstracts for the Oral Presentations

Development of Cd-Free Quantum Dots for Industrial Applications


Nayoun Won

Nayoun Won, Taekhoon Kim, Deukseok Chung, Jonghoon Won, Sanghyeon Park, Tae-Gon Kim and Shinae Jun

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Colloidal quantum dots (QDs) are considered among the most promising emissive materials due to their unique optical properties, including high color purity, excellent quantum efficiency, and tunable emission wavelengths. QDs based on cadmium or lead, such as CdSe, CdS, PbS, and $CsPbBr_3$, have been extensively studied, with well-established synthesis and application techniques, despite growing concerns over their toxicity and environmental impact. In contrast, InP-based QDs, which can emit in the visible range and offer relatively low toxicity, have been regarded as an promising alternative for display applications. However, compared to CdSe-based QDs, InP QDs have faced significant challenges in achieving high optical quality due to their relatively high covalent bonding nature, which makes them more susceptible to oxidation and complicates to control of structural defects. In this talk, I will introduce InP-based QDs that exhibit nearly unity photoluminescence quantum efficiency and high stability in the fabrication process and the operation. Based on this superior optical property, the QDs could be applied for the color conversion pixels of various types of blue light sources such as OLEDs, micro-LEDs, etc. Especially, combining red-emitting QDs with blue micro-LEDs presents a promising strategy to overcome the low external quantum efficiency typically associated with red micro-LEDs.

Emerging Trends and Technological Challenges in Advanced Semiconductor Packaging: A Focus on Chiplet Integration and Micro-LED Applications


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There is a growing interest in advanced semiconductor packaging technologies, as they are increasingly recognized as key enablers in the realization of AI semiconductors, alongside cutting-edge semiconductor node technologies. Unlike conventional packaging approaches, advanced packaging is typically implemented at the 300mm silicon wafer level or based on fan-out technology. This distinction significantly raises both the scale of required investment and the level of technical expertise needed.

One of the core concepts in advanced packaging is chiplet integration, which demands the development of novel and innovative techniques. The bump pitch required for chiplet implementation is below 40 µm, necessitating ultra-high precision and accuracy. Various technical approaches are being explored to meet these stringent demands.

Another emerging technology area closely related to chiplet integration is micro-LEDs. While traditionally associated with display technologies, micro-LEDs are now being investigated as core components for optical interfaces in semiconductor packaging. Interestingly, the pitch requirements for micro-LED assembly are comparable to those of chiplets, and the technology roadmaps for both fields show significant overlap.

This presentation aims to provide an overview of the current technological developments in these areas and to discuss the advantages and limitations of various approaches being pursued. As a promising solution to the challenges in high-precision integration, laser-assisted bonding (LAB) technology will be introduced. Based on several case studies developed by the Electronics and Telecommunications Research Institute (ETRI) of Korea, we will highlight how LAB technology can serve as a potential game-changer in the field of advanced semiconductor packaging.

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Ultrafast, Reworkable Glass Interposer Interconnection via Photo-Induced Reversible Polymer Crosslinking

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Advanced packaging technologies utilizing glass interposers require reliable, ultrafast interconnection methods suitable for high-density chiplet integration. This study presents a novel interconnection technique employing photo-induced localized heating of metal nanostructures and reversible polymer crosslinking via the Diels-Alder reaction. Initially demonstrated for stretchable electronic applications, the method uses intense pulsed light (IPL) to induce rapid, localized heating of Ag nanowire (AgNW) networks embedded in a reversibly crosslinkable polyurethane (rcPU). This mechanism facilitates robust, adhesive-free bonding characterized by high optical transparency and superior mechanical reliability.

In this research, we aim to extend the concept to glass interposer-based advanced packaging. Preliminary results demonstrated excellent adhesion strength, minimal electrical resistance increase, and reworkability without compromising device integrity. The unique advantage of IPL-induced localized heating significantly reduces thermal stress and damage risks associated with conventional bonding methods, ensuring the integrity of sensitive semiconductor devices. Additionally, the reversible crosslinking capability enables straightforward repair and maintenance processes, thus enhancing the overall sustainability and lifecycle of packaged devices. The technique's compatibility with fine-pitch interconnections and thermal stability makes it ideal for next-generation heterogeneous integration applications, particularly beneficial for emerging fields such as advanced computing, communication modules, and flexible electronics. Further investigation will focus on demonstrating practical integration with functional chiplets and optimizing reliability for commercialization.

Enhanced Low-Temperature Sinter Bonding by Hybridization of Cu Microparticles and Self-Reducible Cu_xO Nanoparticles

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To realize high-reliability bonding for next-generation power semiconductors, a composite paste consisting of copper (Cu) microparticles and self-reducible copper oxide nanoparticles (Cu_xO-NPs, Figure 1.) was developed for low-temperature sintering. Silver nanoparticles have been extensively researched so far as these bonding materials; however, studies have shifted the focus to copper nanoparticles from the perspectives of cost and ion migration resistance. [1] The Cu_xO-NPs, characterized by a composition rich in metallic Cu, were synthesized on the surface of Cu microparticles to form a core–shell structure. These nanoparticles exhibit self-reduction behavior at temperatures as low as 100 °C, facilitating early-stage sintering and enhancing inter-particle diffusion through in-situ generation of metallic Cu.

The composite pastes were prepared using either flake-like or spherical Cu microparticles. Hot-press sintering was conducted at 200 °C and 15 MPa for 15 minutes. The design and application of the fixtures for low temperature sintering with a unique pressure and temperature is presented separately. [2] Shear strength measurements and cross-sectional SEM analysis revealed that the flake-type Cu particles provided significantly higher bonding strength (up to ~30 MPa) compared to spherical particles, owing to larger neck formation via face-to-face contact. Additionally, the optimized Cu_xO-NP content minimized porosity by efficiently bridging interstitial voids and promoting uniform sintering. However, excessive nanoparticle loading caused agglomeration, leading to increased porosity and reduced mechanical strength. Sintering mechanism of the hybrid paste was illustrated in Figure 2.

These results demonstrate that sintering efficiency and bonding strength are governed by both particle morphology and the dispersion state of the nanoparticles. The combination of self-reducible nanoscale activators with structurally favorable microparticles enables dense Cu joints at significantly reduced temperatures, without the need for reducing gas environments. This approach offers a promising pathway for practical, low-cost Cu interconnects in advanced packaging platforms such as chiplets and wide-bandgap semiconductor modules.

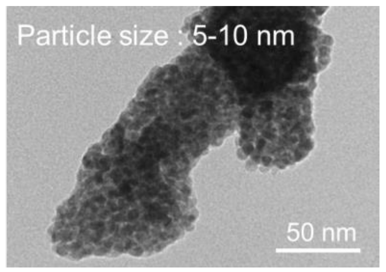

Fig. 1. CuxO nanoparticles prepared by chemical reduction stabilized by alcohol-amine compounds.

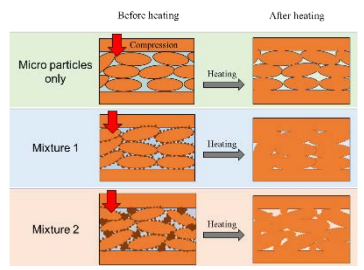

Fig. 2. Sintering mechanism of hybrid paste of Cu microparticles and CuxO nanoparticles.

[1] K. Tamura, M. Nishio, M. T. Nguyen and T. Yonezawa, *Mater. Trans.*, **66**, 265 (2025).

[2] T. Yonezawa and H. Tsukamoto, *Next Res.i*, **2**, 100278 (2025).\

Exploration of Low-Melting Nano-Solders and Their Effects on Structure and Properties of E-Textile Gas Sensors

Daniel C. Liu

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Electronic Textiles (E-textiles) have a broad range of promising applications, including healthcare monitoring, fitness sports apparel, assistive technology for individuals with disabilities, interactive educational tools, and environmental monitoring. However, mounting and joining electronics on fabrics normally requires high temperatures to activate and melt the metallic solders, potentially jeopardizing the fabric substrate's integrity. Although Sn-Pb-based solder is the most widely used low-melting soldering material, its toxicity and non-sustainable characteristics have led to investigations into Pb-free low-melting solders such as Sn-In and Sn-Bi alloys as alternative solutions. In soldering, both microparticles and nanoparticles offer distinct advantages. Nanoparticles are often preferred due to their high surface area and unique melting behavior at the nanoscale, which may enhance wetting and mechanical properties, resulting in lower melting temperature processing and bonding. This work synthesized Pb-free, low-melting Sn-In nanoparticles via surfactant-assisted reduction methods and utilized them as a nano-soldering material to improve bonding between sensing materials and the fabric substrate (Figure 1). Gas-sensitive nanoparticles, such as graphene oxide for ammonia, are selected as the working materials and screen-printed onto the fabric. Upon exposure, gas vapors interact with the sensing materials, altering the printed fabric's electrical conductivity, which can be converted into signals to detect the presence of harmful gas vapors and provide information on their identities and concentrations. Studies incorporating these low-melting nano-solders into the nanocomposite will evaluate their enhancement of mechanical properties and gas-sensing responses alongside traditional chemical crosslinking methods. Additional studies using Sn/In nanoparticles to connect multiple sensors for simultaneous gas detection will also be conducted to assess their effectiveness as soldering materials. The electrical resistance, morphology, and elemental composition of the soldered composite will be analyzed to verify bonding success. Lastly, the fabric sensors could be integrated into circuitry with an LED light or other types of visual or audio signals to display the gas response, which could be incorporated into the clothing of civilian or combat users, providing real- time warnings of hazardous gas vapors in their surroundings for personal protection or health monitoring (Figure 2).

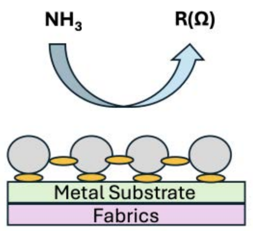

Fig. 1. Nano-Solders (orange) jointing Graphene Oxide (grey), and metal coated Fabrics for E-Textile Ammonia Gas Sensing

Fig. 2. Assembly and production of E-Textile Gas Sensor Devices: Nano-inks printed on Fabrics, with button and Velcro attachments, and A Signal Processor

Cu-Mo nanocomposites as an interlayer for joining in thermal management systems

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Effective heat removal from electronic devices is a challenging issue due to a lack of materials having a high thermal conductivity as well as an appropriate coefficient of thermal expansion fitting those of typical device materials (e.g. Si, SiC, or GaN). In this context, Cu-Mo nanocomposites are promising substrate materials, as they combine high thermal conductivity of copper and low coefficient of thermal expansion of molybdenum. By refining the microstructure to the nanoscale, these composites offer enhanced thermal performance, improved mechanical strength, and better interface stability compared to their coarse-grained counterparts. A critical requirement for heat removing materials is their good bondability for integration into the thermal management system. However, the main challenge of joining nanocomposites lies in preserving their unique nanoscale structure and properties during the joining process, as conventional high-temperature methods can lead to grain growth, interfacial degradation, and loss of performance.

This study presents the successful attempt to join nanostructured Cu-Mo composites with Si chips and Cu heat sink materials using sinter-bonding with commercial nano Ag paste and micro-Cu paste. For this purpose, Cu-Mo nanocomposites with thickness of 0.5 mm were produced by high-pressure torsion (HPT) from commercially available Cu-Mo laminates. Standard Cu-Mo micro-laminates (1.1 mm thick) were used as reference. For joining with nano Ag paste, the Cu-Mo nanocomposites were coated with ~2.5 µm pre-metallization Cu layer. The joint configuration of the investigated system is illustrated in Fig. 1.

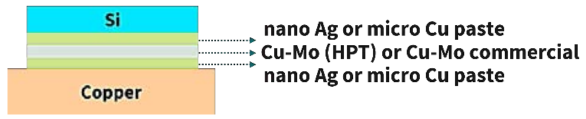

Fig. 1. The scheme of the investigated joints

SEM analysis revealed that sintering temperatures up to 275 °C did not affect the microstructure of nano structured Cu-Mo HPT composite, thus preserving its as-manufactured properties. Good-quality joints, with minimal porosity and good interfacial contact, were obtained. Mechanical tests demonstrated that sintering with nano Ag paste facilitates the fabrication of joints with acceptable shear strengths for both HPT processed Cu-Mo composite and commercial laminates. This indicates that Cu-Mo HPT composite serves as a successful interlayer in joining Cu to Si, offering the additional advantage of reduced joint thickness – a critical factor in the miniaturization of modern electronics. Moreover, the nanostructured Cu-Mo HPT composite exhibited compatibility with both Cu and Si when sintered using Cu paste, without the need for pre-metallization of the interlayer surface. These findings confirm the feasibility of achieving sufficiently reliable joints with Cu-Mo HPT composites, paving the way for their application in electronics and temperature-resistant systems.

Keywords: Cu-Mo nanocomposites, High Pressure Torsion, joining, nanopaste, sinterbonding

Femtosecond laser 3D structuring and micro-welding for glass based micro-device fabrication


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Glass is widely employed as a substrate material for biochemical and photonic devices owing to its excellent optical transparency, biocompatibility, and chemical inertness. However, its intrinsic brittleness presents significant challenges for micromachining using contact-based approaches such as mechanical drilling or conventional long-pulse lasers, which often cause collateral thermal damage. Femtosecond lasers provide a compelling alternative, offering precise material removal or localized modification through nonlinear multiphoton absorption, thereby enabling micrometer-scale resolution. This capability has facilitated the extensive utilization of femtosecond lasers in advanced semiconductor and display manufacturing processes. Furthermore, laser pulse trains with repetition rates in the MHz regime can induce localized heat accumulation near the voxel located at the interface between two glass substrates, enabling direct, adhesive-free glass-to-glass welding. In this presentation, we demonstrate the fabrication of various glass-based microdevices exclusively using laser processing, followed by wet etching, with a single femtosecond laser 3D direct writer capable of both high-precision micromachining and direct welding. We also present the performance evaluation of the laser-fabricated glass devices to verify their functional effectiveness [1-5].

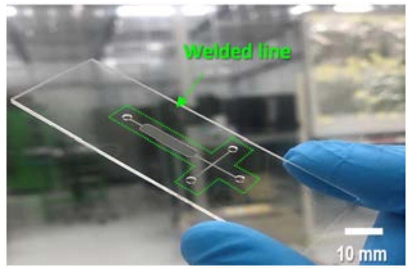

Fig. 1. Microfluidic droplet generator fabricated by selective laser etching and direct welding

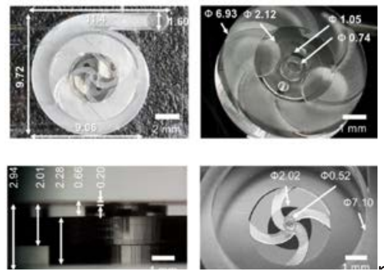

Fig. 2 Magnetic-active centrifugal micropump

Acknowledgment:

This research was supported by the Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea under Grant No. RS-2024-00416213.

[1] S. Kim, J. Kim, Y-H Joung, J Choi, and C. Koo, "Bonding Strength of a Glass Microfluidic Device Fabricated by Femtosecond Laser Micromachining and Direct Welding", Micromachines, 9(12)., 639 (2018).

[2] S. Kim, J. Park, S. So, S. Ahn, J. Choi, C. Koo, Y. H. Joung : Characteristics of an Implantable Blood Pressure Sensor Packaged by Ultrafast Laser Microwelding, Sensors 19 (8), 1801 (2019)

[3] S Kim, J Kim, YH Joung, S Ahn, C Park, J Choi, and C Koo, Monolithic 3D micromixer with an impeller for glass microfluidic systems", Lab on a Chip 20, 4474-4485 (2020)

[4] J. Kim, S. Kim, J Choi, and C. Koo,, "A 3D Miniaturized Glass Magnetic-Active Centrifugal Micropump Fabricated by SLE Process and Laser Welding", Micromachines, 13., 1331 (2022).

[5] D Yeom, J Kim, S Kim, S Ahn, J Choi, Y Kim, and C Koo, "A Thermocycler Using a Chip Resistor Heater and a Glass Microchip for a Portable and Rapid Microchip-Based PCR Device", Micromachines 13 (2), 339 (2022)

Femtosecond laser multiple-pulse heating for copper microfabrication


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Femtosecond laser direct writing using multiphoton absorption has garnered significant interest for metal micropatterning [1]. To date, noble metals such as gold (Au) and silver (Ag) have been successfully patter ned through photochemical reduction processes [2]. However, extending this technique to copper (Cu)-bas ed materials remains challenging due to their inherently low precipitation rates. To address this limitation, we are developing multiphoton-absorption-induced thermochemical precipitation. In this process, femtosec ond laser pulses induce multiphoton absorption in glyoxylic acid copper (GACu) complex solution, followed by thermochemical precipitation driven by thermal energy generated during the deactivation process [3]. Unlike photochemical reactions, thermochemical reactions are more difficult to spatially confine due to th ermal diffusion. To improve control over the precipitation area and particle growth, a surfactant, n-decan oylsarcosine sodium salt (NDSS), was added to GACu complex solution. NDSS served to regulate nanoparti cle (NP) growth by capping the nucleated Cu NPs, thereby suppressing excessive precipitation.

Figure 1 shows a hypothesis of the Cu precipitation during the multiple pulse irradiation. Femtos econd laser pulses with the wavelength of 515 nm, pulse duration of 256 fs, repetition frequency of 5 MHz, and pulse energy of 10 nJ were focused onto GACu complex solution on silica glass substrates. The number of pulses was controlled from 50 to 40000 using a mechanical shutter. Figure 2 shows a TEM i mage of the Cu NPs after 1000 pulse irradiations. Compared to those formed in the absence of NDSS, t he NPs were notably smaller. A distinct Cu dot was formed after 20000 pulses, consistent with the prop osed mechanism of mli-pulse-induced Cu precipitation and sintering. The details of the transient phenome na, including multiphoton absorption characteristics and precipitation dynamics, will be presented.

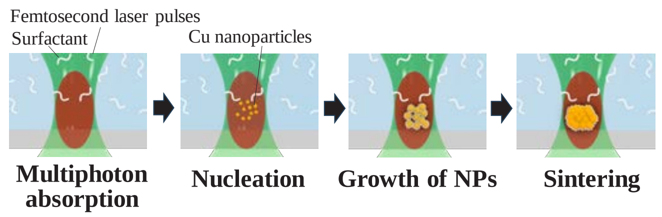

Fig. 1. Hypothesis of Cu precipitation from GACu complex solution by irradiating multiple pulses.

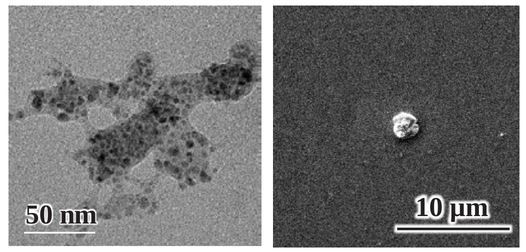

Fig. 2. TEM image of the precipitated NPs after irradiating 1000 pulses (left). FE-SEM image of the precipitated Cu dot after irradiating 20000 pulses (right).

[1] Alina A. Manshina, Ilya I. Tumkin, Evgeniia M. Khairullina, Mizue Mizoshiri, Andreas Ostendorf, Sergei A. Kulinich, Sergey Makarov, Aleksandr A. Kuchmizhak, Evgeny L. Gurevich,
"The Second Laser Revolution in Chemistry: Emerging Laser Technologies for Precise Fabrication of Multifunctional Nanomaterials and Nanostructures", Advanced Functional Materials, 2405457 (2024)
[2] Shoji Maruo and Tatsuya Saeki, "Femtosecond laser direct writing of metallic microstructures by photoreduction of silver nitrate in a polymer matrix", Optics Express, 16(2), 1174-1179 (2008).
[3] Nam Phuong Ha, Tomoji Ohishi, and Mizue Mizoshiri, "Femtosecond laser multiple pulse-induced thermochemical copper precipitation from glyoxylic acid copper complex ink with surfactant", Journal of Physics D: Applied Physics, 58, 105302 (2025).

Micro-welding of glass by multi-spot beam of picosecond pulsed laser with high repetition rate

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Micro-welding of two glasses without any intermediate layer by a picosecond pulsed laser have attracted attention in the field of glass products. Nonlinear absorption phenomenon is ignited by high-intensity ultrashort pulsed laser focusing into a micro-spot inside the glass, which can melt the grass locally. The sudden temperature and the stress change inside the molten area and the energy concentration near focusing point cause cracks, and the welding quality would be deteriorated. On the other hand, a spatial light modulator (SLM) can control the focusing characteristic of laser beam by calculating a computer-generated hologram (CGH) [1], and the single laser beam can be focused into multi-spot with controlled energy distribution. This function has a possibility to control the formation process of molten area by varying energy distribution in micro-welding of glass by the ultrashort pulsed laser, which would contribute to the improvement of joint strength.

Figure 1 shows the schematic illustrations of joining experiment for 2 glass plates. In order to avoid the influence of optical contact force, the irradiation area of 1.0 mm width was prepared, and the laser beam scanning was conducted at scanning speed of 60 mm/s. A picosecond pulsed laser of 1064 nm wavelength and 10 ps pulse duration was used at 1.0 MHz pulse repetition rate. The modulated laser beams by SLM were focused around the interface of borosilicate glasses by an objective lens of 0.65 numerical aperture.

Figure 2 shows the evaluation results of breaking strength and the appearances of molten shape, when the distance between focusing points d_w was varied for 3-point focusing. The pulse energy of 1-point beam was 1.5 μJ, and the total energy of 3-point focusing was 4.5 μJ. Breaking stress was measured by cross tension test, and the effect of molten area shape on the breaking stress was evaluated. The spaces between laser spots were melted by heat conduction, and molten area shape could be controlled by dividing into multiple spots of laser beam. When the distance between the focusing points d_w was set to 15 μm, a round shape of molten area were formed, which leads to improving the joining strength.

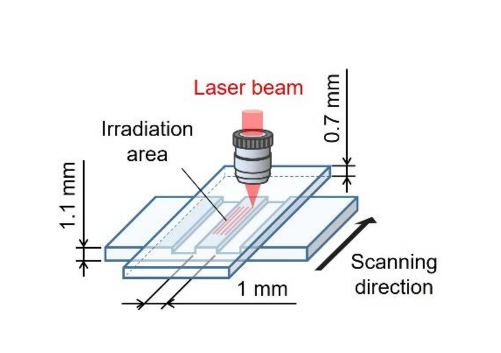


Fig. 1. Schematic illustration of joining experiment for 2 glass plates.

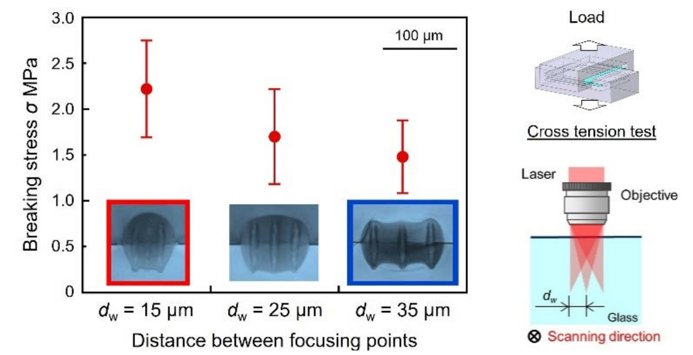
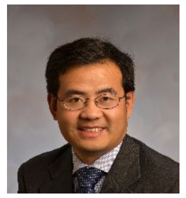


Fig. 2. Effect of molten area shape on breaking stress by using 3-spot beam of 4.5 μJ total pulse energy.

[1] R. D. Leonardo, Computer generation of optimal holograms for optical trap arrays, Optical Express, 15, 4, 1913-1922 (2007).

Femtosecond Laser Processing of Ultra-Sensitive SERS Substrate for PFOA Analysis



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Surface-Enhanced Raman Spectroscopy (SERS) enables highly sensitive detection of molecules at the trace level, but its limitation of detection is highly dependent on the substrate design. In this paper, we report an fs laser-fabricated SERS substrate designed for optimal sensitivity as well as analysis of perfluorooctanoic acid (PFOA) degradation experiments. A 1 mm groove was ablated on a microscope glass slide using fs laser pulses, and silver nanoparticles synthesized by fs laser ablation in liquid were drop-cast onto it. The groove was filled to the surface, forming a confined SERS-active region. The substrate demonstrated reliable detection of methylene blue (MB) at concentrations down to 10^{-12} M, with an estimated enhancement factor of ~10^7. Thermal optimization of the substrate revealed that post-treatment at 140 °C produced the highest SERS activity, with rising temperatures (160 °C) reducing hotspot density through nanoparticle merging. This optimized platform was subsequently employed to detect and monitor photocatalytic degradation of PFOA at different concentrations. Following degradation with varying times, the SERS spectra indicated significantly decreased PFOA peaks and till totally disappearance and emergence of new features, with successful molecular breakdown confirmed. These results validate our fs laser-based approach to obtain thermally tunable SERS substrates suitable for both ultra-trace detection and degradation analysis.

Fig. 1 shows the Raman spectrum of PFOA after 2 hours degradation. The green boxes show new peaks that don't correspond to any PFOA flake or aqueous peaks, indicating successful PFOA molecular breakdown. Fig. 2 shows the SEM images of SERS substrate optimized at 140°C and 160°C. At 160°C it is clearly visible that silver nanoparticles melted and coagulated into bigger spherical particles closing the hotspots whereas at 140°C, there are plenty of nanogaps left among the nanoparticles.

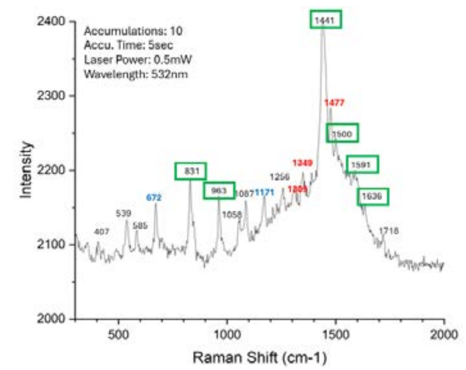

Fig. 1.Cross section of W CW laser processed area, detailing microcracking

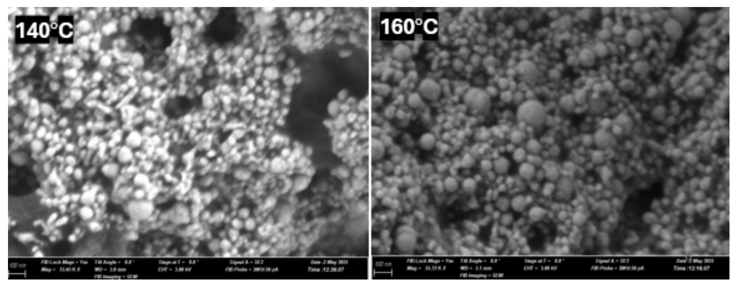

Fig. 2. Cross section of W fs laser processed area, showing absence of cracking.

Acknowledgement This work is supported by a seed grant of the Institute for a Secure & Sustainable Environment at the University of Tennessee Knoxville.

Fabrication of Gold Nanobowl SERS Substrates by Femtosecond Laser for biosensing


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This study introduced a novel approach to fabricate gold nanoparticles decorated bowl-shaped silica structure (gold nanobowls) for surface-enhanced Raman scattering (SERS) substrates. Previous techniques (such as template metal deposition method, and combination of soft lithography and nanosphere lithography) involved multiple reagents and steps to fabricate bowl-shaped structures [1-3], in contrast, our approach employed femtosecond laser processing: (1) silica spheres etched by hydrofluoric acid to form bowl-shaped silica structures (Figure 1), and (2) femtosecond laser reduction of gold ions and joining of nanoparticles to achieve gold nanobowls (Figure 2).

We studied the mechanism of bowl-shaped structures formed by hydrofluoric acid etching and the formation mechanism of gold nano-bowls was discussed.Gold nanobowls were produced with high surface area and tunable plasmonic properties, which were used for SERS applications. The bowl-shaped geometry was expected to enhance localized surface plasmon resonance, yielding SERS enhancement factors higher than 10^6 with high reproducibility due to uniform morphology. The SERS performances (enhancement factor, reproducibility, sensitivity) were evaluated through Raman experiments using standard probe molecules (rhodamine 6G). We also discussed the gold nanoparticles joining induced by femtosecond laser and its influences on SERS performances. In addition, the gold nanobowls were applied in practical applications for biosensing.

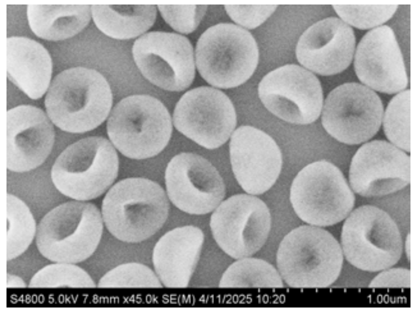
Fig. 1. SEM image of silica nanobowls.

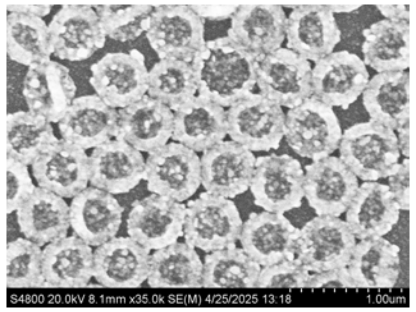
Fig. 2. Silica nanobowls decorated by gold nanoparticles , forming gold nanobowls.

[1] Zhu, Kai and Zhou, Tong and Chen, Peng and Zong, Shenfei and Wu, Lei and Cui, Yiping and Wang, Zhuyuan,Long-lived SERS Matrix for Real-Time Biochemical Detection Using "Frozen" Transition State, ACS Sensors, 8, 3360-3369 (2023).
[2] Mao, P., Liu, C., Favraud, G. et al. Broadband single molecule SERS detection designed by warped optical spaces. Nat Commun 9, 5428 (2018).
[3] Kahraman, M., Daggumati, P., Kurtulus, O. et al. Fabrication and Characterization of Flexible and Tunable Plasmonic Nanostructures. Sci Rep 3, 3396 (2013).

Low-Temperature Bonding of Nanotwinned Silver Films for High-Density Interconnection


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The rapid advancement of artificial intelligence (AI), Internet of Things (IoT), and 5G technologies necessitates high-density integration, submicron-scale features, and ultra-reliable interconnects in next-generation 3D integrated circuits (3D ICs) [1]. Conventional Sn-based solders face fundamental limitations in fine-pitch applications due to molten Sn extrusion-induced bridging. The thermo-compression bonding (TCB) of nanotwinned metals, characterized by its low-temperature bonding capability, high reliability, and fine pitch interconnection ability, has emerged as a crucial technology for high-density chip interconnects [2, 3].

This work presents a comprehensive study on the fabrication, bonding mechanisms, and reliability of nanotwinned Ag (NT-Ag) for high-density interconnects. The (111)-oriented NT-Ag films were deposited on polycrystalline Cu pillars using magnetron sputtering for achieving low-temperature Cu-Cu bonding in air. The sputtering parameters were optimized to control key microstructural characteristics, such as grain size, transition layer thickness, and texture. Then, the low-temperature TCB process of NT-Ag was performed, the interfacial microstructures of bonded joints were characterized to investigated the underlying bonding mechanisms under pressure-thermal coupling conditions. Finally, a comprehensive analysis of aging reliability evaluation results for NT-Ag bonded joints, encompassing microstructural evolution and shear strength variations during high-temperature aging processes was presented. Insights from this work offer an innovative approach to achieving high-density interconnection at low temperatures for 3D integration.

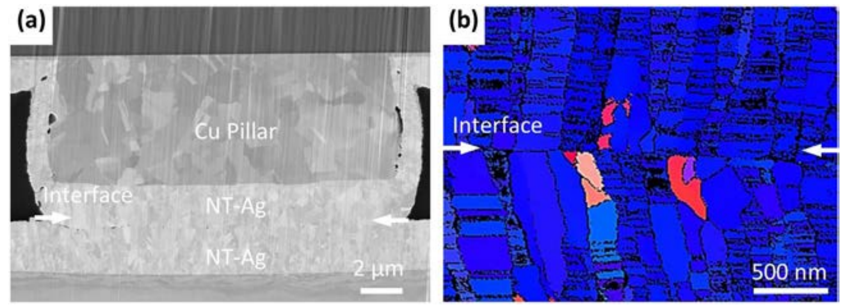

Fig. 1. Cross-sectional microstructure of flip-chip bonded joints via TCB of NT-Ag films: (a) SEM image and (b) inverse pole figure (IPF).

[1] Lau J H, "Recent advances and trends in heterogeneous integrations", Journal of Microelectronics and Electronic Packaging, 16., 45-77 (2019).
[2] Lu D S, Pan H, Ji H J, et al., "Influence of (111) texture on bonding strength in low-temperature bonding of nanotwinned Ag films: Experimental insights and void closure modeling", Materials & Design, 240., 112839 (2024).
[3] Chang S Y, Chu Y C, Tu K N, et al., "Effect of anisotropic grain growth on improving the bonding strength of <111>-oriented nanotwinned copper films", Materials Science and Engineering: A, 804., 140754 (2021).

Conductive paths in electrically conductive adhesives containing spiny silver particles

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Electrically conductive adhesives (ECAs) consisting of silver particles and thermosetting resins are one of the candidates for low-temperature process materials as an alternative to Sn-Ag-Cu solders. In general, the conductive mechanism of ECAs is explained by percolation theory [1]. The electrical resistivity of ECAs depends on the resistance between Ag particles and the number of conductive paths. These are influenced by many factors, such as the type of material, the shrinkage of the resin, the surface condition of the particles and the shape of the particles [2]. The purpose of this study is to clarify the effect of Ag particle shape on the conductive paths associated with the electrical resistivity of ECAs.
In this study, spherical and spiny Ag particles were used as filler materials. Figure 1 shows the spiny Ag particles with 3 μm of mean particle size. Figure 2 shows the electrical resistivity of ECAs containing spherical or spiny Ag particles against the volume fraction of Ag particles. The resistivity of ECA containing spiny Ag particles was found to be lower than that of ECA containing spherical Ag particles. The percolation threshold of ECA containing spiny Ag particles was determined to be 10.0 vol%, which is smaller than that of ECA containing spherical particles, which was found to be 13.1 vol%.

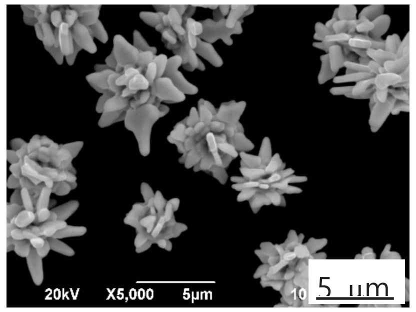

Fig. 1 Morphology of spiny silver particles

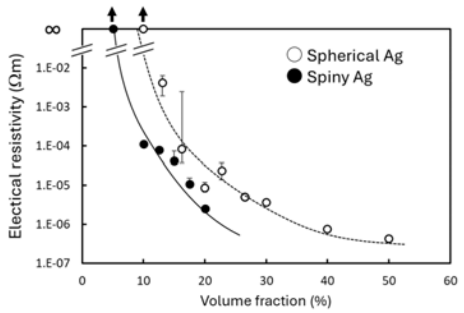

Fig. 2 Electrical resistivity of electrically conductive adhesives containing spherical or spiny silver particles against volume fraction of silver particles.

The serial-sectioning observation using a FIB-SEM were performed on ECA containing spiny silver particles to reveal the dispersion of the particles, the contact between the particles, and the conductive paths in the epoxy resin matrix. The spiny Ag particles were in contact with each other at multiple contact points. The numerical simulation revealed that the number of continuous conductive paths in the ECA containing the spiny Ag particles was larger than that containing the spherical Ag particles, which suggests that the ECA containing the spiny Ag particles exhibited a lower electrical resistivity than that containing spherical Ag particles.

[1] S. Kirkpatrick, "Percolation and conduction", Reviews of modern physics, vol.45, 574-588 (1973).
[2] D. Lu, A.K. Tong, C.P. Wong, "Conductivity mechanisms of isotropic conductive adhesives", IEEE Trans. Electronics Packaging Manufacturing, Vol.22, 223-227 (1999).

Interfacial Phenomena in Solid-State Bonding for Electronics Packaging Applications

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The integration of silicon nitride (β-Si_3N_4) with Cu is critical for high-power electronics; however, conventional bonding methods like active metal brazing (AMB) face reliability issues. This study investigates the atomistic mechanisms of a robust bonding strategy using Ti induced TiN interlayer. Through a combined approach of experimental analysis using transmission electron microscopy (TEM) and first-principles calculations based on density functional theory (DFT), we elucidated the principles governing interfacial stability.

Our findings show that Ti's strong affinity for β-Si_3N_4 promotes the formation of a structurally coherent TiN interlayer. TEM observations identified five distinct, low-misfit crystallographic orientation relationships (ORs), demonstrating the system's high structural adaptability. DFT calculations further revealed the most energetically favorable OR ($[0001]_{\beta\text{-}Si_3N_4} \parallel [01\bar{1}]_{TiN}$). The TiN-intermediated Cu/β-Si_3N_4/Cu substrates exhibited excellent long-term reliability under thermal cycling tests.

This work provides fundamental atomistic insight into Ti-mediated metal-ceramic bonding and establishes a combined computational-experimental framework for designing robust interfaces. These findings offer practical guidelines for engineering high-reliability components for next-generation power electronics.

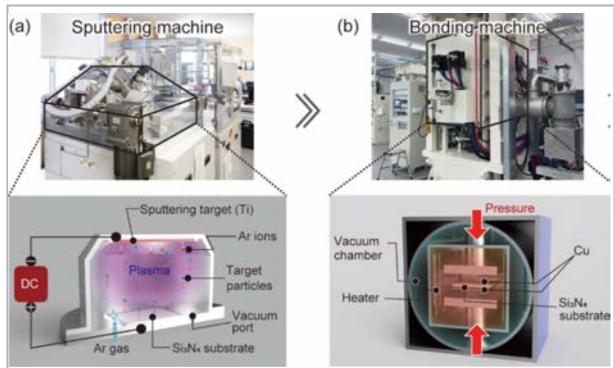

Fig. 1. Fabrication process for the Ti-mediated Cu/β-Si_3N_4/Cu substrate: (a) Ti deposition onto both sides of the β-Si_3N_4 substrate; (b) bonding with Cu sheets under uniaxial pressure.

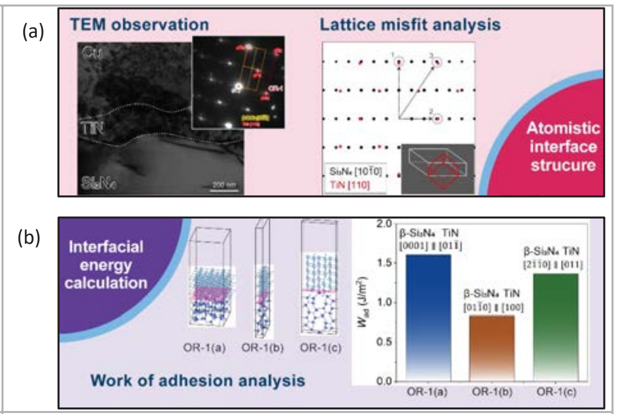

Fig. 2. Experimental and first-principles results: (a) TEM observation image of the Cu/TiN/β-Si_3N_4 interface and lattice misfit analysis; (b) calculation of work of adhesion (W_{ad}) of TiN/β-Si_3N_4 interface model by DFT.

AI-Linked Instrumented Indentation for Local Properties, Internal Stress, Fracture Toughness, and Reliability Assessment of Micro/Nano Joints


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Micro- and nano-scale joints contain steep gradients in strength, internal stress, and interfacial integrity arising from thermal cycles and reaction layers. This work presents an AI-linked instrumented indentation approach for non-destructive evaluation of local mechanical properties, fracture toughness indicators, and internal stress states, including thermal and residual stresses, within confined joining regions.
Load–depth data are analyzed to extract flow properties, deformation signatures, stress-sensitive parameters, and indentation-based toughness metrics that reflect interface crack resistance and damage evolution. These features feed into physics-informed and machine-learning models to predict fatigue life and interfacial degradation in solder joints, diffusion bonds, and nano-bonded metallization layers.
The same framework enables rapid QC by correlating indentation parameters with joining conditions and early defect formation, offering a scalable solution for high-reliability micro- and nano-joining systems.

Influence of cold rolling induced microstructure on oxidation-free Cu sintering behavior in air at 250°C


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This study was carried out to realize Cu sintering in the air atmosphere and investigate the driving force of oxidation-free Cu sintering. Cu sintered joints were successfully achieved at 250 °C under a uniform pressure bonding below 10 MP air. An oxygen-blocking mechanism was employed, in which oxygen access was instantaneously suppressed across the entire volume of the die-attach specimen during sintering. As a result, high bonding strengths exceeding 54.53 MPa were achieved after 30 minutes of sintering. Notably, no oxidation layer was observed at the bonding interface at 250 °C in the air atmosphere. The bonding strength was fundamentally attributed to the interfacial connected ratio between the Cu substrate and Cu sintered layer. Furthermore, the results confirmed that cold rolling the Cu substrate before sintering is the critical factor affecting grain refinement and interfacial bonding. This study systematically investigated the structural characteristics of Cu-sintered joint involved in the rolling percentage of the Cu substrate and clarified the bonding mechanism by correlating the microstructural evolution with the mechanical behaviors.

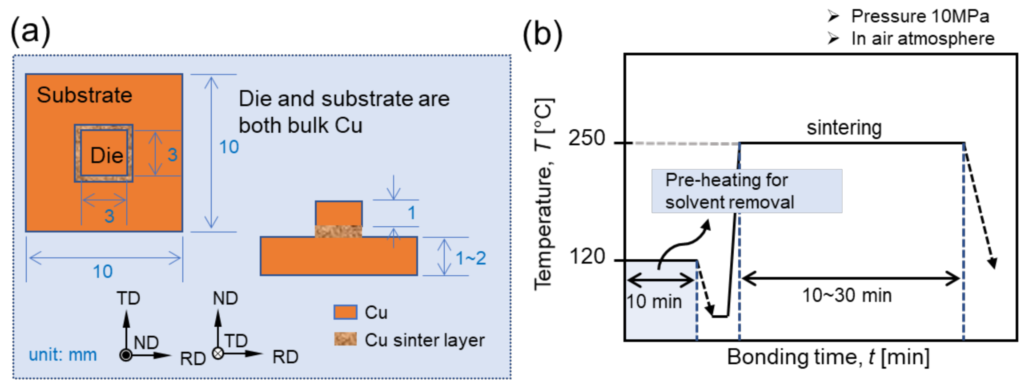

Fig. 1(a) a dimension of Cu sinter bonded structure and (b) die-bonding condition

Modified Nickel Nanopastes for Pressure-Reduced Nanojoining: Shear Strength and Microstructure of Joints

Benjamin Sattler

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State-of-the-art nanojoining processes typically require a joining pressure to achieve optimal results [1-2]. However, the resulting mechanical stress can lead to several drawbacks, including potential damage to sensitive components, limitations in joint geometries, and increased process complexity. To address these challenges, new compositions for nanopastes were developed in the course of this work that exhibit improved behavior in a pressure-free joining process compared to reference pastes. These modified nanopastes contain a component that reaches its liquid state at the process temperature (see Fig. 1). The liquid phase provided by a low melting element is intended to reduce porosity in the joint seam and enhance the bonding between nanoparticles and the base material. This study presents results on the strength of the produced joints under various process parameters. Additionally, the microstructure of these joints is analyzed and discussed (Fig. 2 represents the example of an In-containing paste).

Fig. 1. Joining samples with Indium-modified Ni nanopaste, after application and pre-drying.

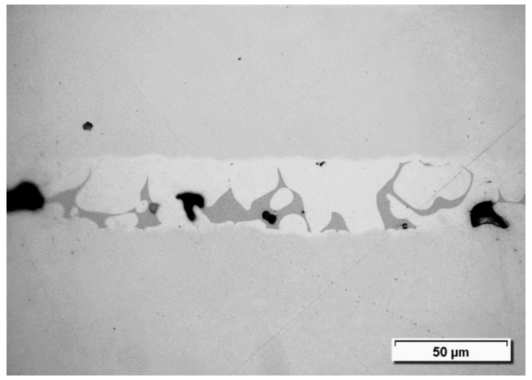

Fig. 2. Joining seam for pressureless joined sample (holding time is 360 s and joining temperature 975°C).

[1] Yamakawa, T.; Takemoto, T.; Shimoda, M.; et al., "Influence of Joining Conditions on Bonding Strength of Joints: Efficacy of Low-Temperature Bonding Using Cu Nanoparticle Paste." In: Journal of Electronic Materials, vol. 42, No. 6, 1260–1267 (2013).
[2] Ma, C.; Xue, S.; Bridges, D.; et al., "Low temperature brazing nickel with Ag nanoparticle and Cu-Ag core-shell nanowire nanopastes." In: Journal of Alloys and Compounds, vol. 721, 431–439 (2017)

Cu-oxide + PEG nanopastes for sinter-bonding: Effect of particle size and heating rate

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Sinter-bonding with Ag-based sinter pastes is a well-established joining process, e.g. for die-attach in power electronics. In the last years, Cu-based sinter pastes were introduced as a more cost-effective, but also more oxidation-sensitive alternative to Ag. To tackle the problem of oxidation during manufacturing, storage, and usage of the Cu-based pastes, two main approaches exist: (i) the use of surfactants to supress Cu-oxidation, or (ii) the in-situ production of sinter-active metallic Cu during the bonding process. In-situ production can for instance be achieved by reductive decomposition of Cu-complexes, by gaseous reduction of Cu-oxides, or by reduction of Cu-oxides via organic reducing agents, for instance polyethylene glycol (PEG; cf. [1]).
In this work, we performed an in-depth analysis of the in-situ reduction of CuO particles by PEG to elucidate the reaction pathways, reduction kinetics, and sintering behaviour by employing calorimetry (DSC) coupled with thermogravimetry (TG) and mass spectrometry (MS), as well as in-situ synchrotron X-ray diffraction (XRD). DSC-TG-MS was used to follow the redox reaction between CuO and PEG via the associated heat evolution (DSC), the amount of volatile products (TG), as well as their chemical nature (MS). In-situ synchrotron XRD combined with Rietveld analysis was employed to trace the crystalline phase fraction, as well as the crystallite size, as function of temperature for different heating rates. Pronounced effects of initial CuO particle size, respectively specific surface area, as well as of heating rates on the in-situ redox reaction between CuO and PEG were observed.

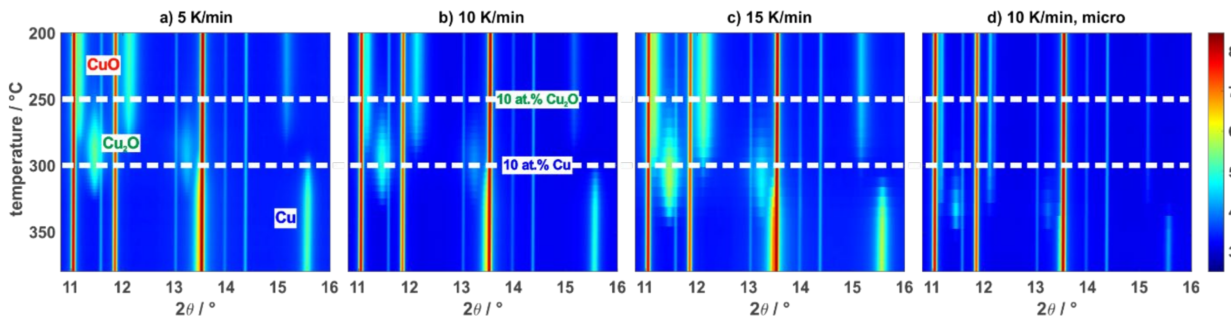

Fig. 1. In-situ synchrotron XRD intensity charts for a selected 2θ- and *T*-region indicating the disappearance, respectively appearance, of CuO, Cu_2O, and Cu upon heating. The continuous reflections pertain to the Al_2O_3 and $MgAl_2O_4$ substrate phases. a) - c) CuO nanopaste heated at 5, 10, and 15 K·min^{-1}, respectively; d) CuO micropaste heated at 10 K·min^{-1}. The dashed horizontal lines indicate formation of 10 at.% of Cu_2O, respectively Cu, for the CuO-nanopaste at a heating rate of 10 K·min^{-1}.

[1] T. Fujimoto, T. Ogura, T. Sano, M. Takahashi and A. Hirose, "Joining of Pure Copper Using Cu Nanoparticles Derived from CuO Paste", Materials Transactions, 56, 992-996 (2015).

The effect of transfer mold-post mold curing process on in-air Cu sintering and porous sheet bonding applications

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This study investigated the effect of the transfer mold-post mold curing (PMC) process on the in-air Cu sintering die-attach and Ag porous sheet bonding die-attachments. Furthermore, Cu sintering and Ag porous sheet bonding are performed on the bare Cu surface and the Ag plating surface, adhesion properties between epoxy molding compound (EMC) and metallized surface finishes with Cu and Ag were clarified. the Ag sintering die-attach was realized on Ag plated TO-247-3L (Ag substrate) lead frame using an Ag porous sheet at 145 °C for 10 min with 10 MPa, while Cu sintering die-attach was formed on the TO-247-3L(bare Cu substrate) lead frame using a Cu paste at 250 °C for 10 min with 10 MPa. After die- attach processes, EMC-PMC process was carried out at 175 °C for 5 h, subsequently laser decapsulation was performed to investigate the adhesion properties between epoxy mold and Cu surface and Ag surface. Consequently, the initial Ag sintering die-attach indicated an approximately 82% increase in die-bonding strength after EMC-PMC process, while the initial Cu sintering die-attach showed only 19% increase in die-bonding strength. In addition, Ag substrate surface was formed approximately 4 MPa low adhesion strength with epoxy mold, in contrast Cu substrate surface was achieved sufficient adhesion strength with 15 MPa to epoxy mold. Cu sintering die-attach verified sufficient thermal stability and adhesion strength with epoxy mold at EMC-PMC process, in contrast Ag sintering die-attach occurred grown of sinter layer and die-bonding strength through EMC-PMC process and showed the insufficient adhesion strength with epoxy mold. This study systematically identifies not only the die-attach process but also the types of surface treatments and EMC adhesion characteristics resulting from these joining processes, and provides guidelines necessary for manufacturing processes such as mass production of power semiconductor module applications.

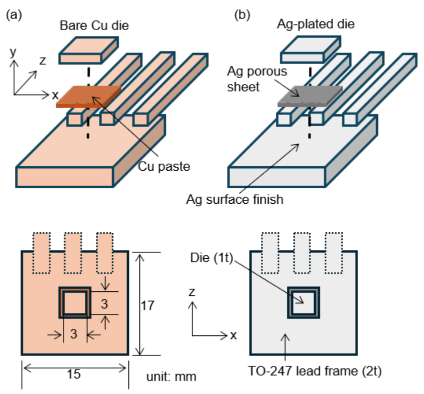

Fig. 1. Geometrical and material information of (a) Cu sintering die-attach and (b) Ag sintering die-attach.

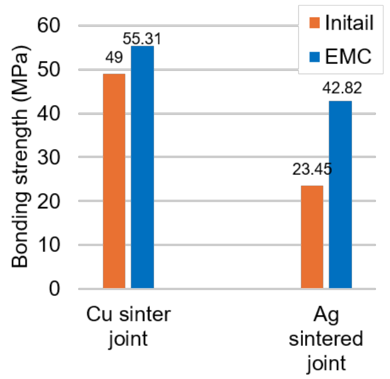

Fig. 2. Bonding strength of Cu sintering and Ag sintering joints before and after EMC-PMC process.

Laser-Based Processes and Equipment for Advanced Semiconductor and Display Packaging


Seungman Kim

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The rapid advancement of semiconductor and display technologies demands packaging solutions capable of supporting higher integration densities, improved electrical performance, and diverse form factors. As device architectures evolve toward 2.5D and 3D integration and chiplet-based systems, the complexity and precision requirements of packaging processes are also increasing. Traditional mechanical and chemical techniques often face limitations in precision, scalability, and material selectivity, making it difficult to meet the stringent demands of next-generation devices. In this context, laser-based processes are gaining prominence for their unique advantages, including non-contact operation, highly localized processing, and excellent thermal control. Laser technologies offer unmatched precision, superior scalability, and advanced process control, while minimizing mechanical stress and contamination risks. Furthermore, they enable the processing of a wide range of materials, such as brittle substrates and flexible polymers. These strengths are accelerating the adoption of laser technologies in critical areas of advanced packaging, helping to meet the rigorous performance and reliability requirements of next-generation semiconductor and display devices.
This presentation will focus on three key laser-based technologies that are critical enablers for next-generation devices. These include laser-assisted microchip transfer and laser lift-off for high-precision placement and selective layer separation; laser-assisted debonding and slicing for ultra-thin wafer fabrication with enhanced reliability; and laser-based fine electrode formation and removal for high-resolution, flexible interconnect structures.
As semiconductor and display devices continue to evolve, the role of laser-based processes will become increasingly vital. Ongoing advancements in laser sources, beam delivery systems, and intelligent process control are further expanding the capabilities and applications of these technologies, paving the way for the next wave of innovation in advanced packaging.

Laser Joining and Transfer of Nanostructures for Microwave and Optical Devices


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Laser processing enables precise, on-demand modification and fabrication of functional structures, allowing for the manipulation of microwaves and light across a broad spectrum of applications. In this presentation, we present laser-based joining and transfer techniques for nanostructures in both microwave and optical devices.

For microwave applications, we introduce a laser joining method that transforms nanoplate membranes from dielectric to conductive, enabling one-step fabrication of highly sensitive microwave humidity sensors. The effective complex dielectric permittivity of untreated nano-silver exhibits a positive correlation with moisture levels, facilitating humidity detection via microwave frequency response. Additionally, we demonstrate laser patterning of liquid metals to create stretchable artificial magnetic conductors (AMCs), designed to lower the specific absorption rate (SAR) in ultra-wideband (UWB) wearable antennas.

On the optical front, laser joining and transfer of nano-silver and nano-silica are employed to tailor nanostructure configurations and modulate optical properties at the macroscale. This includes the fabrication of optical coatings with controlled absorbance or scattering, offering potential for transparent display applications. At the nanoscale, in-situ single-point nano-welding with a tightly focused laser enables localized modification of plasmonic photonic circuits. We demonstrate on-demand reconfiguration of silver nanowire waveguides into optical beam splitters by introducing additional output ports.

In general, these results highlight the versatility of laser processing as a platform for the fabrication, reconfiguration, and functional enhancement of nanodevices, with promising implications for future microwave and optical systems.

Monitoring and Diagnosis of Microcrack Formation in Battery Can-Cap Laser Welding Processes

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Laser welding is widely used in the assembly of prismatic battery can-cap components due to its high precision and process efficiency. However, the formation of microcracks during welding poses a significant threat to structural integrity and sealing performance. This study presented an integrated monitoring and diagnostic approach for detecting microcrack formation in laser-welded can-cap assemblies. A combination of high-speed molten pool and infrared (IR) imaging was employed to capture real-time process behavior and identify abnormal signatures associated with crack initiation. Convolutional Neural Networks (CNNs) were used to classify image features, while a Generative Adversarial Network (GAN) model enhanced data quality and defect detection accuracy. The correlation between predicted defects and actual crack formation was validated through X-ray non-destructive testing. The proposed method enables the detection of non-visible defects during battery manufacturing and supports real-time monitoring of the laser welding process.

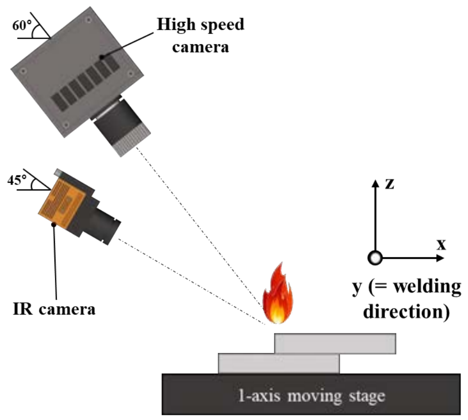

Fig. 1 Experimental setup

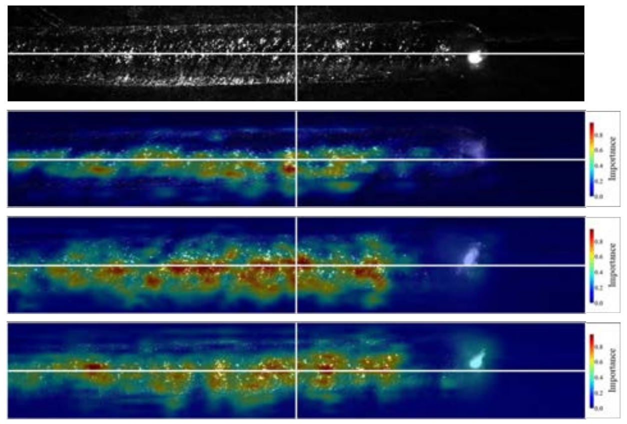

Fig. 2 Crack-related visualization via Grad-CAM

Microscale Solid-State Printing of Dissimilar Metals Using Laser-Induced Supersonic Impact Printing (LISIP)

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In this work, we present a novel solid-state micro-joining technique, named laser-induced supersonic impact printing (LISIP) for 2D/3D printing of metallic materials [1]. In LISIP, the laser shock-induced impact loading is utilized to trigger the adiabatic shearing phenomenon at metal-metal interfaces towards solid-state micro-bonding of metallic materails. The design of LISIP is discussed in details. Experimental exploration of LISIP process capability was conducted, with focus on 3D micro-lamination of metallic structure, additive manufacturing of dissimilar materials, and printing-on-demand direct writing at various length scales from micrometer to centimeter. Steel, copper, aluminum, titanium, and magnesium alloys were used as foil and/or substate for experimentation. The fundamental mechanisms involved in LISIP was investigated using first-principles modeling and finite element method simulation. The technical challenges and future research directions of LISIP were discussed.

[1] Y. Liao, F. Rubbi, B. Mao, B. Li, F. Delzendehrooy, M. Haque, “A novel solid-state metal additive manufacturing process – Laser-induced Supersonic Impact Printing (LISIP): Exploration of process capability“, Additive Manufacturing, 93, 104356 (2024).

Liquid Interlayer Assisted Femtosecond Laser Welding of Glasses for Device Packaging

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Femtosecond laser welding has emerged as a significant technology for joining transparent materials, and welding of glass materials has been extensively researched for in recent years [1, 2]. However, achieving a robust connection requires optical contact between two glass substrates during laser processing, which complicates the welding process and increases costs. To achieve high-strength welding of glass samples without optical contact, the substrates are tightly pressed against each other to minimize the gap, allowing the layers melted by the laser irradiation to completely fill the gap. The tight pressing, however, results in generation of stress in the welded sample. To overcome this issue, we present femtosecond laser welding of non-optical contact glasses with the assistance of water/silver ion solution interlayer. The welding quality is examined and compared with other methods, showing that the glasses welded by our method has high uniformity with high bonding strength (>18.3 MPa). The principle behind achieving high-quality welding is also discussed to elucidate the superiority of this method. In addition, we demonstrate the presented method can be also used for welding of dissimilar materials (glass-silicon, glass-sapphire). For demonstration of device packaging, a naked solar cell was sealed by the presented method which was successfully operated in water, showing the potential applications in the semiconductor packaging.

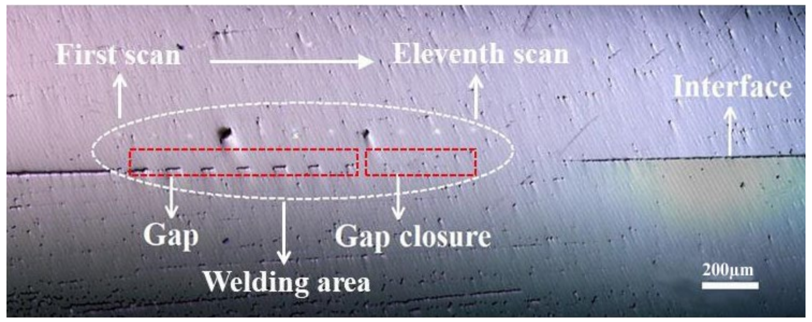

Fig. 1. Cross-sectional view of glasses welded by multi-scanning the focused femtosecond laser beam assisted with liquid interlayer. With increasing the number of scans, the sample gap is completely sealed.

[1] S. Wu, D. Wu, J. Xu, Y. Hanada, R. Suganuma, H. Wang, T. Makimura, K. Sugioka, K. Midorikawa, Characterization and mechanism of glass microwelding by double-pulse ultrafast laser irradiation, Opt. Express, 20 (2012), pp. 28893-28905.
[2] K. Cvecek, S. Dehmel, I. Miyamoto, M. Schmidt. A review on glass welding by ultra-short laser pulses, Int. J. Extrem. Manuf. 1(2019), 042001.

Rapid Electromagnetic Heating and Intermetallic Compound Formation in Transient Inductive Chip-Level Bonding Using SnCuSn Foil for Microelectronic Applications

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This study presents a combined experimental and finite element (FE) simulation-based study on intermetallic compound (IMC) formation during transient inductive chip-level bonding using SnCuSn foil for microelectronic packaging applications. The objective is to investigate the behavior of localized heating and the subsequent phase evolution under rapid electromagnetic (EM) excitation. A copper (Cu) coil is used to selectively heat the bonding region, enabling the formation of the intermetallic phases Cu_6Sn_5 and Cu_3Sn, as confirmed through metallographic analysis.

Figure 1 illustrates the schematic structure of the power electronics module and bonding setup, including the copper coil and bonding interface. Finite element simulations, carried out in COMSOL Multiphysics, were used to model the electromagnetic heating profile and subsequent temperature-driven phase evolution. These simulations provide insight into transient heat distribution and intermetallic growth, as shown in Fig. 2.

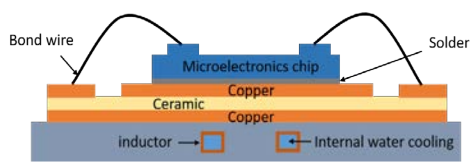


Fig. 1. Schematic structure of a power electronics module in accordance to [1].

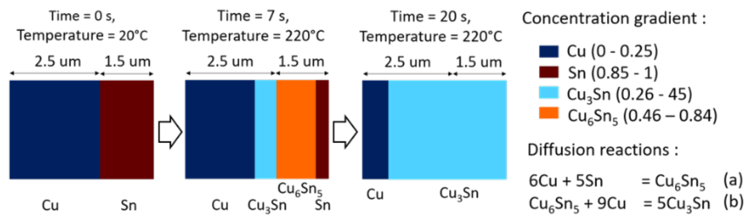
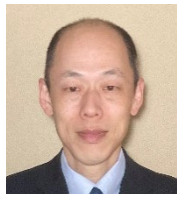


Fig. 2. FE simulation of intermetallic formations of Cu and Sn.

Experimental trials were performed to validate the simulation results by controlling heating parameters and analyzing the resulting IMC formation through metallographic characterization. The strong correlation between the simulation and experimental outcomes confirms the effectiveness of this method for achieving localized, rapid, and robust bonding. This approach is particularly well-suited for thermally sensitive microelectronic systems that require minimal heat impact on adjacent components.

[1] Chironjeet Chaki, Manoshi Chaki, Keya Roy, "Development of a Simplistic Method to Simulate the Formation of Intermetallic Compounds in Diffusion Soldering Process", American Journal of Materials Synthesis and Processing. Vol. 4, No. 1, pp. 54-61 (2019)

Visual Inspection of Solder Joint under the Molten State in Robot Soldering System



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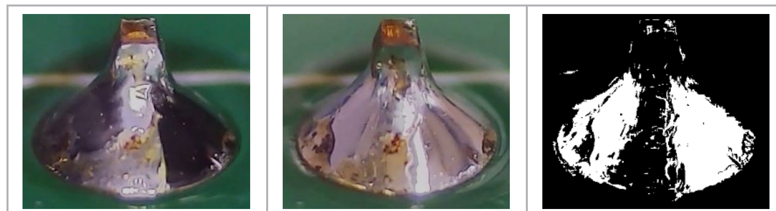
To minimize process time, it is highly desirable to perform inspections immediately after soldering, without waiting for complete solidification. However, molten solder surfaces exhibit strong specular reflections and unstable morphology, making defect detection during this stage extremely challenging [1]. To address this issue, an in-process, non-destructive inspection system was proposed, targeting two major defect types: excess solder volume and poor wetting. Unlike neural network-based inspection systems, which require extensive training datasets and suffer from increased decision times as the number of defect types grows [2], the proposed method relies on computationally efficient luminance difference calculations against averaged reference images of defect-free solder joints. This approach significantly reduces both computational cost and waiting time for solidification, making it well-suited for real-time inspection during soldering operations.

To detect excess solder volume, a novel image processing technique was developed that capitalizes on the differences in surface reflectivity between molten and solidified solder, achieved by switching between coaxial and ambient lighting conditions (Fig. 1). This method successfully delineated the molten solder boundaries before solidification, resulting in a 17% improvement in inspection accuracy compared to conventional methods. In detecting poor wetting, an inspection accuracy exceeding 95% was consistently maintained from immediately after soldering iron retraction until complete solidification at 11[s], using the same camera angle as employed for excess solder volume inspection prior to solidification (Fig. 2).

This study demonstrates that real-time, reliable defect detection during soldering can be achieved without the need for extensive data preparation, offering a promising solution to enhance both product quality and productivity in automated soldering systems.



(a) Coaxial lighting. (b) Ambient lighting (c) Binarized difference image

Fig. 1. Binarized image generated by comparing differences under coaxial and ambient lighting conditions.

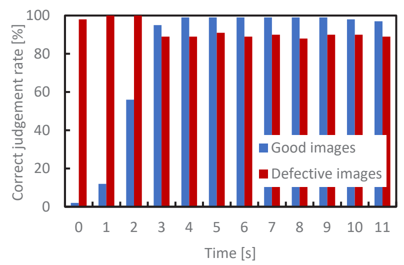


Fig. 2. Accuracy of poor wetting detection at different shooting timings.

[1] S. K. Nayar, Arthur C. Sanderson, Lee Weiss, David Simon,"Specular surface inspection using structured highlight and Gaussian images," IEEE Transactions on Robotics and Automation, Vol. 6, No. 2 (1990), pp. 208-218.
[2] N.S.S. Mar, "Vision-based classification of solder joint defects," Master of Engineering (Research) thesis, School of Engineering Systems (2010).

Innovative implementation of a direct cooling system for large-area joints in power inverters

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A traction inverter represents a key component of an electric vehicle (EV), serving the crucial function of converting direct current (DC) into alternating current (AC). Power modules for high voltage and high-power density undergo a sequence of processes, including die-attachment, wire bonding, and epoxy molding compound (EMC) processing on a substrate. Conventional power modules have been bonded to the heatsink using a thermal interface material (TIMs) and is mechanically fastened. However, TIMs exhibit relatively low thermal conductivity, typically within the range of 5 W/mK, and undergo evaporation from organic liquid bases, which significantly reduces their durability and heat resistance. It is considered dangerous to apply to cars with high-density power modules with a 15-year warranty, and direct cooling systems using metallic materials are being proposed as an alternative. Moreover, Tier 1 suppliers and automotive OEMs desire to receive assemblies that combine the power module and heatsink. A direct cooling system using metal-based solder can reduce the thermal impedance between the power module and the heatsink, and provide superior cooling performance based on high thermal conductivity and bonding stability. Typically, solder joints are formed through a process known as reflow. The peak temperature during this process can approach 300 °C depending on the melting point of the solder. Reflow involves the transfer of heat through thermal convection, resulting in the formation of defects such as cracks within the power module. These defects emerge due to disparities in the internal substrate and junction thermal expansion coefficients. Consequently, there is a necessity to concentrate research into low thermal strain bonding techniques for direct cooling systems.

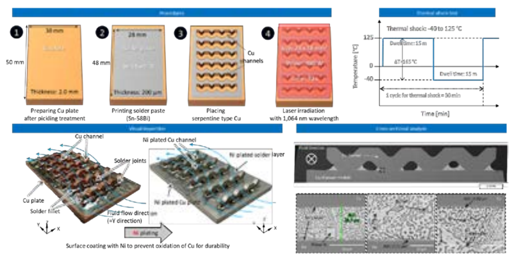

Fig. 1. Schematic diagrams of procedures, thermal shock test, visual inspection and cross-sectional analysis.

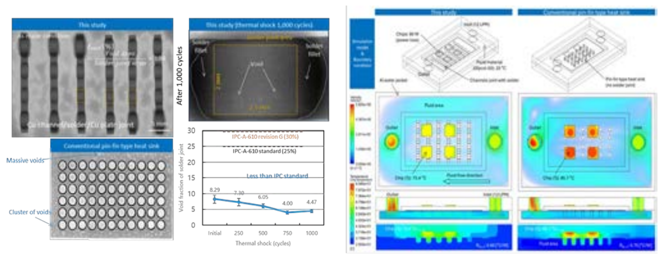

Fig. 2. Comparative analysis of voids and thermal flow analysis for traditional and new methods.

In this study, a direct cooling system with low thermal deformation of the power module based on low melting point solder, instantaneous joint formation and Cu channels was implemented. The instantaneous low-temperature bonding process resulted in the formation of voids in the joints, with a volume less than 10% of the total joint area. This is considered to be adequate to meet the requirements of the IPC-A-610 standard. A cross-sectional analysis was performed to investigate the stability of the joint using Cu channels, and a computational fluid dynamics simulation was performed to compare it with a conventional pin-fin heat sink in terms of thermal flow. The novel bonding design and process of heat sinks can minimize thermal deformation at the bonding interface of power modules due to instantaneous heat input.

Pressureless Transient Liquid Phase Sintering Based on $Cu@Cu_6Sn_5$-based Preforms for High-Power Device Packaging

Yichen Zhu

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With the application of high-power devices, the demand for advanced high-temperature resistant packaging materials has increased significantly. Transient liquid phase sintering (TLPS) has attracted widespread attention from the electronics industry due to its advantages of "low-temperature manufacturing and high-temperature service". However, the Cu_6Sn_5 skeleton structure generated by the rapid reaction between Sn-based solder and Cu particles will seriously hinder the liquid solder from wetting substrates, resulting in large-area voids at the interface. At present, the fabrication of TLPS solder joints is mainly achieved by applying hot pressure to increase the contact area between particles. For current highly integrated devices, it is obviously unacceptable to apply high pressure. Therefore, in this work, a new composite preform based on $Cu@Cu_6Sn_5$ was designed, and TLPS solder joints were fabricated without hot pressure.

It can be found that the solder wetting in the Cu@ Cu_6Sn_5 joint is significantly better than that in the Cu-based joint. The average shear strength of $Cu@Cu_6Sn_5$-based joints and Cu -based joints is 54.5 MPa and 20.9 MPa, respectively. The above results show that Cu_6Sn_5 coating can significantly promote the wetting of solder in the manufacture of pressureless TLPS solder joints.

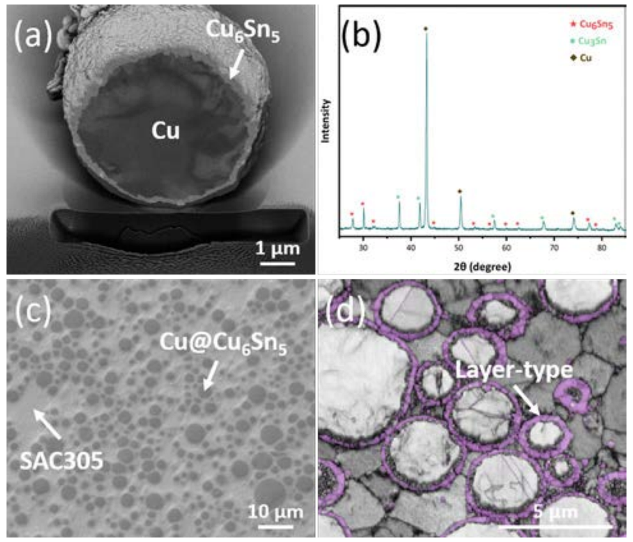

Fig. 1. The $Cu@Cu_6Sn_5$ particle characterization: (a) the cross-sectional SEM image; (b) XRD results. The $Cu@Cu_6Sn_5$-based composite preform characterization: (c) the cross-sectional SEM image; (d) the band contrast figure.

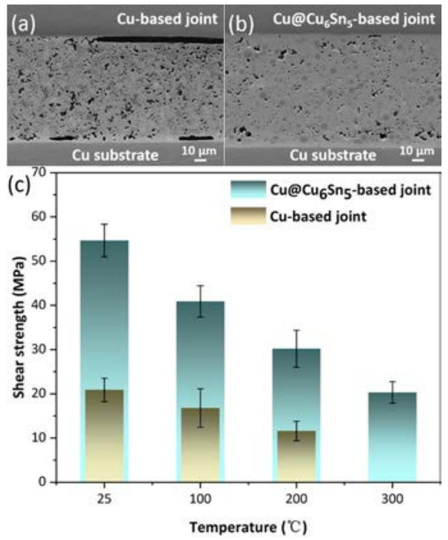

Fig. 2. Cross-section SEM images of solder joints: (a) Cu-based joints; (b) $Cu@Cu_6Sn_5$-based joints; (c)Shear strength of joints at 25 °C, 100 °C, 200 °C and 300 °C, respectively.

Self-Assembled Rosette-Like Porous Silver Microparticles for Power Electronics Packaging

Bolong Dong

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Nano-sintered silver technology enabled low-temperature connection and high-temperature service while exhibiting excellent electrical and thermal conductivity after sintering. These properties met the stringent requirements for die-attach materials used in the harsh and complex environments associated with third-generation semiconductor applications. However, research on the sintering behavior of nanostructured micron-sized silver particles in such materials remained insufficient and required further investigation. In this study, rosette-like porous silver microparticles (AgMPs) were synthesized using a liquid-phase reduction method. The AgMPs were formed through the in-situ self-assembly of silver nanoflakes. Numerous nanoflake structures, approximately 20 nm thick, were uniformly distributed on the particle surfaces. This surface nanostructuring resulted in an ultrahigh specific surface area of 17.793 m^2/g. The elevated surface energy significantly lowered the initial sintering temperature to 109.3 °C. Additionally, the micron-scale size of the particles contributed to their excellent size dispersion stability. The sintering behavior of the synthesized rosette-like porous AgMPs was systematically investigated, with a particular focus on the effect of the surface coating in the context of low-temperature interconnect applications. Thermal decomposition of the organic surface coating removed barriers to surface diffusion, exposed additional active sites, and facilitated sintering driven by surface diffusion. Silver paste formulated with these AgMPs exhibited excellent performance, achieving an average shear strength of 65.7 MPa under air sintering conditions (200 °C, 15 MPa, 10 minutes). These rosette-like porous AgMPs represent a promising candidate for advanced packaging interconnect materials.

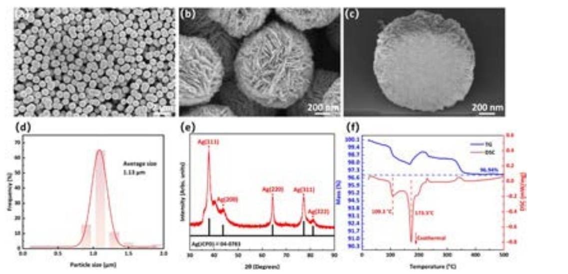

Fig. 1. The morphology and characterization of rosette-like AgMPs (a, b) SEM images of the morphology of the AgMPs at different magnifications, (c) SEM images of the cross-sectional morphology of the AgMP, (d) Particle size distribution, (e) X-ray diffraction pattern, (f) DSC-TG curve

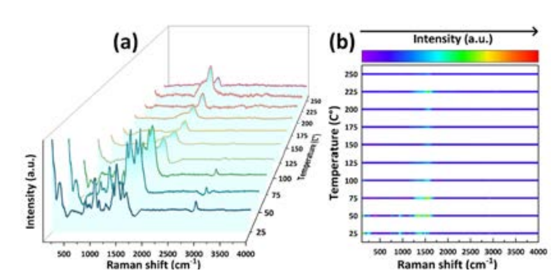

Fig. 2. In-situ high-temperature Raman spectra of rosette-like AgMPs (a) 3D plot from 25 °C to 250 °C, (b) Contour plot from 25 °C to 250 °C.

Copper electrodeposition for solder joint applications

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Electrodeposition is a cost-effective and scalable technology to fabricate the Cu metallizations in integrated-circuit packaging. The texture and grain size of the Cu electroplated films can be manipulated through careful formulation of plating parameters such as additive concentrations and current modes. Once the Cu metallizations are formed on different level of packages, they are joined together with solders to form solder joints as interconnects. There are numerous solder joints in an electronic packaging body, bearing a great responsibility for signal transmission, heat dissipation, mechanical support, and so on. Therefore, a comprehensive study of any possible reactions in the Cu/solder joints and the resulting microstructural changes is vital for reliability assessment. Herein, three important research topics regarding the solder joints with electroplated Cu will be briefly introduced.

First, organic additives are important ingredients in the electrolytic solutions to achieve conformal electroplating. However, co-deposition of additives inevitably causes the impurity residues in the Cu electroplated films. Once the impurity concentration is excessive, the Cu/solder joints undergo destructive structural change after soldering and aging reactions. The impurity effects are strongly concentration dependent and different additive molecules might interplay to strengthen or weaken the impurity effects. Therefore, careful formulation of additives is practically important in the Cu electrodeposition.

Second, specific formulation of additives can modulate the atomic reduction and deposition, thereby producing a Cu film with a specific texture like twins or with a high variety in grain size from nanocrystals to ultralarge grains. These specific structures significantly affect the Cu/solder reactions and the joint's microstructures.

Third, the rapid development of multi-level chip stacking technology drives the transition of joint configuration to solderless Cu-Cu direct bonding. The Cu electroplated films with variable textures are promising candidates in the Cu-Cu direct bonding. Nanocrystals have high thermal instability and numerous grain boundaries, so the grain growth easily occurs at the bonding interface between two nanocrystalline Cu in contact to achieve a reliable and robust Cu-Cu joint. More interestingly, significant cross-interface grain growth is observed as the two contacting Cu have different grain sizes, effectively eliminating the original bonding interface.

Highly active bayberry-like porous silver microparticles for low temperature sintering joining

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Silver paste is commonly used in power electronics for die attachment due to its low-temperature sintering, high melting point, and excellent electrical and thermal conductivities in joints. However, the mismatch in thermal expansion coefficients (CTE) and the high Young's modulus of sintered silver increase thermal stress, making the joints more prone to cracking and failure. This study presents a simple method for synthesizing bayberry-like silver microparticles (AgMPs) via in situ assembly of silver nanorods. This approach yields particles with nanoscale structures and mesopores, enhancing sintering activity and allowing sintering at 149.7 °C. The porous AgMPs reduce the joint density, lowering the Young's modulus and effectively mitigating thermal stress. The joints, with small grains and a complex substructure, exhibit high shear strength (112.50 MPa at 250 °C). The Young's modulus is adjustable and remains low (15.11–29.61 GPa) due to the AgMPs' pores. These bayberry-like AgMPs are promising for die-attach materials in electronic packaging.

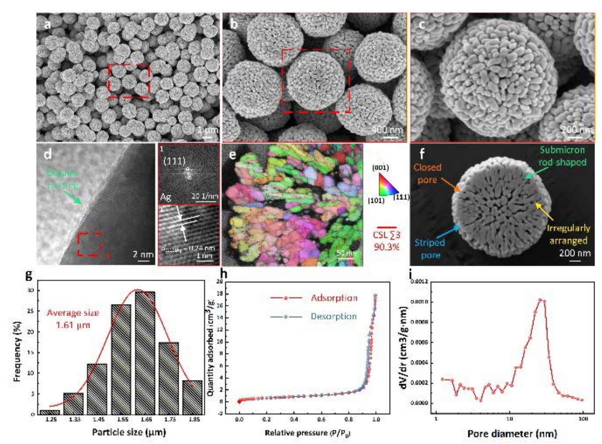

Fig. 1. Characterization of bayberry-like porous AgMPs: SEM images of the morphology of the AgMPs at different magnifications: a 5k, b 20k, and c 40k; d high-resolution TEM images of the AgMP edges; e ransmission Kikuchi diffraction of unripening bayberry-like porous AgMPs f SEM images of the cross-sectional morphology of the AgMPs; g particle size distribution of AgMPs; h adsorption and desorption isotherms of AgMPs; i surface micropore size distribution of AgMPs.

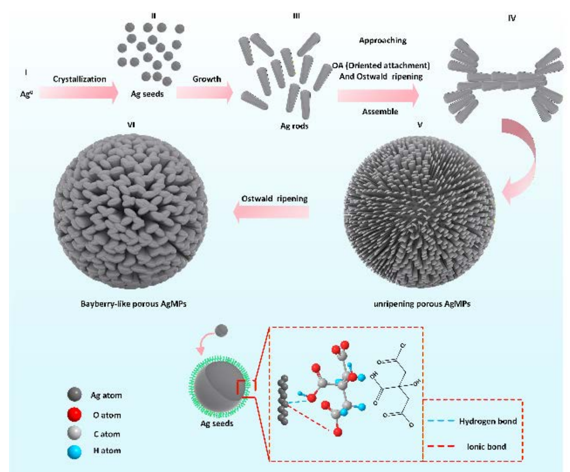

Fig. 2. schematic of the assembly of bayberry-like porous AgMPs.

Current-assisted low-temperature sinter joining improving interfacial property

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A low-temperature sinter joining process using nanoscale to microscale materials has been attracting attention as a promising technology for next-generation power devices. We have studied direct sinter joining process for both metals and non-metallic materials including semiconductors such as Si and SiC by utilizing the redox reaction induced decomposition of metal precursors [1]. However, forming strong interfaces between dissimilar materials is often challenging due to differences in their bonding characteristics, which can result in lower joint strength or require more severe processing conditions [2]. In this study, we focused on the formation process of interface: interfacial joining can be established by in-situ nucleation of metals derived from the precursors. This indicates the migration of ions temporary present during the joining contributes to the formation of interface. In this study, we demonstrate the current-assisted Ag sinter joining process to semiconductor materials by utilizing ion migration [3].
We found that the novel joining process enabled low-temperature Ag sintering to non-metallic substrate even at room-temperature condition, as shown in Fig. 1. The microstructure and its evolution were characterized by microstructural analyses including transmission electron microscopy and X-ray nanotomography. It was revealed the transportation of in-situ generated Ag toward the interface, driven by the electric current, leads to the formation of an initial Ag layer on the substrate, which plays a significant role in enhancing the interfacial sinterability. Further, we also found that the Ag migration can be applied to the interfacial joining between the substrate and preformed materials, allowing flexible control of microstructure and its properties in microjoint. Further details and findings will be addressed in the presentation.

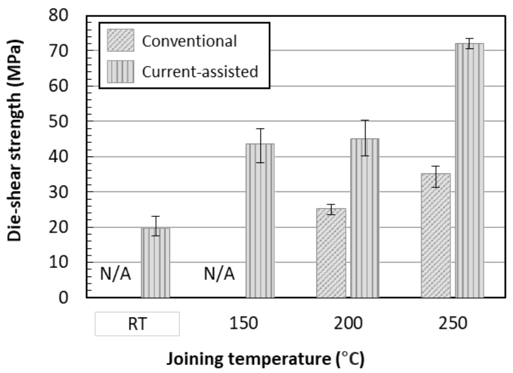

Fig. 1. Comparison of shear strength between conventional direct sinter joining and current-assisted sinter joining as a function of temperature.

[1] T. Matsuda, K. Inami, K. Motoyama, T. Sano, and A. Hirsoe, Sci. Rep. 8, 10472 (2018).
[2] T. Matsuda, R. Seo, A. Takeuchi, K. Uesugi, M. Yasutake , M. Kambara, A. Hirose, Mater. Sci. Eng. A 923, 14769 (2025).
[3] T. Matsuda, T. Matsuda, M. Kambara, A. Hirose, Mater. Des. 252, 113780 (2025).

From Atomic Metrology to Nanobonding with Cs-STEM in Perovskite Oxide Layers and Membranes

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Since the launch of commercially available spherical aberration-corrected (Cs) transmission electron microscopes twenty years ago, continuous improvements in instrument stability, usability, detector hardware, and both online and offline software for data acquisition and processing, have led to atomic-resolution analyses being not just feasible, but routinely applicable for solving a wide range of materials problems. In this talk, I shall highlight the impact of these capabilities on our research into perovskite-structured transition metal oxide systems. The focus will be on Cs-scanning transmission electron microscopy (STEM), where a sub-Å electron probe is applied for both imaging, and analytics using energy dispersive X-ray and electron energy-loss spectroscopies.

To illustrate the possibilities that these techniques bring for performing metrology at the atomic scale, I will profile our results on precision-engineered functional oxide thin films and superlattices, where radio frequency magnetron sputtering and pulsed laser deposition are used to grow epitaxial layers on high quality single crystal substrates, atomic row by atomic row. Through the quantitative study of atomic column positions with few picometer precision, coupled to careful analysis of contrasts in imaging and diffraction with comparison to simulations, I will show how Cs-STEM enabled the identification of a new type of coherent interface in orthorhombic perovskite thin films [1]. Equally, I will discuss its importance on our research into the metal-to-insulator transition of rare-earth nickelates, where Cs-STEM analytics are used to validate the nature of chemically modulated superlattices, and even visualize the electronic nature of two compounds bonded together at different nanoscale repetition lengths [2, 3].

While, in the above work, bonding across atomic layers is implicit, recently we have turned our attention to the question of whether initially uncoupled perovskite oxides can be induced to bond together. Here, we take advantage of the innovation of creating free-standing perovskite membranes via the dissolution of a sacrificial layer in epitaxially deposited systems. Choosing a prototypical system of a $SrTiO_3$ membrane mechanically transferred to a Nb-doped $SrTiO_3$ carrier substrate, we find that, while thermal annealing alone does not bond the two together, the addition of raster-scanning with the high energy STEM probe reconfigures residual Sr and Ti atoms in the gap between membrane and carrier substrate into perfect, ionically bonded $SrTiO_3$ crystal lattice [4]. As such, our STEM probe becomes not just a metrological tool, but also a device for precisely controlled writing of nanobonding between the two oxide materials. Considering that the analysis implies that radiolysis is the critical beam-induced mechanism for stimulating the atomic reconstruction and bonding, other configurations for more versatile, larger-scale writing of nanobonded membranes are now being explored.

[1] D.T.L. Alexander, H. Meley, M.M. Schmitt, B. Mundet, J.-M. Triscone, P. Ghosez, and S. Gariglio, “Engineering Symmetry Breaking Interfaces by Nanoscale Structural-Energetics in Orthorhombic Perovskite Thin Films”, ACS Nano, 19, 10126-10137 (2025).
[2] C. Domínguez, A.B. Georgescu, B. Mundet, Y. Zhang, J. Fowlie, A. Mercy, A. Waelchli, S. Catalano, D.T L. Alexander, P. Ghosez, A. Georges, A.J. Millis, M. Gibert, and J.-M. Triscone, “Length scales of interfacial coupling between metal and insulator phases in oxides”, Nat. Mater., 19, 1182-1187 (2020).
[3] B. Mundet, C. Domínguez, J. Fowlie, M. Gibert, J.-M. Triscone, and D.T.L. Alexander, “Near-Atomic-Scale Mapping of Electronic Phases in Rare Earth Nickelate Superlattices”, Nano Lett., 21, 2436-2443 (2021).
[4] G. Segantini, C.-Y. Hsu, C.W. Rischau, P. Blah, M. Matthiesen, S. Gariglio, J.-M. Triscone, D.T.L. Alexander, and A.D. Caviglia, “Electron-Beam Writing of Atomic-Scale Reconstructions at Oxide Interfaces”, Nano Lett., 24, 14191-14197 (2024).

A High-Performance Nano-Copper Paste with Good Oxidation Resistance


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Copper nanoparticles (Cu NPs) are promising candidates for next-generation interconnect materials in power electronics due to their excellent electrical and thermal conductivity and low cost. However, their susceptibility to surface oxidation hinders sintering and device integration. In this work, Cu NPs were synthesized via an alcohol-phase reduction method using 2-pyridinemethanol, a low-boiling-point nitrogen-containing dispersant, to enhance oxidation resistance. The modified Cu NPs showed uniform quasi-spherical morphology (20–30 nm) and were coated with a ~1.5 nm organic layer. The TEM interplanar spacing and XRD analysis confirmed its identity as pure copper crystal, while FT-IR and XPS analysis verified the surface coordination between Cu and 2-pyridineethanol. TG-DSC demonstrated improved thermal stability, with the oxidation onset temperature increasing from 94.8°C (unmodified) to 141.3°C (modified). The nanoparticles were formulated into a screen-printable paste and applied to bond AlN chips onto PCB substrates via fluxless sintering at 275°C. SEM and CSAM images revealed dense joints with minimal porosity, and high joint strength (85.8 MPa). Synchrotron-based XANES and EXAFS further elucidated the Cu–N coordination mechanism. High-resolution TEM of sintered structures showed grain growth, dislocation interactions, and nano-twin formation, while EBSD analysis confirmed equiaxed grains, abundant low-angle grain boundaries, and isotropic crystallographic orientation. These microstructural features explain the joint's superior mechanical properties and reliability. This work presents a viable surface-engineering strategy for oxidation-resistant Cu NPs in high-performance electronic packaging.

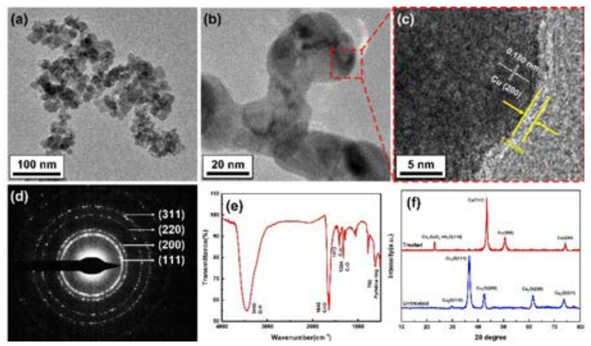

Fig. 1. (a) TEM image of copper nanoparticles, (b-c) magnified region, (d) diffraction rings of copper nanoparticles, (e) FT-IR analysis results, (f) XRD analysis results

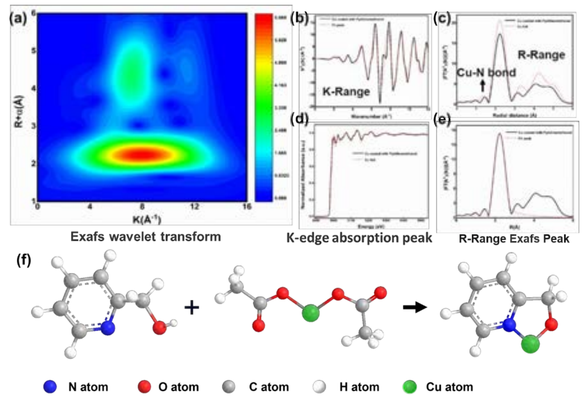

Fig. 2. (a) EXAFS wavelet transform, (b) Cu K-edge extended XANES oscillation functions κ3χ(k), (c) Magnitude of k3-weighted fourier transforms of the Cu edge XANES spectra, (d) Cu K-edge XANES spectra, (e) Fourier-transform magnitude of the k^2-weighted EXAFS spectra in R-space, (f) The coordination diagram of 2-pyridinemethanol

Micro-anchor structures for joining dissimilar metals for multi-material additive manufacturing


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The joining of dissimilar metals has been studied for various industrial applications for the use of synergetic effect between unique properties of two alloys. With joining of dissimilar metals, multi-material additive manufacturing can be used to fabricate components with multiple materials possessing new functionalities that cannot be realized by a single material with a capability of producing complex 3D structure. Laser direct energy deposition (L-DED) is a well-known metal additive manufacturing technology which are relevant to multi-material fabrication. However, for many combinations of dissimilar metallic materials, brittle intermetallic phases are easily formed at interfaces that often result in delamination cracking and make the materials difficult to be joined. In this study, a L-DED processing method is developed to achieve multi-material components with a strong interface bonding, based on micro-anchor structures produced in the L-DED process. Mechanical joining of dissimilar metals such as Fe/Al could be successfully done, which can be used for the multi-material additive manufacturing of dissimilar metals.

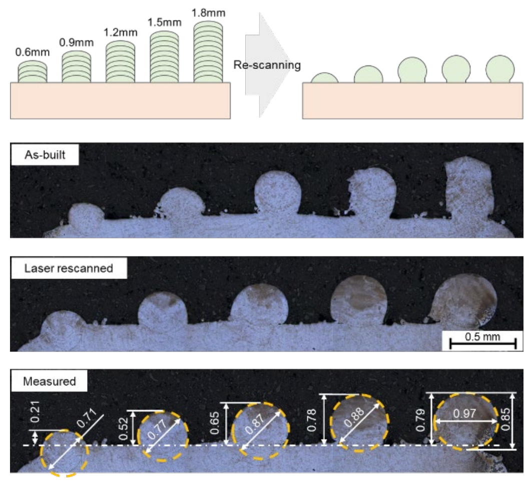

Fig. 1. Cross-section images of the micro-anchor structures produced by L-DED process for mechanical joining of dissimilar metals.

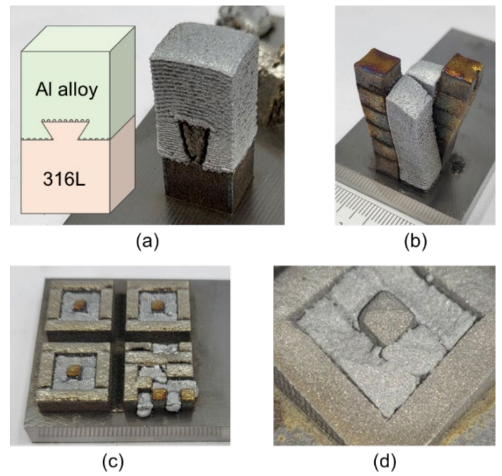

Fig. 2. Application of micro-anchor connection: (a) strengthen structure by macroscopic anchor, (b) square pillar building through the sine line, (c) QR code and (d) its cross-section of one side.

Recent Developments in Resistance Projection Welding for Automotive and Secondary Battery Manufacturing

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Modern automobiles demand lightweight yet robust joining solutions for dissimilar thick short flange aluminum components, which pose challenges due to limited bonding area and load capacity. A new method, projection-assisted resistance line welding (PA-RLW), was introduced to form projection welds by creating two optimized projections in one aluminum sheet to localize current flow and control heat distribution. An up-slope current profile reduces the G/R ratio, promoting a transition from columnar to fine equiaxed grains in the fusion zone, as revealed by EBSD. The schematic in Fig. 1 illustrates the up-slope current schedule and corresponding simulation results showing controlled heat and current localization at the projection sites. The characteristic force-time curve was analyzed alongside interrupted joints to understand the physical stages of PA-RLW, which include projection collapse, localized melting, weld pool formation, and merging into a line weld. This controlled growth minimizes weld spread and suits short flange aluminum applications. Fig. 2 compares the weld morphology and microstructures of PA-RLW, conventional RSW, and laser seam welding (LSS), showing that PA-RLW produces a more uniform fusion zone with fine equiaxed grains and higher misorientation angles—indicating greater grain refinement and improved mechanical performance. Validation through finite element analysis, infrared thermography, and high-speed imaging confirmed the mechanism. PA-RLW achieved superior load-bearing capacity compared to RSW and laser welding, and the force-time behavior offers a novel monitoring metric for broader RSW applications..

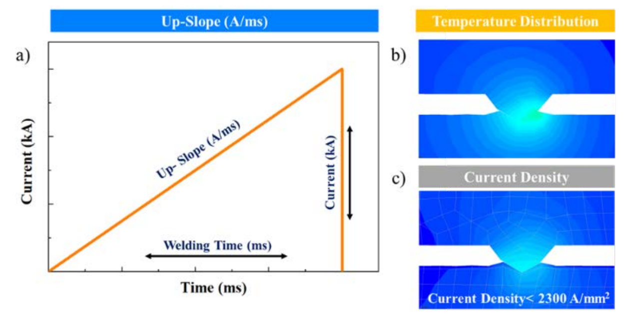

Fig. 1. Schematic of up-slope welding schedule (b) Simulated temperature distribution at the interface (c) Current distribution showing lower current density at the interface of projections

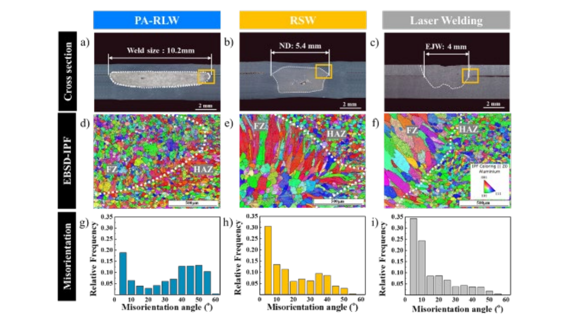

Fig. 2Weld cross sections corresponding to (a) PA-RLW, (b) RSW, and (c) LSS, and EBSD-IPF images of (d) PA-RLW, (e) RSW, and (f) LSS, and their corresponding misorientations maps (g) PA-RLW, (h) RSW, and (i) LSS, respectively.

Acknowledgments
This work was supported by the Institute of Information & Communications Technology Planning & Evaluation (IITP)-Innovative Human Resource Development for Local Intellectualization program grant funded by the Korea government (MSIT)(IITP-2025-RS-2020-II201791)

Data-Driven Evaluation of Ultrasonic Welds Quality in Multi-Layer Ultra-Thin Copper Foil Stacks Using Process Signals

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As shown in Fig. 1, the increasing demand for high-efficiency electric vehicle (EV) batteries has led to the application of ultrasonic welding as a joining method for ultra-thin multilayer copper foils [1, 2]. Ultrasonic welding is a solid-state process that offers the advantages of low heat input and the ability to minimize micro-gaps in multilayer foil stack joints. However, ensuring consistent welds quality in such multilayer structures remains a critical challenge, especially because it is practically impossible to inspect every electrical connection inside the battery post welding.

Therefore, this study aimed to characterize and classify the ultrasonic welds quality of multilayer copper foils using in-situ LVDT (Linear Variable Differential Transformer) and power signals. As the welding energy increased, indentation expanded and the effective thickness decreased. Notably, sound joints were achieved under specific process conditions (1.0 bar, 25 µm amplitude, 0.4 s welding time), and the formation of the welds was gradually developed from the outermost to the innermost layers.

Based on these results, a data-driven approach was applied to evaluate the quality of ultrasonic welding. In Fig. 2, it can be observed that excessively welded joints (W.E. > 900 J) show a gradually increasing pattern after the first peak, whereas insufficiently welded joints (W.E. < 300 J) exhibit a decreasing trend after the first peak. In addition, various signal features such as peak height and power fluctuation patterns were analyzed based on welding time to identify the joining behavior and energy transfer characteristics.

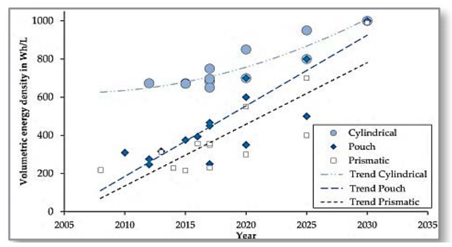

Fig. 1. Trends in volumetric energy density for different battery cell types.

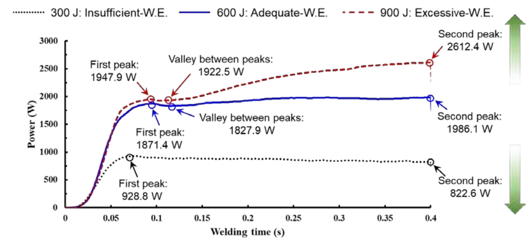

Fig. 2. Comparison of power signal with classified welding energies.

During ultrasonic welding, real-time acquisition of LVDT and power signals enabled clear differentiation between insufficient, sufficient, and excessive welds. These results suggest that process signals can serve as a foundation for future real-time quality monitoring systems and are expected to facilitate the implementation of intelligent welding systems in high-throughput battery manufacturing lines.

[1] O. Alšauskas et al., Global EV Outlook 2024 – Analysis (International Energy Agency), (2024).
[2] T. Chen, Y. Jin, H. Lv, A. Yang, M. Liu, B. Chen, and Q. Chen, “Applications of lithium-ion batteries in grid-scale energy storage systems,” Transactions of Tianjin University, vol. 26, pp. 208–217 (2020).

Phosphoric Acid-Based Surface Modification for Direct Bonding of Aluminum and Polypropylene Used in Lithium-Ion Battery Pouch Films


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Pouch-type lithium-ion batteries are widely utilized and studied due to their high energy density, light weight, and excellent space efficiency [1]. Recently, aluminum-laminate films have been adopted as outer packaging materials for pouch cells, where aluminum is typically bonded to various polymers using adhesives [2]. However, the use of adhesives can lead to increased interfacial thickness, thermal degradation, and weak bonding strength, resulting in reduced mechanical stability under external impact [3]. To address these limitations, this study introduces a phosphoric acid-based surface modification method for aluminum to enable direct bonding with polypropylene without the use of adhesives via injection molding. Prior to bonding, the aluminum surface underwent degreasing, alkaline etching, and acid cleaning processes. Anodization was then conducted in a phosphoric acid solution to form aluminum oxide layers of varying thicknesses, followed by thermal bonding with unoriented polypropylene. The effect of oxide layer thickness on bonding strength was systematically investigated. A maximum shear strength of 21 MPa was achieved when the oxide layer thickness reached approximately 600 nm. Fig. 1 presents a cross-sectional TEM image of the sample with the highest bonding strength, revealing an intimate and well-defined interface. Fig. 2 shows that this strength was maintained after thermal shock testing at –20 °C and 80 °C, with only a 4% reduction observed after high-temperature and high-humidity testing at 85 °C and 85% relative humidity. Additionally, the joint exhibited excellent resistance after immersion in a $LiPF_6$-based electrolyte. These results suggest that phosphoric acid anodization is a promising approach for enhancing adhesion between aluminum and polypropylene without adhesives.

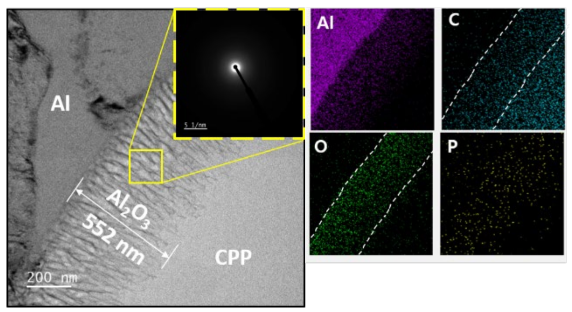


Fig. 1. Cross-sectional TEM image, SAED pattern, and EDS mapping results of the aluminum sample bonded with CPP.

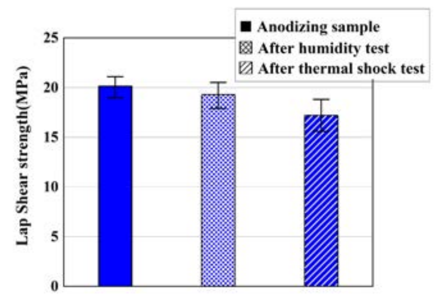
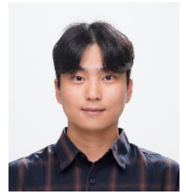


Fig. 2. Graph of lap shear strength results for bonded samples before and after reliability tests.

[1] F. Czerwinski, "Current trends in automotive lightweighting strategies and materials", *Materials*, vol. 14, 6631 (2021).
[2] G. Oh, "Development of printed pouch film and flexible battery", *Batteries*, vol. 10, 244 (2024).
[3] Y. Tomita, "Degradation behaviors of adhesion strength of structural adhesive for weld-bonding under high temperature and humidity conditions", *Procedia Engineering*, vol. 184, pp. 231–237 (2017).

Investigation of Lamination Bonding Behavior in Ultra-Thin Foil Stacks Using Vaporizing Foil Actuator Welding


Jungyu Choi

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In this study, the lamination bonding behavior of multilayered ultra-thin foil stacks was investigated using the Vaporizing Foil Actuator Welding (VFAW) process. VFAW employs a high-current pulse to rapidly vaporize a metallic foil, generating a high-velocity pressure wave that drives solid-state bonding between materials. During this process, the materials experience extreme interfacial pressure without melting, which activates atomic diffusion across the interface, leading to the formation of new atomic bonds. This mechanism enables the achievement of high-strength joints even in ultra-thin structures while minimizing microstructural changes typically associated with fusion-based joining processes. The stable consolidation of stacked foils was achieved through process optimization based on both experimental trials and numerical simulations. Finite element modeling was employed to predict pressure wave propagation, deformation behavior, and interfacial bonding conditions during the VFAW process, providing valuable insights for refining welding parameters. Experimentally, cross-sectional observations using scanning electron microscopy (SEM) were performed to evaluate interfacial continuity, and identify potential microcracks, while transmission electron microscopy (TEM) was additionally used to characterize crystallographic changes and phase distributions at high resolution. Electrical resistance measurements were conducted to assess the degree of interfacial continuity and functional integration. The mechanical reliability of the joints was further evaluated through strength measurements. The results demonstrate that VFAW-based lamination bonding can be effectively applied to advanced manufacturing fields requiring reliable nano/micro-scale joining, such as micro-battery electrodes, implantable medical devices, and lightweight microelectromechanical systems (MEMS). Moreover, the findings highlight the broader applicability of VFAW to dissimilar material systems, paving the way for innovative multilayer joining technologies in electronics, biomedical engineering, and aerospace industries.

LIFT for printing and assembly – a study on optimized water-based inks for batteries


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The laser-induced forward transfer (LIFT) is a digital direct additive manufacturing tool, so changes in the geometry or the process parameters can be fast applied. Furthermore, it is a nozzle-free printing technique [1] enabling the process to be integrated into a wide range of possible applications in both research and industry. In research the technique is used for printing proteins [2], biological cells [3], suspensions [4], and solid materials mostly metals [5]. Furthermore, whole components can be transferred what has been demonstrated in research with resistors, capacitors, and diodes [6] to name a few and is applied for example for printing µLED for displays in the industry [7]. A functional circuit can be printed by applying the LIFT process with conductive material, e.g. solid copper or silver nanoparticles to connect the printed components. For the power supply of these printed circuits lithium-ion batteries can be printed as well. In the battery research the LIFT-process can provide a versatile tool to boost the development by rapidly manufacturing prototypes. To further optimize the lithium-ion battery advanced electrode architectures and high capacity materials as nano-scaled silicon are under development. The high capacity material silicon (3579 $mAh \cdot g^{-1}$) has one order of magnitude higher theoretical specific capacity than the commonly used graphite (372 $mAh \cdot g^{-1}$) but during lithiation silicon undergoes a volume expansion of up to 300 %, which leads to fast mechanical degradations of the electrodes. Advanced electrodes architectures can help to overcome this challenge and can increase the power density, energy density, the cycling stability, and the electrode wettability.
In this work, a tripled frequency UV-laser with a pulse width in the nanosecond range was used to perform the LIFT-process. First, the composition of the electrode ink was optimized. For this purpose, polyacrylic acid (PAA) was introduced as a suitable binder for silicon-containing electrodes in electrode printing, as polyvinylidene difluoride (PVDF) has mostly been used so far for electrode printing, but the binding forces from the PVDF to the particles are too weak to withstand the volume expansion of the silicon during cycling. For the printing process with an electrode ink with a protic binder (PAA) a solvent with lower vapor pressure as water is required, which leads to the introduction of a glycerol-water mixture. First the influence of the glycerol content on the electrochemical properties of silicon was investigated. For the silicon a specific capacity of more than 3000 $mAh \cdot g^{-1}$ was reached. Additionally, the influence of different conductive additives with different particle sizes were investigated with the focus of reached specific capacity of silicon and the cyclability. Furthermore, for different glycerol contents in the solvent process parameters were identified at which the edge quality of the printed electrode areas is improved. Finally, the possible application spectrum of this new paste technology in additive and joining processes is outlined.

[1] Serra, P.; Piqué, A. Introduction to Laser-Induced Transfer and Other Associated Processes. In Laser Printing of Functional Materials. Electronics, 3D Microfabrication and Biomedicine, 1. Auflage ed.; Piqué, A., Serra, P., Eds.; Wiley-VCH Verlag GmbH & Co. KGaA: Weinheim, Germany, 2018; pp. 3-13.
[2] Dinca, V.; Farsari, M.; Kafetzopoulos, D.; Popescu, A.; Dinescu, M.; Fotakis, C. Patterning parameters for biomolecules microarrays constructed with nanosecond and femtosecond UV lasers. Thin Solid Films 2008, 516, 6504-6511.
[3] Kryou, C.; Zergioti, I. Laser-Induced Forward Transfer on Regenerative Medicine Applications. Biomed. Mater. Devices 2022, 1, 5-20.
[4] Rapp, L.; Ailuno, J.; Alloncle, A.P.; Delaporte, P. Pulsed-laser printing of silver nanoparticles ink: control of morphological properties. Opt Express 2011, 19, 21563-21574.
[5] Bohandy, J.; Kim, B.F.; Adrian, F.J. Metal-Deposition from a Supported Metal-Film Using an Excimer Laser. J. Appl. Phys. 1986, 60, 1538-1539.
[6] Arnold, C.B.; Serra, P.; Piqué, A. Laser direct-write techniques for printing of complex materials. MRS Bull. 2007, 32, 23-31.
[7] Haupt, O.; Brune, J.; Fatahilah, M.; Delmdahl, R. MicroLED´s: high precision large scale UV laser lift-off and mass transfer processes. In Proceedings of the Laser-based Micro- and Nanoprocessing XVI, 2022; pp. 119890I119891-119890I119897.

Advances in advanced power electronics packaging technology


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Power semiconductors in electric vehicles play a key role, like the heart of an electric vehicle, converting the DC of the battery into AC to drive the motor and controlling the voltage and frequency. Electrical losses processed during power conversion are released as heat, which is the fundamental reason for failure of power electronics (PE) systems. Here we have the power electronics packaging at how packaging technology has evolved and where it is headed from a material, structural, and manufacturing perspective that are important in thermal management of power electronics. In this context, this work presents the direction of development of mass production technology through new technologies and systematic analysis of the light and dark sides of sintering bonding technology using Ag, Cu, etc. at the current point in time when commercialization of silicon carbide metal-oxide-semiconductor field effect transistors (SiC MOSFETs) has begun. Through comparative analysis and application case studies, this presentation outlines the pathway for transitioning sinter bonding methods into high-volume manufacturing. Emphasis is placed on the practical requirements for reliability, cost-effectiveness, and compatibility with existing assembly lines. By identifying both the potential and limitations of these emerging bonding techniques, this work aims to offer insights into the future direction of power electronics packaging for next-generation electric vehicle systems.

Challenges and thoughts on trend to nanojoining


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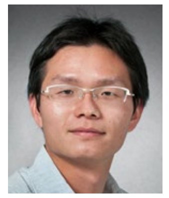
The term "nano" has evolved from unit prefix known by some specialists only into a frequently used designation in a wide range of applications and technological fields. Nanojoining however has gained an increasing importance and a major role for joining of microelectronics. This is - amongst others – due to the increase of operation temperatures and reliability requirements e.g. in power electronics, leading to limits of existing joining technologies as soldering or wire bonding and requiring joints allowing higher operation temperatures, but being manufactured at the same joining temperatures.

From a theoretical point of view, nanomaterials offer a simple approach because of the change of physical properties with decreasing dimensions, expedited in the low range. In reality however, further impacts and mechanisms must be considered, linked with a number of interactions or interdependencies. Furthermore, in electronics, the role of materials or material choices is sometimes underestimated. Therefore, the need of holistic considerations is given at last in the same amount as in other technological fields, by all means partly more in electronics.

Starting with some early developments, the assessment leads to a holistic approach, as a tool allowing a more comprehensive development procedure. Using the example of mixed joints, the not primary, but nevertheless determining role of materials is discussed. Followed by a comparison of acting mechanisms in selected joining technologies, some trends and open items for future development of nanojoining shall close this contribution.

Resistance microwelding of NiTi and SS wires for biomedical applications


Peng Peng

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NiTi shape memory alloys are widely recognized as promising biomedical materials due to their superelasticity and shape memory effect [1]. Stainless steel (SS), with its excellent mechanical properties, corrosion resistance, and low cost, has been used in medical implants for over a century [2]. Recently developed biomedical devices, such as multifunctional guidewires, require reliable joining between NiTi and SS [3]. However, over two decades of research has shown that this dissimilar metal combination is challenging to join—fusion welding often leads to brittle weld zones, while solid-state welding presents significant processing difficulties.

By controlling the interfacial melted liquids, a solid-state welded interface was successfully achieved in the resistance microwelded (RMWed) joint. An ultrathin reaction layer (~850 nm), predominantly composed of Laves phase, enabled strong metallurgical bonding without inducing excessive brittleness. The Joule heating effect suppressed work hardening and preserved the superelasticity of the NiTi side. The resulting joint demonstrates excellent potential for multifunctional biomedical applications, exhibiting full functional performance on the NiTi side, flexible deformation capability on the SS side, high resistance to hydrogen embrittlement and electrochemical corrosion, and significantly reduced Ni ion release and cytotoxicity. This work also offers new insights into processing control strategies for dissimilar-metal welding.

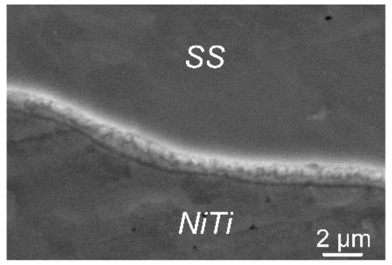

Fig. 1. SEM image showing the NiTi-SS RMWed interface.

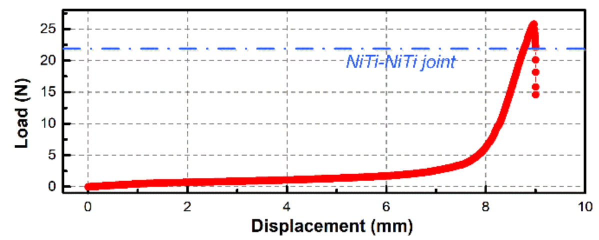

Fig. 2. Load-displacement curve of the NiTi-SS RMWed joint during tensile-shear test (reference line indicates the failure load of the NiTi-NiTi joint).

[1] K. Otsuka and X. Ren, "Physical metallurgy of Ti-Ni-based shape memory alloys", Progress in Materials Science, 50, 511-678 (2005).
[2] A. Bekmurzayeva, W.J. Duncanson, H.S. Azevedo, and D. Kanayeva, "Surface modification of stainless steel for biomedical applications: Revisiting a century-old material", Materials Science and Engineering: C, 93, 1073-1089 (2018).
[3] K. Zhang, J. Li, A. Anousheh, J. Li, F. Parniani, C. Zang, X.S. Tang, Y.N. Zhou, and P. Peng, "Interfacial liquid control to realize superior comprehensive properties of microwelded NiTi-stainless steel joints for multifunctional biomedical device fabrication", Journal of Materials Science and Technology, 233, 304-318 (2025).

Designing Nanoparticle Assemblies Driven by Water Molecules


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In the past few decades, much exciting progress has been made in the controllable synthesis of nanoparticle with well defined sizes and morphologies. The focus of synthetic efforts tends to be shifting to creation of secondary structures consisting of nanoparticles, i.e., nanoparticle-assembled structures, owing to their unique collective properties [1,2].

Here, we report "one-pot" synthesis of the nanoparticle assembly of magnetite (Fe_3O_4)[3,4]. Fe_3O_4 is a representative of the large family of ferromagnetic ferrites with inverse spinel structure. The Fe_3O_4 nanopartilces were spontaeously assembled by reductive aging of ferric precursor ($FeCl_3{\cdot}6H_2O$) in ethylene glycol (EG) in the presence of potassium acetate (KOAc) (Fig.1). It was demonstrated that water from FeCl3·6H2O plays an important role in the assembly of nanoparticles. The nanoparticle assembly exhibited superparamagnetism, provided that the size of the nanoparticles that constitute them was approximately 10 nm or less [4]. We have also successully synthezied the magnetic nanoparticle-assembled bicontinuous porous microparticles in an an environmentally friendly manner [5]. The macoscopic functions of the bicontinuous porous microparticles and their possible application will be shown in this presentation.

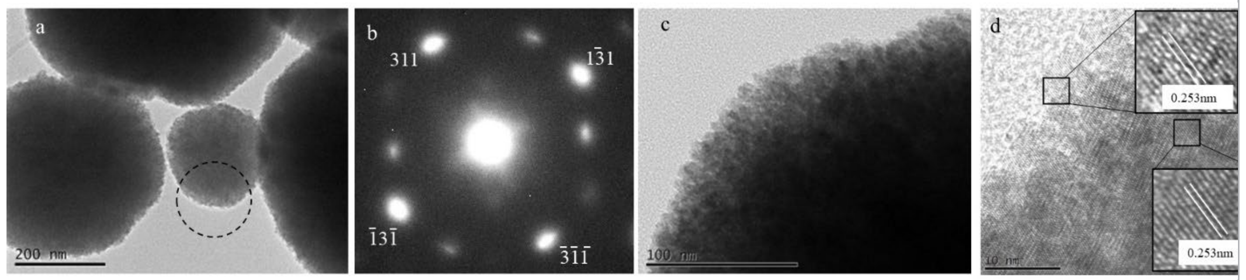

Fig. 1.a) TEM image of the Fe_3O_4 nanoparticle-assembly. b) SAED pattern of the circled region in a. c) HRTEM image of the edge of the microparticles. d) Magnified HRTEM images of c.

[1] A. Marsalin and R. Manr, "From formation to functionality: Insights into mesocrystal development and applications", J. Solid Sate Chem., vol.347, 125331 (2025).
[2] A. Rao, S. Roy, V. Jain, and P. Pillai. "Nanoparticle Self-Assembly: From Design Principles to Complex Matter to Functional Materials", ACS Appl. Mater. Interfaces, Vol.15, 25248-25274 (2023).
[3] H. Abe, K. Kuruma, T. Murakami, M. Takahashi, K, Sato, T. Naka, and Y Suzuki, "Magnetite nanocrystal clusters transformed from ferric precursor and their colloidal magnetorheology", IOP Conf. series: Mater. Sci. Eng., vol.479, 012043 (2019).
[4] H. Abe, T. Naka, K. Sato, Y. Suzuki, and M. Nakano, "Shape-Controlled Syntheses of Magnetite Microparticles and Their Magnetorheology", Inter. J. Mol. Sci. Vol.20, 3617 (2019).
[5] H. Abe and T. Kozawa, submission in preparation
[6] T. Kozawa and H. Abe, submission in preparation

Influence of Additional Elements and Rolling Processing on the Superplasticity of Sn-Bi Based Alloys


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This article presents information that helps to clarify the superplastic deformation behavior of lead-free, low-melting Sn-Bi-based solders. The Sn-Bi-based solders form a hypoeutectic microstructure that is composed of the primary β-Sn phases and Sn-Bi eutectic structure from networked Sn and Bi phases. Sn-Bi-based solders have a lower melting point (139℃) than that of lead-free Sn-Ab-Cu solder (about 220℃) or eutectic Sn-Pb solder (183℃); thus, it is a promising material for low-temperature soldering. However, the hard, brittle quality of bismuth makes Sn-Bi-based solder less ductile. This problem has been addressed in previous studies [1-3]. These studies showed that adding a third element improves the ductility of Sn-Bi-based materials. The purpose of this study is to determine the strain rate sensitivity indices of Sn-35Bi, Sn-37.5Bi, and Sn-40Bi-based alloys and to investigate the influence of rolling processing on the superplastic deformation.

Fig. 1 shows a double-log plot of the relationship between true stress and true strain rate at 80°C for Sn-35Bi-0.1Zn and Sn-37.5Bi-0.1Zn. Both results show correlation coefficients above 0.9, which are acceptable for determining m-values. At 80°C, the correlation coefficients are 0.29 and 0.22, respectively. Neither result exceeded 0.3, the threshold for fine-grain superplastic deformation. This is assumed to be due to an increase in the proportion of the Sn primary crystal and a decrease in the proportion of the Sn-Bi eutectic crystal as the Bi concentration decreases. It is also due to the breaking of the three-dimensional network structure of the Sn-Bi eutectic structure, which makes superplastic deformation more difficult. Indices m were also obtained for rolled-alloy samples. A double-log plot of the relationship between true stress and true strain rate at 25°C for Sn-40Bi-0.1Cu and Sn-40Bi-0.01Ni is shown in Fig. 2. The index m at 25°C was larger than that of the sample without the rolling process. At 80°C, the values were almost the same. This is due to the preferential formation of microstructures that are easily deformed in the tensile direction by rolling.

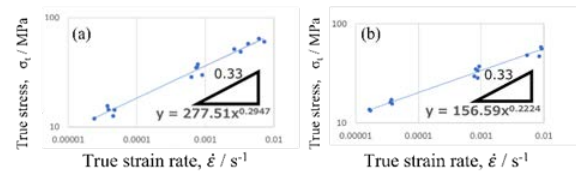


Fig. 1. Relationship between true stress and true strain rate for Sn-35Bi-0.1Zn (a) and Sn-37.5Bi-0.1Zn (b) alloys at 80℃.

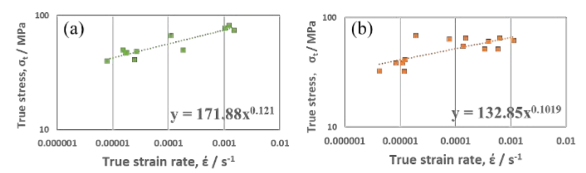
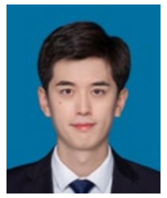


Fig. 2. Relationship between true stress and true strain rate for Sn-40Bi-0.1Cu (a) and Sn-40Bi-0.01Ni (b) alloys at 25℃.

This work was supported by the AMADA FOUNDATION grant number AF-2024027-B03 and the inter-university cooperative research program(202412-CRKEQ-0031) of the Institute for Materials Research, Tohoku University.
[1] H. Takao, A. Yamada, H. Hasegawa, and M. Matsui, "Mechanical properties and solder joint reliability of low-melting Sn-Bi-Cu lead-free solder alloy", J. Jpn. Inst. Electron. Packag., 5, 152-158 (2002).
[2] J. Umeyama and A. Yamauchi, "Tensile behavior and superplastic deformation of Sn-Bi-Cu alloy", Mater. Trans., 60, 882-887 (2019).
[3] Y. Hirata, C. Yang, S. Lin, and H. Nishikawa, "Improvements in mechanical properties of Sn-Bi alloys with addition of Zn and In", Mater. Sci. Eng. A, 813, 141131_1-8 (2021).

Neuromorphic computing Enabled by heterogeneous integration of 2D Material


Jinpeng Huo

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The increasing demand for energy-efficient and scalable artificial intelligence highlights the need for neuromorphic hardware capable of autonomous operation with minimal external circuitry. In this work, we demonstrate a self-powered optical spiking neural network (SPOSNN) that integrates optical–electrical–optical (OEO) feedback directly within a photonic platform. The proposed system consists of compact, two-terminal photonic synapses and neurons, forming a fully integrated OEO loop that supports both spike generation and dynamic feedback without requiring external bias or active control elements. This architecture significantly reduces system complexity and power consumption, while enabling high-speed, event-driven signal processing. We experimentally demonstrate reliable spiking behavior, homeostatic feedback modulation, and fully autonomous operation under ambient illumination. The integrated system exhibits strong potential for scalable, ultrafast, and parallel neuromorphic computing, offering a viable path toward low-power AI hardware beyond traditional electronics.

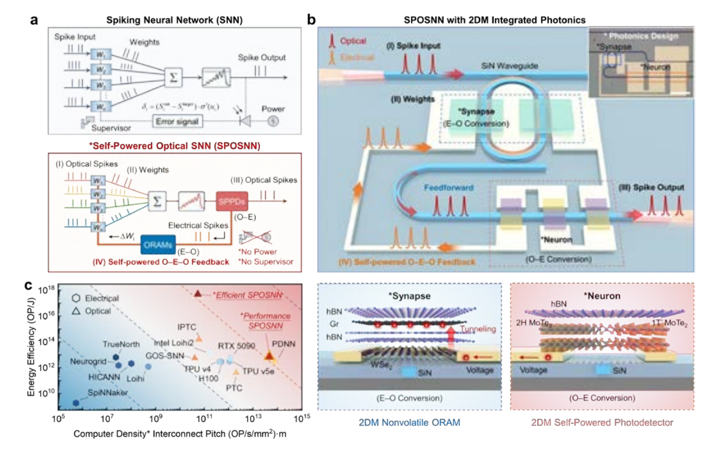
Fig. 1. Energy-efficient neuromorphic processing via self-powered optical spiking neural networks with 2D material-integrated photonics.

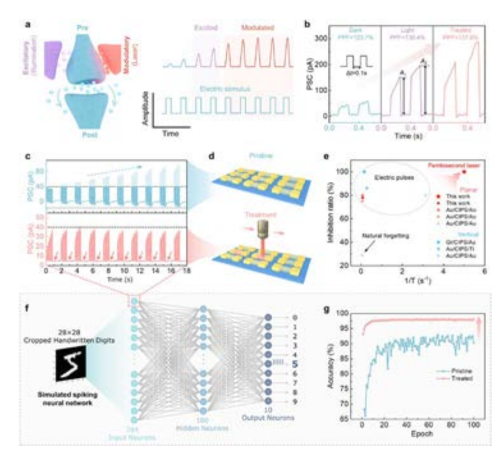
Fig. 2. Robust Neuromorphic Computing Enabled by Femtosecond Laser-Modulated Divergent Ion Dynamics in $CuInP_2S_6$.

Reference

[1]B. J. Shastri, A. N. Tait, T. F. De Lima, W. H. P. Pernice, H. Bhaskaran, C. D. Wright, and P. R. Prucnal, "Photonics for artificial intelligence and neuromorphic computing," Nature Photonics, vol. 15, pp. 102–114, 2021.
[2]K. Roy, A. Jaiswal, and P. Panda, "Towards spike-based machine intelligence with neuromorphic computing," Nature, vol. 575, pp. 607–617, 2019.

Effect of Palladium Doping in Gold Wire Bonding on Aluminum Pads in High-Temperature


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This study investigated interfacial reactions and structural changes in gold wires with varying palladium (Pd) content (0, 0,05, 0.1, 0.3, 1.0%) bonded to 5 ㎛ – thick aluminum (Al) pads under high-temperature aging at 175℃ for up to 1,000hours.

For conventional 1 ㎛ – thick Al pads, limited Al availability restricted intermetallic compound (IMC) growth beyond a certain thickness[1] over time. In contrast, thicker 5 ㎛ - thick Al pads provided sufficient Al sources, enabling nearly complete conversion of the 1st ball bond region into IMC as aging progressed.

Without Pd, rapid gold diffusion deformed the 1st ball bond shape after 500 hours, By 1,000 hours, gold depletion at the bond top formed a thin neck and cracks. Increasing Pd content created a Pd-rich barrier between the 1st ball bond and IMC, [2] slowing gold diffusion into the Al pad and preserving gold integrity beyond 500 hours.

However excessive Pd(≥0.3%) suppressed gold diffusion compensation in the lower Al pad, leading to void formation from Al migration. This demonstrates that while moderate Pd enhances high-temperature reliability, excessive amount in thick Al pads may cause void-related failures.

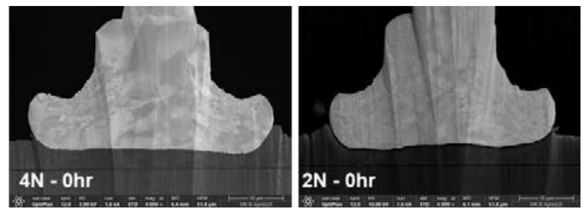

Fig. 1. Corss-sectional SEM images of the 1st ball bond after bonding (a) 4N gold wire and (b) 2N gold wire

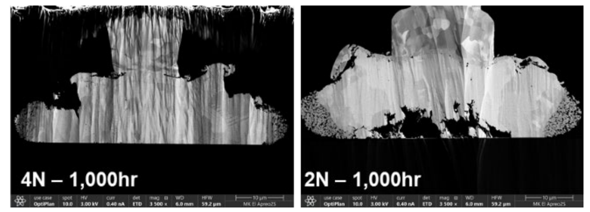

Fig. 2. Corss-sectional SEM images of the 1st ball bond after 1,000 hours of high-temperature reliability (a) 4N gold wire and (b) 2N gold wire

[1] N.J. Noolu, N.M. Murdeshwar, K.J. Ely, J.C. Lippold and W.A. BaeslackⅢ, "Degradation and failure mechanisms in thermally exposed Au-Al ball bonds", Materials Research Society, 19., 1374-1386 (2004).
[2] Y.C. Choi, S.C. Teck, L.T. Poh, H.P, Hoon and S. Diong, "Towards Higher Reliability Challenge of Au-Al intermetallic system", International Electronic Manufacturing Technology, 175-178 (2006).

Targeted Induction Heating of High-Power Device Interconnects on Circuit Boards

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High-power devices are widely used in power supply, motor drive, medical treatment, and industrial automation. Therefore, reliably interconnecting these devices with complex circuit boards is critical. High-power devices feature large heat dissipation pins, necessitating substantial energy input localized specifically at solder joints. However, few localized heating processes suit such demanding energy requirements, creating challenges for interconnecting high-power devices to intricate boards. This work proposes a novel focused induction heating method (N-FIHM), utilizing combined external and internal magnetizers to focus magnetic fields and boost heating efficiency. Results demonstrate the N-FIHM effectively concentrates magnetic fields at solder joints, significantly increasing temperature. Compared to traditional induction heating at identical coil positions and heating times, solder joint magnetic field density surged 7-fold (0.02 T to 0.14 T), and temperature rose remarkably 6.9-fold (45 °C to 310 °C).

Additionally, this study explores how structural parameters of the external tapered magnetizer influence magnetic field focusing and heating efficiency. Key parameters include the inner-outer magnetizer distance, outer magnetizer wall thickness, magnetizer-substrate gap, outer magnetizer height, and its inner diameter. Crucially, the inner-outer magnetizer distance most significantly impacts efficiency. Solder joint temperature escalated sharply from a minimum of 120 °C to a maximum of 401 °C.

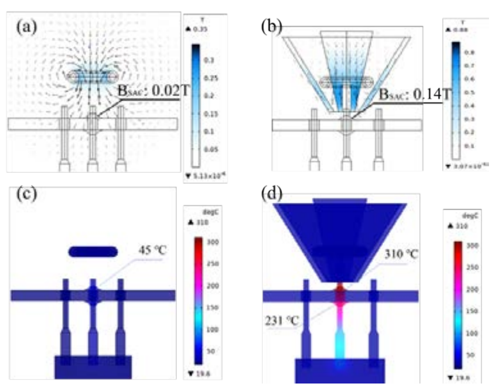


Fig. 1. Magnetic and heat distribution : (a) and (c) traditional induction heating, (b) and (d) N-FIHM

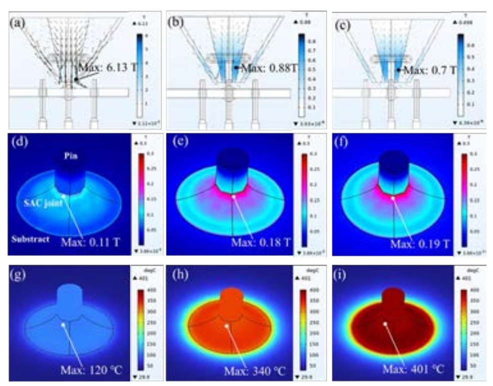
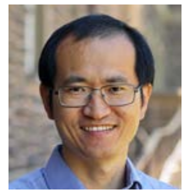


Fig. 2. The magnetic and heat distribution corresponding to the height change of the external conical magnetizer

Uncovering Diffusion Pathways and Phase Segregation in Alloys and Oxides via Atomistic Simulations



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Elemental redistribution in materials due to diffusion often leads to the degradation of key properties such as mechanical strength, electrical conductivity, and catalytic activity. Experimentally characterizing this redistribution and its influencing factors remains a significant challenge. Computational simulations offer a powerful alternative for uncovering the underlying atomistic mechanisms and diffusion pathways.

In this talk, I will present a first-principles-based simulation framework for modeling diffusion and the resulting phase transitions—without relying on empirical parameters. This approach aims to identify the evolving rate-limiting steps during material evolution without preconceived assumptions. The framework begins with density functional theory (DFT) calculations to determine the energetics of various local environments. These data are then used to train an efficient surrogate Hamiltonian via cluster expansion. Finally, kinetic Monte Carlo (KMC) simulations, with ion hopping barriers updated on-the-fly, are employed to model system evolution over timescales reaching seconds.

I will demonstrate the utility of this framework through two case studies: (1) self-hardening in Al alloys due to Si clustering during shelf aging, and (2) oxide composition evolution in Ni-based alloys. In the Al alloy system, we find that Si aggregation is strongly correlated with void formation. Vacancies not only facilitate rapid Si diffusion but also act as a binding agent for Si atoms. In the Ni alloy system, we track compositional changes over time that lead to the formation of a passivation film. Notably, the dominant local motifs vary depending on whether Al or Cr is the principal alloying element, resulting in distinct passivation behaviors.

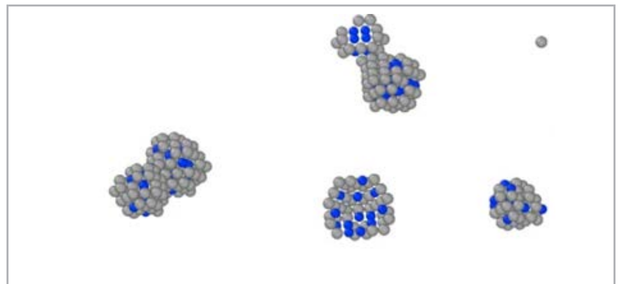

Fig. 1. Simulated Si clustering around voids in Al-Si alloys. Only undercoordinated atoms are displayed: blue spheres represent Si atoms; grey spheres represent Al atoms.

Interlayers in multi-material joining guided by thermodynamic design of high-entropy alloys

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There is a growing demand across various industries such as aerospace, automotive, and electronics for materials with superior mechanical and functional properties. However, it is often difficult for a single material to simultaneously satisfy diverse property requirements such as strength, ductility, and corrosion resistance. As a result, the need for multi-material structures, which can utilize the unique properties of different materials in combination, is increasing.
To fabricate such multi-material structures, joining of dissimilar materials is essential. However, the formation of intermetallic compounds (IMCs) can significantly reduce the mechanical strength of the joint during dissimilar metal joining. This study applied a high-entropy alloy (HEA) interlayer during friction stir welding (FSW) of dissimilar Al-Ni and Al-Fe materials to minimize IMC formation. Furthermore, post-weld heat treatment (PWHT) was performed to recover the precipitation hardening effect of heat-treatable aluminum alloys, which tends to deteriorate due to high-temperature exposure during FSW. The HEA interlayer effectively suppressed the formation of brittle IMCs during FSW and continued to inhibit their growth even after PWHT. Additionally, the precipitation hardening of Al alloys was recovered, enabling the joint to achieve a strength level comparable to that of the base material. The findings of this study are expected to contribute to the advancement of dissimilar material joining technologies and serve as a valuable foundation for the practical implementation and industrial application of lightweight, high-strength multi-material structures.

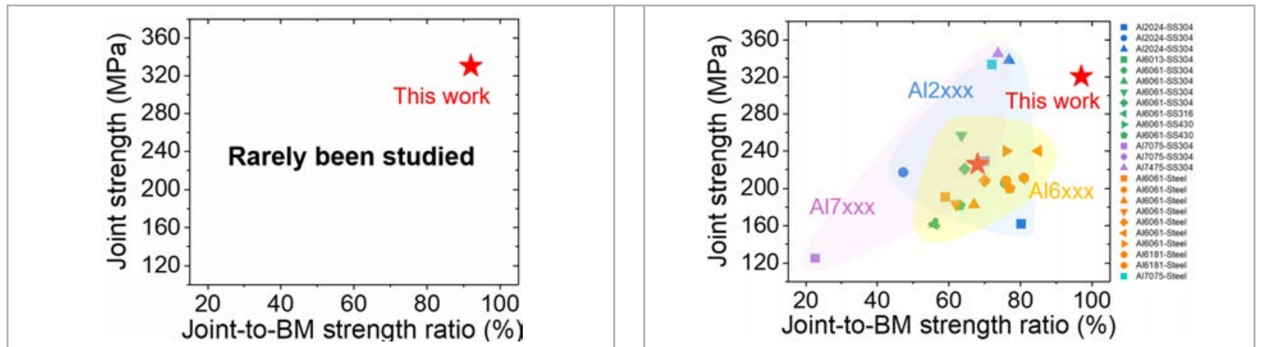
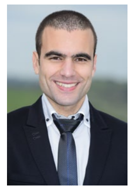


Fig. 1 Ashby's chart for joint strength with respect to the base metal strength for Al-Ni dissimilar joints

Fig. 2 Ashby's chart for joint strength with respect to the base metal strength for Al-Fe dissimilar joints

(Acknowledgement) 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)) **(KRIT-CT-23-007, Intelligent Additive Manufacturing Research Laboratory).**

Welding of High Entropy Alloys



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Welding is part of any structural engineering component. When it comes to high entropy alloys, welding is still in its infancy. Here, we will shown of the selection of the filler metal during gas metal arc welding of high entropy alloys can drastically influence the microstructure, phase composition and mechanical response of the welded joints.
By combining advanced microstructure characterization, thermodynamic modelling and mechanical property assessment it is possible to tune the mechanical performance of the joints depending on the targeted application.

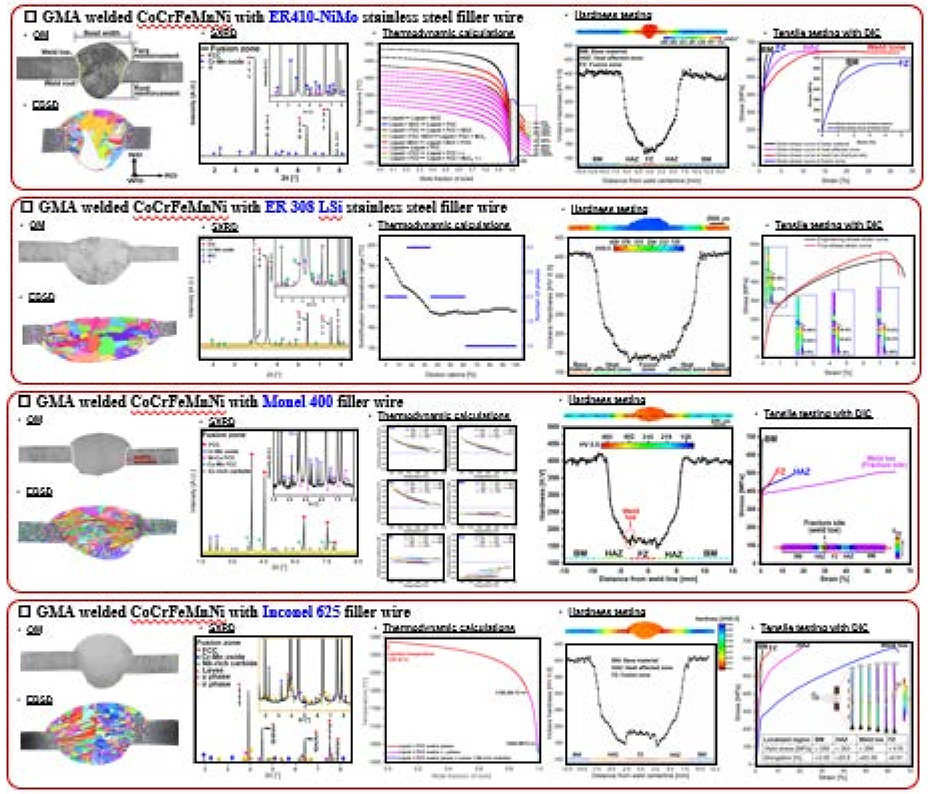

Fig. 1. Impact of filler metal selection on microstructure and properties of CoCrFeMnNi high entropy alloys.

On the Strength of Welds of Thin Cu Wires Welded by Joule Heat

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This presentation reports the strength of thin Cu wires welded by Joule heat [1]. Tips of two Cu wires of 25 μm thick were brought into contact together by a manual manipulator [Fig. 1(a)], and then, the constant direct current of 1.07 A was supplied to the wires using a pair of Ag terminals. It was found that the boundary of the contact disappeared after the current supply, indicating that a good welding was achieved [Fig. 1(b)]. Figure 1(c) shows an example of the load-displacement curves for the welded Cu wires (#4) together with that of the Cu wire as received (ar). All welded Cu wires were broken outside the weld, and the fracture points were located within 0.1 mm of the weld. This indicates that all welds were stronger than the wires themselves after the current supply. However, the breaking load of the welded Cu wires (#4) was lower than that of the Cu wire as received. The fracture surface of the welded Cu wire [Fig. 1(d)] showed a ductile fracture similarly to that as received [Fig. 1(e)]. The tensile strength of the welded Cu wires was 136 MPa, approximately two-thirds the strength of the Cu wire as received (210 MPa).

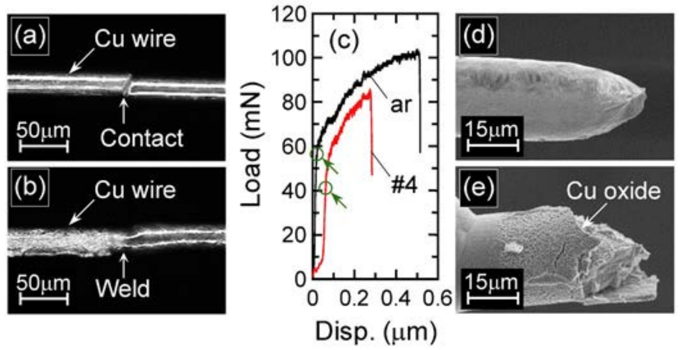

Fig. 1. Digital microscope images around the contact (a) before and (b) after the current supply. (c) Load-displacement curve of the welded Cu wires together with that of the as-received Cu wire. SEM images around the fractured positions of (d) the as-received Cu wire and (e) the welded Cu wires. Reprinted from ref. [1], copyright (2023), with permission from AVS.

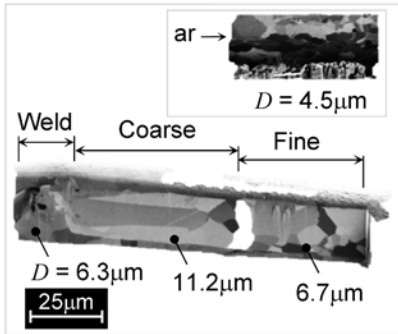

Fig. 2. SIM image of the cross section of welded Cu wires. The SIM image of the as-received Cu wire is shown as inset. Reprinted from ref. [1], copyright (2023), with permission from AVS.

Figure 2 shows the scanning ion microscopy (SIM) image of the cross section of the welded Cu wires. The diameter of the grain (*D*) of the Cu wire as received measured by the intercept method was 4.5 μm (see inset). On the other hand, grain size of the welded wires was divided into 3 regions: the weld, the region within and over 60 μm from the weld. The values of *D* of each region were determined to be 6.3, 11.2 and 6.7 μm, respectively. The welded Cu wires broke in the coarse grain region, confirming that the decrease in strength of the welded wires was due to grain growth during the welding. A method of welding the wires with reduced grain growth will be introduced in the presentation. [This work was supported by JSPS KAKENHI Grant Number 22H01350.]

[1] H. Tohmyoh and T. Sakatoku, "Grain growth of Cu wires during Joule heat welding", J. Vac. Sci. Technol. B, 41, 012206 (2023).

Metal-Polymer Dissimilar Material Joining Technology Using Plasma-Assisted Hot Pressing Method

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Hybrid metal–polymer materials have gained considerable attention due to their lightweight, mechanical robustness, and cost-effectiveness, making them attractive for automotive, aerospace and medical applications. Thermoplastics, in particular, are favored for their processability, recyclability, and compatibility with automated manufacturing, enabling high-volume production and advanced joining methods that eliminate the need for adhesives or mechanical fasteners. Direct thermal joining techniques—such as ultrasonic, induction, laser, and friction heating—allow the formation of strong interfacial bonds by melting the polymer and promoting adhesion with the metal surface. Effective bonding relies on chemical interactions, particularly hydrogen bonding between metal oxides and polar functional groups on the polymer. However, thermoplastics lacking such functional groups present challenges for conventional bonding methods. To address this, atmospheric pressure radio frequency (RF) plasma jets as shown in Fig. 1 offer a promising solution by simultaneously modifying the polymer surface with reactive species and providing localized heating. These plasma jets enhance surface functionality and support the hot-pressing process, enabling strong bonds without additional adhesives. In previous studies, aluminum alloys A1050, A5052 and pure titanium TP340 and Ti-6Al-4V (Ti-64), along with the high-performance thermoplastic PEEK, were directly bonded following surface pre-treatment with atmospheric-pressure RF plasma jets and subsequent hot pressing, thereby substantiating the beneficial effects of plasma treatment on joint strength [1-3]. As shown in Figure 2, plasma irradiation of PEEK dramatically increased the bond strength of the Ti-64/PEEK joint to 11.2 MPa. In this presentation, we will report on the results of our investigation into the direct bonding of metals and polymers using atmospheric pressure RF plasma treatment, and the effects of physical and chemical surface conditions on bonding.

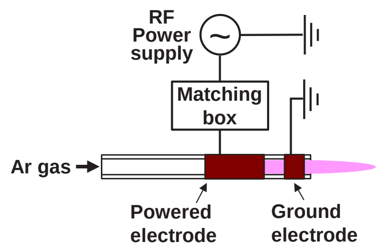

Fig. 1. Schematic illustrations of apparatus used to generate an atmospheric pressure RF plasma jet,

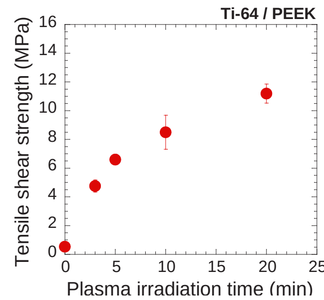

Fig. 2. Variation in tensile shear strength of Ti-64/PEEK bonded samples as a function of plasma irradiation time.

[1] K. Takenaka , A. Jinda , S. Nakamoto , et al. "Influence of pre-treatment using non-thermal atmospheric pressure plasma jet on aluminum alloy A1050 to PEEK direct joining with hot-pressing process", Int J Adv Manuf Technol 130, 1925-1933 (2024).
[2] K. Takenaka , A. Jinda , S. Nakamoto , et al. "Improving bonding strength by non-thermal atmospheric pressure plasma-assisted technology for A5052/PEEK direct joining", Int J Adv Manuf Technol 130, 903-913 (2024).
[3] K. Takenaka, S. Nakamoto , R. Koyari, et al. "Influence of pre-treatment with non-thermal atmospheric pressure plasma on bond strength of TP340 titanium-PEEK direct bonding", Int J Adv Manuf Technol 134, 1637-1644 (2024).

HPT processing of Cu-Mo composites for tailoring thermal properties for thermal management

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Modern electronic systems with growing power density demand advanced materials capable of effective thermal management. These materials must offer high thermal conductivity and controlled thermal expansion to dissipate heat efficiently and maintain long-term reliability. Cu-Mo composites are promising candidates for such applications due to their favourable combination of thermal properties. However, conventional manufacturing techniques, such as powder metallurgy, often result in porosity and limited control over microstructure, negatively affecting performance. In contrast, severe plastic deformation methods—such as high-pressure torsion (HPT)—offer a possibility to produce fully dense, nanostructured materials with improved homogeneity and mechanical properties.

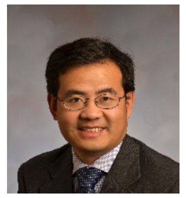
The aim of this study is to develop Cu-Mo nanocomposites specifically tailored for electronic packaging applications, such as thermal interface materials in joints between Si or SiC and Cu. The work focuses on utilizing high-pressure torsion (HPT) to fabricate these composites with homogenous microstructures. Two Cu-Mo nanocomposites with different chemical composition (namely 20 and 30% of Mo) were processed with varying numbers of HPT revolutions (from 10 to 200) starting from a stack of individual macroscopic layers. For both compositions, a homogeneous nanostructure consisting of equiaxed Cu grains (~30 nm in diameter) and uniformly dispersed Mo particles (~20 nm) was achieved after 200 revolutions. This indicates that HPT processing can effectively transform multilayered systems into nanostructured, homogenous materials. The grain refinement achieved in the Cu matrix was significantly more pronounced compared to pure Cu, which typically shows grain sizes around 250 nm after HPT.

Laser flash analysis (LFA) measurements revealed that the thermal conductivity of the Cu-Mo composites was only slightly reduced relative to bulk Cu, making them suitable candidates for use as heat spreaders and thermal interface materials. The lack of porosity and uniform dispersion of Mo contribute to the composites' thermal stability, essential for reliable performance in high-power electronic devices. The study of thermal stability revealed that the microstructure is relatively stable and only a moderate growth (to about 80 nm) of Mo nanoparticles is observed after annealing at 800^{o}C. Moreover, such a microstructure coarsening contribute to the improvement of thermal conductivity which is a promising observation for joining applications, where reliable joint and enhanced properties could be obtained at the same time.

This study demonstrates that HPT is an effective route for manufacturing Cu-Mo composites with controlled microstructures and optimized thermal properties from both custom-stacked and commercial multilayered precursors. These materials show strong potential as next-generation thermal interface materials for advanced electronic systems involving Si/SiC–Cu joints.

Keywords: Cu-Mo composites, thermal interface materials, high-pressure torsion, nanostructured materials, thermal conductivity.

Cracking Behavior and Laser Direct Energy Deposition of Tungsten



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Tungsten (W) is a refractory metal with outstanding high melting point, enhanced mechanical strength and thermal conductivity, making it a strategic material for aerospace, fusion energy, and electronics. However, additive manufacturing (AM) of W remains extremely challenging due to severe cracking driven by its high Ductility-Brittle Transition temperature (DBTT), and steep thermal gradients during laser processing. This work investigates the use of high-repetition-rate high power femtosecond (fs) laser induced direct energy deposition to mitigate cracking during the AM of W. In contrast to conventional continuous-wave (CW) lasers, fs lasers deliver energy in ultrashort pulses, enabling localized melting with minimal thermal diffusion. Comparative experiments between fs and CW laser processing of W demonstrate that fs laser melting occurs at significantly lower power levels, narrower heat-affected zones, and, crucially, a complete suppression of cracking. Cross-sectional analysis shows fs-processed samples possess differing grain sizes. No cracks were observed in fs-processed specimens, while CW laser samples exhibited frequent solidification and thermal cracks. These improvements are attributed to the shallow, wide melt pool geometry and reduced thermal gradients enabled by fs laser irradiation, which suppress crack-initiating residual stresses. This work presents a promising path for crack-free AM of W using fs lasers.

Figure 1 presents a clear comparison between samples processed with CW and fs lasers. The CW processed region (Fig. 1) shows extensive cracking along grain boundaries, indicative of severe thermal stress and inadequate crack suppression during solidification. In contrast, the fs processed region (Fig. 2) exhibits no visible cracks, demonstrating the efficacy of fs laser irradiation in mitigating thermal gradients and suppressing crack formation. These results directly support the hypothesis that fs lasers enable a more favorable thermal profile for crack free additive manufacturing of tungsten.

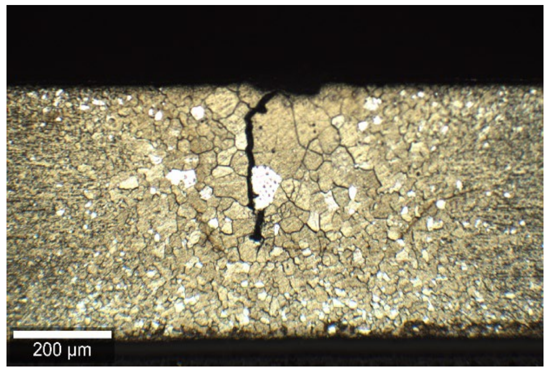

Fig. 1.Cross section of W CW laser processed area, detailing microcracking

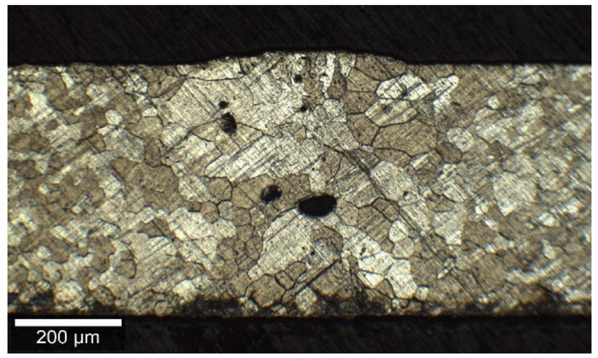

Fig. 2. Cross section of W fs laser processed area, showing absence of cracking.

Mechanical Reliability of Thin Film Materials for Semiconductors, Displays, and More


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Advanced thin films are ubiquitous and important in many modern technologies. Most prominent applications include microelectronic devices, fuel cells, solar cells, OLED displays for which electrical, electrochemical, and optical properties of thin films are critical. However, while significant efforts have been directed to improving those properties, mechanical integrity of the thin films has been often ignored and even sacrificed. For example, new materials with unknown mechanical properties are increasingly being used, and in many cases they turn out to have inferior mechanical reliability. To make matters worse, thin film devices are being attempted to be mounted on flexible, foldable and even stretchable substrates, and this dramatically increases film deformation and stress resulting in cracking and delamination. All of these trends significantly sacrifice mechanical integrity of thin films and reduce device yield and reliability. This talk presents novel methods to measure and enhance mechanical properties of advanced thin films for semiconductors, displays, and more. The topics to be discussed are 1) novel tensile testing of ultra-thin films on liquid surface platform, 2) adhesion and cohesion of advanced thin films, 3) warpage analysis by the digital image correlation (DIC) technique, and 4) stress reduction by controlling neutral planes.

Small-scale Local Residual Stress Measurement Technique: Slitting Method Based on FIB-μDIC


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As nano-/microjoining technologies continue to advance in response to aggressive device scaling, modern semiconductor architectures such as 3D ICs and High Bandwidth Memory (HBM) increasingly employ complex, heterogeneous material interfaces and multilayer geometries. These architectures inevitably develop residual stresses due to mismatches in thermal expansion, lattice constants, and local processing history. Such stresses can induce critical failures—including cracking and delamination—within joined interfaces, thereby undermining device performance and reliability. Understanding and quantifying these stresses at the microscale is therefore critical for robust nano-/microjoining design and reliability assurance.

However, conventional residual stress measurement techniques—such as wafer curvature, X-ray diffraction (XRD), and Raman spectroscopy—struggle to assess stress distributions in patterned and multilayered structures with nanoscale thicknesses. These techniques are either limited by material dependence or insufficient spatial resolution. To overcome these challenges, we are developing a method that integrates the classical slitting technique with high-resolution Digital Image Correlation (DIC) and Focused Ion Beam (FIB) micromachining, specifically designed for thin-film nano-/microjoined structures.

In our approach, custom micro-patterns are fabricated via lithography and protected by a sacrificial polymer layer during FIB milling. Local stress relaxation is induced by micrometer-scale slits milled into the film, and the resulting displacement field is captured using DIC. Based on this displacement field, slit geometry, and known material properties, a neural network-based inverse model is developed to reconstruct local residual stress distributions. This method provides a semi-non-destructive, high-resolution stress mapping tool suitable for nano-/microjoining interfaces.

Complementary finite element simulations were conducted to validate the plane-strain assumption and to optimize slit geometry based on aspect ratio and stress field localization. The effects of non-equibiaxial stress conditions—often present in anisotropic or multilayered systems—were also explored. The proposed method enables accurate interpretation of complex residual stress states in advanced semiconductor and microelectronic devices, offering valuable insights for failure prevention and joining reliability optimization.

This presentation will cover the theoretical framework, experimental implementation, and numerical validation of the FIB-μDIC slitting method, highlighting its applicability to the mechanical reliability analysis of nano-/microjoined structures.

Interfacial adhesion and fracture behavior in BEOL structures

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Interfacial adhesion in back-end-of-line (BEOL) structures is a key factor governing the mechanical reliability of state-of-the-art semiconductor devices. In this study, the adhesion energies of representative thin films used in BEOL structures, including Cu interconnects, capping layers, and inter-metal dielectric layers, were quantitatively evaluated through double cantilever beam (DCB) fracture mechanics testing. In addition, fracture behaviors and adhesion mechanisms under different material and surface treatment conditions were examined using micro- and nanoscale characterization techniques. In particular, the adhesion and fracture behavior at the Cu–SiCN interface exhibited significant variation depending on the surface treatment conditions and the mode mixity of the applied loading. Loading mode-controlled experiments and finite element analyses were conducted to validate these findings and clarify the underlying mechanisms.

Acknowledgements
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Effects of carbon nanotubes in enhancing the thermal and mechanical properties of W/Cu-CNTs/CuCrZr alloy joints

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W-based materials as the plasma facing materials are required to be bonded to CuCrZr alloy in the plasma facing components (PFCs). Confronting the extreme working condition of PFCs, it is necessary to achieve high strengths of the W/CuCrZr alloy joints while improving their thermal conductivities at the same time.

Carbon nanotubes (CNTs) are attractive reinforcement materials in improving the strength and thermal conductivity of composites due to their high thermal conductivity, low coefficient of thermal expansion (CTE), and excellent mechanical properties [1]. The incorporation of CNTs into the bonding of W and CuCrZr alloy can be achieved by introducing a Cu-CNTs interlayer, and the mechanical strength of the joints can be enhanced due to the load transfer effect [2]. Meanwhile, the thermal mismatch between W and Cu-CNTs interlayer can be reduced due to the low CTE of the CNTs, which reduced the interfacial thermal resistance [3]. Thermal conductive networks can also be constructed in the interlayer, and the heat at the interface can be transferred rapidly [4].

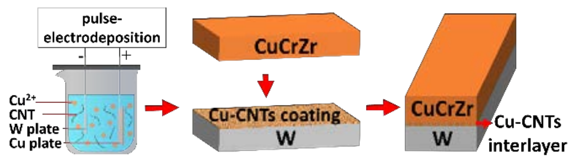

Fig. 1. Schematic illustration of bonding process of W/Cu-CNTs/CuCrZr alloy joint.

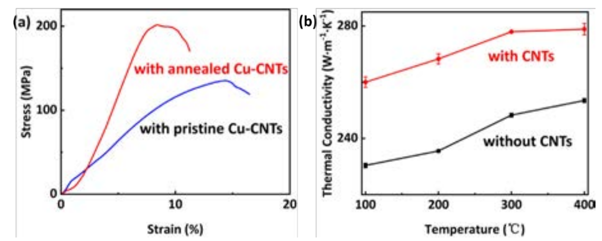

Fig. 2. Properties of the W/Cu-CNTs/CuCrZr alloy joints: (a) shear strengths, (b) thermal conductivities.

The preparation process of the W/Cu-CNTs/CuCrZr alloy joints consists of Cu-CNTs co-deposition on the surface of W, annealing of Cu-CNTs coating, and diffusion bonding with CuCrZr alloys (see Fig. 1). Through the Cu-CNTs co-deposition and the subsequent bonding process at 980 ℃, CNTs distributed uniformly in the composite interlayer without obvious entanglement, and the thermal and mechanical properties of the W/Cu-CNTs/CuCrZr alloy joints were improved by exploiting the high strength, high thermal conductivity, and low CTE of the CNTs (see Fig. 2).

[1] Q. Zou, C. Xu, Z. Dong, D. Wu, X. An, J. Jie, Deformation behavior and mechanical properties of rolled carbon fiber reinforced Al-matrix composites via protection with Sn layer, J. Mater. Process. Technol. 315, 117902 (2023).
[2] T. Xu, X. Ma, C. Wu, J. Zhang, W. Ke, M. Yang, Comprehensive regulation of carbon nanotubes on laser welded joints of aluminum alloy: From morphology, solidification, microtexture to properties, J. Mater. Process. Technol. 338, 118793 (2025).
[3] K. Chu, C. Jia, On the thermal expansion of CNT/Cu composites for electronic packaging applications, Appl. Phys. A 111(2), 439-443 (2013).
[4] Z. Wang, Z. Wu, L. Weng, S. Ge, D. Jiang, M. Huang, D.M. Mulvihill, Q. Chen, Z. Guo, A. Jazzar, X. He, X. Zhang, B.B. Xu, A Roadmap Review of Thermally Conductive Polymer Composites: Critical Factors, Progress, and Prospects, Adv. Funct. Mater. 33(36), 2301549 (2023).

Effect of Temperature Variation on Residual Stress in Cu/PI Structures for Fan-Out Package

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In recent years, semiconductor packaging technology has developed rapidly in response to increasing demands for miniaturization, high integration, and cost reduction. Among various packaging approaches, fan-out wafer-level packaging (FOWLP) technology has attracted significant attention because it eliminates the need for printed circuit boards, is thinner than conventional packages, and offers the potential to reduce process costs. The redistribution layer (RDL) in FOWLP typically consists of a laminated structure comprising a Cu RDL layer and a polyimide (PI) insulating layer. For reliable performance, this structure must maintain high adhesion and exhibit excellent reliability during thermal cycling and high-temperature heat treatment tests. However, previous studies have shown that peeling can occur during the RDL formation process due to the mismatch in the coefficient of thermal expansion (CTE) between the Cu RDL layer and the PI. Furthermore, during reliability testing, oxygen can penetrate the PI layer and form an oxide at the Cu/PI interface, which can further accelerate delamination. Thermal stress arising from this CTE mismatch can lead to warping and peeling of the RDL structure. Therefore, in this study, we investigated the thin-film stress in the Cu RDL/PI stacked structure by measuring real-time curvature changes using a multi-beam optical sensor (MOS) system under varying temperature conditions.

Acknowledgements: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. RS-2023-00239657) and, the Korea Institute for Advancement of Technology(KIAT) grant funded by the Korea Government(MOTIE) (RS-2024-00409639, HRD Program for Industrial Innovation)

Evaluation of Fracture Morphology of Al/Cu Joints for Development of Separation Techniques for Joining Dissimilar Matals

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Dissimilar material joining technology, which joins different materials, requires reliable joint strength that does not fracture at the interface. On the other hand, from the standpoint of recycling, it is desirable to properly separate the joint at the interface between dissimilar materials. Therefore, there is a need to create a dissimilar-material joint that can ensure both reliable joint strength and proper separation at the dissimilar-material interface. In this study, a basic investigation of dissimilar-material joints that can be properly separated at the dissimilar-material interface while maintaining strength was conducted using the local stresses generated at the joint interface during tensile deformation, as shown in Fig. 1 .

Fig. 2 shows the stress-displacement curve of the joint at friction shortening of 2.0 mm in the tensile test and a photograph of the joint after fracture. The strength of the joints increased with an increase in a friction shortening and then decreased. The joints with a 0.1 mm friction shortening fractured at the joint interface during uniform deformation, resulting in low strength. This is considered to be due to insufficient interfacial reaction. The joint with a 3.0 mm a friction shortening fractured in the A1050 base metal after exhibiting the maximum tensile strength. In this joint, softening of the base metal due to heat input was observed. On the other hand, the joint with a friction shortening of 2.0 mm exhibited a neck in A1050 (arrow in the figure) and fractured at the joint interface during non-uniform deformation after the joint exhibited UTS. Under these conditions, it can be said that the strength is maintained while the dissimilar materials are properly separated at the interface.

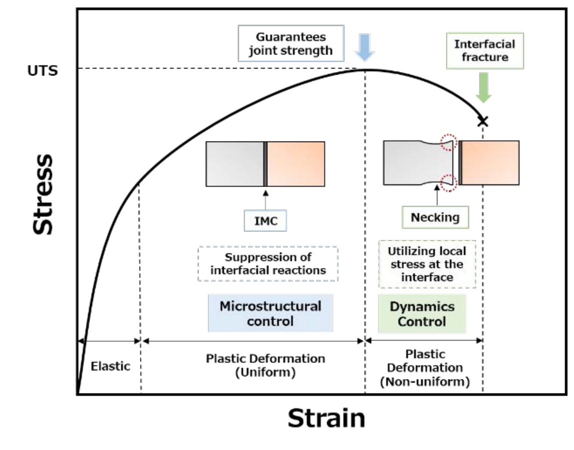

Fig. 1. Concept of separable joining of dissimilar materials using local stress

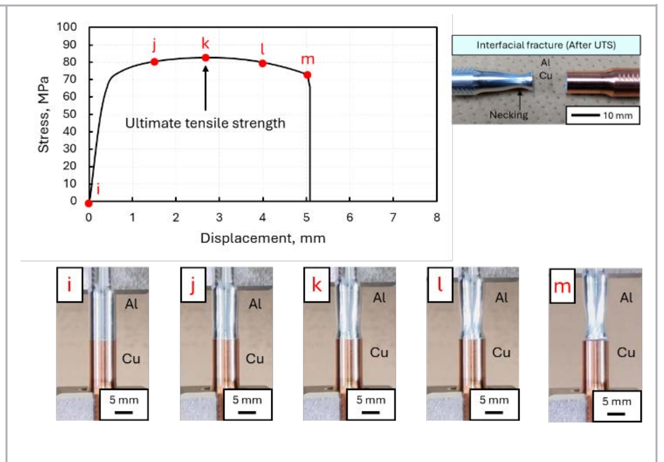

Fig. 2. Stress-displacement curves and fractured specimens of A1050/C1020 joints at friction shortening of 2.0 mm.

Experimental and numerical study on the mechanical impact of surface roughness in TGV glass

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Through Glass Via (TGV) plays a crucial role as an advanced interconnect technology in 2.5D and 3D packaging structures for high-frequency and high-density electronic devices. Unlike traditional Through Silicon Via (TSV), which uses silicon as the substrate, TGV employs glass as an interposer material due to its superior electrical and optical properties. TGV technology has gained significant attention for its applications in radio-frequency/microwave components, photonics, MEMS packaging, and heterogeneous integration.

Nevertheless, mechanical properties of the glass in TGV directly affect the stability and long-term reliability of the packaging structure. In the TGV manufacturing process, the roughness of the glass surface (see Fig. 1) has a significant impact on the quality of metal deposition, interfacial bonding strength, and the mechanical behavior of the overall packaging structure. To investigate the mechanical response of glass with different roughness, this study performs scratch testing, analyzes its hardness, fracture toughness, friction characteristics, and interfacial bonding force, and explore its influence on the stability of TGV structure. Particularly, scratch testing is used to analyze the friction characteristics of glass surfaces and the material's resistance to damage under shear loads, in order to further explore the effect of roughness on the interfacial bonding force of TGV structures. Experimental characterization, including hardness uniformity and scratch testing, was performed on glass samples with varying roughness. This study provides experimental evidence for optimizing the TGV manufacturing process and serves as a numerical approach for evaluating the effect of surface roughness of glass in electronic packaging, aiding in the development of more precise processing parameters, improving the stability of TGV packaging technology, and promoting its application in high-density integrated circuits, 5G communication, and advanced optoelectronic packaging.

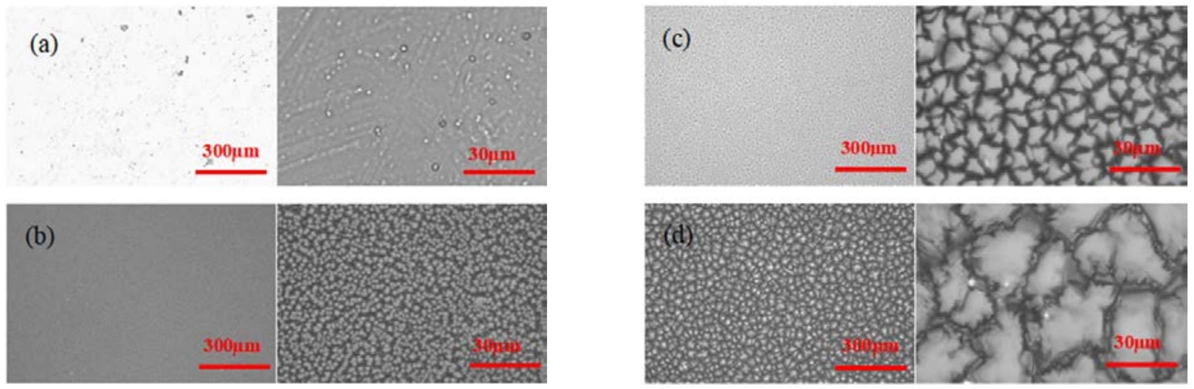

Fig. 1. Morphology of glass surface with different roughness observed by an optical microscope. (a) Polished glass at two magnifications; (b) Glass with Ra 100nm at two magnifications; (c) Glass with Ra 200nm at two magnifications; and (d) Glass with Ra 700nm at two magnifications.

Evaluation and Analysis of the Quantitative Interfacial Adhesion Energy of SiO_2-SiO_2 Bonding Interfaces

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For recent continuous pitch downscaling and high performance, as well as for the reduction of manufacturing costs through efficient novel processes, a three-dimensional (3D) integration scheme has been proposed as a fine-pitch interconnection method for advanced stacked devices. As a result, 3D packaging technology is being actively researched, and the Cu/Dielectric hybrid bonding technique, which enables 3D packaging, is emerging as a next-generation key technology. However, since the Cu surface easily oxidizes, the resulting oxide layer inhibits Cu diffusion and requires high temperatures and pressures to remove it. Although bonding at temperatures above 400°C is typically necessary to remove this oxide layer, such high temperatures can impose thermal limitations on other devices during the packaging process. Therefore, research on various plasma treatments to remove the oxide layer and activate the Cu surface is essential to enable Cu-Cu bonding at low temperatures. In particular, in hybrid bonding structures, not only the Cu surface but also the dielectric surface is affected by plasma treatment, necessitating studies on the effects of plasma treatment on the bonding characteristics of dielectric-dielectric interfaces. Although some studies have reported on the interfacial adhesion energy of Cu-Cu and dielectric-dielectric structures bonded after two-step Ar/N_2 plasma treatment, there have been very few studies that address the effects of post-annealing and subsequent reliability evaluations under temperature and humidity conditions on the quantitative interfacial adhesion energy of SiO_2-SiO_2 interfaces. In this study, the effects of post-annealing and reliability under temperature and humidity testing were evaluated for the quantitative interfacial adhesion energy of SiO_2-SiO_2 interfaces bonded after two-step Ar/N_2 plasma treatment using double cantilever beam testing. Furthermore, the delaminated surfaces after adhesion energy evaluation were analyzed using field emission scanning electron microscopy and X-ray photoelectron spectroscopy to confirm the fracture paths.

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Air Exposure Time Effect on the Interfacial Adhesion Energy of the Cu-Cu Bonding Interface after Ar/N_2 2-step Plasma Treatment

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For the recent trend of continuous pitch downscaling, improved performance, and reduced manufacturing costs via advanced processing, three-dimensional (3D) integration has been proposed as a fine-pitch interconnection solution for next-generation stacked devices. As a result, 3D packaging technologies, particularly Cu/dielectric hybrid bonding, have emerged as a key approach. However, after the chemical mechanical polishing process, which is a critical step in hybrid bonding, the Cu surface becomes exposed to air, leading to the formation of a Cu oxide layer. Consequently, a high bonding temperature of approximately 400 °C is typically required to remove this oxide layer. Yet, high temperatures limit the thermal budget, especially when packaging other devices. Therefore, achieving Cu-Cu bonding at lower temperatures is essential. To achieve low-temperature Cu-Cu bonding, studies have been conducted on plasma treatments aimed at removing the oxide layer and activating the Cu surface. In particular, research has reported that Ar/N_2 two-step plasma treatment can activate the Cu surface and form a copper nitride layer, which prevents oxidation and enables low-temperature bonding. However, the copper nitride layer formed by Ar/N_2 two-step plasma treatment is inevitably exposed to air after plasma treatment under manufacturing conditions. Therefore, it is necessary to evaluate whether this layer can reliably prevent oxidation during air exposure. To our knowledge, there have been few studies on the effect of air exposure time on the quantitative interfacial adhesion energy of the Cu-Cu bonding interface after Ar/N_2 two-step plasma treatment. In this study, to analyze the effect of air exposure time after Ar/N_2 two-step plasma treatment on the quantitative interfacial adhesion energy of the Cu-Cu bonding interface, the quantitative interfacial adhesion energy of the Cu-Cu bonding interface was measured using a double cantilever beam test. To understand the interfacial adhesion behavior, the delaminated surfaces were analyzed using scanning electron microscopy and X-ray photoelectron spectroscopy.

Acknowledgements: This research was supported by the National Research Foundation (NRF) funded by the Korean government (MSIT) (No. RS-2024-00423772) and, the Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE) (RS-2024-00409639, HRD Program for Industrial Innovation)

Cu-to-Cu direct bonding in the air atmosphere without oxidation for advanced 3D packagin g in various pressure condition

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This study was conducted to implement Cu-to-Cu direct bonding in the air atmosphere without oxidation for advanced 3D packaging and investigate its bonding mechanism. Cu-to-Cu direct bonding was successfully achieved at 250 °C without expensive pre-treatment like chemical-mechanical process or high-vacuum room. During bonding, oxygen can not access the Cu and Cu interface, therefore, there is no oxidation layer and some micro-voids along the bonded Cu interface are observed. In the contacted Cu surface, Cu grain boundaries can diffuse according to the various bonding conditions, pressure, temperature, bonding time and roughness, resulting in different shape and size of micro-voids and interface connected ratio. The connected ratio and micro-voids sizes can affect the die-shear strength. Among those conditions, pressure is well-known as most important factor of Cu-Cu bonding and we implement Cu-to-Cu direct bonding with various pressure condition. As a result, the shear strength changes from 35 MPa to 47 MPa, and the micro-void diameter size decreases from 171 nm to 57 nm according to the pressure. This study clarified the Cu-to-Cu direct bonding mechanism by correlating the microstructural evolution with pressure change.

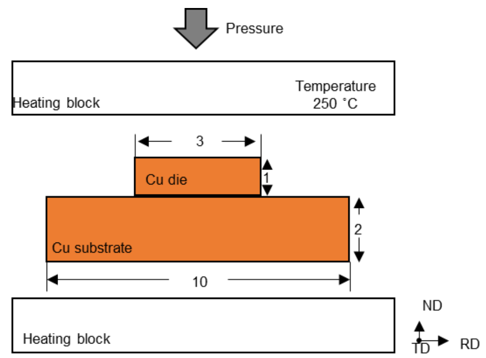

Fig. 1. A schematic diagram of manufacturing and th e dimension of Cu-Cu direct bonded structure

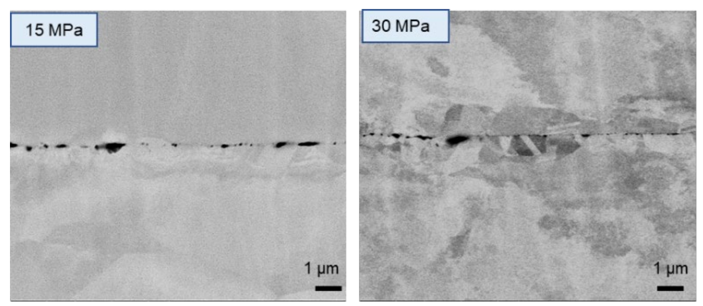

Fig. 2. Cross-sectional SEM images of each pressure condition

Suppressing Kirkendall voids in solder joints by eliminating sulfur in nt-Cu/Zn metallization

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As a highly promising candidate material, nanotwinned copper (nt-Cu) possesses excellent mechanical properties, and high resistance against electro migration [1, 2]. Lu et al. [3] first prepared a random crystal orientation nt-Cu through pulse electroplating. Subsequently, many researchers added additives to realize the direct current electroplating nt-Cu, which can regulate the directional growth of IMCs [4]. However, the presence of additives can bring sulfur contamination into the Cu pad, leading to the formation of numerous Kirkendall voids (KVs) [5]. Therefore, it remains challenging to find a method to suppress sulfur enrichment and inhibit the formation of KVs.

In Fig. 1, SnS is favored to form at the interface due to its lowest formation energy. SnS significantly reduce the vacancy formation energy of the IMCs, thereby promoting the formation of Kirkendall voids. Therefore, this study introduces Zn to suppress the formation of Kirkendall voids. In Fig. 1(e), a Zn layer is electroplated onto the surface of nt-Cu. Heat treatment facilitates the diffusion of S and Zn to form ZnS. Finally, ZnS distribute at the grain boundaries of $Cu_6(Sn,Zn)_5$ after reflowing and thermal aging. In Fig. 2, only $Cu_6(Sn,Zn)_5$ formed at the nt-Cu/Zn interface, with no Kirkendall voids observed. In Fig. 2(c), nt-Cu/Zn reduced the growth rate of IMCs by 33.6% compared to pc-Cu. In Fig. 2(d), fracture surfaces of nt-Cu/Zn metallization solder joints contained dimples, characteristic of ductile fracture failure. The nt-Cu/Zn metallization layers significantly enhance the shear strength of solder joints after thermal aging, with a 128.9% increase compared to pc-Cu layers.

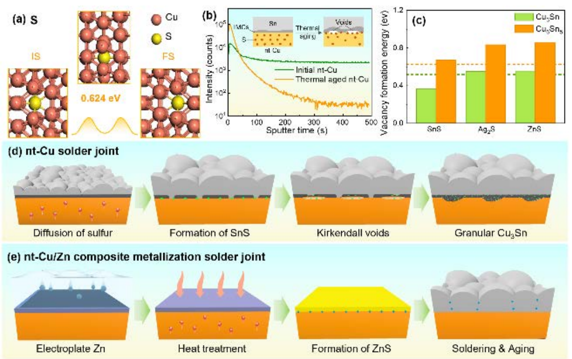

Fig. 1. (a) Diffusion paths and diffusion barriers of S. (b) The distribution of S within initial nt-Cu and thermal aged nt-Cu. (c) Vacancy formation energies at the interfaces. The interfacial evolution diagrammatic sketch of (a) nt-Cu and (b) nt-Cu/Zn.

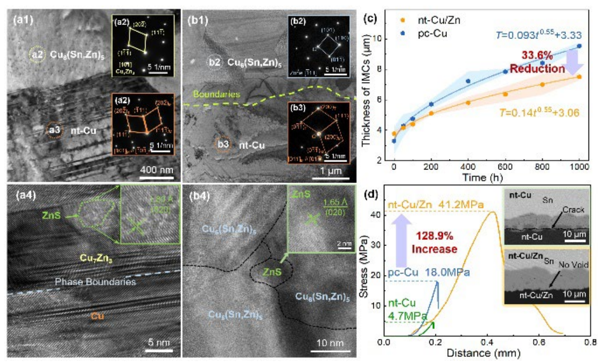

Fig. 2. TEM image of (a1-a4) nt-Cu/Zn layer and (b1-b4) nt-Cu/Zn solder joints aged at 150℃ for 800h. (c) The thicknesses of IMCs for nt-Cu/Zn and pc-Cu solder joints. (d) The stress-displacement curves of solder joints after thermally aging.

[1] K. Lu, "Stabilizing nanostructures in metals using grain and twin boundary architectures", Nature Reviews Materials, 1(5), (2016).
[2] Z.Q. Liu, "Characterization of Cu-Cu direct bonding in ambient atmosphere enabled using nt-copper", Mater. Chem. Phys., 306, (2023).
[3] Z. Cheng, H.F. Zhou, and L. Lu, "Extra strengthening and work hardening in gradient nanotwinned metals", Science, 362(6414), (2018).
[4] Y.H. Tian, "Study on Cu6Sn5 morphology and grain orientation transition at the interface of (111) nt-Cu and liquid Sn", JMR&T, 26, (2023).
[5] T.C. Liu, C. Chen, and K.N. Tu, "Eliminate Kirkendall voids in solder reactions on nanotwinned copper", Scripta Materialia, 68(5), (2013).

Constrained Conformal Soldering Technology for Complex Structure Using Metal Aerogel

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The integration of functional devices on complex three-dimensional surfaces can enhance the rigid equipment's capabilities in sensing, displaying, detecting, intervening, and other aspects. However, capturing the characteristic points of complex three-dimensional structures is challenging, and the uncontrolled overflow and wetting of liquid solder also lead to the inapplicability of soldering technology. Meanwhile, existing adhesive materials and traditional flat packaging technologies are unable to achieve connection to nonlinear surface while ensuring mechanical and electrical performance. Due to the above issues, the three-dimensional packaging and integration of existing complex electronic systems have not been achieved. Therefore, this research proposes the use of highly elastic and active metal nanowire aerogels as reactive matrices. By leveraging nano-sintering effects or forming gradient composite structures with low-melting-point solder materials, flexible preformed sheets with adaptive deformation and wetting constrained metallurgical bonding capabilities have been developed. This enables the conformal soldering for complex structures at low temperatures without additional auxiliary structures or solder masks, and also preventing issues such as local structural mismatch, solder overflow, volatile pores, and compositional segregation that may affect performance or reliability.

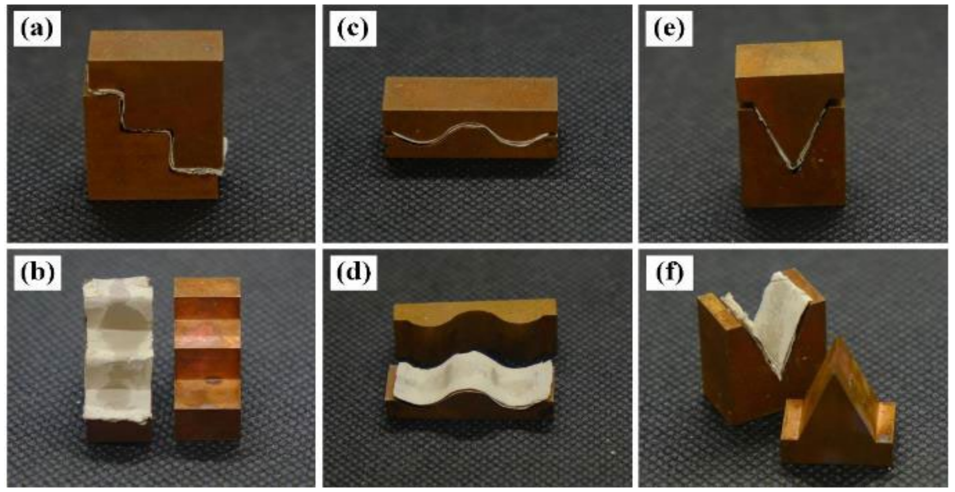

Fig. 1. Adaptive interconnection of metal gel-based composite soldering sheets on structures of (a-b) continuous step-like pattern, (c-d) wavy pattern and (e-f) V-shaped groove.

Ruthenium-Cultured Bacterial Biofilms as Integrated Systems for Electrochemical and Photoelectrochemical Reduction of Carbon Dioxide

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Most of the bacterial species form biofilms, in which microorganisms are attached to a surface and they are held together by extracellular polymeric substances that they produce. They tend to grow almost everywhere both on living or non-living surfaces. Biofilms are able to propagate charge within their structures and to transfer effectively electrons at interfaces, as well as they could exhibit electrocatalytic properties (e.g. in Microbial Fuels Cells). The application of microbes provides better flexibility: experiments with fuel cells can be operated at normal conditions (temperatures and pressures). Wide variety of microbial metabolic pathways gives the possibility to use aggregates of bacteria in diverse processes. Proposed electrochemical studies using bacterial biofilms (in the form of thin coatings on the glassy carbon electrodes) can be considered as an attempt to find efficient methods of using the energy produced by microorganisms and converting it to electricity.

The ultimate goal of the present research has been to determine whether it is possible under laboratory conditions to perform electrocatalytic processes using the integrated layers composed of aggregates of bacteria in pristine or modified (joint with metallic Ru) forms. A biofilm formed by a strain of Yersinia enterocolitica (Y. enterocolitica) is characterized by a high physicochemical stability over a wide pH range (4-10) and temperatures (0-40°C).The subject of interest is a fairly complex reaction, electroreduction of carbon dioxide. There has been growing interest in the search of electrocatalytic and photoelectrochemical systems capable of efficient conversion of carbon dioxide into fuels and utility chemicals. Our previously performed studies have clearly shown that the Y. enterocolitica biofilm itself has no activity with respect to reduction of CO_2, however it acts as a good matrix for the catalytic (e.g. noble metal or metaloorganic) centers, because it affects the reaction mechanism and appears to decrease overpotential of the electroreduction processes. The conducted research shows that the composite materials containing bacterial biofilms can be successfully used to construct systems that have an electrocatalytic reactivity toward the reduction of carbon dioxide. We will also address the possibility of nanojoining the organometallic ruthenium (II) complex in the biological layer (biofilm). Indeed, the ruthenium (II) complex has been immobilized in the biofilm matrix by successive modification of the liquid medium (Luria-Bertani medium) for culturing bacteria with a solution of the complex compound. In addition, the biological matrix was used (along with the ruthenium (II) complex molecules dispersed in its layer) as a protective coating, stabilizing the unstable p-type semiconductor - copper (I) oxide. The proposed integrated co-catalytic system showed activity during the photoelectrochemical reduction of carbon dioxide and stability under semi-neutral experimental conditions. Finally, we are going to address the design of the above-mentioned catalytically active systems emphasizing the need to control the structure of the studied hybrid materials (in addition to their stability). Among important issues is the viability of bacteria in the biological membrane as well as elucidation of the role of the bacterial biofilm integrated with Ru during the carbon dioxide reduction.

Ultrasonic Evaluation of Thermoplastic Weld Quality under Variable Temperature

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This study introduces a non-destructive ultrasonic evaluation method to assess the weld quality of polypropylene (PP) sheets fabricated under different thermal conditions. Due to the inherent high attenuation of ultrasonic waves in polymeric materials, optimal testing parameters were first established to enhance signal reliability. A novel quality index was proposed, defined as the amplitude ratio between signals reflected from intermediate interfaces and those from the backwall. This index was used to generate C-scan images for visual inspection of weld quality. To validate the ultrasonic results, destructive lap-shear tests were conducted according to standardized methods. The shear strength correlated with ultrasonic imaging outcomes, confirming that the proposed method effectively identifies weld imperfections. The results suggest that ultrasonic evaluation provides a viable approach for inspecting thermoplastic welds with high precision, especially when process temperature is a key variable.

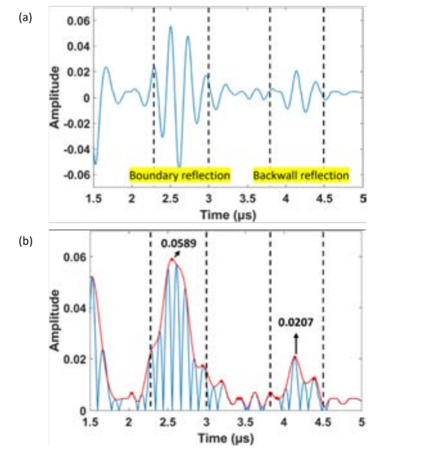

Fig. 1. Ultrasonic signal for defect detection; (a) raw ultrasonic reflection signal, and (b) enveloped signal of the absolute value and peak value extraction.

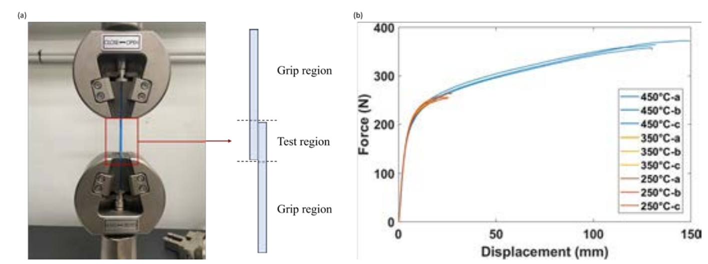

Fig. 2. Lap-shear test of PP sheets; (a) experimental setup, and (b) temperature-dependent F-D curves

[1] Kim, Changhyeon, et al. "Inspection of welded quality in thermoplastic welding using ultrasonics under different temperature conditions." Journal of Mechanical Science and Technology 38.10 (2024): 5209-5218.
[2] Crecraft, D. I. "The measurement of applied and residual stresses in metals using ultrasonic waves." Journal of Sound and Vibration 5.1 (1967): 173-192.
[3] Villegas, Irene Fernandez, and Calvin Rans. "The dangers of single-lap shear testing in understanding polymer composite welded joints." Philosophical Transactions of the Royal Society A 379.2203 (2021): 20200296.

Abstracts for the Oral Presentations

Development of Sn-Bi alloys for low-temperature soldering applications

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Sn–Pb solder is extensively used in electronic packaging because of its advantageous mechanical and electrical properties. However, the implementation of the EU Restriction of Hazardous Substances (RoHS) directive has restricted the use of lead-containing materials in electronic products, thereby accelerating the development of lead-free solder alternatives. Among these, low-temperature soldering has gained increasing attention, driven by the demand for energy savings, carbon reduction, and the need to minimize thermal damage and warpage during the reflow process. Sn–Bi alloys, in particular, have emerged as promising candidates for low-temperature lead-free applications owing to their low melting point and cost-effectiveness. Solder materials are available in various forms, including pastes, wires, preforms, and solder balls. Among the fabrication methods, electrodeposition offers a precise and efficient approach, allowing direct deposition of solder alloys onto substrate pads with advantages in alignment accuracy and thickness control. However, electrodepositing Sn–Bi alloys poses challenges due to the significant difference in the reduction potentials of Sn and Bi ions, increasing the tendency for Bi to undergo displacement deposition on Sn as well as the difficulty in the composition control. To overcome this issue, multilayer electroplating followed by thermal treatment is employed to form Sn–Bi solder alloys with controlled composition and microstructure. In this work, vertically stacked structures of Sn/Bi bilayers were fabricated using electroplating. Interfacial liquation occurred as the Sn/Bi bilayers underwent thermal treatment at temperatures higher than the eutectic temperature of Sn-Bi. The Sn/Bi bilayer transformed into a homogeneous alloy structure after thermal treatment. The composition of the resulting Sn–Bi alloy can be adjusted from eutectic to hypoeutectic by changing the Sn/Bi thickness ratio to study the thermal behavior and microstructural evolution upon heat treatment. Furthermore, a trace amount of Ag was introduced to investigate its influence on the microstructural evolution of the Sn-Bi alloy. The original vertical bilayer configuration was modified to a horizontal structure, forming a Sn–Bi diffusion couple and increasing the interfacial diffusion distance to facilitate more precise diffusion analysis.

Corrosion and inhibition study of copper in el ectronic packaging


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As semiconductor integrated circuits continue to evolve toward miniaturization and high-density integration, three-dimensional integrated circuit (3D IC) technology has gradually become a mainstream solution in advanced packaging. Due to its excellent electrical conductivity and favorable electroplating characteristics, copper is widely used as a bonding material in packaging processes. Whether in solder joining or Cu-Cu bonding, the microstructure of copper has a significant impact on performance. Additionally, during photolithographic etching processes, when alkaline photoresist strippers are used, copper interconnects exposed to the alkaline environment face a serious risk of corrosion. To ensure both bonding reliability and process stability, this study investigates the corrosion behavior of electroplated copper films with different microstructures in alkaline solutions by introducing single or composite inhibitors. Copper samples were prepared via electroplating, with grain size controlled. Electron backscatter diffraction (EBSD) analysis revealed that ultra-large grain (ULG) copper samples primarily exhibited a (100) preferred orientation, with an average grain size of approximately 15-20 µm. In contrast, sub-micron grain (SMG) and ultra-fine grain (UFG) copper samples showed random grain orientations, with grain sizes of 2-5 µm and 163-168 nm, respectively. The study found that composite inhibitors significantly increased the charge transfer resistance (R_{ct}), indicating that interactions between inhibitor molecules and metal atoms promoted the formation of a protective film on the copper surface. Moreover, copper samples with smaller grain sizes exhibited superior corrosion resistance in alkaline environments. This is likely due to the higher number of active sites in fine-grained copper, which facilitates the formation of a dense passivation film. These findings further demonstrate the critical influence of microstructure on process performance.

Develop Electroplated Composite Copper Films with Different Grain Sizes for Cu-Cu Bonding


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To achieve miniaturized layouts, direct Cu-Cu bonding has emerged as a promising solution for providing high interconnect density with pitches of 10 µm or smaller. The conventional method for Cu-Cu bonding, thermocompression bonding (TCB), typically requires high temperatures of around 300 °C for 60 min. However, high temperature operation may cause mechanical damages such as warpage and thermal cracks. This highlights the urgent need to reduce the thermal budget for direct Cu-Cu bonding. Nanocrystalline Cu, characterized by a high density of grain boundaries, enhances surface activity and facilitates Cu-Cu bonding at relatively low temperatures. However, such materials also face challenges of grain instability and propensity for coarsening.

To address this dilemma, we propose a novel composite Cu structure by filling micro-crystals into a porous nanocrystalline framework through two-step electroplating process. First, the evolution of hydrogen gas during the electroplating process creates numerous pores within the framework, while the use of a low-concentration inhibitor combined with high current density promotes the rapid dendritic growth of Cu, forming a porous structure composed of nanoscale grains. Second, the micro-crystals are deposited into the pores through normal electroplating.

This structural design not only preserves the advantage of high diffusion rates inherent to nanocrystalline grains but also synergistically combines the benefits of nanostructures with stable microcrystalline grains. We anticipate that this approach will enable more stable, low-temperature, and high-efficiency Cu-Cu bonding technology.

Thermal Shock and Joining Characteristics of Lotus-Type Porous Copper/Dissimilar Materials Depending on Pore Filling Ratio


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Lotus-type porous copper (LPC) is a metallic material characterized by elongated cylindrical pores, resulting in anisotropic thermal conductivity, excellent fluid permeability, superior ductility, and high energy absorption capability. To explore its industrial applicability, particularly in power module applications for electric vehicles, we investigated the potential of LPC joints. With the increasing use of wide band gap (WBG) semiconductors in electric vehicles, power modules are experiencing higher thermal loads, leading to thermal stress due to mismatched thermal expansion coefficients among stacked heterogeneous materials, which threatens module reliability. As automotive electronics demand high reliability even under extreme conditions, effective thermal stress mitigation and heat management technologies are essential. However, research on LPC joints under such conditions is still lacking. In this study, we evaluated the performance of LPC joints bonded to dissimilar materials under power module operating conditions to assess their ability to address current reliability issues. Comparative experiments were conducted between LPC joints and non-porous Cu joints, focusing first on the changes in joint properties, and subsequently on thermal shock testing to evaluate application potential. The influence of filler material infiltration into LPC pores on yield strength, ductility, and thermal conductivity was also systematically investigate

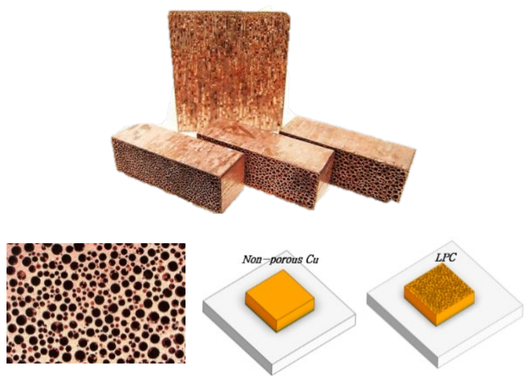

Fig. 1. Lotus-type porous copper and jointed specimen

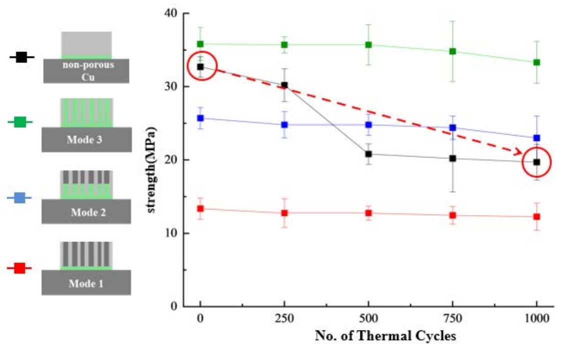

Fig. 2. Change in shear strength for each condition by pore filling rate according to the number of thermal shocks

Study on Bonding of AMB Substrate for Power Semiconductors Using Lotus-type Porous Copper


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The increasing environmental concerns have brought electric vehicles (EVs) into the spotlight as the next-generation automobiles. EVs rely on electric motors powered by batteries, with power semiconductors playing a critical role in energy conversion during operation. However, power semiconductors generate significant heat during operation, leading to cracks and reduced durability. To address this, this study proposes the application of lotus-type porous copper to the Active Metal Brazing (AMB) substrate, which is responsible for thermal management and electrical insulation in power semiconductor modules. The conventional AMB substrate, composed of copper (Cu) and alumina (Al_2O_3), suffers from thermal stress due to differences in their coefficients of thermal expansion (CTE). To mitigate this, lotus-type porous copper with a lower elastic modulus and higher flexibility than dense copper was employed. Three types of lotus-type porous copper specimens with different porosities (37%, 42%, 47%) were prepared and bonded to Al_2O_3 substrates. The bonding strength was evaluated, and microstructural analyses were performed. Furthermore, thermal shock tests were conducted to assess the durability of the joints under repeated thermal cycling conditions. The results demonstrate the potential of porous copper structures in enhancing the reliability of AMB substrates for power semiconductor applications.
Key Words: Lotus-type porous copper, Al_2O_3, Brazing, Active Metal, Power module

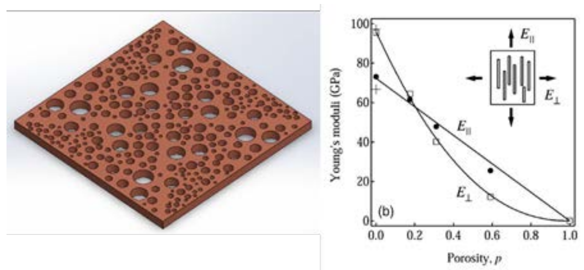

Fig. 1. Schematic Diagram of Lotus-Type Porous Copper(left) and Elastic Modulus of Lotus-Type Porous Copper as a Function of Porosity(right)[1]

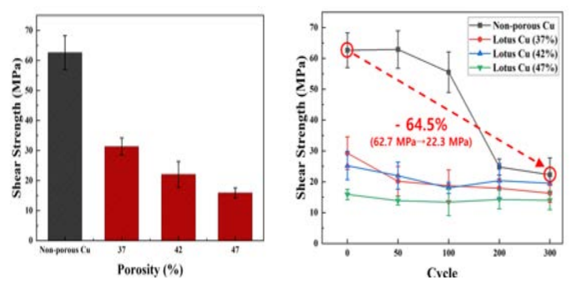

Fig. 2. A Comparison of shear strength of non-porous copper and lotus-type porous copper with varying porosity(left), and the shear strength degradation under thermal shock cycles(right)

[1] T. Ichitsubo, M. Tane, H. Ogi, M. Hirao, T. Ikeda, and H. Nakajima, "Anisotropic elastic constants of lotus-type porous copper: Measurements and micromechanics modeling", *Acta Materialia*, vol. 50, pp. 4105–4115 (2002).

Plasma Interface Engineering for Modulating Robust MoS_2-MoO_3 Neuromorphic Devices

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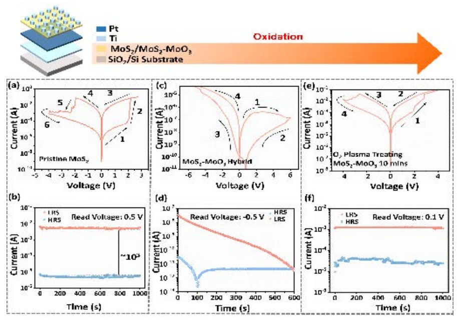
MoS_2 has garnered increasing attention from researchers in the field of neuromorphic computing device due to its multifunctional properties and efficient charge transport characteristics derived from two-dimensional layered structure[1]. Few-layers (<5 nm) /monolayer (<1 nm) MoS_2 devices achieve low-power operation and high switching ratios[2]. However, their robustness during long-term potentiation (LTP) and long-term depression (LTD) cycling tests remains insufficiently explored or rarely reported. Here, we discover that natural oxidation of multilayer MoS_2 (50–100 nm) forms a MoO_3 surface layer, and a sandwich-structured neuromorphic device fabricated from this MoS_2-MoO_3 hybrid material exhibits exceptional LTP/LTD cycling robustness. Notably, O_2 plasma treatment enables reversible switching between volatile and non-volatile states in the hybrid interface device.

First, we examine the resistive switching properties of three device configurations (Figure 1) : pristine MoS_2, naturally oxidized MoS_2-MoO_3, and O_2 plasma-treated MoS_2-MoO_3. The pristine MoS_2 device exhibits non-volatile switching, contrasting sharply with the volatile characteristics of the naturally oxidized MoS_2-MoO_3 hybrid device. However, O_2 plasma engineering restores non-volatility in the hybrid device, demonstrating tunable interfacial switching for customizable applications.

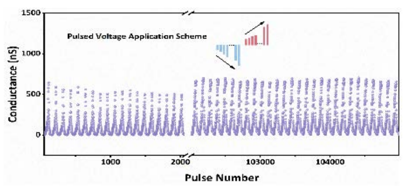
During LTP/LTD cycling tests, the MoS_2-MoO_3 hybrid interface device shows no significant degradation even after modulation by over 10^5 voltage pulses, demonstrating exceptional robustness (Figure 2). A dynamic conductance modulation range of ~85× further proves its potential for neural network computing applications.

In short, our work demonstrates a simple plasma-processed strategy to reversibly switch between volatile/non-volatile states for customizable MoS_2-MoO_3 device functionality, and LTP/LTD cycling test highlights its neuromorphic potential.



I-V Curves and Retention

Fig. 1. I-V characteristics (a) of pristine MoS_2 device and retention (b), I-V characteristics (c) of MoS_2-MoO_3 device and retention (d), as well as I-V characteristics (e) and retention (f) of MoS_2-MoO_3 device after O_2 plasma treatment.



LTP/LTD Cycling Test

Fig. 2. LTP/LTD cycling test of the MoS_2-MoO_3 hybrid interface neuromorphic device exceeding 10^5 voltage pulses.

[1] Anhui Liu, Xiaowei Zhang and Ziyu Liu et al., "The Roadmap of 2D Materials and Devices Toward Chips", Nano-Micro Lett., vol.16, 96-119 (2024).

[2] Renji Xu, Houk Jang, and Minhyun Lee et al., "Vertical MoS_2 Double-Layer Memristor with Electrochemical Metallization as an Atomic-Scale Synapse with Switching Thresholds Approaching 100 mV", Nano Lett., vol.19, 2411-2417 (2019).

Interface-Engineered Nano-joining Between NiCo Nanoparticles and Polyimide-Based Covalent Organic Framework for High-Performance Oxygen Evolution Reaction Catalysis

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Electrochemical water splitting is a highly promising technology for the storage and conversion of renewable energy through hydrogen production. However, the sluggish kinetics of the oxygen evolution reaction (OER) at the anode presents a significant bottleneck to the overall efficiency of water electrolysis. Despite substantial advancements, state-of-the-art OER catalysts still face critical limitations, including a heavy reliance on expensive noble metals and persistent challenges in reducing overpotentials. Nanomaterials, owing to their unique physical and chemical properties—such as high surface area and size-dependent effects—hold great promise as electrocatalysts. However, their inherent structural instability and susceptibility to degradation under prolonged operation remain major concerns. Therefore, establishing effective nano-joining between active nanoparticles and stable supporting matrices has become a crucial strategy to maintain both catalytic activity and structural integrity. To address these challenges, we developed a novel heterogeneous catalyst by integrating NiCo bimetallic nanoparticles into a polyimide-based covalent organic framework (PI-COF). The PI-COF contains alkaline-hydrolyzable imide units, which act as chemically reactive anchoring sites, promoting robust nano-joining between the metal nanoparticles and the supporting framework. This strong interfacial bonding enables the uniform deposition of 5–20 nm NiCo nanoparticles on the spherical PI-COF surface, and facilitates efficient electron transfer across the joined interface. The resulting catalyst demonstrates exceptional OER performance, benefiting from high atomic utilization, bimetallic synergistic effects, and durable nanojunctions between active sites and supporter. Under alkaline conditions, it achieves an overpotential of 300 mV at 10 mA cm^{-2}, outperforming commercial RuO_2. Moreover, chronopotentiometric analysis confirms its excellent long-term durability, with no observable potential decay over time—underscoring the effectiveness of the nano-joining strategy in preserving both structural and functional integrity. This work introduces an innovative design framework that leverages nano-joining principles and interfacial engineering to develop high-performance, durable electrocatalysts for water oxidation.

Evaluation of Cu-Sn Transient Liquid Phase Bonding Characteristics with Lotus-Type Porous Copper Interlayer for Power Module Applications


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With the increasing power density and miniaturization of power modules, the demand for bonding technologies capable of ensuring high-temperature reliability has grown. Transient liquid phase (TLP) bonding, which produces thermally stable joints through the formation of high-melting-point intermetallic compounds (IMCs), has emerged as a promising solution. However, conventional TLP bonding often requires prolonged processing times and can result in void formation. To address these challenges, the use of unidirectional porous metals, known as lotus-type porous metals, has been proposed. These materials exhibit anisotropic mechanical properties due to their aligned pore structure. This study investigates the microstructure and mechanical properties of TLP-bonded joints incorporating lotus-type porous copper (Lotus Cu) as an interlayer, compared to conventional TLP joints without it. Bonding was performed under vacuum at 300 °C for 60, 120, 180, and 240 minutes using Sn-3.0Ag-0.5Cu (SAC305) solder. Cross-sectional and fracture surface analyses were conducted, and shear strength was evaluated. The results showed that Lotus Cu TLP joints bonded for 60 and 120 minutes achieved superior shear strengths exceeding 30 MPa, attributed to the suppression of crack propagation along the porous structure. Fracture path analysis revealed that Lotus Cu effectively altered crack growth directions, enhancing joint reliability. Additionally, the evolution of IMC thickness and void formation behavior was analyzed to explain the mechanical performance trends with bonding time.

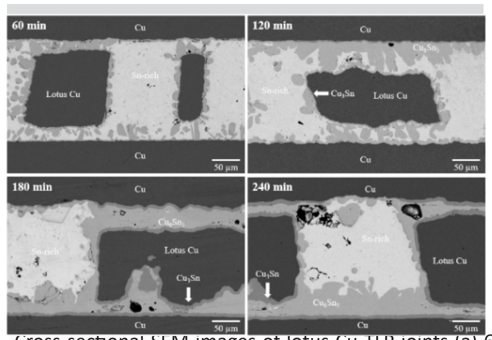
Fig. 1. Cross-sectional SEM images of lotus Cu TLP joints (a) 60 min, (b) 120 min, (c) 180 min, and (d) 240 min.

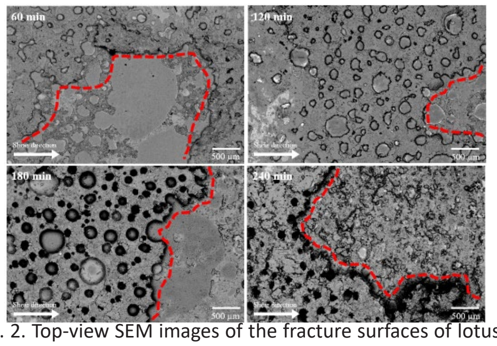
Fig. 2. Top-view SEM images of the fracture surfaces of lotus Cu TLP joints (a) 60 min, (b) 120 min, (c) 180 min, and (d) 240 min.

Study on the correlation between microstructure and electromigration characteristics of the solder joints formed by intense pulsed light soldering

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In this study, the electromigration behavior of Sn-58Bi solder joints was evaluated using intense pulsed light (IPL) soldering, which can minimize waste heat and reduce power consumption, in response to the increasing demand for carbon emission reduction. The IPL soldering samples were fabricated with 80 and 140 pulse cycles, and a comparison was made with reflow soldering samples. A current density of 1200A/cm² was applied to all samples, and the electromigration characteristics were observed by setting the convection oven temperatures to 90°C and 100°C to examine the changes over time. At 90°C, the reflow and IPL 80 cycle samples showed a 10% resistance increase and failure after approximately 500 hours, while the IPL 140 cycle sample showed a failure after approximately 800 hours. At 100°C, the reflow and IPL 80 cycle samples showed a 20% resistance increase and failure after approximately 160 hours, while the IPL 140 cycle sample showed a failure after approximately 200 hours with an 8% resistance increase.

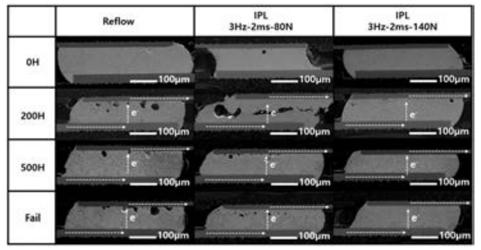
Fig. 1. SEM images of the entire solder joints subjected to electromigration experiments over time for reflow soldering and IPL soldering samples with 80 and 140 pulse cycles at 90°C in a convection oven

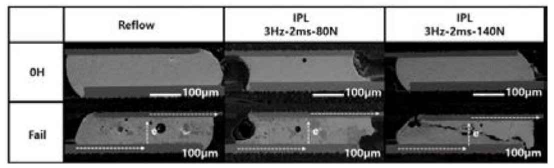
Fig. 2. SEM images of the entire solder joints subjected to electromigration experiments over time for reflow soldering and IPL soldering samples with 80 and 140 pulse cycles at 100°C in a convection oven

Figures 1 and 2 show the 90°C IPL 80 cycle sample after 200 hours and the 100°C IPL 140 cycle sample after 200 hours, respectively, where phase separation of Sn and Bi due to electromigration was observed. Regardless of the soldering process, the solder interior exhibited an Sn-Bi eutectic structure. At the chip-substrate interface, Ni_3Sn_4 IMC was formed, and as the experiment duration increased, Sn-Ni-Bi-Au IMC formed on top of the Ni_3Sn_4 IMC. Notably, in the samples where failure occurred at 100°C, Ni was gradually consumed at the substrate interface, and $(Ni,Cu)_3Sn_2$ IMC formed due to Cu diffusion. Additionally, the Bi-rich layer accumulated on the chip side, reaching 25 µm at 90°C and 51 µm at 100°C.

Acknowledgements: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. RS-2023-00247545)

Elemental segregation-induced variation of phase stability in additively manufactured Fe-SMA

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Metal components produced by laser-based metal additive manufacturing (AM) techniques suffer from rapid cooling during solidification and cooling, resulting in unique solidification structures such as cellular structure and micro-elemental segregation on cell boundaries. It has been reported that the elemental segregation on the cell boundaries decorated with a high density of dislocation is responsible for the higher strength of the additively manufactured metallic materials. It also acts as a preferential nucleation site for precipitates during solidification, cooling, and post-heat treatment. In another aspect, elemental segregation may induce a different phase stability than the nominal composition expected. In this study, the unique behavior Fe-based shape memory alloy fabricated by laser powder bed fusion (LPBF) will be introduced. First, the high pseudo-elastic behavior of Fe-based shape memory alloy produced by LPBF was investigated. From our study, we found that it is closely related to elemental segregation-induced variation of phase stability. The results in this study may give new insight into the design of novel alloys suitable for AM.

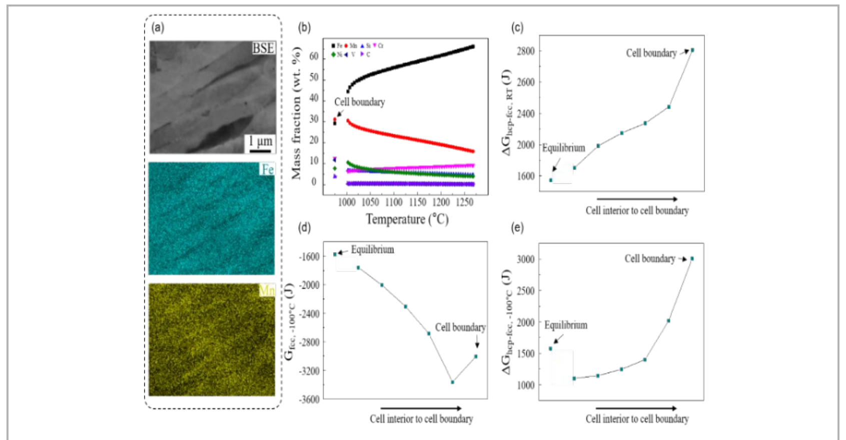

Fig. 1. (a) Elemental segregation on the cell boundary, (b) Calculated chemical composition by Scheil model and (c-d) Calculated Gibbs free energy changes based on (b)

A Study on the Trend and Competitiveness of Domestic defense Semiconductor Industry

Chang Ho Kim

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The technology of high-tech semiconductors also changes the status of allies and allies because the level of semiconductor technology greatly affects the level of technology of defense weapons systems.[1] Defense semiconductors are key components used in military equipment and systems. This requires high performance, reliability that operates stably even after long use, and durability that operates normally in extreme environments. Currently, defense semiconductors are used in electronic optical systems, radars, unmanned systems, artificial intelligence, high-performance sensors, and CPUs, and more and more demand is expected.[2]

Therefore, a strategy to strengthen domestic defense semiconductor competitiveness is needed, but it is only being studied in the field of private sector semiconductors, and there are rare cases of research on strategies to strengthen defense semiconductor competitiveness.

In this study, the characteristics of defense semiconductors, the state of the defense semiconductor industry, and the state of defense semiconductor policy were reviewed. Based on this, We would like to present strategies for institutionalizing semiconductor acquisition procedures and strengthening domestic productivity in defense semiconductors to strengthen domestic defense semiconductors.

The research result of this paper, a plan to strengthen the competitiveness of defense semiconductors, is expected to help not only policymakers but also various people solve and overcome practical problems with defense semiconductors.

[1] Stockholm International Peace Research Institute, The SIPRI Yearbook 2024 (2024)
[2] A. Hamissi et al., IEEE Transactions on Intelligen Transportation Systems, Vol. 26. no. 2, pp. 1395-1418 (2025)

Development of a Low-Silver, Flux-Free Brazing Alloy for Cu-SUS Joint with Heat Treatment-Optimized Properties


Chan Yang Lee

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The disimmilar joining technology, which joins two or more materials with different properties, compositions, and characteristics, is increasingly being utilized in industries that require high performance, lightweighting, and multifunctionality. Currently, research is being conducted on the development of a dissimilar brazing process and materials that can minimize thermal deformation and residual stress by melting only the filler metal without melting the parent metal. Flux is used to remove the oxide film on the metal surface and improve wettability for reasons such as securing joint quality and process stability, but the development of a flux-free filler metal and process are required for reasons such as environmental regulation response, process efficiency, and manufacturing of high-reliability parts.

In this study, we studied the development of a new filler metal that enables brazing without using flux by adding P, and additionally designed a new filler metal alloy that minimizes the use of expensive Ag and controls low melting temperature and narrow melting range during brazing. The microstructural analysis of the joint showed that a small amount of Cu3P was formed on Cu-Sn and Cu-Ag phases when 5 wt% P was added, and that a uniform crystal structure was formed through effective solid-liquid phase control when 20 wt% Sn was added. Additional heat treatment studies were conducted to improve the mechanical properties of the weld, and suitable heat treatment process conditions were derived by identifying the correlation between the formation and growth of IMCs and the fracture behavior.

Development of a Low-Silver Filler Metal for Brazing Dissimilar Copper and Stainless Steel with Enhanced Joint Properties


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As the aerospace, automotive, electronics, and energy industries continue to advance, there is an increasing demand for the development of dissimilar material joining technologies that combine two or more materials with distinct properties to achieve high performance not attainable with single commercial materials. Among the various methods for joining dissimilar materials, brazing is one of the most generally used methods, because it enables the formation of joints at relatively low temperatures without melting the base materials, thereby ensuring excellent mechanical strength and bonding reliability. In applications such as heat exchangers and piping components, where both high thermal conductivity and corrosion resistance are required, copper (Cu) and stainless steel (SUS) are often used together. Silver (Ag)-based filler metals are commonly employed to braze these dissimilar metals due to their good wettability and low melting points. However, commercial Ag-based brazing fillers typically contain 30–40 wt.% of silver, resulting in significant cost burdens and economic limitations for large-scale applications. Another problem is that the Cr_2O_3 oxide layer on the stainless steel surface inhibits the wettability of the filler metal, it was reducing the bond strength. So flux is usually required to solve this problem.

In this study, Sn and P were added to achieve high-performance Cu/SUS bonding without flux, and a brazing filler metal with reduced Ag was developed to reduce the cost and improve economic efficiency. The application of the developed filler metal to the dissimilar joining of copper and stainless steel showed that phosphorus effectively removed the oxide layer on the stainless steel surface. In addition, tin enhanced the mechanical properties of the joint by promoting the formation of a uniform and dense intermetallic compound layer at the interface. the addition of 5 wt% P resulted in the formation of small amounts of Cu_3P and Ag phases within the Cu-Sn or Cu-Ag matrix. Moreover, the addition of 20 wt% Sn led to the formation of a dense and uniform grain structure through effective control of the solid–liquid phase range. As a result, the 10Ag-65Cu-5P-20Sn filler metal developed in this study demonstrated excellent bonding performance while offering economic and environmental advantages over conventional filler metals. Therefore, it is considered to be effectively applicable to the field of heat-dissipating materials for copper–stainless steel dissimilar joining.

Development of a Flexible Technique for RF Welding of Innovative Recyclable Mono-Material Packaging Films

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A capacitive high frequency technology has been developed for the welding of innovative recyclable mono-material packaging films. Compared to established methods where heat is applied externally to the packaging material, this high-frequency technology offers short process times and is independent of thermal conductivity parameters and film thicknesses. This allows for an effective and high-quality processing of mono-layer films. However, many packaging materials based on polyolefins, such as Polyethylene or Polypropylene, exhibit insufficient dielectric properties, with a dielectric loss tangent tan(δ) < 0.001.

To address the limitations of conventional materials, a high frequency technology with adjustable frequency in the form of a packaging demonstrator (Fig. 1) has been developed. This system is suitable for novel mono-materials and offers several advantages such as high seam strengths, minimal structural impact on the materials being joined and homogeneous heating across the entire joining surface.

Additionally, a test setup to determine the relationship between relative permittivity (ε_r) and loss tangent (tan(δ)) was developed (Fig. 2). Using the COMSOL Multiphysics RF module, the setup was simulated and the relative permittivity and loss tangent was calculated by analyzing the scattering (S)-parameters of reflection and transmission across a frequency sweep. Mono-packaging materials based on Polyethylene were also developed and enhanced with varying proportions of vinyl acetate co-polymers to improve the welding suitability of conventional materials.

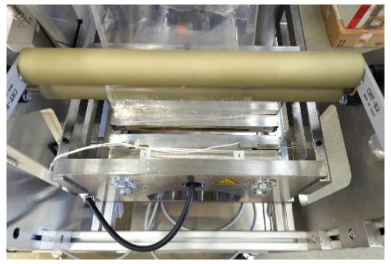

Fig. 1. Sealing demonstrator front view with sealing unit

Fig. 2. Illustration of the developed εr-tan(δ) test set

Experimental validation was performed by measuring the foil's dielectric response using an radio frequency (RF) test fixture and a vector network analyzer. The results from simulation and experiment are compared to ensure accuracy and material consistency. Finally, experments were conducted using these packaging materials on the demonstrator. Quality tests of the seals, such as peel- and leakage tests, were performed to evaluate the effectiveness of the technology.

Developing of Bonding Process Technology for MLCB Electronic Components with Various Process Conditions

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Lithium-ion batteries have been widely used in various electronic devices and electric vehicles because their high energy density and long lifespan. However, they consist of liquid electrolytes formulated with highly flammable organic solvents. In other words, thermal runaway can occur under conditions such as external impact, overcharging or internal short circuits, and it is associated with safety issues due to the risk of ignition and explosion. To overcome these limitations of conventional lithium-ion battery, multi-layer ceramic battery (MLCB) has been considered a promising next-generation alternative. The all-solid-state MLCB is a type of electronic component that uses a solid ceramic electrolyte and forms a battery by stacking multiple layers into a miniaturized package. MLCB is gaining attention as alternatives to lithium-ion battery in various industries including wearable devices such as smartwatches, IoT applications, and medical equipment. Meanwhile, it must be mounted on a substrate and packaged to apply MLCB to various electronic devices and modules. This allows the MLCB to be protected from external impacts and vibrations, thereby improving reliability, and prevents performance degradation caused by environmental factors such as moisture and dust. Although bonding process technology is essential for mounting MLCB electronic components onto packaging substrates, research on this subject is lacking. The difference in the coefficient of thermal expansion (CTE) between the printed circuit board (PCB) and the MLCB is greater than the CTE mismatch between PCB and conventional multi-layer ceramic capacitor (MLCC), which can lead to reliability issues such as cracking or delamination during the process. Therefore, a new bonding process for MLCB mounting is required compared to traditional MLCC. Thus, in this study, a Pb-free solder paste was applied to a PCB using the surface mount technology (SMT) process, and MLCB electronic components were bonded using laser and hot air. After the bonding process, characteristics such as voids and the shape and height of fillets in the joints were analyzed using scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS). The joint characteristics were then compared according to the different bonding processes.

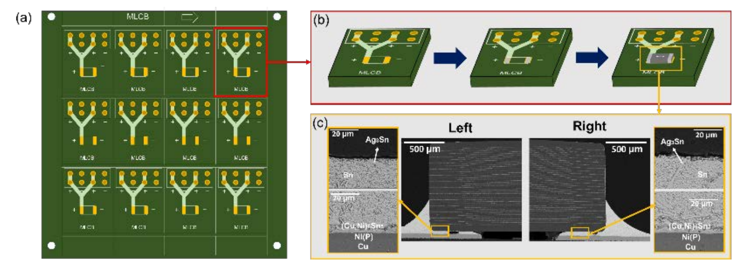
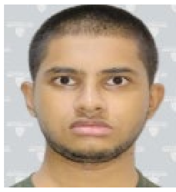


Fig. 1. Schematic diagram of (a) the substrate and of (b) fabrication procedure, (c) cross-sectional SEM micrographs for MLCB after the bonding.

Laser Microwelding of Si Die to Cu Lead Frame



Arko Roychoudhury

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High-power electronic systems—including aerospace sensors, electric vehicle (EV) inverters, and renewable energy circuits—require Si die-to-Cu lead frame bonds capable of >300°C operation. Conventional tin solders degrade at these temperatures due to brittle Cu-Sn intermetallic formation [1] and violate the restriction of hazardous substances (RoHS) directives (>85 wt% Pb) [2]. Alternative die-attach materials like Ag paste [3], nano-Cu paste [4], and Au-based eutectics [5] address temperature limitations but introduce trade-offs, especially at high cost. These constraints underscore the urgent need for RoHS-compliant, high-throughput die-attach solutions.

To address the requirements of high-temperature, high-strength die attachment bond, this work demonstrates that pulsed laser microwelding could achieve Si die attachment on a Cu lead frame without obvious damage to the Si die, as schematic shown in Fig. 1. A carbon black surface treatment reduces the reflectivity of the laser from 79.6% to 31.3%, enabling joining at lower peak powers (<2.45 kW). Silver interlayer promotes the formation of a dendritic Cu–Ag microstructure at the interface, which facilitates strong metallurgical bonding and improved joint integrity, as shown in Fig. 2. The optimized joint exhibited a shear load of 32.3 N, exceeding the MIL-STD-833 requirement. This process has the potential to be used a die attachment alternative for power electronics packaging.

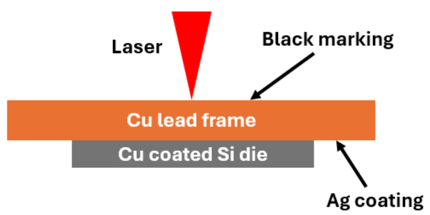

Fig. 1. Schematic illustration of laser welding

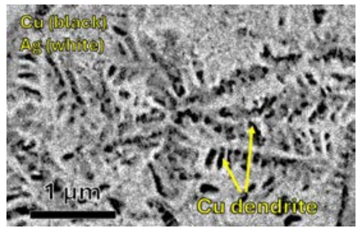

Fig. 2. SEM-BSE image of the bonding interface, for a pulse duration of 3ms, and peak power of 2.45 kW

[1] Y. Bettahi and C. Richard, "Evolution of microstructure of Lead-Free Cu/Sn solders and copper oxide phase precipitation in Cu3Sn intermetallic during thermal cycling", *Microelectronics Reliability*, vol. 92, pp. 20-26 (2019).
[2] K.S. Siow, "Mechanical properties of nano-silver joints as die attach materials", *Journal of Alloys and Compounds*, vol. 514, pp. 6-19 (2012).
[3] J. Heilmann, B. Wunderle, U. Zschenderlein, C. Wille and K. Pressel, "Physics of failure based lifetime modelling for sintered silver die attach in power electronics: Accelerated stress testing by isothermal bending and thermal shock in comparison", *Microelectronics Reliability*, vol. 145, p. 114973 (2023).
[4] Y.S. Tay, L. Yang, H. Zhang, H.B. Kor, L. Zhang, H. Liu, V. Gill, A. Lambourne, K.H.H. Li, Z. Chen and C.L. Gan, "Ruggedized sensor packaging with advanced die attach and encapsulation material for harsh environment", *Microelectronics Reliability*, vol. 150, p. 115115 (2023).
[5] G. Zeng, S. McDonald and K. Nogita, "Development of high-temperature solders: Review", *Microelectronics Reliability*, vol. 52, pp. 1306-1322 (2012).

Machine Learning-Based Prediction of Mechanical Properties of Metal Thin Films via Nanoindentation FEA with Imperfect Indenter Tip Geometry

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Nanoindentation testing is widely utilized for quantitatively evaluating the mechanical properties of metallic thin films and has become a critical tool for analyzing mechanical strength and deformation behavior. Recently, the integration of Finite Element Analysis (FEA) and machine learning techniques has facilitated the development of predictive models for mechanical properties based on nanoindentation data. However, most existing studies assume an idealized spherical indenter geometry, often neglecting imperfections at the indenter tip and the influence of surface roughness observed under real experimental conditions.

In this study, a confocal laser scanning microscope was employed to capture the actual 3D surface geometry of the spherical indenter, which was subsequently incorporated into the FEA model. A machine learning model was initially trained using a simulation-based dataset assuming an ideal spherical indenter. Transfer learning was then performed using computational data reflecting the actual, imperfect indenter geometry.

The revised machine learning model was validated through nanoindentation experiments conducted on real metallic specimens. This research addresses the limitations of conventional models by incorporating realistic experimental conditions, and proposes an advanced predictive framework that enhances the accuracy and applicability of next-generation nanoindentation-based mechanical property characterization.

Acknowledgement: This research was supported by the Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea through the Korea Institute for Advancement of Technology (KIAT) (RS-2024-00409639, 2024 Human Resources Development Program for Industrial Innovation).

Interlayer Delamination Simulation of Hybrid Bonding Based on Nanoindentation Testing

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Hybrid bonding, a direct wafer-to-wafer bonding technique used in 3D integrated circuits (3D ICs) and advanced packaging, enables high-density interconnections without the need for intermediary layers. This technology facilitates the miniaturization and high integration of semiconductor packages. Interfacial adhesion energy plays a critical role in determining the mechanical stability and reliability of such bonded interfaces. Insufficient adhesion energy may lead to interfacial delamination, thereby degrading the overall reliability. Therefore, quantitative evaluation and optimization of adhesion energy are essential. Conventional mechanical tests, such as three-point/four-point bending and Double Cantilever Beam (DCB) tests, have been widely used to assess the adhesion strength of hybrid bonding interfaces. However, these methods primarily measure the average adhesion and are limited in evaluating local interfacial adhesion properties. In this study, nanoindentation experiments combined with finite element analysis (FEA) were employed to investigate interfacial delamination at hybrid bonding interfaces. To examine the influence of indentation geometry on delamination behavior, three types of indenters with different half-angles were used. The projected delaminated area around the indentation site was analyzed to establish its correlation with interfacial adhesion energy.
This work was supported by the Ministry of Trade, Industry and Energy (MOTIE, Korea) through the Korea Institute for Advancement of Technology (RS-2024-00409639, 2024 Industrial Innovation Talent Growth Support Program).

Simulation of friction stir welding process with Lagrangian based finite element method


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Friction Stir Welding (FSW) is a solid-state joining technique where heat generation from tool rotation and severe plastic deformation of the material occur concurrently. This study presents a fully coupled thermo-mechanical analysis of the FSW process using ABAQUS/Explicit 6.12, with a comparative evaluation of the Arbitrary Lagrangian-Eulerian (ALE) and Coupled Eulerian-Lagrangian (CEL) methods. The Johnson-Cook constitutive model was employed to incorporate temperature- and strain rate-dependent plasticity, with process conditions including a tool tilt angle of 1°, rotational speed of 400 RPM, and a plunge depth of 0.34 mm.

Time-dependent variations in heat generation, reaction force, and contact pressure were analyzed to assess the thermo-mechanical behavior across the three process stages: plunge, pre-heating, and linear welding. The ALE method enabled stable simulations without mesh distortion, capturing asymmetric thermal fields and material flow. In contrast, the CEL method distinctly revealed void formation and tunnel defects due to inadequate material stirring. Additionally, flow stress fluctuations—driven by slip/sticking behavior—were strongly coupled with temperature and strain rate, contributing to inhomogeneous flow and defect generation.

This study elucidates the fundamental mechanisms of defect formation in FSW and highlights the respective advantages and limitations of ALE and CEL approaches, offering valuable insights for predictive modeling and process optimization.

Acknowledgement
This work was supported by Korea Institute for Advancement of Technology(KIAT) grant funded by the Korea Government(MOTIE)(RS-2024-00409639, HRD Program for Industrial Innovation)

A Semi-Analytical Approach for Numerical Analysis of Residual Stress in Oxide Scale Grown on Hot-Rolled Steels

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In this study, we developed a semi-analytical approach for the numerical analysis of residual stress in oxide scales formed on hot-rolled steels. The oxide scale, formed during the hot rolling process, experiences complex interactions due to thermal and mechanical influences, significantly affecting the material's integrity and performance. Our research focuses on integrating various stress components such as thermal stress, growth stress, and creep behavior to predict the residual stress within the oxide layer.

The semi-analytical method combines analytical expressions for each stress component with numerical integration to account for their cumulative effects. Validation through instrumented indentation tests confirms the reliability of our model, which considers thermal expansion coefficient (CTE) differences, scale growth, and creep-induced stress relaxation. Our findings indicate that thermal stress resulting from CTE differences significantly impacts the overall residual stress, with growth stress contributing a compressive component during cooling, and creep behavior playing a minor role in stress relaxation. This comprehensive approach enhances the accuracy of residual stress prediction, facilitating the optimization of material design and processing conditions for hot-rolled steel products.

Acknowledgement
This (paper/research/work/...) was supported by Korea Institute for Advancement of Technology(KIAT) grant funded by the Korea Government(MOTIE)
(RS-2024-00409639, HRD Program for Industrial Innovation)

Fabrication of Wafer-Level RDL Structure for 3D-IC Process Integration

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Semiconductor packaging technology is evolving toward a three-dimensional integrated circuit structure to achieve high integration and high performance, and 3D-IC is attracting attention as a core technology for advanced packaging due to functional integration [1]. Especially in chip stacking structures based on TSV (Through-Silicon Via) and hybrid bonding, precise integration and implementation of various process elements, such as RDL (Redistribution Layer) and bumps, are essential, in addition to interconnects [2].

In this study, we aim to explore the possibility of integrating stacking processes during the process integration stage by designing a wafer-level-based RDL structure, which is one of the essential elements required for 3D-IC process integration. We are currently designing and directly fabricating an RDL structure that includes a daisy chain model. This structure can be influenced by various conditions before and after the integration process, so we aimed to consider the interconnectivity between processes during the design stage.

The proposed RDL structure is applied to the 3D packaging process flow, which includes TSV or bonding processes. This is expected to validate the effectiveness of the RDL structure from a process integration perspective.

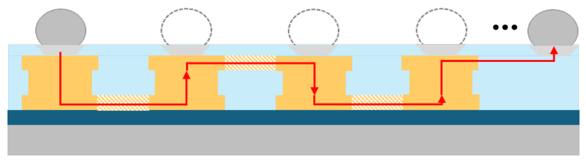

Fig. 1. RDL structure designed with a daisy chain model.

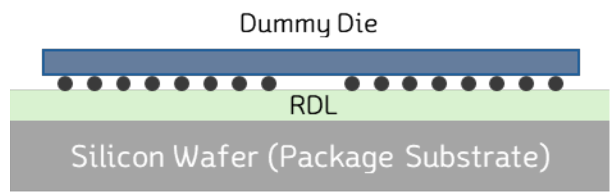

Fig. 2. Structural schematic of a Chip on Wafer (COW) die for 3D-IC integration.

[1] S. Zhang, Z. Li, H. Zhou, R. Li, S. Wang, K.-W. Paik, and P. He, "Challenges and recent prospectives of 3D heterogeneous integration," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 2, 100052 (2022).
[2] J. Lau, P. Tzeng, C. Lee, C. Zhan, M. Li, J. Cline, K. Saito, Y. Hsin, P. Chang, Y. Chang, J. Chen, S. Chen, C. Wu, H. Chang, C. Chien, C. Lin, T. Ku, R. Lo, and M. Kao, "Redistribution layers (RDLs) for 2.5D/3D IC integration," *Journal of Microelectronics and Electronic Packaging*, vol. 11, pp. 16–24 (2014).

Cu Electroplated Bonding of LED Chips on Ni-Plated Fabric Flexible Substrates for Wearable Devices

Gieop Lee

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To utilize wearable devices, it is crucial to bond the device to a flexible substrate while maintaining flexibility and high adhesion. In this experiment, we fabricated a Ni-plated fabric substrate (conductive fabric substrate) and bonded the LED chip to the fabric substrate using copper electroplating. A CNT and Pd composite solution was sprayed onto the surface of the fabric substrate, and then nickel electroless plating was used to fabricate a conductive fabric substrate. To determine the electrical properties of the fabricated substrate, surface resistance was analyzed using a four-point probe. The results showed that conductivity improved with increasing electroless plating time. Furthermore, stable electrical properties were observed during tensile, bending, and torsion tests. Next, copper electroplating was used to bond the LED chip to the fabricated Ni-plated fabric substrate. SEM analysis confirmed good bonding between the fabric substrate and the LED chip. Furthermore, the V_f change of the LED chip was measured to be less than 6% even under radius deformation. This indicates that the copper used for bonding the light source and the fiber substrate provides sufficient mechanical strength to withstand bending stress as well as strong adhesion to fix the light source to the fiber substrate. These results suggest that this bonding approach can be applied not only to wearable displays but also to flexible electronic systems and bio-integrated devices, thereby contributing to the advancement of next-generation wearable bonding technologies.

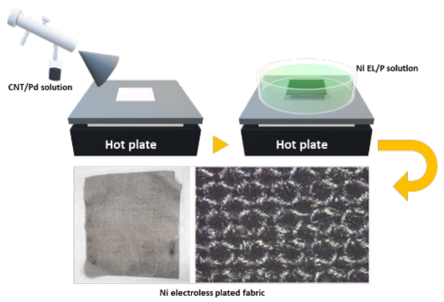

Fig. 1. Schematic diagram of the electroless plating process and Ni electroless plated fabric.

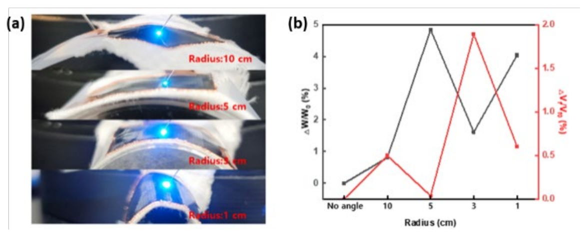

Fig. 2. (a) Image of decreasing the radius from 10 cm to 1 cm, (b) V_f characteristics and rate of change measured by radius reduction in samples with completion of adhesion and transcription.

Evaluation and Optimization of Anisotropic Nanoindentation Characteristics on Metal Surfaces Using Digital Image Correlation (DIC) Technique

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Tensile testing has drawbacks such as complex specimen preparation and difficulty in evaluating material anisotropy. In contrast, the Continuous Indentation Testing Method (CITM) offers a simpler approach for measuring mechanical properties and allows for the evaluation of local characteristics in specific regions. Moreover, when CITM is combined with Digital Image Correlation (DIC) using a spherical indenter, it enables the visualization of surface displacement and strain, thereby allowing for the quantitative assessment of material anisotropy. In this study, among various DIC programs, the commercially available yet free software n_{corr} was used for measurements. To determine the optimal experimental conditions, a series of tests were conducted. As experimental methods, two approaches were applied: generating a random scratch pattern on the surface using SiC polishing paper (grit number #600 to #1200 in 200-grit intervals), and forming a random speckle pattern using white and black spray paints. The DIC program parameters were set with a subset size of 20 to 40 pixels (in 10-pixel intervals) and a subset spacing of 1 to 3 pixels (in 1-pixel intervals). Using the strain ratio in the x and y directions, the anisotropy of the material was evaluated, and the most suitable and optimized experimental method was comparatively analyzed. This research was supported by the Korea Institute for Advancement of Technology (KIAT) funded by the Ministry of Trade, Industry and Energy (MOTIE, Korea) in 2024 (Project No. RS-2024-00409639, Human Resources Development Program for Industrial Innovation).

Evaluation of Substrate Influence on the Nano-Hardness of Cu Films Deposited on PI Using Contact Area Calibration

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With the rapid advancement of wearable electronics, the demand for technologies utilizing flexible devices has significantly increased, leading to active research on their mechanical reliability. While the mechanical properties of metal thin films are typically evaluated using nanoindentation testing, measurements on flexible substrates often result in underestimated values due to substrate effects. In this study, a contact area function was introduced to evaluate the influence of the substrate and to measure the nano hardness of thin films at various depths. Cu thin film with a thickness of 1 μm was deposited on a PI substrate via sputtering, and nanoindentation was performed up to a depth of 300 nm. Based on the assumption that the indentation size and mechanical response under identical loading conditions are equivalent, the contact area function for the Cu/PI specimen was derived using results from Cu films deposited on Si wafers. The variation in hardness with respect to indentation depth was analyzed, and FE analysis was employed to visualize the stress field beneath the indenter across the film–substrate interface.

This research was supported by the Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea through the Korea Institute for Advancement of Technology (KIAT) (Project Number: RS-2024-00409639, Human Resources Development Program for Industrial Innovation in 2024).

Nanoindentation-Induced Fracture Behavior and of Ni-Rich NCM Nanoparticles with Photolithographic Process

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With the growing interest in environmental issues, lithium-ion batteries are being widely used in real-life applications due to their excellent performance in terms of cost, power output, and energy density, making them a promising alternative to fossil fuels. In particular, Ni-rich NCM (Nickel Cobalt Manganese) cathode materials, which are key components of lithium-ion batteries, offer not only high capacity but also cost competitiveness. However, the repeated charge-discharge cycling induces particle volume changes, which leads to crack formation and acts as a major cause of capacity fading. In addition, during the electrode fabrication process, excessive pressure applied in the calendering process—intended to maximize energy density—can potentially damage the particles. This mechanical damage may further promote undesirable reactions with the electrolyte, leading to degradation of electrochemical performance. In this study, the mechanical fracture characteristics of individual Ni-rich NCM particles were quantitatively evaluated, and their correlation with electrochemical performance was analyzed. For the experiment, a photoresist (PR) was coated on a wafer and patterned to form circular holes of various sizes, into which individual NCM particles were randomly placed. Subsequently, nanoindentation tests were performed using a flat punch indenter. By analyzing the maximum indentation load and indentation depth from the load–displacement curves, the fracture behavior of the particles was quantitatively assessed. Furthermore, the relationship between mechanical and electrochemical properties was investigated based on charge–discharge test results, and finite element analysis (FEA) was employed to further understand the potential fracture behavior under indentation.

This research was supported by the Ministry of Trade, Industry and Energy (MOTIE, Korea) through the Korea Institute for Advancement of Technology (KIAT), under the 2024 Industrial Innovation Talent Growth Support Program (Project No. RS-2024-00409639).

Comparative Analysis of Laser and Conventional Soldering Methods in Multi-Reflow Processes for MLCC Assembly

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Recent automotive electronic modules require packaging solutions that are lightweight, compact, and capable of conforming to freeform surfaces. To meet these demands, polycarbonate (PC)-based substrates have attracted increasing attention due to their mechanical formability and processability. However, PC materials are sensitive to high-temperature exposure, which limits their compatibility with conventional reflow soldering. Additionally, as packages become more miniaturized and highly integrated, limited space for flux gas release during soldering increases the risk of void formation and compromises solder joint reliability. To address these challenges, this study employed polycarbonate-based printed circuit boards (PCBs) featuring an electroless nickel immersion gold (ENIG) surface finish and Sn-57Bi-1Ag Pb-free solder paste with a low melting point. A laser-based localized soldering process was adopted to minimize thermal damage to the substrate while ensuring reliable multi-layer ceramic capacitor (MLCC) solder joints. Furthermore, a two-step laser reflow process was applied, where the first irradiation completed the primary soldering, and the second promoted the release of flux gases, thereby reducing the risk of void formation. Fig. 1 presents a comparison of solder joint quality between the conventional single-step reflow process and various multi-reflow conditions applied in this study. In the conventional process, numerous voids were observed, whereas all multi-reflow conditions resulted in a noticeable reduction in void formation. In particular, some of the multi-reflow conditions exhibited the most stable joint characteristics. Meanwhile, under relatively low thermal input conditions, solder ball defects were observed, likely due to insufficient thermal energy during the first irradiation, which led to incomplete melting of the solder paste. If the solder is not fully melted, residual flux or un-melted solder particles can be ejected during the subsequent step and solidify as solder balls. These findings suggest that the multi-reflow process is more effective than the conventional single-step method in suppressing voids and improving joint reliability. They also highlight the importance of optimizing the thermal conditions of the initial step. In addition, a shear test was conducted to evaluate mechanical reliability, and a thermal shock test was performed to assess thermal reliability.

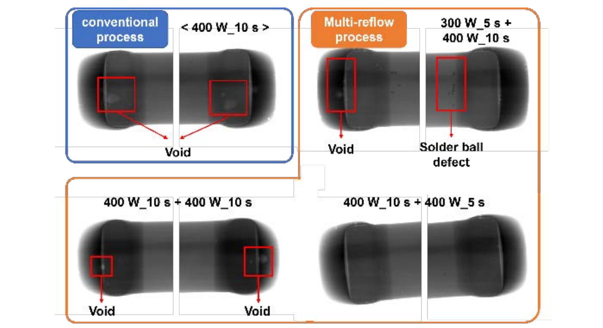

Fig. 1. X-ray analysis of solder joint defects in MLCCs

A Fundamental Study on the Optimization of the Laser Cleaning for Lubricating Oil Removal on the Surface of Aluminum Heat Exchanger Components

Sunghwan kim

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Heat exchanger systems must operate reliably even under extreme thermal and pressure conditions, with surface cleanliness and corrosion resistance being critical performance factors. However, contaminants generated during machining and assembly processes are major causes of quality degradation and reduced durability [1,2]. Conventional chemical cleaning and mechanical polishing methods have shown limitations due to environmental concerns, the use of hazardous substances, and difficulties in precise control. As a result, the need for alternative cleaning technologies is growing [3]. Laser cleaning has gained attention as a high-precision, non-contact, non-consumable, and eco-friendly technique. In this study, we aim to develop an environmentally friendly and high-efficiency process by applying laser cleaning technology to the manufacturing of heat exchanger components.

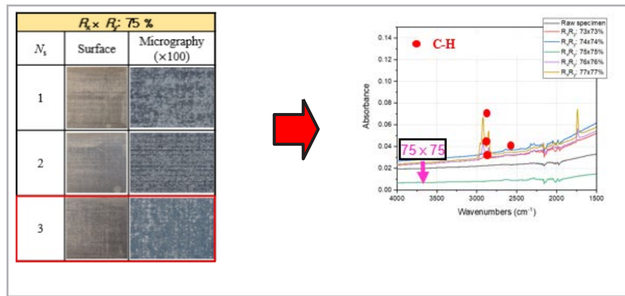

Fig. 1. Surface **images and FTIR graph of vaporizing press oil**

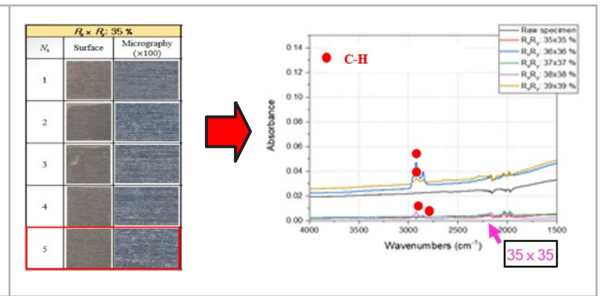

Fig. 2. **Surface images and FTIR graph of mineral oil**

To remove lubricants from the surface of aluminum alloys, the cleaning characteristics were analyzed according to laser parameters such as power, beam overlap rate, and number of passes. For vaporizing press oil, the highest removal rate was achieved under the conditions of 100 W power, −3 mm defocus distance, 75% overlap rate, and 3 scan passes. In contrast, for mineral lubricant, optimal removal was observed at 200 W power, +2 mm defocus distance, 35% overlap rate, and 5 scan passes. These results indicate that the cleaning characteristics of laser processing vary depending on the viscosity of the lubricant. The findings suggest that laser cleaning has strong potential as an effective and environmentally friendly alternative to conventional chemical cleaning processes.

This research was supported by Ministry of the Interior and Safety, Korea Planning & Evaluation Institute of Industrial Technology(project number : 20024457). Following are results of a study on the "Leaders in INdustry-university Cooperation 3.0" Project, supported by the Ministry of Education and National Research Foundation of Korea

[1] Ali, M., Ul-Hamid, A., Khan, T., Bake, A., & Butt, H. Corrosion-related failures in heat exchangers. Corrosion Reviews, 39(1), 65–81 (2021).
[2] Kumar, P., & Pai, A. (2014). An overview of welding aspects and challenges during manufacture of Intermediate Heat Exchangers for 500MWe Prototype Fast Breeder Reactor. Procedia Engineering, 86, 239–246 (2014).
[3] LeBlanc, C., Jankaskaus, J., Tenney, H., & McGuigan, S. Guidebook of Part Cleaning Alternatives. North Carolina Department of Environment and Natural Resources (1997).

Tailoring Electromechanical Characteristics of Metal Films for AI-Empowered Electronic Skins: A Leaf-Bioinspired, Micro/Nano Dual Scale Synergistic Regulation Strategy


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The booming development of electronic skins necessitates flexible sensors with various functions and highly stretchable flexible electrodes/circuits that exhibit distinctly opposite requirements of electromechanical properties, both of which are difficult to be fulfilled on a single material. Here, a leaf-bioinspired, micro/nano dual scale synergistic regulation strategy is innovatively proposed to tailor the film electromechanical characteristics from strain-sensitive sensors to strain-insensitive electrodes. It is revealed that the synergistic effect of microscale surface structuring on the substrate and nanoscale defect implantation inside the film induces a sophisticated crack pattern evolution from cut-through cracks to winding cracks to tiny network-like cracks, which facilitates a remarkable of stretchability regulation (12.5% to 325%) with a nearly 25-fold improvement. By featuring these unique and valuable properties, the proposed metal films can serve as temperature sensors, strain sensors and flexible electrodes/circuits, and further construct an all-metal film-based electronic skin incorporating three types of flexible components as a proof-of-concept demonstration, exhibiting broad prospects in human movement monitoring and smartphone charging. On this basis, an artificial intelligence (AI) technology is introduced to manage sensor signals, thereby enabling sign gesture translation and speech recognition. This bioinspired structure and micro/nano dual scale mechanism of action will undoubtedly spark more sophisticated flexible structural designs by synergistic effects and accelerate the industrialization application of common metal film materials in wearable electronic devices.

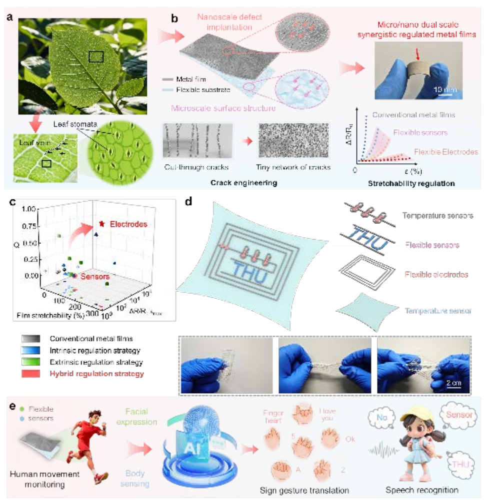
Fig. 1. The design principle and the overall performance of the leaf-bioinspired, micro/nano dual scale synergistically regulated metal films.

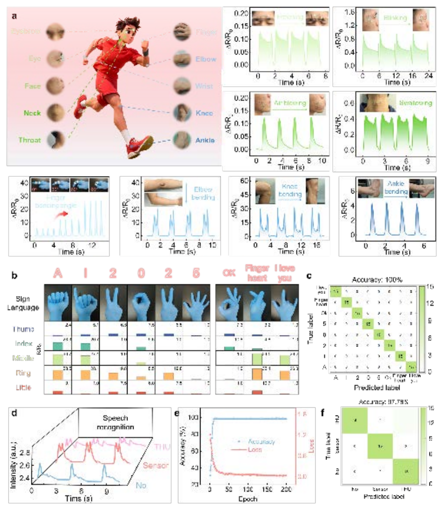
Fig. 2. The application scenarios of flexible sensors in human movement monitoring and AI-driven sign gesture translation or speech recognition.

Microstructural Evolution and Reliability of Laser Solder Ball Jetted SAC305/ENIG Joints Subjected to Multiple Reflow Cycles

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The development of flux-free laser solder ball jetting (LSBJ) has been spurred by the increasing need to address stringent pitch tolerances and high assembly precision in advanced 3D electronic packaging. Despite its advantages, LSBJ remains underexplored in the current literature. This study presents the development of flux-less LSBJ technology to meet new packaging requirements. The authors adhered SAC305 solder balls (~100 µm) to the Electroless Nickel Immersion Gold (ENIG) Cu-pad surfaces using LSBJ. Under multiple reflow conditions (0, 2, 4, 6, 8, and 10 cycles), shear strength, solder joint microstructure, and intermetallic compound (IMC) growth kinetics were systematically investigated. The results revealed that the initial reflow cycle significantly enhances the bonding interface by promoting IMC formation. However, with continued reflow cycling, the growth of brittle IMCs such as Ag_3Sn and Cu_6Sn_5 leads to a temporary reduction in shear strength due to the thickening of the IMC layer. Following the first reflow, the average shear strength of LSBJ-formed solder bumps increased from 35 MPa to 44 MPa. A peak shear strength of 60 MPa was observed and stabilized after approximately five reflow cycles. Overall, the average shear strength remained relatively stable beyond this point, with the IMC thickness consistently thinner than that observed in conventionally reflowed joints.

Analysis of Al-Cu-Cu Overlap Weldment according to Wobbling Amplitude during Laser Dual Beam Welding


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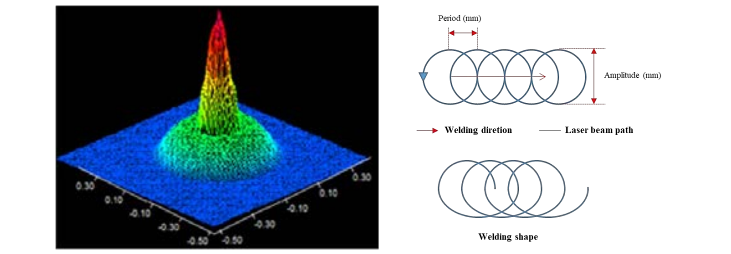
Research on battery manufacturing technology, which is a core component of eco-friendly electric vehicles, is being actively conducted. Recently, various technologies such as bus bar welding using a laser, battery module housing, and surface modification of battery parts have been applied [1]. In particular, in the bus bar welding part between the battery cells and the cells, intermetallic compounds may be generated in the welding part due to the aluminum-copper heterojunction. This may reduce the energy efficiency of the battery and cause a battery fire [2,3].

Therefore, in this study, a study was conducted to improve mechanical and electrical properties by suppressing spatter generation and growth of intermetallic compounds when welding different materials of copper and aluminum through the application of laser wobbling.



(a) Dual beam laser profile (b) Laser wobble condition

Fig. 1. Dual beam laser profile and laser wobble condition

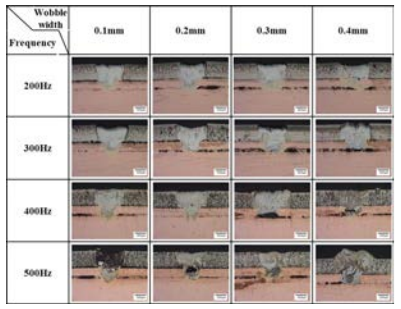


Fig. 2. Weld section by wobbling condition

The experiment was conducted at an output of 3.0 kW and a welding speed of 200 mm/s by overlapping at a frequency of 200 ~ 500 Hz with a 0.1 mm ~ 0.4 mm wobbling amplitude. In wobbling welding, the penetration of the aluminum base material appeared relatively deep by the overlapping rate, and the improved bead width could be confirmed by the wobbling amplitude. In addition, intermetallic compounds are accelerated in generation when the laser beam overlapping rate is high and were mainly observed at the point forming the interface of different materials.

This research was supported by Ministry of the Interior and Safety, Korea Planning & Evaluation Institute of Industrial Technology(project number : 20024457). This research was supported by the Industrial Innovation Infrastructure Establishment Project of the Ministry of Trade, Industry and Energy, "Advancement of Manufacturing Equipment Base for E-mobility using Laser Technology" (Project Number 00430048).

[1] Tobias Solchenbacha, Peter Plappe, Wayne Cai. 2014. Electrical performance of laser braze-welded aluminum–copper interconnects. Journal of Manufacturing Processes 16 pp.183–189 (2014).

[2] Peng Li, Zhenglong Lei, Xinrui Zhang, Jinge Liu, Yanbin Chen. 2020. Effects of laser power on the interfacial intermetallic compounds and mechanical properties of dual-spot laser welded–brazed Ti/Al butt joint Optics&Laser Technology 124 105987 (2020)

[3] Daniel Wallerstein, Eugenio Luis Soll, Fernando Lusquinos, Rafael Comesana, Jesús del Val, Antonio Riveiro, Juan Pou. 2021. Advanced characterization of intermetallic compounds in dissimilar aluminum-steel joints obtained by laser welding-brazing with Al–Si filler metals. Materials Characterization 179 111345 (2021)

Effect of Lotus Cu on thermal shock properties in Ag-Sintered joints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This study examines the effect of unidirectional porous copper (Lotus Cu) on the thermal shock properties of Ag-sintered interfaces for Si/Cu bonding. In high-performance wide-bandgap semiconductor power modules, the large coefficient of thermal expansion (CTE) mismatch generates significant thermomechanical stresses, leading to interfacial degradation. Lotus Cu, with high vertical thermal conductivity and a low elastic modulus [1], was introduced as an alternative joining material. Si/Ag/Lotus Cu and Si/Ag/bulk Cu joints were fabricated via Ag sintering and evaluated through thermal cycling tests (−55 °C to 150 °C). After 500 cycles, bulk Cu joints exhibited extensive delamination, whereas Lotus Cu joints maintained partial bonding with only localized interfacial damage. These results suggest that the unique pore structure of Lotus Cu can redistribute thermal stress, provide more complex crack propagation paths, and potentially improve the reliability.

Key Words: Lotus-type porous copper, CTE mismatch, Thermal cycling reliability

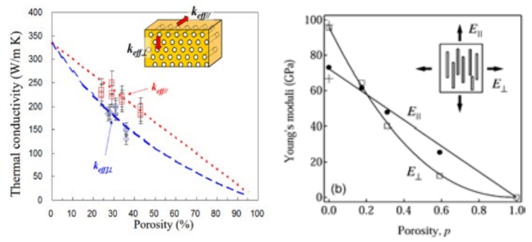

Fig. 1. Schematic Diagram of Thermal Conductivity(left) and Elastic Modulus of Lotus-Type Porous Copper as a Function of Porosity(right) [1]

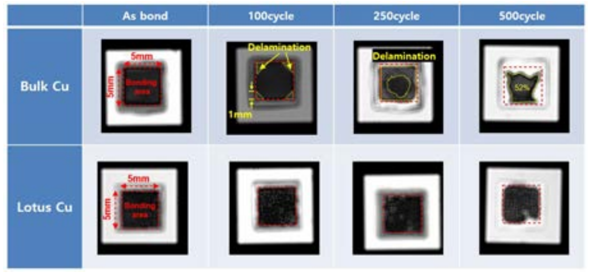

Fig. 2. SAT comparison of Bulk Cu and Lotus Cu under thermal cycling

[1] *Nakajima, Hideo. Materials Sciences and Applications 9.02 (2018): 258.*

Effect of Dy_2O_3 Nanoparticle Addition on the Mechanical and of Sn–Bi Based Solder

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In the past, Pb–Sn solders were widely used in the electronics industry; however, due to environmental regulations restricting the use of lead, research on lead-free solders has become increasingly active. With the continued miniaturization and high integration of electronic devices, heat generation issues have intensified, often leading to warpage at solder joints, which in turn degrades reliability through failures such as electrical short circuits. To address these challenges, growing attention has been directed toward low-temperature solders that enable reduced processing temperatures.

In this study, Dy_2O_3 nanoparticles were incorporated into a representative low-temperature solder, the Sn–Bi alloy system, with the aim of enhancing its mechanical and physical properties. The addition of nanoparticles promotes grain refinement and suppresses interfacial reactions, thereby reducing IMC thickness and improving tensile strength and elongation. Specifically, Sn57.6Bi0.4Ag solder specimens with Dy_2O_3 nanoparticle additions were fabricated, and their Vickers hardness, tensile strength, elongation, spreadability, and melting behavior were systematically evaluated.

The results revealed that Dy_2O_3 addition led to a slight increase in Vickers hardness and a marginal decrease in melting temperature. Furthermore, improvements in spreadability and tensile strength were observed. These findings demonstrate that incorporating Dy_2O_3 nanoparticles into Sn–Bi–Ag solders is an effective strategy for enhancing the performance of low-temperature solder materials.

Effect of Intense Pulsed Light soldering condition on the Microstructural Evolution and Reliability of SAC 305 Solder Joints in LED Packages

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The increasing trend toward finer-pitch electrode design in advanced semiconductor technology has accelerated power consumption, as noted by Green Peace and McKinsey. Conventional reflow soldering has been widely applied in LED packaging; however, its high thermal budget can lead to substrate warpage and degradation of thermally sensitive components. In contrast, the Intense Pulsed Light (IPL) soldering process, which utilizes high-energy light pulses to achieve rapid and localized heating, has emerged as a promising low-temperature alternative.

In this study, an energy-efficient IPL soldering process was applied for the fabrication of mini flip-chip–type LED packages using Sn–Ag–Cu (SAC305) solder to investigate the resulting microstructural evolution and reliability of the solder joints. SAC solder joints were fabricated under various IPL conditions by adjusting pulse number and pulse width, while maintaining constant pulse intensity. The number of pulses ranged from 30 to 48, and the pulse width varied from 2.5 to 3.0 ms. The microstructural characteristics were analyzed using scanning electron microscopy (SEM) and electron probe microanalysis (EPMA), and the formation of intermetallic compound (IMC) layers at the solder/Cu interface was examined. The long-term reliability was evaluated through shear strength measurements after accelerated thermal aging for 300, 500, and 1000 h.

The experimental results revealed that increasing the pulse number and width promoted IMC growth at the solder/Cu interface, which significantly influenced joint morphology and bonding integrity. The optimal condition was determined to be 3/2.5/36 (three pulses, 2.5 ms width, 36 repetitions), resulting in uniform IMC formation and minimized void generation. Under this condition, the IPL-sintered joints exhibited equal or higher shear strength compared with reflowed joints even after 1000 h of aging. Electrical characterization via current–voltage (I–V) analysis confirmed stable LED operation with negligible electrical degradation.

Temperature profile analysis demonstrated that IPL soldering effectively achieved melting and metallurgical bonding within seconds while maintaining substrate temperature substantially lower than that of reflow soldering. This result confirms that IPL soldering offers a rapid and energy-efficient alternative.

Overall, IPL soldering provides a viable replacement for conventional reflow processes in flip-chip LED assembly by enabling strong and reliable joints under reduced thermal stress. This approach highlights a potential pathway toward next-generation high-density, low-temperature microelectronic packaging technologies.

Keywords: Intense Pulsed Light (IPL), SAC305 solder, Flip-chip LED, Intermetallic Compound (IMC), Shear Strength, Reliability, Low-Temperature Soldering

Investigation of electrochemical migration behavior of various surface treatment

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Recently, SiC semiconductors have received increasing attention. However, conventional SAC305 solder, widely used in electronic packaging, possesses a melting point that is inadequate for the high operating temperatures required by SiC devices. Consequently, alternative sintering methods utilizing nanoscale Ag or Cu particles are being actively explored. While Ag has excellent thermal and electrical conductivities, its high cost and vulnerability to electrochemical migration have prompted growing interest in Cu-based sintering systems. Nevertheless, the practical application of Cu is hindered by its tendency for rapid oxidation.
In this study, weak acids such as acetic acid and organic fruit acids were employed as reducing agents during the sintering of oxidized Cu nanoparticles across various temperature ranges. The microstructures of the resulting sintered compacts were characterized using scanning electron microscopy (SEM), and their specific resistances were measured with a four-point probe. Ascorbic acid yielded both the lowest resistivity and the most uniform, well-sintered microstructure among all reducing agents tested. The electrochemical migration (ECM) behavior was investigated under applied voltages of 7, 9, and 11 V by monitoring time to failure and dendrite morphology. Additionally, the corrosion rate of the sintered materials was compared via polarization resistance measurements, highlighting the influence of different reducing agents on reliability.

Keywords: Sintering; SiC; Electrochemical migration; Cu nanoparticles; Weak acid; Microstructure.

Interfacial Enrichment of Bismuth and Its Impact on the Reliability of Low-Temperature Solder Joints

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In semiconductor packaging, optimizing process temperature is crucial to address reliability concerns related to mechanical and thermal issues such as warpage and thermal shock, which can compromise device integrity. Additionally, high process temperatures entail significant energy consumption, contributing to increased carbon emissions. Therefore, lowering process temperatures is essential for enhancing reliability and achieving carbon neutrality.
Research continually explores methods to reduce soldering process temperatures. The commonly employed SAC 305 solder, with a melting point of approximately 217°C, can be supplemented by employing alloys with lower melting points. For instance, bismuth-containing alloys are notable. While adding bismuth lowers the melting point, it introduces brittleness that may negatively impact the reliability of the hybrid solder joints. The distribution behavior of bismuth within solder joints significantly influences properties such as crack susceptibility and drop impact strength, thus affecting overall reliability.
This study investigates the impact of maximum peak temperature optimization during soldering to control the bismuth content—specifically, the bismuth mixed ratio (BMR)—within hybrid solder joints. By adjusting the peak temperature, we aim to optimize joint strength and reliability. Results indicate that, generally, the distribution of bismuth varies markedly with peak temperature, predominantly accumulating near the PCB electrode interface, with the extent increasing as the peak temperature rises. The distribution and concentration of bismuth were analyzed using Electron Probe Micro-Analyzer (EPMA). Reliability assessments, including drop tests, demonstrated that non-uniform bismuth distribution at the surface finish interface correlates with decreased reliability, whereas uniform distribution significantly enhances joint reliability.
To elucidate the underlying failure mechanisms, cross-sectional analysis of solder joints was performed using Scanning Electron Microscopy (SEM) combined with SEM-Energy Dispersive Spectroscopy (EDS). Cracks initiated at the brittle intermetallic compounds (IMCs) formed by bismuth, facilitating crack propagation.

Keywords: low-temperature soldering, bismuth, reliability test, Electron Probe Micro-Analyzer (EPMA).

Electroplating of Copper for Through-Glass Via Filling

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Through-Silicon Via(TSV)s have long underpinned three-dimensional integration in advanced packaging but they incur challenges including complex etch/liner stacks, parasitic losses, and thermo-mechanical reliability concerns under dense integration. Through-Glass Via(TGV)s have emerged as an attractive alternative, offering high resistivity and low dielectric loss of the substrate, smooth sidewalls favorable for metallization, and compatibility with panel-level processing. Despite these advantages, translating TGVs into robust interconnects requires addressing metallization bottlenecks that hinder uniform copper filling at high aspect ratios.

A central challenge in TGV metallization is achieving continuous and conformal seed coverage on chemically inert glass surfaces while maintaining rapid, void-free filling during subsequent copper deposition. Conventional electroplating initiated from line-of-sight physical seeds can leave discontinuities that promote seam formation and bottom voids. In this work, we adopt a hybrid strategy in which an electroless copper seed layer is first deposited after catalytic activation to establish continuous, conformal nucleation throughout the via, followed by electroplating to complete the fill. This sequence is designed to couple the coverage advantages of electroless deposition with the throughput of electroplating.

Using the electroless-seed layer approach, we achieved faster via-closure kinetics and more uniform microstructures compared with electroplating-only baselines, with a marked reduction in centerline seams and subsurface voids. Cross-sectional analysis confirmed continuous seed continuity from top to bottom and dense copper after the electroplating step. These results indicate that combining electroless copper seeding with electroplating is an effective and scalable strategy for TGV copper filling, improving fill quality and process robustness relative to electroplating alone and supporting reliable interconnect formation for next-generation heterogeneous integration.

Analysis of Palladium Diffusion from ENEPIG Surface Finish into Solder Joint

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ABSTRACT

ENEPIG (Electroless Nickel Electroless Palladium Immersion Gold) surface finish comprises nickel, gold, and palladium layers. Each element prevents various issues and ensures high reliability. Unlike OSP and ENIG finishes, ENEPIG includes a palladium layer, which acts as a diffusion barrier between the nickel and gold layers, preventing gold from diffusing into the nickel. Additionally, palladium stabilizes electrical connections, reducing contact resistance, and plays a crucial role in mechanical, electrical, and thermal reliability tests.

In this study, we compare and analyze the characteristics of ENEPIG surface finish by varying the thickness of the palladium (Pd) layer. The Pd layers were set at thicknesses of 0.05µm, 0.1µm, and 0.15µm. SAC 305 solder balls were used to form ball grid array (BGA) solder joints with SAC 305 solder paste. The resulting intermetallic compounds (IMCs) were analyzed using Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), and Electron Probe MicroAnalyzer (EPMA). SEM analysis confirmed that the shape and size of the IMCs varied with the thickness of the Pd layer. Furthermore, we investigated the dissolution of Pd into the solder joint during the formation process. TEM was utilized to analyze the small amounts of dissolved Pd, and TEM-EDS was used to determine the composition of the metal layers and IMCs in the ENEPIG surface finish samples.

This analysis revealed that the amount of dissolved Pd within the solder joint differed according to the thickness of the Pd layer. Consequently, we confirmed that the Pd layer thickness affects the shape and size of the IMCs. EPMA was utilized to compare the composition and concentration of Pd and other elements within the IMCs.

EV 배터리 접합 기술 실증 지원 센터

EV Battery Joining Technology Demonstration Center

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– 사업 기간 : 2024.05.01. ~ 2028.12.31.

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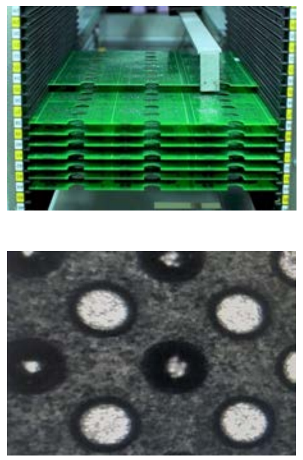
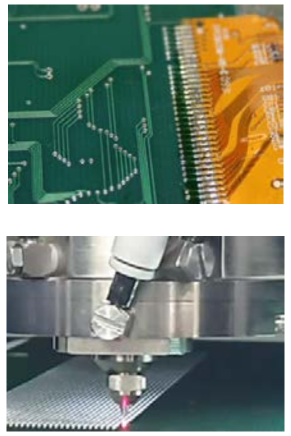
WORLD'S NO. 1
LASER MICRO SOLDERING SOLUTION

FC BGA LASER MICRO-BUMP MOUNTER



- Micro Solder Ball Ø 45-80um
- 1 BY 1 LASER REPAIR
- Dimple-free / Incline-free
- AI CPU/GPU FC-BGA Substrate

BGA PCB & FPCB LASER JETTING SYSTEM



- Solder Ball Ø 200-760um
- Jetting Speed ≥ 5Shots/sec
- PCB/FPCB Ball Mounting

PROBE CARD HIGH SPEED BONDING SYSTEM

- Pin WAFER LEVEL
- UPH 500 2D MEMS Pin
- Accuracy : <±4μm(x,y), ±7μm(z)
- Fine Pitch Min. 50μm
- HBM/DRAM/NAND/CIS Probe Card

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Chonnam national university

Energy Convergence Core-Facility

About the center

Director Prof. Jun-Seok Ha (Chonnam national univesity)

Vision Establish a research support hub for energy convergence in the era of carbon neutrality

Research PEC · Solar cell · Advanced materials · Semiconductor

Next-generation power semiconductor materials and device

Personnel
- 20 participating professors
- 7 dedicated technical/support staff

Space
- Cleanroom for process equipment
- Specialized analysis laboratories

This research was supported by the Ministry of Education through the Basic Science Research Capacity Enhancement Project, operated by the Korea Basic Science Institute (KBSI) and the National Research Facilities & Equipment Center (NFEC)

Facilities

MOCVD
ZEUS230G
SYSNEX

MOCVD-based epitaxial growth equipment for compound semiconductors such as Ga_2O_3.

FE-SEM
SU5000
Hitach

High magnification/ resolution(1.2 nm) , EDS based qualitative and quantitative analysis of samples

XRD
Empyrean
Malvern Panalytical

X-ray diffraction for chemical composition and crystal structure analysis

AFM
NX10
Park systems

Surface roughness analysis by detecting atomic force interactions between the probe and the sample surface

Process equipment

Spin coater, mask aligner, Maskless lithography system, Metal E-beam evaporator, Oxide E-beam evaporator, ICP-RIE, Asher, Metal sputter system, Oxide sputter system, Metal thermal evaporator, Atomic layer deposition system (ALD)
Thermal chemical vapor deposition (CVD) system, Rapid thermal annealing (RTA) system, Dicing saw

Analysis equipment

FE-SEM, XRD, Gas chromatograph (GC), Liquid chromatograph (LC), Raman spectrometer, Surface profiler, Optical microscope, Differential scanning calorimeter (DSC), Quantum efficiency measurement system, Prism coupler,
UV-Visible spectrophotometer, Bending tester, Sheet resistance measurement system, Atomic force microscope (AFM)

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CORE Energy convergence Core-Facility

IMT CO., LTD.

Brief	Established at Year 2000
Products	Dry cleaning (Laser, CO2 Jet), Precise inspection (Wafer, fine surface), VPD ICPMS

Benefits: Productivity Up · Cost Down · Clean Technology

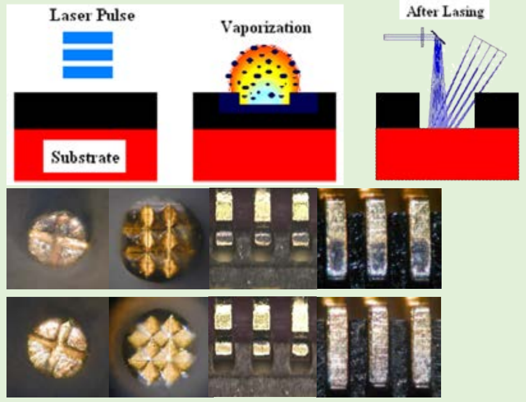
Core Technology

Laser Cleaning	Inspection	CO2 Jet Cleaning
✓ Wafer Probe card cleaning ✓ Chip tester board cleaning ✓ Battery contact cleaning ✓ Metal / Ceramic parts cleaning	✓ Roughness measurement ✓ Polishing measurement ✓ Surface inspection	✓ Wafer cleaning ✓ OLED cleaning ✓ Camera cleaning ✓ Lens/glass cleaning

Core Technology (DRY cleaning)

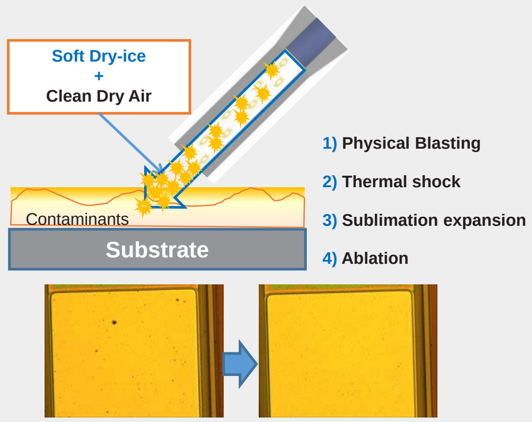
Laser Cleaning

: Dry cleaning technique which removes contaminants selectively from the surface by inducing a proper laser-contaminants interactions.



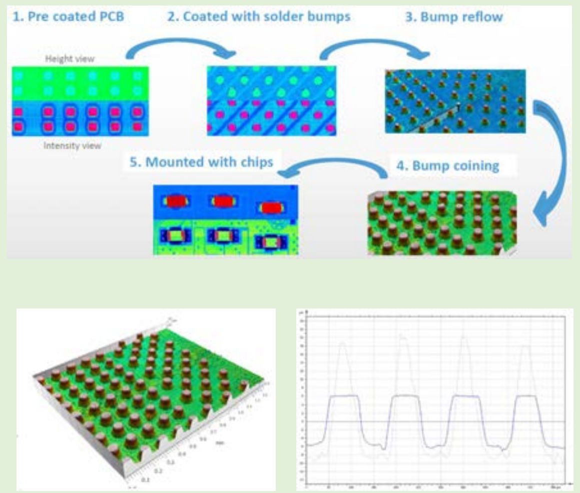
CO2 Jet Cleaning

: Generates and shoots the small and soft dry ice power by IMT patented nozzle system to target then removes contaminants without surface damage.

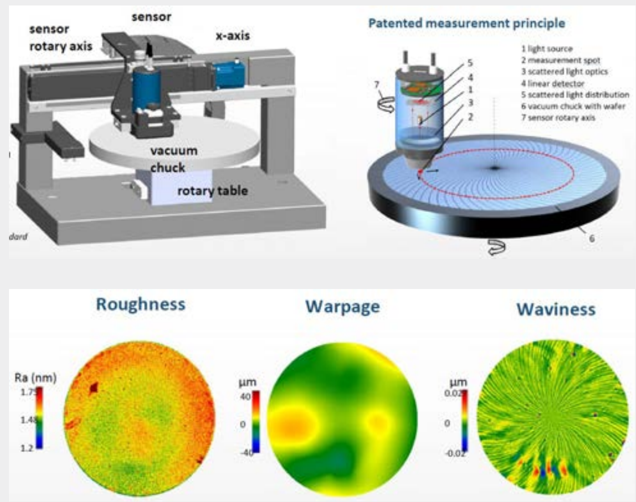


Core Technology (Precise Inspection)

Surface Inspection



Roughness Measurement



X-ray Automatic Vision Inspection System

TXM-XUi

Nanoscale 4D X-ray Solution

Technical Advantages

5 Times faster shooting than existing equipment

Metal Jet X2.5*
Phase optics X2

Providing image processing solutions

Image processing
by sample using big data

Large-area shooting approximately 10 times lager than existing equipment

Large FOV implementation

Providing Non-destructive, High-speed, Large-area, High-resolution Solutions

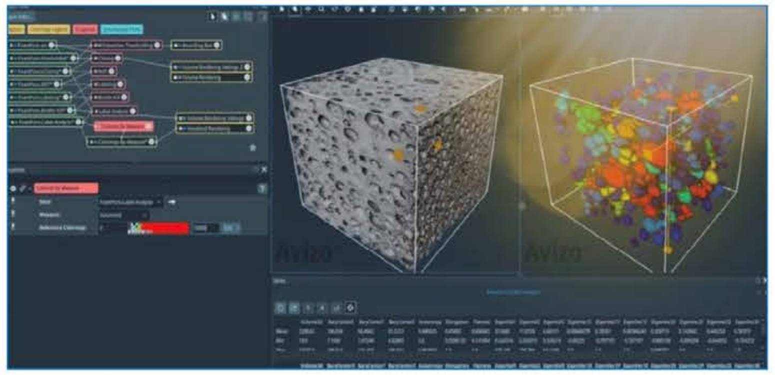
Technical Data

Imaging	Nano Mode	Micro Mode
Spatial resolution	40nm ~ 100nm	500 nm
Field of view	100um x 70um ~ 270um x 230um	1.6 mm x 1.4 mm
Magnification	160x ~ 60x	10x

X-ray Source	Nano Mode	Micro Mode
Source type	Liquid metal jet	Liquid metal jet
X-ray photon energy	9.2 keV	9.2 keV

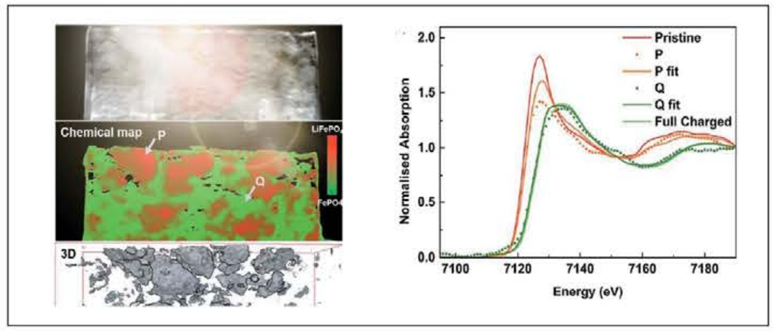
X-RAY IMAGING AND SOLUTION

Nano-scale phase contrast tomography X-ray optics High precision analysis method



BATTERY IMAGING

Nano-scale X-ray imaging solution Spectroscopic X-ray imaging(XANES, XRF imaging) Synchrotron based analysis for battery material & system Method (X-ray imaging, HRPD, Soft X-ray spectroscopy)



XAVIS

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