The 18th U.S.-Korea Forum on Nanotechnology:

Sensors Related to Human Cognition and Sustainability in Semiconductor Manufacturing

Date: September 23(Mon.) & 24(Tues.), 2024

Venue: Arizona State University

Day 1

September 23, 2024 (Monday)
Devil's Oasis, Arizona State University

Opening Session Co-chairs: Ahmed Busnaina/ Jo-won Lee	08:00-08:30	■ **Registration**
	08:30-08:45	■ **Welcoming Remarks** · **Zachary Holman, Vice Dean for Research and Innovation, Arizona State University** · **Jinho Ahn, President, Korea Nanotechnology Research Society** · **Seongsin Margaret Kim, Program Director, National Science Foundation**
	08:45-10:25 (25 min / talk, Q&A)	■ **Keynote Speeches** · **Birgit Schwenzer, Program Director, National Science Foundation** - *Sustainability and nanotechnology* · **Jinho Ahn, President, Korea Nanotechnology Research Society** - *Nano Technology and EUV Lithography* · **Victor Zhirnov, Chief Scientist, Semiconductor Research Corporation** - *New roadmap for micro- and nanoelectronics: where the semiconductor industry is headed over the next 5, 10, 20 years?* · **Om Nalamasu, Chief Technology Officer, Applied Materials** - *Inventions to innovations in deeptech with materials engineering and open innovation*
10:25-10:45		Coffee Break & Group Photo
Poster Session Chair: Myung S. Jhon	10:45-11:15 (4 min / talk, Q&A)	· **Jungwon Choi, University of Washington** - *High-frequency power electronics using eGaN devices* · **Jihoon Seo, Clarkson University** - *Sustainable innovations in CMP slurries from synthesis methods to environmental impact* · **Inhee Lee, University of Pittsburgh** - *Millimeter-scale smart sensing semiconductor devices for biomedical applications* · **Hyunwoong Ko, Arizona State University** - *Generative diffusion modeling for predictive digital twins of sustainable nanoparticle electronics printing* · **Ivan Sanchez Esqueda, Arizona State University** - *Direct synthesis and CMOS integration of 2D materials towards logic and memory devices* · **Arunkumar Venkataronappa, IBM** - *CMP process optimization for DIW conservation and metal loss reduction* · **Sri Siva Rama Krishna Hanup Vegi, Intel** - *Semiconductor manufacturing going green - role of chemical mechanical planarization (CMP) process*

11:15-12:30		Poster Exhibition & Lunch
Session I **Sustainability in Semicon-ductor Manufacturing** Co-chairs: Ahmed A. Busnaina (Northeastern University) / Tae Gon Kim (Hanyang University)	12:30-14:30 (15min /talk, Q&A)	· **Ahmed Busnaina, Northeastern University** - *Sustainable semiconductor additive manufacturing of micro and nanoscale electronics*
		· **Tae Gon Kim, Hanyang University** - *Converging AFM solutions: pioneering nanotechnology for advanced industries*
		· **Paul Westerhoff, Arizona State University** - *How can fabs reduce their water footprints: From industrial wastewater reuse to atmospheric water harvesting as make-up supplies for ultrapure water*
		· **Heeyeop Chae, Sungkyunkwan University** - *Low global warming gases for plasma etching processes*
		· **Bruno Azeredo, Arizona State University** - *Microscale additive manufacturing of high-surface area nanoporous copper: towards hierarchical structures and 3D circuits*
		· **Haeseong Lee, Jeonju University** - *Electromagnetic shielding effectiveness measurements on nanomaterials for the sustainability in semiconductor industry*
		· **Fazleena Badurdeen, University of Kentucky** - *Towards circular and sustainable semiconductor manufacturing*
		· **Susannah Calvin, Apple** - *Climate & Computing*
14:30-14:45		Coffee Break
Session II **Sensor related to Human Cognition** Co-chairs: Elias Towe (Carnegie Mellon University)/ Tae-Woo Lee (Seoul National University)	14:45-17:30 (15min/ talk, Q&A)	· **Kenneth Shepard, Columbia University** - *Interfacing to the nervous system with CMOS bioelectronics*
		· **Tae-Woo Lee, Seoul National University** - *Organic nervetronics for neuroprosthetics*
		· **Michael J. Sailor, University of California San Diego** - *Silicon-based nanoparticles for tissue-specific drug delivery to the brain*
		· **Jinmyoung Joo, Ulsan National Institute of Science and Technology** - *Nanoparticles at the interface of blood-brain barrier*

		· **Mehdi Nikhah, Arizona State University** - *Engineering organotypic disease on-a-chip models; harnessing innovations in microfluidics, biomaterials and single-cell resolution analysis*
		· **Oh Seok Kwon, Sungkyunkwan University** - *Artificial human eyes with photo-receptonics*
		· **Doug Weber, Carnegie Mellon University** - *Sensing and stimulating the brain to restore neurological function*
		· **Youngbin Tchoe, Ulsan National Institute of Science and Technology** - *Electrocorticography microdisplay for high precision intraoperative brain mapping*
		· **Sameer Sonkusale, Tufts University** - *Sustainable point of care diagnostics for human health and wellness*
		· **Jiwon Lee, Pohang University of Science and Technology** - *Image sensing technologies, challenges and vision*
		· **Josh Hihath, Arizona State University** - *Integration of biomolecular electronic devices and sensors*
18:30 ~		Dinner

Day 2

September 24, 2024 (Tusday)
Galleria A and B room, DoubleTree by Hilton Phoenix/Tempe

Discussion / Working Groups	9:00-12:00	■ **Group Discussion Workshop** - *Group 1 : Sustainability in Semiconductor Manufacturing (Co-chairs: Ahmed Busnaina, Tae Gon Kim)* - *Group 2 : Sensor related to Human Cognition (Co-chairs: Elias Towe, Tae-Woo Lee)*
12:00-13:00		Lunch
Wrap up Discussion & Recommendations	13:00-13:30	■ **Poster Award Presentation** ■ **Draw-up Recommendation to the Governments** ■ **Signature of Overall Summary and Recommendation**
Closing	13:30-14:30	■ **Closing Remarks**

The 18th U.S.-Korea Forum on Nanotechnology: Sensors Related to Human Cognition and Sustainability in Semiconductor Manufacturing

Participation

The program will take place on Monday and Tuesday, September 23&24,2024

Program & Presentation

The format will be similar to prior forums. On the first day, participants will be giving keynote speeches (25 minutes) oral presentations (15 minutes), and the young scientists will participate in a poster session, which will include a 4-minute presentation. All presenters should participate in the group discussion workshop (3 hours) on the second day.

Meeting Location

9/23 Devil's Oasis, Sun Devil Marketplace, Arizona State University, 660 South College Avenue, Tempe
9/24 Galleria A and B room, DoubleTree by Hilton Phoenix/Tempe

Dates & Time

September 23 & 24th, 2024 @ 8:30 a.m.
Lunch will be provided for all participants.

Conference Hotel

DoubleTree by Hilton Phoenix/Tempe

Supporting Organization

National Science Foundation (USA)
Ministry of Science and ICT (Korea)
National Research Foundation (Korea)
National Nanotechnology Policy Center (Korea)
Korea-US Science Cooperation Center (USA)

Organizers

Korea Nanotechnology Research Society (Korea)
Carnegie Mellon University (USA)
Northeastern University (USA)
University of Pittsburgh (USA)
Arizona State University (USA)

Organizing Committee

USA	Korea
Myung S. Jhon (Chair) Ahmed Busnaina Elias Towe In Hee Lee Hyunwoong Ko Bruno Azeredo	Jinho Ahn (Chair) Jo-won Lee Hee Sung Moon Sang Joon Cho Tae Gon Kim

The 18th U.S.-Korea Forum on Nanotechnology: Sensors Related to Human Cognition and Sustainability in Semiconductor Manufacturing

You are cordially invited to participate in the 18th U.S.-Korea Forum on Nanotechnology. The purpose of the Forum on Nanotechnology is to provide a common platform for researchers from both countries to engage in discussions on emerging technologies that contribute to next-generation semiconductors. This year's Forum will provide opportunities for discussion on sustainability in semiconductor manufacturing and sensors related to human cognition where nanotechnology convergence provides critical solutions to our most pressing technological challenges.

Through this annual Forum, the United States' National Science Foundation and Korea's Ministry of Science and Information and Communication Technology (ICT) have been vigorously supporting and encouraging a common platform for the exchange of ideas for the promotion of research collaboration in nanotechnology. These Forums continue to thrive on the recommendation of the Korea-U.S. Joint Committee on Scientific and Technological Cooperation. The first Forum was initiated two decades ago, and since then, the locations of the Forum have alternated between Korea and the United States. Because of the wide array of technical challenges to which nanotechnology can be successfully applied, each previous Forum had a different emerging technology focus. New this year, the 18th Forum will include three keynote speakers, eight senior presenters, eight early-career presenters from the U.S., and a roughly equal number of presenters from Korea.

An additional objective of this year's Forum is to promote the exchange of researchers between the two countries to catalyze research collaborations. The outcomes of the Forum are expected to lead to recommendations with milestones that the governments of both countries can implement in areas where semiconductor technology plays an essential role.

We are looking forward to seeing you in Tempe in September!

Organizing Committee

Opening Session

Co-chairs

Ahmed Busnaina, Northeastern University 08p

Jo-won Lee, 3D Printing Research Organization 9p

Ahmed Busnaina

William Lincoln Smith Professor, Distinguished University Professor and Director of the Advanced Nanomanufacturing Cluster for Smart Sensors and Materials, and the NSF Nanoscale Science and Engineering Center for High-rate Nanomanufacturing
Northeastern University

467 Egan Center, 360 Huntington Avenue, Boston, MA 02115

Tel (617) 373-2992 | Email: a.busnaina@northeastern.edu
URL: www.northeastern.edu/cssm, www.nanomanufacturing.us

Ahmed A. Busnaina, Ph.D. is the William Lincoln Smith Chair Professor, Distinguished University Professor and founding Director of the National Science Foundation's Nanoscale Science and Engineering Center for High-rate Nanomanufacturing since 2004, the Advanced Nanomanufacturing Cluster for Smart Sensors and Materials since 2015 and the NSF Center for Microcontamination Control at Northeastern University, Boston, MA since 2002. He is also the founder and CTO of Nano OPS, Inc. since 2017. Prior to joining Northeastern University in 2000, he was a professor and a director of the Particulate Control Lab at Clarkson University from 1983-2000. Dr. Busnaina is internationally recognized for his work on nano and micro scale defects mitigation and removal in semiconductor fabrication. He specializes in directed assembly-based nano and microscale printing of inorganic and organic conductors, semiconductors, and dielectrics for making micro and nanoscale interconnects, transistors, sensors, LEDs, and other devices. He developed many techniques for directed assembly-based additive manufacturing of nanoscale electronics, sensors, advanced and heterogeneous electronic packaging, and other optical and bio applications. His research support exceeds $60 million. He authored more than 600 papers in journals, proceedings, and conferences. He also has 25 granted and 45 pending patents. He organized and chaired over 175 conferences, workshops, sessions, and panels for many professional societies. He was awarded the 2020 American Society of Mechanical Engineers (ASME) William T. Ennor Manufacturing Technology Award and Medal for his contributions to the printing of nanoelectronics. He is a fellow of the National Academy of Inventors, fellow American Society of Mechanical Engineers, the Adhesion Society, and a Fulbright Senior Scholar. He was awarded the 2006 Nanotech Briefs National Nano50 Award, the Innovator category, the 2006 Outstanding Faculty, the 2006 SØren Buus Outstanding Research Award, the 2005 Aspiration Award, and the 2016 Outstanding Translational Research Award at Northeastern University. He is an editor of the journal of Microelectronic Engineering and an associate editor of the Journal of Nanoparticle Research. He also serves on many advisory boards, including Samsung Electronics, the Journal of Particulate Science and Technology, the Journal of Electronic Materials Letters, the Journal of nanomaterials, and the Journal of nanomanufacturing.

Jo-Won Lee

Chairman, 3D Printing Research Organization
E-mail: jowon@3dpro.or.kr | Web: http://www.3dpro.or.kr

*** Education**

1971-1978 : B.S. in Metallurgical Eng. from Hanyang Univ.
1980-1983 : M.S. in Metals Science from Penn State Univ.
1982-1986 : Ph.D. in Metals Science from Penn State Univ.

*** Professional Positions**

1978-1980 : Researcher at ADD
1985-1990 : Research Associate at Carnegie Mellon Univ.
1990-1992 : Visiting Scientist at IBM T. J. Watson Research Center
1992-2000 : General Manager and Project Manager at SAIT
2000-2010 : Director at The National Program for Tera-level Nanodevices
2010-2019 : Professor at Hanyang University
2019-2023 : President at National Nanofab. Center
2023-Present: Chairman at 3D Printing Research Organization

*** Research Field and Interests**

His field of research is primarily neuromorphic devices with a variety of experiences such as magnetic media/head, high Tc superconducting devices, diamond devices and nanoelectronics/memory.

*** Professional Activities**

In 2001, he was a general secretary of the governmental planning committee for the 10 years Korea Nanotechnology Initiative. This plan has been revised in 2005 under the guidance of Dr. Lee as a principle investigator. He was serving as a first vice president of Korean nanotechnology research society in charge of international affairs and a chairman of advisory committee for nanotechnology information. He was also working as a Korean-side chairman of advisory committee for Korea-US nanotechnology forum and was an NT focal point of Korea-UK focal point programs. He has been also serving as Chair, NANO KOREA 2006, 2007, 2008 and 2009

Symposium Steering Committee. He completed national nanotechnology roadmap (Feb. 2008) and national nanotechnology standardization development roadmap (Oct. 2007) as a principle investigator. He was served as a general chair of IEEE-Nanotechnology Conference 2010. He was a chair of study group on neuromorphic devices in Korea.

He also served as a chairman of Korea Infrastructure Organization for Nanotechnology from 2020-2023.

Welcoming Remarks

- **Zachary Holman**
  (Vice Dean for Research and Innovation, Arizona State University)
- **Jinho Ahn**
  (President, Korea Nanotechnology Research Society)
- **Seongsin Margaret Kim**
  (Program Director, National Science Foundation)

Seongsin Margaret Kim

Dr. Margaret Kim currently works as a Program Director of EPMD (Electronics, Photonics, and Magnetic Devices) of the Electrical, Communication and Cyber Systems (ECCS) division in the Directorate for Engineering (ENG).

Dr. Kim received her Ph.D. in Electrical and Computer Engineering, M.S in Physics from Northwestern University, and B.S in Physics from Yonsei University in South Korea.

She has been a Professor in the ECE department at the University of Alabama since 2007. Before joining UA, she was a Research Associate and Consulting Assistant/Associate Professor at Stanford University from 2003-2007, and also worked at Agilent and Samsung before then.

Her research interests in photonics, metamaterials, and THz technologies are targeted for future biomedical diagnostics platforms, quantum sensing, quantum networks, 6G/7G and beyond, AI-aided bio-imaging, space exploration, underwater imaging, and understanding of the brain. At NSF, she has been involved in Future for Semiconductors, Quantum Information Science and Engineering (QISE), in addition to core programs. She is also interested in human-centered technology in addition to the various programs she manages.

Keynote Speeches

Birgit Schwenzer
(Program Director, National Science Foundation)

Jinho Ahn
(President, Korea Nanotechnology Research Society)

Victor Zhirnov
(Chief Scientist, Semiconductor Research Corporation)

Om Nalamasu
(Chief Technology Officer, Applied Materials)

Birgit Schwenzer

National Science Foundation

Birgit Schwenzer is a Program Director for the Solid State and Materials Chemistry (SSMC) program in the Division of Materials Research at the National Science Foundation (NSF). She is also the representative for NSF's Directorate for Mathematical and Physical Sciences on the U.S. National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET). Prior to joining NSF in 2016, Dr. Schwenzer was a staff scientist at the Pacific Northwest National Laboratory. Her research background includes synthesis and characterization of inorganic structures, composite materials and organometallic compounds predominantly for optoelectronic, energy conversion and storage or catalytic applications. She has extensive experience in structure-property relationship investigations for inorganic nano- and microstructures with a focus on vibrational and optical spectroscopy as characterization tools. In addition to scientific publications and authoring a book chapter titled "Energy Conversion and Storage" in Bioinspired Inorganic Materials: Structure and Function, (ed. S. R. Hall, The Royal Society of Chemistry, 2019), Dr. Schwenzer holds five U.S. or international patents, was a co-recipient of an R&D 100 Award ("Graphene Nanostructures for Lithium Batteries") in 2012, and she received a NSF Director's Award for Superior Accomplishment in 2024.

Birgit
Schwenzer

| Abstract

Sustainability and Nanotechnology

Birgit Schwenzer
National Science Foundation

This presentation will highlight current examples of nanotechnology advances that have already lowered the environmental impact of several manufacturing processes. Printed electronics, nanocatalysts, and sensing technologies for environmental and clinical applications either have been commercialized or are in the process of technological adoption. A strong case can be made that nanoscience and nanotechnology have the potential to play an important role in sustainability in many other ways as well. They can contribute solutions to address the climate crisis. Energy storage and electrification of the transportation sector as well as carbon management/carbon capture are only two examples that seem ripe for innovation.

Jinho Ahn

President, Korea Nanotechnology Research Society, Korea
Executive Vice President of Research, Hanyang University, Korea

Jinho Ahn received his B.S. and M.S. degrees from Seoul National University, and Ph.D. degree from the University of Texas at Austin all in Materials Science and Engineering. He worked for Microelectronics Research Laboratory at NEC, Tsukuba, Japan, and joined Hanyang University in 1995 as a professor of Materials Science and Engineering. He worked as a Director of Nano and Convergence Technology at National Research Foundation of Korea, and the Vice President of Academic Research, the President of Industry University Cooperation Foundation at Hanyang University. He is now the President of Korea Nanotechnology Research Society, and Executive Vice President for Research of Hanyang University. He received the Semiconductor Technology Lifetime Achievement Award in 2015 from the President of Korea.

Jinho Ahn

| Abstract

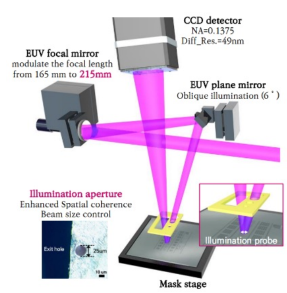
Nano Technology and EUV Lithography

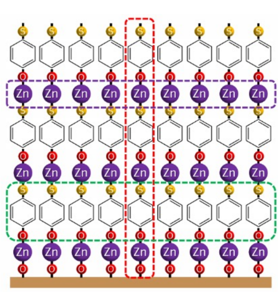
Jinho Ahn
Hanyang University, Republic of Korea

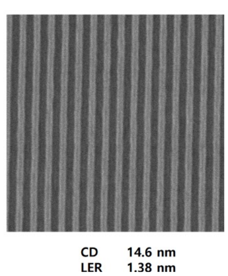
E-mail address: jhahn@hanyang.ac.kr

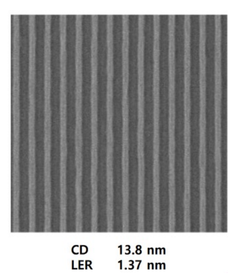
The semiconductor industry is not only at the forefront of nanotechnology applications but also the sector that most critically depends on its advancements. Among the cutting-edge technologies driving semiconductor production, Extreme Ultraviolet (EUV) Lithography emerges as the most advanced. EUV technology exerts a profound influence, both in terms of its groundbreaking technical innovations and its substantial economic implications.

With the use of wavelengths that have never been utilized before, many previously employed techniques have become obsolete. However, with the introduction of the first-generation technological solutions, EUV lithography has become an essential component for the mass production of cutting-edge semiconductor devices. Nonetheless, to achieve further improvements in exposure performance, the development of second-generation technologies has become necessary. This presentation will provide a comprehensive overview of EUV lithography technology and introduce the nanotechnology research related to EUV that we are currently conducting.









Victor V. Zhirnov

Semiconductor Research Corporation

Victor Zhirnov is Chief Scientist at the Semiconductor Research Corporation. He is responsible for envisioning new long-term research directions in semiconductor information and communication technologies for industry and academia. His semiconductor experience spans over 30 years in the areas of materials, processes, devices physics and fundamental limits. Victor served as the Chair for the Emerging Research Device (ERD) Working Group for the International Technology Roadmap for Semiconductors (ITRS) and for the 2030 Decadal Plan for Semiconductors. Victor received the M.S. in applied physics from the Ural Polytechnic Institute, Ekaterinburg, Russia, and the Ph.D. in solid state electronics and microelectronics from the Institute of Physics and Technology, Moscow, in 1989 and 1992, respectively. He has authored and co-authored over 150 technical papers and contributions to books.

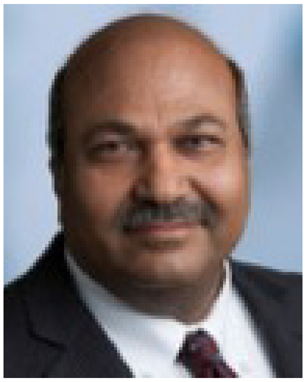
Victor V. Zhirnov

| Abstract

NEW ROADMAP FOR MICRO- AND NANOELECTRONICS: WHERE THE SEMICONDUCTOR INDUSTRY IS HEADED OVER THE NEXT 5, 10, 20 YEARS?

Victor Zhirnov
Semiconductor Research Corporation

In the past, the role of strategic planning for semiconductor industry was met by the international technology roadmap for semiconductors (ITRS), serving as a guiding light that provided manufacturers, designers, equipment suppliers, and researchers with direction years in advance. By providing a common framework for coordination across semiconductor industry stakeholder and, technology development efforts were efficient and aligned. However, the dissolution of the ITRS in 2015 left a void, leading to years of disconnected efforts. Recognizing the need for unified guidance, the industry rallied for the creation of a new strategic plan – the microelectronics and advanced packaging technologies (MAPT) roadmap (2023) that was developed through the synergistic efforts of industry, academic and government experts. This comprehensive plan outlines ambitious goals for the industry's future (https://srcmapt.org/).



OMKARAM (OM) NALAMASU, Ph.D.

President, Applied Ventures
Chief Technology Officer and Senior Vice President,
Applied Materials
408-986-7294 | Om_nalamasu@amat.com

Dr. Omkaram (Om) Nalamasu is senior vice president and chief technology officer (CTO) of Applied Materials, Inc. where he leads the company's R&D, innovation, and value-added strategic partnerships with global academia, research institutes, customers, supply chain partners, and government funding agencies.

He is also the president of Applied Ventures, LLC, the venture capital fund of Applied Materials and one of the leading global corporate venture groups with over $450M investments in 90+ companies across 19 countries and nine portfolio company IPOs to date. In this role, he has established a number of successful public-private partnerships, pioneering joint investment funds with Korea, Taiwan, and NY Empire State Development organizations.

He currently leads 5 new market growth businesses through commercialization chasm to $B annual revenue businesses through internal scaling as well as scaling externally through spin-out/JV/divestment strategies.

Dr. Nalamasu joined Applied in 2006 after serving as an NYSTAR Distinguished Professor of materials science and engineering at Rensselaer Polytechnic Institute, where he also served as vice president of research. Prior to that, he has held key research and development leadership positions at AT&T Bell Laboratories, Bell Laboratories/Lucent Technologies, and Agere Systems, Inc. While at Bell Labs, he established the United States' first public-private partnership for nanotechnology commercialization.

Dr. Nalamasu has made seminal contributions to the fields of optical lithography and polymeric materials science and technology. He has received numerous awards, authored more than 180 papers, review articles and books, and holds more than 120 worldwide issued patents.

He received numerous recognitions and awards for his contributions including IRI (Innovation Research Interchange) Innovation Leadership Award, IEEE Fellow, Member of US National Academy of Engineering, IEEE Frederick Philips Award, ACS Roy W. Tess award and Japan Photopolymer Science and Technology award. He serves on several national and international advisory boards including on the boards of The Tech Interactive in San Jose, GSA (Global Semiconductor Association), Singapore's AME IAP, and Global Corporate Venture Leadership council.

He received his Ph.D. from the University of British Columbia, Vancouver, Canada.

Om
Nalamasu

| Abstract

Inventions to Innovations in Deeptech with Materials Engineering and Open Innovation

Om Nalamasu
Applied Materials

Material engineering, the ability to manipulate materials with atomic control on an industrial scale and it has been the foundation of the Semiconductor industry and is the backbone of the modern industrial society. Open innovation is the methodology that combines an organization’s internal capabilities with external resources to drive a cost and time effective approach to enter new markets with high success rate. Investing in start-ups through Corporate Venture Capital (CVC) groups is one such effective open innovation tool. Applied Ventures (AV) is the corporate venture arm of Applied Materials and has invested nearly half a billion dollars in 90 start-ups in 19 countries. AV has established a number of successful public-private partnerships, pioneering joint investment funds with Korea, Taiwan, and NY Empire State Development organizations.

In this presentation, I will detail the role of CVC to be an effective open innovation collaboration and partnership tool to turn the promise of Materials Engineering to build a better future by addressing the pressing challenges of our times with innovative technologies, products and services.

Poster Session

Chair

Myung S. Jhon, Carnegie Mellon University 23p

Dr. Myung S. Jhon

Carnegie Mellon University

https://www.cheme.engineering.cmu.edu/directory/bios/jhon-myung.html

Dr. Jhon is a Professor Emeritus of Chemical Engineering, a member of the Data Storage Systems Center (DSSC) and the Institute for Complex Engineered Systems (ICES) at Carnegie Mellon University in Pittsburgh, PA. Professor Jhon received his B.S. in Physics from Seoul National University, Korea, and his PhD in Physics from the University of Chicago. He has served as visiting professor in several institutions, including the U.S. Department of Energy (National Energy Technology Laboratory and Sandia National Laboratories); the Department of Chemical Engineering, University of California, Berkeley; IBM Almaden Research Center, San Jose; and the Naval Research Laboratory, Washington, D.C. He served as a consultant to the United Nations Industrial Development Organization, and also served as a Corporate Science and Technology Advisor for Mitsubishi Chemical Corporation (Japan) for several years. He served as the President & CEO of Doosan DND Co., Ltd (Korea) and also served as a World Class University Professor at Sungkyunkwan University in Korea and served as a Distinguished Advisor for Exa Corporation.

Professor Jhon is internationally known for his work in the fields of information storage systems, computational science, nanotechnology, engineering policy, semiconductor, graphene, organic light-emitting devices (OLED), and chemical mechanical polishing (CMP). He is a Fellow of the Korean Academy of Science and Technology. He served as an advisory committee member for a Korean national program for Tera-level nanodevices, and is serving as the chair of advisory board and a lead organizer of the US-Korea Nanotechnology Forums. He has contributed 823 publications (481 refereed publications and 341 technical reports) in the areas of information storage systems, nanotechnology, computational methods (lattice-Boltzmann method, finite element method, smoothed particle hydrodynamics, atomistic, Monte Carlo, molecular dynamics & multiscale simulation, and parallel computing), fuel cell, equilibrium and non-equilibrium statistical mechanics, nucleation, fluid and solid mechanics, interfacial dynamics, polymer engineering, rheology, multiphase flow, tribology, chemical kinetics, and OLED & CMP equipment. He is also dedicated to the educational process, as is evident from his numerous teaching awards and his role as an ABET evaluator (Akron, Worcester Polytechnic Institute, Rochester, Tufts, Stanford, Connecticut, Tennessee Tech, Stevens Institute of Technology, Maryland, and Florida), and Carnegie Institute of Technology Faculty Chair & undergraduate chair in his department. Currently, he is completing an undergraduate textbook entitled Principles of Fluid Mechanics, part of which is published on the Carnegie Mellon website. He has won a number of teaching and research recognition awards, including the Ladd, Teare, Ryan, Dowd, and Li Awards.

Jungwon Choi

Assistant Professor
Department of Electrical and Computer Engineering
Member Faculty, Clean Energy Institute
UPWARDS Faculty
University of Washington

Jungwon Choi is an Assistant Professor in the Electrical and Computer Engineering department at the University of Washington. She received her Ph.D. degree in Electrical Engineering at Stanford University in 2019, M.S. in Electrical Engineering and Computer Science from the University of Michigan, Ann Arbor, in 2013, and B.S. in Electrical Engineering from Korea University in Seoul, Korea, in 2009. From 2019 to 2023, she was an assistant professor in the ECE department at the University of Minnesota, Twin Cities. Her research interests include high-frequency power converters, wireless power transfer for battery-powered vehicles, industrial and biomedical applications, magnetic designs, controls at high-frequencies, energy storage, and wide bandgap devices. In 2017, she was selected to the Rising Stars in EECS, received Unlock Idea awards from Lam Research in 2019 and 2020, and the National Science Foundation (NSF) CAREER award in 2021. She is an Associate Editor of the IEEE Journal of Emerging and Selected Topics in Industrial Electronics. Also, she is an Organizing Committee and Vice Chair of the IEEE Energy Conversion & Expo (ECCE) 2023, Technical Program Committee, and Organizing Committee of the IEEE Workshop on Control and Modeling for Power Electronics (COMPEL) 2023 and 2024, respectively.

Jungwon Choi

| Abstract

High-frequency Power Electronics using eGaN Devices

Jungwon Choi
University of Washington

The growing need for high-power applications has prompted research and development into resonant power converters with high power density. By utilizing advanced wide bandgap devices like enhancement mode gallium nitride (eGaN) transistors and Silicon Carbide (SiC) MOSFETs, we can push the boundaries of size, switching frequency, and efficiency in power converters, enabling them to operate under high-frequency, high-power conditions. Nevertheless, GaN FETs have relatively low breakdown voltage and a notable positive thermal coefficient in their conduction characteristics. In this presentation, I will describe the performance of eGaN FETs in MHz, KW resonant power converters and demonstrate how to optimize power converter design using eGaN FETs for high-frequency, high-power operation.

Prof. Jihoon Seo

Clarkson University, Potsdam, NY

Dr. Seo is an Assistant Professor of Chemical and Biomolecular Engineering at Clarkson University in NY, USA. He holds a Ph.D. in Energy Engineering and a Bachelor of Engineering in Materials Science and Engineering from Hanyang University in South Korea. His research focuses on novel planarization and cleaning technologies in manufacturing processes. Dr. Seo collaborates with semiconductor manufacturers and equipment suppliers, advancing CMP through the development of cutting-edge processes and materials. He has established partnerships with various semiconductor companies and supports many chipmakers in driving sustainability in CMP consumable manufacturing through the Semiconductor Research Corporation EHSS program. Clarkson has been recognized as a global leader in the CMP field. Currently, Prof. Seo is leading the CMP team at Clarkson University.

Dr. Seo has served on the CAMP Faculty Advisory Board, the planning committee of the CAMP CMP Symposium, and as a guest editor for a special issue of the ECS Journal of Solid State Science and Technology. He has also served as a peer review panelist for the CMP Focus Issue on ECS Solid State Science & Technology, and as a technical committee member of the Microelectronic and Advanced Packaging Technologies Roadmap. Furthermore, Dr. Seo is deeply committed to Workforce Development in the semiconductor industry and has provided valuable insights into the field for students through industry visits.

Jihoon Seo

| Abstract

Sustainable Innovations in CMP Slurries From Synthesis Methods to Environmental Impact

Jihoon Seo
Department of Chemical and Biomolecular Engineering, Potsdam, NY 13699, USA.

As semiconductor technologies continue to advance in areas such as autonomous driving, artificial intelligence, 5G communications, the Internet of Things, and large-scale data processing, the demand for a reliable semiconductor industry is on the rise. This growing demand necessitates the use of advanced device architectures, which heavily rely on two crucial processes: Chemical Mechanical Planarization (CMP) and post-CMP cleaning.

This talk will focus on the development of CMP slurries and post-CMP cleaning solutions, emphasizing their vital roles in these processes. We will delve into the comprehensive development of CMP slurries and post-CMP cleaning solutions, highlighting how synthesis methods can significantly affect the surface chemistry of ceria abrasives and impact the removal rates of SiO2 surfaces during STI CMP.

Our research also demonstrates how our cleaning solutions can effectively remove even the most 10 nm-sized ceria particles from SiO2 surfaces, thereby enhancing process efficiency. Furthermore, we will discuss the use of aliphatic amino acids as environmentally friendly corrosion inhibitors in CMP slurries, offering a sustainable alternative to the traditionally used benzotriazole (BTA) and addressing key environmental challenges. In the context of the rapidly expanding semiconductor industry, it becomes critical to address global sustainability concerns and environmental health and safety (EHS) objectives. Our research proposes a comprehensive methodology for evaluating the sustainability of CMP consumables in semiconductor manufacturing, with a primary focus on CMP slurries due to their significant market share and shorter usage lifetimes. This research serves as a foundation for future CMP sustainability analyses, encouraging self-correction strategies within the CMP community to reduce environmental impact. We will also introduce a robust framework for the Life Cycle Assessment (LCA) of CMP consumables, marking a crucial step toward achieving these sustainability goals. In summary, this talk will explore the intricate details of CMP and post-CMP processes, their pivotal roles in the advancement of semiconductor manufacturing, and the imperative task of aligning these processes with environmental and sustainability objectives

Inhee Lee

University of Pittsburgh

Inhee Lee is an assistant professor in the Electrical and Computer Engineering department at the University of Pittsburgh. Inhee Lee received his B.S. and M.S. degrees in electrical and electronic engineering from Yonsei University, South Korea, in 2006 and 2008, respectively, and a Ph.D. degree in electrical engineering from the University of Michigan in 2014. He was an assistant research scientist at the University of Michigan from 2015 to 2019. Currently, he is leading PITT Circuit Lab developing adaptive, energy-efficient reference circuits, sensor interfaces, energy harvesters, power management circuits, machine learning accelerators, emerging memory interfaces, and Cryogenic-CMOS circuits. Also, he is developing low-power millimeter-scale or even smaller sensing/computing systems for ecological, biomedical, energy exploration, and internet-of-things applications. Dr. Lee is an IEEE senior member and has been serving as a Technical Program Committee (TPC) Member for IEEE Symposium on VLSI Technology and Circuits (VLSI), IEEE Custom Integrated Circuits Conference (CICC), and ACM/IEEE International Symposium on Low Power Electronics and Design (ISLPED). He is the recipient of the ACM Annual International Conference on Mobile Computing and Networking (MobiCom) Best Paper Award.

Inhee Lee

| Abstract

Millimeter-Scale Smart Sensing Semiconductor Devices for Biomedical Applications

Inhee Lee
University of Pittsburgh

Miniature sensing semiconductor devices have unique feature sets that include wireless communication, energy harvesting, and a small form-factor, thus enabling non-invasive, secure placement for the next-generation Internet-of-things applications including biomedical, ecological, surveillance, and infrastructure applications, among others. There has been substantial research on the miniaturization of sensing semiconductor devices. The size of the bare die is often only 1-2 mm; however, the associated systems are typically much larger than just the die, resulting in centimeter-size systems due to included peripherals such as batteries and casings. This leads to a design challenge for the electronics of miniaturized systems because the maximum physical battery size and battery storage capacity are severely limited. I will discuss the challenges in developing small systems and introduce a millimeter-scale system. The semiconductor device has been developed as the world smallest computer. To optimize the performance, the system is constructed from die fabricated in different technologies which are then stacked and wire-bonded together. The stacked structure increases silicon area per unit volume and also makes it easy to swap layers in and out for flexibility in system configuration. Also, I will describe several examples of the miniature smart devices developed for biomedical applications.

Hyunwoong Ko

Assistant Professor
School of Manufacturing Systems and Networks
Arizona State University

Dr. Hyunwoong Ko is an Assistant Professor in the School of Manufacturing Systems and Networks at Arizona State University, where he directs the Digital Manufacturing and Design Laboratory. He joined the ASU faculty in January 2022 after completing postdoctoral training in the Systems Integration Division at the National Institute of Standards and Technology (NIST), USA, where he also conducted research as a research associate during his Ph.D. studies. He received his Ph.D. in mechanical and aerospace engineering from Nanyang Technological University in September 2019. He has developed an interdisciplinary background in AI, data analytics, machine learning, digital twins, and autonomous systems in design and manufacturing. His research team focuses on developing cutting-edge machine learning methods and theories for multimodal and multiscale data fusion, as well as the integration of prior and newfound data-driven knowledge. Dr. Ko's research has been supported by the National Science Foundation (NSF), NIST, and industry partners, including PADT.

Hyunwoong Ko

| Abstract

Generative Diffusion Modeling for Predictive Digital Twins of Sustainable Nanoparticle Electronics Printing

Fatemeh Elhambakhsh, School of Computing and Augmented Intelligence, Arizona State University

Suk Ki Lee, School of Manufacturing Systems and Networks, Arizona State University

Hyunwoong Ko*, School of Manufacturing Systems and Networks, Arizona State University

The distinct geometries, multi-scale material structures, and functional complexities inherent in nanoparticle-based Aerosol Jet Printing (AJP) Additive Manufacturing (AM) require a comprehensive understanding of its diverse physical phenomena to enhance sustainability. With the proliferation of big data, digital twins (DTs) augmented with sophisticated machine learning (ML) techniques improve the comprehension of AJP processes by uncovering crucial causal relationships, notably Process-Structure-Property (PSP) relationships. However, the dynamic intricacies of AJP and the vast quantities and varieties of data present a significant research gap, particularly regarding 1) the integration of causality and 2) the development of sophisticated methods for accurately inferring representations for each modality and their interactions during data fusion. To address this gap, the study presents a generative modeling methodology using a diffusion modeling-based approach, termed AMDiffusion. AMDiffusion facilitates the unprecedented prediction of PSP causal relationships using multi-modal, multi-scale AM data and the generation of newly synthesized PSP features based on learned distributions. The illustrative case study demonstrates how the AMDiffusion methodology adeptly integrates AJP process parameters and printed silver nanoparticle ink lines while capturing new, hidden causal linkage features. By leveraging AMDiffusion's predictive capabilities and focusing on the causal aspects of PSP relationships, this research provides more nuanced and comprehensive insights into nanoparticle electronic printing. Consequently, the proposed methodology has the potential to improve the simulation, prediction, and optimization of nanoparticle printing processes, thereby advancing sustainability via predictive DTs.

*Corresponding author

Ivan Sanchez Esqueda

Arizona State University

Ivan Sanchez Esqueda is an Assistant Professor in the School of Electrical, Computer, and Energy Engineering at Arizona State University (ASU). Prior to his appointment at ASU, he was a research lead at the University of Southern California (USC). His current research is focused on next-generation electronic devices, and on the integration of emerging materials to advance CMOS and beyond-CMOS technologies. His work has contributed to the development of non-volatile memory (NVM), memristors, and field-effect-transistors (FETs) based on 2D and 1D material systems. Dr. Sanchez Esqueda's work includes the characterization and modeling of advanced semiconductor technologies and their response to extreme environments including cryogenic and radiation. Dr. Sanchez Esqueda is a senior member of IEEE, has previously served as associate editor of the IEEE Transactions on Nuclear Science. He is currently an associate editor for the IEEE Transactions on Electron Devices.

Ivan Sanchez Esqueda

| Abstract

Direct synthesis and CMOS integration of 2D materials towards logic and memory devices

Ivan Sanchez Esqueda
Arizona State University

Two-dimensional (2D) materials are of great interest for advanced complementary metal-oxide-semiconductor (CMOS) electronics as well as for beyond-CMOS including neuromorphic and in-memory computing technologies. Hexagonal boron nitride (h-BN), a 2D layered insulator, has attracted much attention for non-volatile resistive-switching (NVRS) devices (i.e., memristors) due to outstanding electronic, mechanical, and chemical stability. However, the integration of h-BN memristors with Si-CMOS electronics is crucial to achieve practical technologies, and existing methods are incompatible with Si integration and manufacturing at the wafer-level. In this talk I will briefly present our recent efforts towards direct synthesis of h-BN films, enabling transfer-free CMOS-compatible memristors with outstanding electrical characteristics. We have demonstrated wafer-scale integration of h-BN memristors with >90% yield, high stability in NVRS characteristics, high conductance programming precision for multistate operation, and remarkable low-frequency noise performance with negligible random telegraph noise (RTN) characteristics. Furthermore, we directly integrate memristive devices on industrial Si-CMOS testing vehicles to demonstrate excellent endurance achieving millions of programming cycles with a high technology readiness level.

Arunkumar G V

IBM Semiconductor Research, Albany

Arunkumar is a CMP Process Engineer at IBM Research, Albany. His research focus is on developing Chemical Mechanical Planarization (CMP Process) for advanced semiconductor nodes; focusing mainly on process optimization, testing, and charactering new CMP consumables, and analyzing inline and electrical performance of the device, and bringing new eco-friendly materials to develop CMP Process. Prior to this, he worked at GlobalFoundries as a CMP Process Engineer in a HVM fab, on 14nm FinFET technology. He received his MS degree from Clarkson University in Electrical Engineering (2022), and Bachelor of Engineering from Visvesvaraya Technological University (2020). During his master's degree at Clarkson University, he worked on developing CMP Slurries and Post-CMP cleaning solutions for semiconductor applications.

Arunkumar G V

| Abstract

CMP Process Optimization for DIW conservation and metal loss reduction

Arunkumar G V
IBM Research, Albany, NY 12203

In 2 nm nanosheet technology, the feature size and dimension of metallization shrink to only a few 10s of nanometers, imposing serious challenges to control metal dissolution from corrosion during CMP, especially in the case of W vias in MOL module and Cu interconnects in BEOL. By nature, W surface is not passivated at pH > 4.0 As a consequence, exposure of W to DIW can lead to serious corrosion. Therefore, optimizing WCMP process by reducing the amount of DIW consumption, e.g., on platen rinse and post buff clean DIW rinse steps would help mitigate W loss and preserve via height. Such process optimization also helped reduce DIW consumption by more than 25% of current usage, making it a more sustainable and environmentally friendly manufacturing process.

“Cu” is most widely used metal for interconnect applications. But it is more prone to corrosion in the CMP step because of the nature of chemicals used in CMP slurry. Similar to W, exposure of un-passivated Cu wafer to DIW and ambient oxygen in CMP tool can induce galvanic corrosion on both Cu conductor and Co liner. For 2nm technology node, Cu barrier polish is usually much shorter than the subsequent brush clean process. As a consequence, “traffic jam” would occur where wafers would sit wet and idle in transient until the cleaner is ready to receive new wafer. Such time lag to reach the wafer from polisher output station to the cleaner module inside the tool will cause galvanic corrosion by extended exposure to DIW and oxygen. By shortening the DIW rinse time and brush cleaning time during brush clean, it is demonstrated that Cu and Co corrosion can be reduced without compromising the cleaning efficiency to remove particles and polish residues.

The two case studies above demonstrate how process co-optimization for CMP performance improvement can co-exist with the conservation of DIW consumption in high volume semiconductor manufacturing.

Ref:

1. W.-T. Tseng, E. Motoyama, K. Motoyama, A. Jog, P. Chu, D. Capaneri, “Nano-scale metal loss during chemical-mechanical planarization”, Inter. Conf. Planarization. Technol. (ICPT), #O32 C-03 (2023).
2. P. Chu, “Tungsten Dissolution in MOL-Root Cause Investigation”, 2024 CAMP Inter. CMP Symp., Lake Placid, NY, USA, Aug. 11 ~ 14, 2024.

Sri Siva Rama Krishna Hanup Vegi

Foundry Technology Development, Intel Corporation

Hanup Vegi is a Module Development Engineer in Foundry Technology Development at Intel Corporation, working in one of the chemical mechanical planarization (CMP) teams in Hillsboro, Oregon. Hanup has graduated with a PhD in CMP from Clarkson University, New York. His research expertise include CMP and post-CMP cleaning, with research papers published that focused on new formulations of post-CMP cleaning solutions for interconnect and shallow trench isolation (STI) applications.

Sri Siva Rama Krishna Hanup Vegi

| Abstract

Semiconductor Manufacturing Going Green - Role of Chemical Mechanical Planarization (CMP) Process

Sri Siva Rama Krishna Hanup Vegi
Foundry Technology Development, Intel Corporation, Hillsboro, OR

Semiconductor industry continues to be meticulous in managing the real estate on the silicon wafer, especially with the nodes size entering the angstrom era. However, industry's carbon footprint does not show any signs of slowdown while it ascents exponentially, stressing the indisputable need for environmental friendly measures. The US CHIPS Act 2022, is keen on analyzing the environmental impact of semiconductor manufacturing facilitated by various hazardous chemicals and leading to a significant amount of chemical waste generation. Huge strides in this direction are already in place at Intel to achieve net-positive water and zero waste to landfills by 2030.

One such process crucial in the semiconductor industry is chemical mechanical planarization (CMP) which uses a wide variety of chemicals, to fabricate super flat and pristine surfaces. While making sure the quality of the final processed wafer is not compromised, use of environmentally friendly chemicals in CMP and post-CMP cleaning solutions are the need of the hour. The process also consumes several gallons of water per wafer, which also highlights the scope for lowering the water consumption rates. While 80-90% of the chemicals used are let downstream without even participating in the actual process, the focus of the engineering teams is to develop CMP process in such a way that the yield goals are met with less hazardous materials and minimal chemical wastage. This eventually aids the industry to achieve high water recycle rate and reduced power consumptions during the chemical mixed processed water treatment.

Session 1

Co-chairs

Ahmed A. Busnaina, Northeastern University 08p
Tae Gon Kim, Hanyang University 41p

Ahmed Busnaina

| Abstract

Sustainable Semiconductor Additive Manufacturing of Micro and Nanoscale Electronics

Ahmed A. Busnaina
Northeastern University

We introduce a sustainable manufacturing technology. This technology will reduce cost by 10-100 times compared to conventional semiconductor manufacturing. It is enabled by directed assembly-based of suspended nanoparticles [1,2] at room temperature and pressure and manufactures devices 1000 faster and 1000 smaller structures than inkjet-based or 3D printing. The process is scalable, environmentally sustainable, and enables precise and repeatable manufacturing of various nanomaterials at a very high rate. This allows the printing of passive and active components monolithically on an interposer platform along with a trace such that the total footprint can be within a few mm of the original IC footprint. The presentation will show the electrical and materials chrematistics of capacitors, resistors, and transistors that are made using a fully additive process down to the submicron scale without using etching, vacuum, or chemical reactions. The presented technology enables the printing of single-crystal conductors and semiconductors [3]. The process demonstrates the manufacturing of transistors with an on/off ratio greater than 10^6.

An immediate application for this technology is advanced packaging where there is a need to shrink the size of interposers and be able to integrate different passive and active components in addition to memory, microcontroller, power electronics, etc. The new ultrafine resolution requirements for 3D heterogeneous integration have moved many advanced packaging processes to foundries instead of traditional packaging processes. This led to a much higher cost that made the most advanced packaging applications out of reach for many small companies. This additive high-throughput manufacturing solution can enable low-cost trace, interconnect, passive, and active components manufacturing.

[1] J. Zhang, G. Wang, Z. Chai, Z. Li, S. Yuan, Y. Wang, Y. Ding, T. Sun, T. Wang, D. Zhao, A. A. Busnaina, T. Ren, and X. Lu, ACS Nano 2024, July 2024.

[2] Z. Chai, A. Childress, and A. Busnaina, ACS Nano, 2022.

[3] Z. Chai, A. Korkmaz, C. Yilmaz, and A. Busnaina, Advanced Materials, 2020, 2000747.

Prof. Tae-Gon Kim

Department of Smart Convergence Engineering,
Hanyang University ERICA, South Korea

Tae-Gon KIM is a professor of Department of Smart Convergence Engineering in Hanyang University ERICA. He is actively engaged in international standardization efforts as the Committee Manager of the ISO TC201/SC9, which is the scanning probe microscopy subcommittee. Additionally, he is actively involved in domestic and international conferences related to semiconductor cleaning, CMP, and surface analysis. He received his Bachelor, Master and PhD from Metallurgy and Material Science and Engineering in 2001, 2003 and 2008 in Hanyang University ERICA, South Korea, respectively. He studied semiconductor cleaning and CMP processes. He was a postdoctoral research fellow in imec and KU Leuven, Belgium in from 2008 to 2010. He was a senior researcher in a scientific advisor of in-line metrology from 2010 to 2019. He was appointed as a professor at Hanyang University ERICA in 2019. In his research career, he has been leading activity on semiconductor cleaning and CMP, advanced film characterization as well as in-line metrology technique for advanced technology node and in-line 3D-AFM technology for 3-dimensional structure characterization such as sidewall characterization of FinFET and Nanowire.

Tae-Gon Kim

| Abstract

Converging AFM Solutions: Pioneering Nanotechnology for Advanced Industries

Tae-Gon Kim[1*], Sang-Joon Cho[2]

[1] Hanyang University ERICA, Republic of Korea
[2] Park Systems Corp., Republic of Korea
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The rapid advancement of industries, particularly the semiconductor sector, has outpaced the traditional research methods and technological developments of academia. To sustain this momentum, the evolution of research methodologies and technological innovations must keep pace. This necessity has brought scanning probe microscopy technology, capable of providing detailed nanometer-scale information, into the spotlight. Among these technologies, the versatile Atomic Force Microscopy (AFM) has already found numerous applications within the semiconductor industry.

As device dimensions continue to shrink, nanometer-sized defects on wafer substrates increasingly limit device performance. Detecting and accurately classifying these defects necessitates additional characterization methods with nanometer-scale resolution, which are crucial not only in the front-end-of-line (FEOL) processes but also in the back-end-of-line (BEOL) processes. While it is well known that AFM can measure mechanical and electrical properties as well as surface morphology, its full potential remains underutilized in industrial applications due to various limitations, including low throughput, limited tip lifespan, and operational complexity.

In Korea, advancements in AFM technology are being made to overcome these limitations. These developments aim to provide high-throughput, high-resolution, and non-destructive methods for obtaining 3D information for nm-scale defect review and classification, with enhanced mechanical and electrical characterization capabilities. For instance, AFM solutions integrated with White Light Interferometry (WLI) have been identified as particularly beneficial in advanced packaging applications, including Through Silicon Via (TSV), Backside Via Stack (BVS), interconnects, and Cu pad measurements.

Through advanced automation processes and comprehensive measurements, including AFM-based physical property assessments, AFM technology will complement manufacturing control tools and offer diverse inspection solutions, thereby contributing significantly to the future development of advanced industries.

Paul Westerhoff

Water for Nano-Fabs: Barriers and Opportunities

Paul Westerhoff is a Regents Professor & Fulton Chair of Environmental Engineering at Arizona State University. He has over 420 peer reviewed publications related to water. He is the Deputy Director of a NSF ERC for Nanotechnology Enabled Water Treatment (NEWT), co-Deputy Director of the NSF Science and Technologies for Phosphorus Sustainability (STEPS) Center, and water-innovation lead for the NSF Southwest Sustainability Innovation Engine (SWSIE). He received several awards including the 2020 A.P. Black award, 2019 NWRI Clarke Prize, and was elected to the National Academy of Engineering in 2023. He is the Exposure co-Chair for the US-EU National Nanotechnology Initiative, and has been working on nano-risks and applications since 2005.

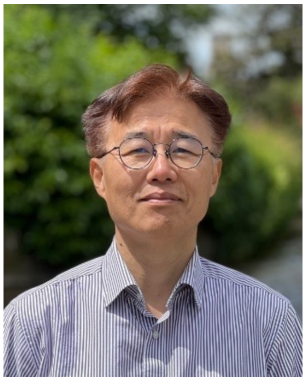
Paul Westerhoff

| Abstract

How can Fabs Reduce Their Water Footprints: From industrial wastewater reuse to atmospheric water harvesting as make-up supplies for ultrapure water

Paul Westerhoff
Arizona State University

Modern Fabs use large volumes of tap water purchased from cities. Approximately 2/3 of the incoming tap water usage is for ultrapure make-up water, and the remaining 1/3 for cooling towers, scrubbers and general operations. First, this presentation will discuss challenges and research opportunities for using industrial wastewater from the Fab not only for cooling, scrubbers, etc. but to augment (reduce reliance) on city tap water – using recovered wastewater ultimately to make chips themselves. Second, this presentation examines an emerging new water source for very high quality water – atmospheric water harvesting – as a way to reduce reliance on tap water provided by cities. The economic feasibility and technical challenges will be identified.



Prof. Heeyeop CHAE

Sungkyunkwan University (SKKU),
Republic of Korea

Heeyeop CHAE received his B.S. and M.S. in chemical engineering from Seoul National University and his Ph.D. in chemical engineering from Massachusetts Institute of Technology (MIT) (2000). After his Ph.D. he joined Applied Materials, a semiconductor equipment company, in California, USA as a senior process engineer. He has been working as a professor in School of Chemical Engineering at Sungkyunkwan University (SKKU) since 2004. He is a vice president of Korean Vacuum Society and The Korea Society of Semiconductor and Display Technology. His research interests include i) plasma-enhanced atomic layer etching and deposition, ii) low global warming etching gas development, iii) plasma monitoring and machine learning and iv) light emitting quantum dot materials and devices.

Heeyeop Chae

| Abstract

Low Global Warming Gases for Plasma Etching Processes

Heeyeop Chae

School of Chemical Engineering,
Sungkyunkwan University (SKKU)
Suwon, 16419, Republic of Korea
Email: hchae@skku.edu

Perfluorocompounds (PFCs) are widely used in various plasma etching processes in semiconductor device fabrication, but they are considered as major greenhouse gases causing global warming. PFC emission can be reduced by optimizing processes, recycling PFCs, abatement after processing, or replacing PFCs with low GWP gases. Among them, replacing PFCs with lower GWP gases is considered as the ultimate solution. Studies have been reported on the potential replacement of PFCs with various hydrofluorocarbons, unsaturated fluorocarbons, hydrogen-containing fluorocarbons, oxygen-containing fluorocarbons, and iodofluorocarbons, to replace PFCs. In this talk, the research on feasibility study of replacing PFCs with fluoroethers, fluoroalcohols, fluoroketones will be discussed for dielectric etching processes. Various fluoroethers, fluoroalcohols, and fluoroketones are pre-screened based on carbon/fluorine atomic ratio in molecules, molecular weight, boiling points, as well as global warming potentials, and ten candidate gases were selected. Various chemical reactions were analyzed in plasma phase and on surface etching for the screened gases. Three different $C_4H_3F_7O$ isomers of fluoroethers and a fluorocalcohol were compared for both reactive ion etching reactions and plasma-based atomic layer etching processes. The emission characteristics of the processes were analyzed, and we demonstrated that the fluoroethers and fluoroalcohols can reduce global warming potential of exhaust gases up to 90%.

Bruno Azeredo

Arizona State University

Dr. Bruno Azeredo is the Fulton Development Associate Professor in the School of Manufacturing Systems and Networks at Arizona State University where he currently serves as Assistant Director of the Manufacturing Innovation Labs. He is also a member of the graduate faculty in Manufacturing, Mechanical, and Materials Engineering. Prior to joining ASU, Dr. Azeredo earned his B.S. in engineering mechanics in 2010, M.S. in theoretical and applied mechanics in 2013, and Ph.D. in mechanical engineering in 2016, all from the University of Illinois at Urbana-Champaign. His research focuses on scalable nanomaterial synthesis and its size-dependent properties with an eye at exploiting them in the production of multi-scale and multi-material structures.

He has graduated 9 MS and 4 PhD students, co-authored +25 journal articles and patents, delivered 18 invited talks, and serves on various roles at ASME's Manufacturing Engineering Division, SME's NAMRC Scientific Committee and the Materials Research Society. He is an associate editor for ASME's Journal of Manufacturing Science and Engineering, and member of the editorial advisory board for npj Advanced Manufacturing. For his contributions to scalable nanomanufacturing, he is recipient of awards such as the 2018 Bisgrove Scholars Award from the Science Foundation Arizona, the 2020 National Science Foundation CAREER award, the 2022 SME Sandra L. Bouckley Outstanding Young Manufacturing Engineer Award and the 2023 US Frontiers of Engineering Symposium Participant, National Academy of Engineering (USA).

Bruno Azeredo

| Abstract

Microscale additive manufacturing of high-surface area nanoporous copper: towards hierarchical structures and 3D circuits

Bruno Azeredo
School of Manufacturing Systems and Networks, Arizona State University

Nanoporous metals have been proposed as electrodes for carbon capture and hydrogen production, sensing in bioelectronics applications, current collectors in batteries, catalysts for carbon-based nanomaterial synthesis, or active material in propellants and structural energetics to overcome limitations in reaction kinetics of their bulk solid counterpart. However, their consolidation into large-scale parts via powder metallurgy while maintaining its mechanical performance is limited by the nanoporous metal's thermodynamic instability during sintering and their poor flowability in powder-based feedstocks. In this work, the synthesis of spherical nanoporous copper micron-sized powders (PCu) is undertaken via dealloying of Cu-Al gas-atomized precursors with high-throughput, moderate flowability, moderate-oxygen content, high-surface area and free of precipitates. PCu is sintered with powder mixtures containing Cu nanoparticles at temperatures as low as a third of its melting point to overcome its thermodynamic instability and preserve its high-surface area. As an example, open-die casting and micro-projection stereolithography were employed to produce conductive copper parts with low-to-moderate strength with preserved nanoporosity (i.e., pore size 24 – 36 nm), and hierarchical features sizes spanning 50 μm and 5 mm. As demonstration of its unique applications, architected 3D printed PCu lattices are designed as transient elements with programmable self-disintegration and self-destruction.

Refs:

1. [1] Niauzorau et al, Applied Materials Today, 2023
   [2] Hasib et al, Composites Part B: Engineering, 2023.

Haeseong Lee

Jeonju University, Republic of Korea

Dr. Haeseong Lee is a material scientist working at Jeonju University as Professor.

His research area was initiated by correlation between structure and properties of materials. He had an opportunity to widen his experience on material characterization and innovative analytical methodologies on nanomaterials and carbon materials. His wide experiences to elucidate carbon & nanomaterials led him to their applications and industrialization for display, semiconductor, nanotech, etc.

His pragmatism on nanotechnologies triggered his interests on international standardization activities. His career on the field of international standardization started with a proposal of a new SC, the title of scanning probe microscopy, under ISO TC201(Chemical Surface Analysis) in 2003. With the approval of his proposal he was appointed as Chair of the new SC9 under TC201 and had maintained the position until 2017. He was also involved in IEC activities when he established a TC under IEC, the title of printed electronics in 2011. Currently he has 3 convenors at ISO TC201 SC9 WG6 (ESPM), IEC TC113 WG14 (electromagnetic compatibility on nanomaterials), ISO TC61 (Plastics) WG5 (electrical, magnetic, electromagnetical and optoelectrical properties on polymers and composites)

Recently he moved toward quantum technology based on his experiences in analyzing superconductivity, basic quantum phenomena such as tunneling current, quantum conductance, etc. He was involved in standardization of quantum technology (QT) in the birth JTC3 and now serve as Chair

Haeseong Lee

| Abstract

Electromagnetic shielding effectiveness measurements on nanomaterials for the sustainability in semiconductor industry

Haeseong Lee[1*], Hyeongrok Yu[2], and Jung Soo Kim[1,2], Hahnhee Lee[3], Sang-Wook Yoon[3]

[1] Jeonju University, Republic of Korea
[2] Korea Institute of Convergence Texitile, Republic of Korea
[3] Korea Testing Laboratory, Republic of Korea
E-mail address: haeseong@jj.ac.kr

Minimization of component size in semiconductor devices results in fundamental thresholds such as tunneling phenomena and electromagnetic interference (EMI) among each component. There are lots of being conducted or conducted R&D projects in order to overcome the inherent limitations using nanomaterials.

This presentation is focused on the EMI measurement issues on nanomaterials. One of the critical topics in this field of technology is lack of a test method on shielding effectiveness (SE) measurement. The existing conventional standard in SE measurement, ASTM D4935, exhibits high-level reliability and reproducibility. However, it has three disadvantages in application to the nanomaterials and requirement from the current technology such as (i) requirement in sample size, (ii) available frequency range (only up to 1.5 GHz), and (iii) a limit on measurement conditions (far-field vs near-field).

This presentation is going to provide update information on how to deal with the above three issues in order to prepare reliable test methods on SE of nanomaterials via standardization activities in IEC TC113 WG14 (Electromagnetic compatibility on nanomaterials).

Fazleena Badurdeen

University of Kentucky

Fazleena Badurdeen is the Earl Parker Robinson Chair Professor in Mechanical Engineering at the University of Kentucky (UK). She is the Director for the Online Manufacturing Systems Engineering MS program and a core faculty of UK's Institute for Sustainable Manufacturing, an internationally recognized center of excellence focused on cutting-edge research and technology development for sustainable products, processes and systems. Prof. Badurdeen is recognized for her expertise in sustainable and circular product design, measurement systems for circularity and sustainability evaluation, and modeling and analysis of manufacturing systems and supply chains. She has served as principal investigator (PI)/Co-PI for externally funded research of nearly $18 million and has published over 150 peer-reviewed papers. Prof. Badurdeen is the founding Chair of the International Forum on Sustainable Manufacturing and has served as a Technical Vice President for the Institute of Industrial and Systems Engineers (IISE). She is also an Editor for the Resources, Conservation, and Recycling journal and serves on the editorial boards of a number of other journals. Prof. Badurdeen received her PhD in Integrated (Industrial and Mechanical) Engineering and MS in Industrial Engineering, both from Ohio University, USA. She also holds an MBA from the Postgraduate Institute of Management, Sri Lanka and BS in Engineering from the University of Peradeniya, Sri Lanka. Prof. Badurdeen is a Fellow of IISE.

Fazleena Badurdeen

| Abstract

Towards Circular and Sustainable Semiconductor Manufacturing

Fazleena Badurdeen
University of Kentucky

The production of semiconductor chips is highly resource-intensive, involving substantial water usage, energy consumption, and emissions. Despite their ubiquity in daily life, the increasingly shorter lifecycles of products containing these chips lead to premature obsolescence. The disposal of these chips generates significant waste streams, containing valuable resources, and raises environmental concerns. Additionally, the chip production demands ever-increasing quantities of rare and valuable materials, which are in limited supply. Efforts to address these issues have primarily focused on lifecycle assessment to evaluate and enhance operational efficiency and waste elimination in manufacturing facilities. However, addressing impacts during manufacturing—one stage of the lifecycle— alone is insufficient to tackle the challenges faced.

This presentation will explore the 6R and total lifecycle-based approach to sustainable manufacturing aimed at decoupling resource extraction and negative environmental impacts from economic growth to promote circularity and sustainability. It will highlight the importance of product, process, and system integration, and the central role of design in transitioning to sustainable manufacturing. Additionally, novel, metrics-based methods for assessing circularity and sustainability will be introduced. These foundational concepts, applicable across various industry sectors, will be leveraged to explore innovative strategies for enhancing circularity and sustainability in semiconductor manufacturing.

Susannah Calvin

Head of ESCI Product & Materials, Apple

Susannah Calvin leads Apple's Environment & Supply Chain Innovation - Product & Materials team, which drives Apple's Carbon, Circularity, Smarter Chemistry, and Safer Manufacturing programs.

Her team is responsible for reducing Apple's carbon and resource footprints, prioritizing recycled and renewable content, proliferating safer chemicals, and incorporating environmental and human rights programs into product features.

Susannah Calvin

| Abstract

Climate & Computing

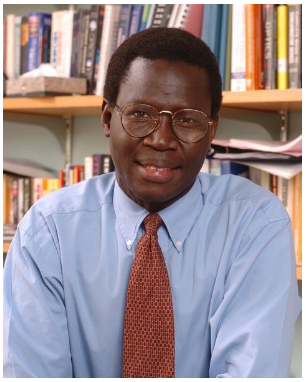
Susannah Calvin
Apple

With semiconductor demands rapidly increasing, it's critically important for all stakeholders in the value chain to better understand and mitigate climate implications of computing"

Session 2

Co-chairs

Elias Towe, Carnegie Mellon University 56p
Tae-Woo Lee, Seoul National University 57p



Elias Towe

Carnegie Mellon University

Elias Towe is currently the Albert and Ethel Grobstein Professor at Carnegie Mellon University. He teaches in the departments of Electrical and Computer Engineering, and Materials Science and Engineering. His research interests are in photonics and the related application areas of quantum computing, quantum communications, neuromorphic computing, and sensing. Prof. Towe was educated at the Massachusetts Institute of Technology, where he received all his academic degrees (S.B., S.M., and Ph.D.) in Electrical Engineering and Computer Science. He was also a Viton Hayes Fellow while at MIT. His professional awards and honors include the NSF Young Investigator award, the Outstanding Technical Achievement Award from the Office of the US Secretary of Defense, and the Commonwealth of Virginia Scholar Award. Dr. Towe is a Fellow of the Optical Society of America, the IEEE, the American Physical Society, and the American Association for the Advancement of Science.

Tae-Woo Lee

Professor at the Department of Materials Science and Engineering
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Research Areas : Display/Solid state lighting electronics, Perovskite electronics, Solar cells, Nanowire electronics, Flexible neuromorphic and bio electronics, Graphene electronics

Short Biography and Research Interest

Tae-Woo Lee is a professor in the Department of Materials Science and Engineering at Seoul National University, Korea. He received his Ph.D. in Chemical Engineering from Korea Advanced Institute of Science and Technology (KAIST), Korea, in 2002. He joined Bell Laboratories, Lucent Technologies, USA, as a postdoctoral researcher in 2002 and then worked at Samsung Advanced Institute of Technology as a member of the research staff (2003–2008). He was an assistant and associate professor in the Department of Materials Science and Engineering at Pohang University of Science and Technology (POSTECH), Korea, until August 2016. His research interest spans organic, organic–inorganic hybrid perovskite, and carbon materials, and their applications to flexible electronics, printed electronics, displays, solid-state lightings, solar energy conversion devices, and bio-inspired neuromorphic devices. He was appointed as a regular member of Korea Academy of Science and Technology in 2021. He was honored as 2020 Materials Research Society (MRS) Fellow and 2024 SPIE Fellow. To date, he is the author and co-author of 289 papers in high-impact journals including Science, Nature, and their distinguished sister journals.

Selected recent publications

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Y. Lee+, Y. Liu+, D.-G. Seo+, J.Y. Oh, Y. Kim, J. Li, J. Kang, J. Kim, J. Mun, A.M. Foudeh, Z. Bao*, and T-W. Lee* (2022) A low-power stretchable neuromorphic nerve with proprioceptive feedback, Nature Biomedical Engineering 7 (4), 511-519.

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Kenneth Shepard

Columbia University

Kenneth Shepard received the B.S.E. degree from Princeton University and the M.S. and Ph.D. degrees in electrical engineering from Stanford University. From 1992 to 1997, he was a Research Staff Member and Manager with the VLSI Design Department, IBM Thomas J. Watson Research Center, and Yorktown Heights, NY, where he was responsible for the design methodology for IBM's G4 S/390 microprocessors. He was the Chief Technology Officer of CadMOS Design Technology, San Jose, CA, which he co-founded, until its acquisition by Cadence Design Systems in 2001. Since 1997, he has been with Columbia University, New York, NY, where he is currently the Lau Family Professor of Electrical Engineering, Professor of Biomedical Engineering, and Professor of Neurological Sciences (in Neurological Surgery) and the co-founder and the Chairman of the Board of Ferric, which is commercializing technology for integrated voltage regulators; Quicksilver Biosciences, which is commercializing single-molecule bioelectronics diagnostics; and Kampto Neurotech, which is commercializing brain-computer interface devices. His current research interests include power electronics, biophysics, and CMOS bioelectronics.

Kenneth Shepard

| Abstract

Interfacing to the nervous system with CMOS bioelectronics

Kenneth Shepard
Columbia University

A new class of bioelectronics devices is emerging in which an integrated circuit, based on complementary metal-oxide-semiconductor (CMOS) technology, is in direct contact with the biological system to which it is interfacing. There are several advantages to this approach. First, this achieves the very smallest form factors possible by enabling systems in which the entire device is contained on the chip. Second, it enables large arrays of transducers since interfacing electronics can be directly connected to these devices without requiring wire escapes. Lastly, this ensures the highest fidelity signal transduction by locating transduction as close as possible to the signal source.

There are three primary ways in which living systems can interact with CMOS bioelectronics – electrically, through the detection of charge, electric potential, or the reduction-oxidation (redox) properties of molecules; acoustically, usually at ultrasound frequencies; or optically, through the introduction of optical reporters or transducers in the biological system or through endogenous optical absorption properties. We consider examples of CMOS bioelectronics based on each of these transduction methods with application to invasive, minimally invasive, and non-invasive recording and stimulation systems in both the central and peripheral nervous systems. We will particularly highlight a new class of wireless devices for interfacing to the brain that are contained entirely within the subdural space.

Tae-Woo Lee

| Abstract

Organic Nervetronics for Neuroprosthetics

Tae-Woo Lee*[1,2,3]

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Nerve injuries can lead to paralysis, significantly reducing their quality of life and, in severe cases, becoming life-threatening. To address this issue, neuroprosthetics are being developed. However, current neuroprosthetic systems rely on conventional von Neumann architecture, which struggles to replicate the complex behavior of biological nervous systems. In contrast, “nervetronics”—based on ion-gel-gated synaptic transistors—more effectively mimic the functional properties of biological nerves. Crucially, incorporating the short-term plasticity-dominated synaptic properties of nervetronics into neuroprosthetics could lead to significant advancements.

In this study, we demonstrate stretchable neuromorphic efferent nerves that can interface with the muscles of living animals via PEDOT:PSS hydrogel electrodes. Our nervetronic system successfully replicated natural movements in the hind limbs of mice, including bipedal motion and practical tasks such as kicking a ball and walking or running. Additionally, electrophysiological signals recorded from the system were able to induce muscle movement through the nervetronic interface. This work provides fundamental insights and a proof-of-concept for the application of nervetronics in future neuroprosthetic development.

Michael J. Sailor, PhD

University of California, San Diego

Michael J. Sailor holds the rank of Distinguished Professor at the University of California, SanDiego. He was trained as a chemist, receiving a B.S. degree from Harvey Mudd College (1983), and M.S. and Ph.D. degrees from Northwestern University (1988). After post-doctoral studies at Stanford and the California Institute of Technology, he joined the faculty of the UCSD Department of Chemistry & Biochemistry in 1990. He holds Affiliate Appointments in the UCSD Bioengineering Department, the Nanoengineering Department, and the Materials Science and Engineering program. Other appointments include: Invited Professor, CNRS Institut Charles Gerhardt in Montpellier, France (2012); Visiting Professor, High Level Talent Program, Key Laboratory of Organosilicon Chemistry and Material Technology, Hangzhou Normal University, China (2018-2020); and Visiting Professor, Zhejiang University, China (2019-2020). He has supervised more than 160 undergraduate, graduate, and post-doctoral students, and he is the author of more than 230 research publications, one book, and 29 patents. He has founded three companies and has served on the scientific advisory boards of six others. He is an elected Fellow of the American Association for the Advancement of Science, the U.S. National Academy of Inventors, and the Royal Society of Chemistry. He is Associate Editor of the journal ACS Sensors, and he serves on the advisory boards of Advanced Materials, ACS Nano, Nanoscale Horizons, and Applied Physics Letters. Professor Sailor's research focuses on nanotechnology, with emphasis on biomaterials, drug delivery, and sensing applications. He is an expert in the chemistry, electrochemistry, and optical properties of nanomaterials, in particular porous silicon-based systems.

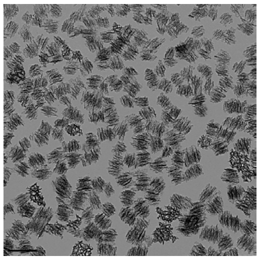
Michael J. Sailor, PhD

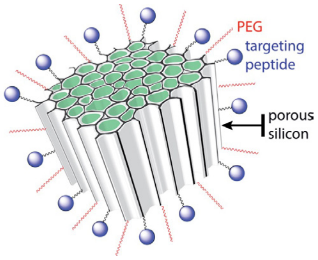
| Abstract

Silicon-Based Nanoparticles for Tissue-Specific Drug Delivery to the Brain

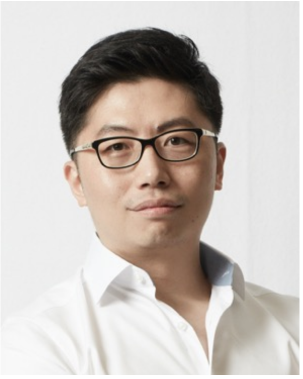
Prof. Michael J. Sailor
Department of Chemistry & Biochemistry, University of California, San Diego

This presentation will highlight some of the challenges and potential solutions for translation of silicon-based nanotherapeutic systems, with an emphasis on sensing and targeting in the brain. Nanophase silicon is one of few semiconductor "quantum dot" materials that is non-toxic and that degrades to non-toxic byproducts in vivo. It offers advantages over polymer-based or lipid-based nanoparticles as a drug carrier, but it also poses several challenges. Advantages include the ability of a nanoscale silicon cage to protect and to load guest molecules such as nucleic acids and proteins at high levels. The fact that it displays intrinsic photoluminescence at tissue-penetrating near-infrared wavelengths avoids the need for additional labels to track the fate of the nano-carrier. The long-lived (microseconds) excited state lifetime that depends on the state of degradation of the material allows an additional dimension for evaluating parameters such as the extent of drug release or the local chemistry in the vicinity of the nanoparticle. Because of the sensitivity of biologics, chemistries used to trap that class of therapeutics must operate under mild aqueous conditions such that the payload becomes trapped without inducing denaturation or decomposition, and the chosen chemistry must still allow attachment of targeting peptides and other moieties to the exterior surface of the nanoparticle to enable selective tissue targeting. Focusing on small peptides as targeting agents, some recent examples of targeting, imaging, and cell penetration properties that show improved therapeutic outcomes for treatment of brain and neuronal injuries will be presented.





Left: Porous silicon nanoparticles by TEM. Nominal particle size is 200nm.
Right: Porous silicon nanoparticle design.



Jinmyoung Joo

Ulsan National Institute of Science and Technology, Republic of Korea

Jinmyoung Joo is currently an Associate Professor of Biomedical Engineering at Ulsan National Institute of Science and Technology (UNIST). He received both BS and PhD in Chemical Engineering from POSTECH. He then continued the study on functional nanomaterials for biomedical applications as a postdoctoral research associate at University of California, San Diego. He started his independent research career as an Assistant Professor at University of Ulsan College of Medicine in 2016, and has moved to UNIST in 2019. His lab has been interested in understanding the interaction of nanomaterials with complex biological systems, engineering novel nanostructures that can effectively understand tissue microenvironment and target diseases such as neurodegenerative diseases and cancer.

Jinmyoung Joo

| Abstract

Nanoparticles at the interface of blood-brain barrier

Jinmyoung Joo[1*]

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Nanotechnology have attracted great attention to molecular biology and translational medicine because life processes are maintained by the action of a series of molecular nanomachines in the cell machinery. Recent advances in nanoscale materials that possess emergent physical properties and molecular organization hold great promise to impact human health in the diagnostic and therapeutic arenas. In order to be effective, nanomaterials need to navigate the host biology and traffic to relevant biological structures, such as diseased or pathogenic cells. Moreover, nanoparticles intended for human administration must be designed to interact with, and ideally leverage, a living host environment. Inspired by nature, we use peptides or aptamers to transfer biological trafficking properties to synthetic nanoparticles to achieve targeted delivery of payloads. In this talk, development of nanoscale materials will be presented with a particular focus on targeted drug delivery to brain. Unique combinations of material properties that can be achieved with nanomaterials provide new opportunities in translational nanomedicine for neuroinflammation and neurodegenerative diseases. This framework for constructing nanomaterials that leverage bio-inspired molecules to traffic diagnostic and therapeutic payloads can contribute on better understanding of living systems to solve problems in human health. The biocompatible and self-destructive nanocarriers present promising potential for therapeutic application via targeted delivery to brain. Tailoring design strategies of the biomedical nanoparticle platforms and their practical applications as a theranostic agent are also discussed.

Mehdi Nikkhah, Ph.D.

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School of Biological and Health Systems Engineering
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Mehdi Nikkhah is currently an Associate Professor of Biomedical Engineering at the School of Biological and Health Systems Engineering (SBHSE), Arizona State University (ASU). He completed his postdoctoral fellowship training at Harvard Medical School and Brigham and Women's Hospital. He received his B.S. in mechanical engineering and M.S. degree in biomedical engineering from Tehran Polytechnic University followed by Ph.D. degree in mechanical engineering from Virginia Tech. Dr. Nikkhah has published more than 80 journal articles (+11,000 citations, H-index of 48), 8 book chapters and 100 peer-reviewed conference papers and holds 10 US patents and invention disclosures. Throughout his career, he has received numerous prestigious awards and recognitions, including the induction into the American Institute for Medical and Biological Engineering (AIMBE) College of Fellows, National Academy of Inventors (NAI) Senior Membership, Arizona Flinn Foundation Award, ASU Biomedical Engineering Outstanding Assistant Professor Award, NSF CAREER Award, and so forth. In addition to his research endeavors, Dr. Nikkhah has been very passionate and deeply committed to educating the next generation of students and scholars, with a particular focus on minority and underrepresented groups in science and engineering. He has trained over 70 individuals, including postdoctoral fellows, PhD/MS students, and undergraduate researchers, from diverse backgrounds in his lab.

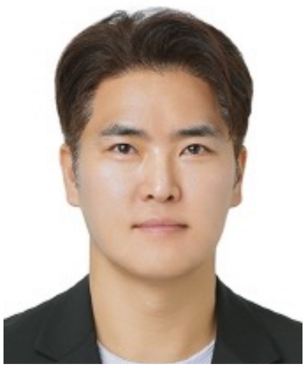
Mehdi Nikkhah

| Abstract

Engineering Organotypic Disease On-a-Chip Models; Harnessing Innovations in Microfluidics, Biomaterials and Single-Cell Resolution Analysis

Mehdi Nikkhah
School of Biological and Health Systems Engineering, Arizona State University

Ex vivo Three-dimensional (3D) organotypic tissue models have emerged as pivotal tools in both biomedical and pre-clinical research arenas. Tissue-on-a-chip technologies have enabled a better understanding of complex human diseases, surpassing the limitations of traditional animal models. These innovative technologies have also greatly streamlined the process of drug development and discovery through establishing scalable and high-throughput miniaturized platforms for efficiently assessing the effectiveness of multiple drugs and compounds. In this seminar, Dr. Nikkhah will introduce his laboratory's multidisciplinary research focus on the integration of microfluidics technologies, advanced biomaterials, and single-cell level analysis to engineer the next generation of physiologically relevant organotypic tissue-on-chip platforms for disease modeling and drug testing applications. The seminar will particularly highlight their work in engineering tumor microenvironment (TME) models, aimed at studying the earliest stages of cancer progression in the metastatic cascade. Additionally, he will briefly touch upon the development of a 3D vascularized human stem cell-derived tissue-on-a-chip model designed for investigating cardiovascular and cerebrovascular diseases.



Prof. Kwon Oh Seok

Advanced Institute of Nanotechnology & Department of Nano Engineering, SungKyunKwan University (SKKU), Suwon, Korea

Prof. Oh Seok Kwon received a B.S. in department of chemistry from Yeungnam University in 2007. Then he joined the research group of Professor Jyongsik Jang at School of Chemical and Biological Engineering of Seoul National University. He received M.S. in 2012 and Ph.D with conducting nanomaterials for sensor applications in 2013. He worked as a postdoctoral researcher at Massachusetts Institute of Technology and Yale University from 2013 to 2015. He worked as a senior researcher of BioNanotechnology research center at Korea Research Institute of Bioscience and Biotechnology (KRIBB). He is working as Associate Professor of Department of Nano Engineering at SungKyunKwan University (SKKU) since 2023. His research interests include sensors related to human cognition, interfacing chemistry, point-of-care devices, nanomaterial based theragnosis and polymerase chain reaction (PCR) instruments.

(*for further information, please visit the website: www.oskwonrnd.com)

Kwon Oh Seok

| Abstract

Artificial human eyes with photo-Receptonics

Oh Seok Kwon
Nano Engineering of Sungkyunkwan University,
Republic of Korea

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Recently, one of the emerging topics in biotechnology is sensors related to human cognition. The mechanism of the human recognition is to understand the relationship between natural human receptors and nerve transmission. However, there are little researches for mimicking human six senses with natural receptors. Therefore, in this group, we have designed natural human receptor-conjugated receptonics which is combined to electronics and receptors. We have developed essential component technologies: natural receptor nanodisc, graphene field-effect-transistor, interfacing chemistry and signal conversion PCB board. We have designed various human mimicking devices such as nanobioelectrnic nose, tongue and eyes. Especially, we are recently demonstrating new concept with receptonics-related to neurotransmitter for human recognition, so we called artificial human eyes.

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Doug Weber, PhD

Akhtar and Bhutta Professor
Department of Mechanical Engineering and
The Neuroscience Institute
Carnegie Mellon University

Doug Weber is the Akhtar and Bhutta Professor of Mechanical Engineering and Neuroscience at Carnegie Mellon University. Dr. Weber received a Ph.D. in Bioengineering from Arizona State University and completed post-doctoral training in the Centre for Neuroscience at the University of Alberta. His primary research area is Neural Engineering, combining fundamental neuroscience and medical device engineering to understand the neural basis of sensory perception, motor control, and neuroplasticity and drive the development of neurotechnologies for restoring sensorimotor functions in patients. A founding member of DARPA's Biological Technologies Office, Weber created and managed a portfolio of neurotechnology research programs to support the White House BRAIN initiative, launched by President Obama in 2013. At CMU, he is co-director of the NeuroMechatronics Laboratory, which is a highly multidisciplinary group of students, post-docs and faculty working on projects spanning fundamental and applied studies in animals and translational research in humans. He is also a founder and Chief Technology Officer of Reach Neuro, Inc., a medical device startup developing a novel therapy for restoring arm and hand function for people with chronic hemiplegia post-stroke.

Doug Weber

| Abstract

Sensing and stimulating the brain to restore neurological function

Doug Weber
Mechanical Engineering and The Neuroscience Institute,
Carnegie Mellon University

Significant advances in materials and microelectronics over the last decade have enabled clinically relevant technologies that measure and regulate neural signaling in the brain, spinal cord, and peripheral nerves. These technologies provide new capabilities for studying basic mechanisms of information processing and control in the nervous system, while also creating new opportunities for restoring function lost to injury or disease. Neural sensors can also measure the activity of motor neurons to enable direct neural control over prosthetic limbs and assistive technologies. Conversely, these neural interface technologies can stimulate activity in sensory and motor neurons to reanimate paralyzed muscles. Although many of these applications rely currently on devices that must be implanted into the body for precise targeting, ultra-miniaturized devices can be injected through the skin or vascular system to access deep structures without open surgery. This talk will focus on efforts to develop wearable and injectable neural interfaces for restoring or improving motor function in people with paralysis due to stroke, spinal cord injury, ALS, and other neurological disorders.

Prof. Youngbin Tchoe

Ulsan National Institute of Science and Technology (UNIST), Republic of Korea

Youngbin Tchoe is an Assistant Professor in the Department of Biomedical Engineering at the Ulsan National Institute of Science and Technology (UNIST), Republic of Korea. He received his Ph.D. in Physics from Seoul National University, working in Prof. Gyu-Chul Yi's lab, where he focused on semiconductor optoelectronic devices. From 2018 to 2023, he was a Postdoctoral Researcher at the Integrated Electronics and Biointerfaces Laboratory at UC San Diego under the guidance of Prof. Shadi Dayeh. During this time, he spearheaded the development of high-channel, high-density brain interface devices using novel materials and fabrication techniques. Dr. Tchoe has authored or co-authored numerous publications in the fields of biointerface and semiconductor devices. He is dedicated to advancing brain-machine interface technology through new approaches and interdisciplinary collaboration.

Youngbin Tchoe

| Abstract

Electrocorticography microdisplay for high precision intraoperative brain mapping

Youngbin Tchoe[1,2], Tianhai Wu[2], Hoi Sang U[2], David M. Roth[2], Dongwoo Kim[2], Jihwan Lee[2], Daniel R. Cleary[2,3], Patricia Pizarro[2], Karen J. Tonsfeldt[2,3], Keundong Lee[2], Po Chun Chen[2], Andrew M. Bourhis[2], Ian Galton[2], Brian Coughlin[4], Jimmy C. Yang[4,5], Angelique C. Paulk[4], Eric Halgren[2], Sydney S. Cash[4], Shadi A. Dayeh[2*]

[1] UNIST, Republic of Korea
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Functional mapping during brain surgery is crucial for identifying and preserving brain regions responsible for vital functions while removing pathological tissues. Traditionally, these procedures rely on verbal interactions between the neurosurgeon and electrophysiologist, leading to inefficiencies in making surgical decision. Moreover, the electrode grids used for measuring brain activity and delineating pathological from functional brain regions suffer from low resolution and poor conformality to the brain surface.

This presentation introduces an intracranial electroencephalogram (iEEG)–microdisplay, featuring freestanding arrays of 2048 GaN micro light-emitting diodes (micro-LEDs) laminated on the back of 1024-channel micro-electrocorticography (ECoG) grid. [1, 2] Through a series of experiments conducted in rat and pig models, we demonstrate that these iEEG-microdisplays enable real-time, high-resolution recording and display of cortical activities by showing spatially corresponding light patterns directly on the brain's surface.

Additionally, the iEEG-microdisplay effectively identified and visualized cortical landmarks and pathological activities. Using a dual-color iEEG-microdisplay, we successfully co-registered functional cortical boundaries with one color while visualizing the propagation of epileptiform activities with another color. These findings suggest that iEEG-microdisplay has significant potential to enhance the monitoring of pathological brain activity in clinical settings.

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Dr. Sameer Sonkusale

Professor
Electrical and Computer Engineering, Tufts University

Sameer Sonkusale is a Professor of Electrical and Computer Engineering at Tufts University, where he holds joint appointments in the departments of Biomedical Engineering and Chemical and Biological Engineering. He also served as a visiting professor at the Wyss Institute at Harvard University and Brigham and Women's Hospital of the Harvard Medical School during 2011-2012 and 2018-2019, respectively. He currently directs an interdisciplinary research group focusing on devices, circuits, and systems for healthcare, biology, life sciences, and the environment. Dr. Sonkusale earned his MS and PhD in Electrical Engineering from the University of Pennsylvania and has received several awards, including the National Science Foundation CAREER award in 2010. He was also honored with a Distinguished Alumni award from his alma mater, BITS Pilani. Dr. Sonkusale is an alumnus of the National Academy of Engineering US Frontiers of Engineering meeting in 2015, and the National Academy of Sciences Arab-America Frontiers meeting in 2014 and 2016. Dr. Sonkusale serves on the editorial boards of several prominent journals, including Scientific Reports (Nature Publishing Group), IEEE Transactions on Biomedical Circuits and Systems, PLoS One, and Electronic Letters. He is a senior member of the IEEE and a member of OSA, MRS, BMES, and AAAS.

Dr. Sameer
Sonkusale

| Abstract

Sustainable Point of Care Diagnostics for Human Health and Wellness

Sameer Sonkusale
Electrical and Computer Engineering, Tufts University

This talk will explore the new realm of making sensors for point of care monitoring of human health and wellness. Issues of sustainability, equity and access is addressed by using low cost materials such as paper, threads and textiles as substrates to make these sensors. These materials offer unique advantages of universal availability, low cost, material diversity and simple ambient processing. They also provide an ideal platform for passive microfluidic sampling and analysis needed for point of care testing. Some examples to be discussed relevant to the theme of the workshop include (1) smart threads for monitoring electrolyte and metabolites in sweat capable of monitoring fatigue (2) Saliva diagnostics using sensing strips and dental floss for monitoring stress (3) Monitoring inflammatory cytokine level in biological fluid using an instrument-free assay. The talk will also provide a roadmap of the development for such sensors and their potential significance.

Professor Jiwon Lee

POSTECH, Republic of Korea

Jiwon Lee received his Ph.D. degree from the Department of Electrical Engineering at the Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea, in 2013. From 2013 to 2018, he served as a senior researcher at Samsung Electronics in Yongin, South Korea. Between 2018 and 2022, he was a Principal Member of Technical Staff at imec, Leuven, Belgium. From 2022 to 2023, he was an associate professor in the Department of Photonics and Nanoelectronics at Hanyang University (ERICA Campus). Since 2024, he has been an assistant professor in the Department of Semiconductor Engineering at POSTECH. He has also been a guest professor at imec, Leuven, since 2023, focusing on topics related to novel image sensors. His research interests include the development of innovative image sensor pixels for various applications.

Jiwon Lee

| Abstract

Image sensing technologies, challenges and vision

Jiwon Lee[1,2]

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[2]IMEC, Belgium
E-mail address: jiwonlee@postech.ac.kr

Image sensors have become an integral part of modern technology, embedded in a vast array of devices and applications. Over the past few decades, continuous advancements have significantly refined image sensor technology, allowing state-of-the-art imagers to approach the theoretical limits of classical photography. These innovations have not only enhanced the quality and performance of traditional imaging but have also paved the way for new possibilities in the field.

The evolution of information processing has played a crucial role in expanding the capabilities of image sensors. What was once limited to capturing images in visible light has now broadened to encompass a variety of wavelengths, including near-infrared (NIR) and short-wave infrared (SWIR). These developments have opened up new avenues for information gathering in fields such as scientific research, medical diagnostics, security, and industrial applications, where the ability to capture images beyond the visible spectrum offers significant advantages.

This presentation provides a comprehensive overview of the current trends in image sensor development, beginning with a fundamental explanation of their operating principles. We will delve into the key factors that have driven these advancements, such as improvements in sensor materials, design innovations, and the integration of advanced processing techniques. Additionally, we will explore some of the most recent breakthroughs in NIR and SWIR image sensors, highlighting their potential impact on various industries and the future direction of image sensor technology.

Josh Hihath

Center for Bioelectronics and Biosensors
School of Electrical, Computer, and Energy Engineering
Arizona State University

Josh Hihath is a Professor in the School of Electrical, Computer, and Energy Engineering and Director for the Biodesign Institute Center for Bioelectronics and Biosensors at Arizona State University. He was previously a professor and Vice Chair for Undergraduate Studies in the Department of Electrical and Computer Engineering at the University of California, Davis. Prior to moving to UC Davis he was a research professor and lab manager at ASU. Dr. Hihath received a B.S. in Electrical Engineering from Kettering University in Flint, Michigan, and M.S. and Ph.D. degrees in Electrical Engineering from Arizona State University. Prof. Hihath is a Senior Member of the IEEE, was recently awarded the UC Davis Graduate Mentoring and Advising award and is an alum of the UC Davis Faculty Leadership Academy. Josh's work is centered at the nexus of engineering, chemistry, biology, and physics, and focuses on understanding the electrical and mechanical properties of nanoscale and molecular systems for applications in electronics, sensing, and health-care.

Josh Hihath

| Abstract

Integration of Biomolecular Electronic Devices and Sensors

Josh Hihath

Center for Bioelectronics and Biosensors
School of Electrical, Computer, and Energy Engineering
Arizona State University

In recent years incredible strides have been made in the development of molecular electronic systems that possess unique functionality. By combining chemical design with physical modeling and electrical characterization techniques it has become clear that molecules are capable of a wide range of impressive electronic functions that extend far beyond the development of standard devices such as transistors and diodes. An array of electromechanical, electrochemical, thermoelectric, and quantum devices now provide promise for memory devices, sensors, and multi-state logic units which could yield new paradigms for in-memory computing, various post von Neumann architectures, or for chemical and biological sensing systems. But, despite these possibilities, one of the major issues that arose in the nascent days of molecular electronics still lingers and limits its ultimate utility. That issue is integration. Despite a wide range of unique devices, and novel chemical and physical properties, it has remained difficult to integrate these materials into a larger-scale system in a way that is reliable, reproducible, and eventually manufacturable. In this talk we will discuss emerging approaches aimed at integrating and characterizing molecular-scale electronic systems to move them from the lab and into applications. We will discuss approaches for integrating top-down lithographic approaches with bottom-up self-assembly methods to make secure and robust covalent contacts to a single-molecule using carbon nanotubes to allow facile integration with traditional photolithographic processes, as well as the use of combined opto-electronic characterization techniques to examine structure-transport relations at the single-molecule level.

Appendix

Brain pool program
by the National Research Foundation of Korea

The Chance for Developing R&D Career in Korea

Brain Pool & Brain Pool Plus

What is Brain Pool (BP) & Brain Pool Plus (BP+)?

- ✓ **Brain Pool(BP)** Inviting overseas researchers for Max. 3 years to Korean institutions
- ✓ **Brain Pool Plus(BP+)** Inviting overseas researchers to Korean Institutions as Tenure

Who is eligible for the program?

- ✓ Researchers in Science and Technology field
- ✓ Ph.D. Holder who is living overseas(If you are invited to universities and research institutions)
- ✓ Ph.D. Holder who is living overseas or who have more than 5 years of onsite R&D experience in the industry regardless of Ph.D. (If you are invited to companies)

Supporting items

Brain Pool

- ✓ 12 months ~ 3 years (~2026.12.31.)
- ✓ Personnel Cost
  (Up to 300 million KRW per year /About 210,000 EUR per year)
- ✓ Cost for Relocation (Airfare etc.)
- ✓ Housing allowance
- ✓ Subsidies for Child Education
- ✓ Extra Funding for Research Activities
  (conference, buying materials for experiments, etc.)

Brain Pool Plus

- ✓ Max. 10 years(4+6)
- ✓ Should be employed as tenure
- ✓ Up to 600 million KRW per year including below items
  (About 425,000 EURO per year)
  - ･Personnel Cost
  - ･All items in Brain Pool
  - ･Student Personnel Costs
  - ･Facility & Equipment Costs
  - ･Material Costs
  - ･Research allowances

How to apply?

1. Find Host institution and Host PI in Korea
2. Agreement with Host PI about Research plan
3. Apply Through Host PI with proposal (www.iris.go.kr)

✓ If you need any help for finding Host PI in Korea, please access RPIK(rpik.or.kr) that has list of Korean research labs!

Schedule of 2024 BP and BP+

Check below QR for more information!

- ✓ **Announcement** 2023 December
- ✓ **Application** 2023 December ~ 2024 May
- ✓ **Selection** (1st call) April / (2nd call) July
- ✓ **Implementation** the 1st of month (after entrance)

･Inviting researchers should enter into Korea before the end of each year

BP & BP+

which invites outstanding overseas researchers in S&T to Korea

Niko Hildebrandt
BP fellow
In Seoul National University

"The Brain Pool Program allows me to collaborate with one of the top international research labs in nanoplasmonics at Seoul National University"

The Brain Pool Program allows me to collaborate with one of the top international research labs in nanoplasmonics at Seoul National University (SNU) and to work on very challenging science that requires the expertise of both my own and my host's research group. My direct implementation at SNU for 28 months is ideal for initiating and fostering collaborations with different researchers in South Korea and establishing long-lasting and successful international networks with broad visibility. Here, I can directly work with and teach students from the host group while, at the same time, discovering the South Korean way of research and education.

Through the Brain Pool Program, my family and myself have the unique opportunity to live in the beautiful and vibrant city of Seoul, to discover many interesting places in South Korea, to embrace Korean culture and learn Hangeul, and to make many new friends. A truly great experience for life and learning. Merci beaucoup!

Simona Georgieva
BP fellow
In Chungbuk National University

"It is a huge honor and responsibility to be a BP fellow. The program enabled me to pursue my research interests and increased the scope of my competences."

It is a huge honor and responsibility to be a BP fellow. The program enabled me to pursue my research interests and increased the scope of my competences. The project not only gave me essential scientific freedom to establish my own research line but also boost my career via exceptional training opportunities.

The funding is crucial and provided the necessary creative freedom to pursue my own research goals and offered me new opportunities for career development via implementing research that would otherwise be difficult to complete. Thanks to BP, I significantly expanded my network of research collaborations that further my research, and which I consider a key factor for my future career.

Il-Hwan Kim
Senior Research Scientist,
Korea Research Institute of Standards and Science,

"As a Korean-American, my lifetime goal was to pursue a research career in Korea, and the Brain Pool program made that possible."

As a Korean-American, my lifetime goal was to pursue a research career in Korea, and the Brain Pool program made that possible. Working overseas seemed like an impossible task at first but the support provided by the BP program helped me to connect with the research institution in Korea, and gave me courage to make the first step toward the goal.

I participated in the KRF(now the BP) program from 2019 to 2020 at Korea Research Institute of Standards and Science. After one year of valuable work experience at KRISS, I decided to further my research career in Korea, and now I am hired as a senior research scientist at my host institution. I strongly encourage scientists from overseas to join the program and gain an exciting research (and life!) experience in Korea.

Brain Pool (BP)
Brain Pool Plus (BP+)

2024

RPiK (Research Position in Korea, rpik.or.kr)

Recruitment matching platform that supports overseas researchers who are seeking jobs and research institutions in Korea to hire outstanding researchers

■ Current membership status

*As of November 2022

- About 364 overseas researchers
- About 406 Korean research institutions
- Lots of job postings uploaded
- Many applications in process

■ Target

- Overseas researchers looking for research institutions in Korea or Research institutions/researchers in Korea that need matching with overseas researchers
- Overseas researchers who want to get a job in Korea or Research institutions/researchers in Korea ready for recruiting overseas researchers

■ Member type

Laboratory Member

(Research labs in Korea)

- Information of laboratory such as records of academic writing and equipment, etc.
- Upload and manage recruitment notifications
- Check the list of overseas researchers
- Set applicants' status and interview schedule

Individual Member

(Overseas Researchers)

- Upload resumes and select desired employment conditions
- Apply 24/7, all year round
- Customized job recommendations according to the applicants' expertise and experiences
- 1:1 Q&A with each laboratory

Brain Pool (BP) Program

Strengthen domestic R&D capabilities and establish an international cooperation network by inviting overseas researchers to Korea

■ Eligible BP Candidates

Overseas residing researchers who hold a Ph.D or (corporate or corporate-affiliated research institute) who have more than 5 years of onsite R&D experience in the industry regardless of a Ph.D

※ **Korean residents abroad, overseas Koreans are also eligible**

Quota for 2024 : **Approx. 86 projects**

■ Details of Support

Research Period	Direct Cost			Indirect Cost
	Personnel Costs	Research Activities Costs	Research Material Costs	
1~3 years	**Min. 5 ~Max. 25 mil KRW per month** ※ Based on the annual salary of the original affiliation of BP fellow	Housing allowance*, airfare, insurance premiums, relocation costs, subsidies for children's education, other direct costs for inviting BP fellows**	**Max. 1 mil KRW for research materials**	**50% of notification rate for host institution** ※ Including subsidies(50%) for assistant staff

* 1 million KRW/month of housing allowance will be supported.

** Other direct costs for inviting BP fellows : Korean language course fee, costs for quarantine(COVID-19), visa issuance fee, etc.

※ In case of corporate and corporate-affiliated research institute, only 50-75% of funding will be offered. (Following National Research and Development Innovation Act of Korea)

※ Details and standards of support will be announced through the separate guidelines for the program.

※ Principal Investigator should be the host researcher from the host institution in Korea and overseas researcher should be the participating researcher.

■ Application Period

Number of call	Application Submission Period
1st Call	Dec. 29th(Fri) 2023 ~ Feb. 29th(Thu) 18:00:00 (KST) 2024
2nd Call	Mar. 11th(Mon) 2024 ~ May. 31st(Fri) 18:00:00 (KST) 2024

* The schedule above is subject to change according to circumstances

Brain Pool Plus (BP+) Program

Securing new growth engine and promoting innovative growth by employing outstanding overseas researchers as full-time researchers in Korean institutions

■ Eligible BP Candidates

Overseas residing researchers who hold a Ph.D or (corporate or corporate-affiliated research institute) who have more than 5 years of onsite R&D experience in the industry regardless of a Ph.D

※ **Korean residents abroad, overseas Koreans are also eligible**

Quota for 2024 : **Approx. 2 projects**

■ Details of Support

Research Period	Direct Costs					Indirect Costs
	Personnel Costs	Research Activities Costs	Student Personnel Costs	Facility·Equipment Costs	Others	
10years (4+6)	(Principal Investigator) More than the level of full-time employee's personnel costs Personnel costs for participating researcher (postdoc, etc.)	Invitation supporting expenses (invitation grant*, housing allowance**) initial costs of setting up a laboratory, airfare, insurance premiums, relocation costs, subsidies for children's education, other direct costs for inviting BP fellows***	Personnel costs for student researcher	Facility·equipment buying·setting/ operation·maintenance costs, rent, research infrastructure costs	Material costs, research allowances, etc.	5%
	Up to a total of 600 million KRW per year					

* The amount of invitation grant will be decided through arrangement between host institution and invited researcher and it should be more than invited researcher's salary at the original affiliated institution.
** 1 million KRW/month of housing allowance will be supported.
*** Other direct costs for inviting BP fellows : Korean language course fee, costs for quarantine(COVID-19), visa issuance fee, etc.
※ ① In case of corporate and corporate-affiliated research institute, only 50-75% of funding will be offered. (Following National Research and Development Innovation Act of Korea)
② After the final selection, details of support may change at the submission of agreement or when signing the agreement due to the possible changes of the policy or circumstances.
※ At the application stage, Principal Investigator should be a personnel department head(dean of academic affairs, head of faculty personnel department, department dean, etc.), overseas researcher should be the participating researcher. After the final selection, overseas researcher must be switched to Principal Investigator.

■ Application Period

Number of call	Application Submission Period
1st Call	Dec. 29th(Fri) 2023 ~ Feb. 29th(Thu) 18:00:00 (KST) 2024
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