YES 2025 YONSEI ENGINEERING SYMPOSIUM

March 23 (Sun) – 25 (Tue), 2025

The Commons, Yonsei University, Korea (연세대학교 백양누리)

Abstract Book

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연세대학교 기계공학과 사회지향 기계기술 글로벌 리더 양성 교육연구단
연세대학교 신소재공학과 인간중심 미래선도 소재 교육연구단
연세대학교 전기전자공학과 글로벌 융합기술 미래인재 교육연구단
연세대학교 화공생명공학과 사회지향 글로벌 초격차 화공인재양성 교육연구단

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YONSEI UNIVERSITY | 140 YONSEI 140th ANNIVERSARY

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Abstract Book

Pleanary Speakers

Mar 24 (Mon), 2025 I Grand Ballroom

09:20 ~10:00
George Gregory Malliaras
University of Cambridge, UK
Materials and Devices for Bioelectronic Medicine

10:20 ~ 11:00
Jun Zhang
HKUST, Hong Kong
Foundation Models for Wireless Communications: From WirelessLLM to WirelessAgent

11:00 ~ 11:40
Atsuo Yamada
The University of Tokyo, Japan
Toward Sustainable and Safe Batteries

Mar 25 (Tue), 2025 I Grand Ballroom

13:30 ~ 14:10
Liwei Lin
UC Berkeley, USA
Intelligent Sensor/Actuator for Human-Machine Interfaces

14:10 ~ 14:50
Jungho Hwang
Yonsei University, Korea
Detection of Virus Aerosols via Air Sampling and PCR Analysis, for the Post-COVID-19 Era

YONSEI UNIVERSITY | YONSEI 140th ANNIVERSARY

YES2025 Secretariat Tel. 042-489-7070 E-mail. yes2025@themiceter.com

Welcome Message

We are delighted to welcome you to YES2025. This symposium serves as a meaningful platform where experts, researchers, and students from diverse fields come together to exchange cutting-edge knowledge and foster collaboration. In an era of rapid change, academic exchange and technological innovation are essential, and gatherings like this play a pivotal role in shaping the future.

At Yonsei University, we remain committed to advancing the frontiers of scholarship and research while cultivating the next generation of leaders. We hope this symposium provides you with valuable opportunities for intellectual and professional growth, inspiring insightful discussions and meaningful connections that lead to new possibilities.

We sincerely appreciate your enthusiastic participation and dedication, and we wish you a successful and inspiring symposium. Thank you.

Chungyong Lee
Dean, College of Engineering
Yonsei University

Committee

* All committee members affiliated with Yonsei University

Co-Chairs, Organizing Committee


Sang-Young Lee


Cheolmin Park


Won Woo Ro


WonHyoung Ryu

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Chulmin Joo


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Chemical & Biomolecular Engineering | Electrical & Electronic Engineering | Materials Science and Engineering | Mechanical Engineering

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Materials Science and Engineering


Yeonsik Choi


Hongkyung Lee


Jang-Ung Park

Mechanical Engineering


Hae-Jin Kim


Wonjung Kim


Woochul Kim

Invited Speakers

March 24 (Mon), 2025

Jake Lah Hall (B147)

Bioelectronics


13:30~14:00
Shabir Hassan
Khalifa University, UAE


14:00~14:30
Jayoung Kim
Yonsei University, Korea


14:30~15:00
Sunghoon Lee
University of Tokyo, Japan


15:00~15:30
Haeryung Lee
Wiley, USA

Bio-mechanics


15:45~16:15
Jae-Sang Hyun
Yonsei University, Korea


16:15~16:45
Yoshiyuki Tagawa
TUAT, Japan


16:45~17:15
Jinkee Lee
SKKU, Korea


17:15~17:45
Hoe Joon Kim
DGIST, Korea

Kwak Joung-Hwan Challenge Hall (B146)

Communication Technology


13:30~14:00
Kaiming Shen
CUHK, China


14:00~14:30
Jeonghun Park
Yonsei University, Korea


14:30~15:00
Jinseok Choi
KAIST, Korea


15:00~15:30
Jemin Lee
Yonsei University, Korea

Bioelectronics


15:45~16:15
Changsheng Wu
NUS, Singapore


16:15~16:45
Yeonsik Choi
Yonsei University, Korea


16:45~17:15
Sanggil Han
Incheon National University, Korea


17:15~17:45
Jang-Ung Park
Yonsei University, Korea

Industrial Bank of Korea Hall (B145)

Environmental and Membranes


13:30~14:00
Zhiping Lai
KAUST, Saudi Arabia


14:00~14:30
Dae Woo Kim
Yonsei University, Korea


14:30~15:00
Tae-Hyun Bae
KAIST, Korea


15:00~15:30
Jong Suk Lee
Sogang University, Korea

Energy Storage


15:45~16:15
Yuzhang Li
UCLA, USA


16:15~16:45
Kyung-Wan Nam
Dongguk University, Korea


16:45~17:15
Hyun-Wook Lee
UNIST, Korea


17:15~17:45
Junghwan Kim
Yonsei University, Korea

March 25 (Tue), 2025

Jake Lah Hall (B147)

Medical-mechanics


10:00~10:30
Beomjoon Kim
The University of Tokyo, Japan


10:30~11:00
Liangcai Cao
Tsinghua University, China


11:00~11:30
Sungwook Yang
KIST, Korea


11:30~12:00
Zijian Zheng
PolyU, Hong Kong

Kwak Joung-Hwan Challenge Hall (B146)

Nanoelectronics


10:00~10:30
Sang-Hoon Bae
WashU, USA


10:30~11:00
Han Wang
University of Hong Kong, Hong Kong


11:00~11:30
Youngmin You
Yonsei University, Korea


11:30~12:00
Sooyeon Cho
SKKU, Korea

Industrial Bank of Korea Hall (B145)

Energy Storage


10:00~10:30
Yong-Ning Zhou
Fudan University, China


10:30~11:00
Seongmin Bak
Yonsei University, Korea


11:00~11:30
Yong Min Lee
Yonsei University, Korea

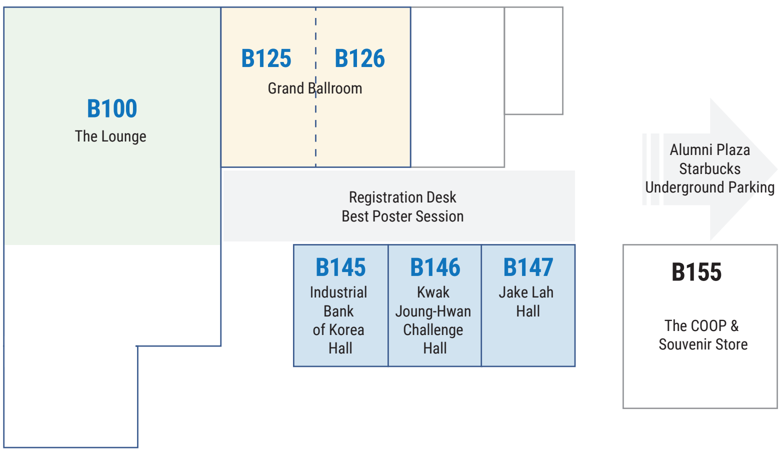

11:30~12:00
Dong-Hwa Seo
KAIST, Korea

Program

Date	Time	Program		
March 23(Sun)	16:00-18:00	Registration		
	18:00-	Welcome Reception		
March 24(Mon)	09:00-09:05	Opening Ceremony		
	09:05-09:15	Welcome Address		
	09:15-09:20	Group Photo		
	09:20-10:00	Plenary Lecture I - George Malliaras (University of Cambridge, UK)		
	10:00-10:20	Coffee Break		
	10:20-11:00	Plenary Lecture II - Jun Zhang (HKUST, Hong Kong)		
	11:00-11:40	Plenary Lecture III - Atsuo Yamada (University of Tokyo, Japan)		
	11:40-13:30	Lunch ※ Invited Only		
	13:30-15:30	Invited Talks (Parallel Sessions) & Special Session (Meeting with Editor)		
		Bioelectronics	Communicatin Technology	Environmental and Membranes
	15:30-15:45	Coffee Break		
	15:45-17:45	Invited Talks (Parallel Sessions) & Special Session (Meeting with Editor)		
		Bio-mechanics	Bioelectronics	Energy Storage
	17:45-18:00	Break		
	18:00-20:00	Banquet		
March 25(Tue)	09:00-10:00	Best Poster Session & Coffee Break		
	10:00-12:00	Invited Talks (Parallel Sessions) & Special Session (Meeting with Editor)		
		Medical-mechanics	Nanoelectronics	Energy Storage
	12:00-13:30	Lunch ※ Invited Only		
	13:30-14:10	Plenary Lecture IV - Liwei Lin (UC Berkeley, USA)		
	14:10-14:50	Plenary Lecture V - Jungho Hwang (Yonsei University, Korea)		
	14:50-15:10	Award & Closing		
	15:10-15:20	Break		
	15:20-18:20	Tour (Changdeokgung Palace, Bukchon Hanok Village) ※ Invited Only		
	18:20-20:20	Dinner ※ Invited Only		

※ Special Session: Closed Session

Venue



B125+B126 **Grand Ballroom**
Opening, Plenary Lecture, Banquet, Award & Closing

B147 **Jake Lah Hall**
Invited Talk (Session 1)

B146 **Kwak Joung-Hwan Challenge Hall**
Invited Talk (Session 2)

B145 **Industrial bank of Korea Hall**
Invited Talk (Session 3)

Lobby Registration Desk, Best Poster Session

Registration Fee ※ only credit card

Participant Category	Overseas	Domestic
Regular	USD 300	KRW 450,000
Student	USD 100	KRW 150,000

Coffee Break

MAR. 24	10:00~10:20 / 15:30~15:45
MAR. 25	09:00~10:00

Banquet

MAR. 24	18:00~20:00
Grand Ballroom	

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- Bioelectronics (2)
- Bio-mechanics
- Communication Technology
- Environmental and Membranes
- Energy Storage (1)
- Energy Storage (2)
- Medical-mechanics
- Nanoelectronics

03 Poster Session

- Chemical & Biomolecular Engineering
- Electrical & Electronic Engineering
- Materials Science and Engineering
- Mechanical Engineering

01
Plenary Lectures

Materials and Devices for Bioelectronic Medicine

George Malliaras
University of Cambridge

Neurological conditions affect one in six people, imposing significant health, economic and societal burden. Bioelectronic medicine aims to restore or replace neurological function with the help of implantable electronic devices. Unfortunately, significant technological limitations prohibit these devices from reaching patients at scale, as implants are bulky, require invasive implantation procedures, elicit a pronounced foreign body response, and show poor treatment specificity and off-target effects. Over the past decade, novel materials and fabrication methods inspired from the microelectronics industry have been shown to overcome these limitations. Recent literature provides powerful demonstrations of thin film implants that are miniaturised, ultra-conformal, stretchable, multiplexed, integrated with different sensors and actuators, bioresorbable, and minimally invasive. I will discuss the state-of-the-art of these new technologies and the barriers than need to be overcome to reach patients at scale.

George Malliaras is the Prince Philip Professor of Technology at the University of Cambridge (UK). Before joining Cambridge, he was a faculty member at Cornell University (USA), and School of Mines of St. Etienne (France). George's research on bioelectronics has been recognized with awards from the European Academy of Sciences, the Materials Research Society, the New York Academy of Sciences, the US National Science Foundation, and DuPont. He received an Honorary Doctorate from the University of Linköping (Sweden) and is Fellow of the Royal Society, the Materials Research Society, Academia Europaea and the European Academy of Sciences.

Foundation Models for Wireless Communications: From WirelessLLM to WirelessAgent

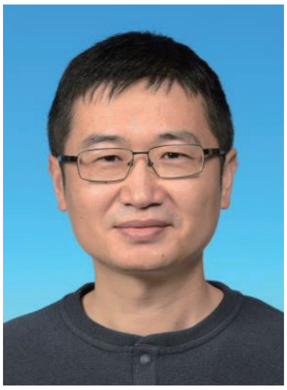
Jun Zhang
HKUST

Abstract

Foundation models, such as large language models (LLMs), deep generative models, and vision-language models (VLMs), have emerged as powerful tools for various applications. In this talk, we will explore the exciting potential of foundation models in revolutionizing wireless communications and networking. Starting with a brief overview of recent developments in foundation models, we will present key requirements and methodologies to develop large language models for wireless communications. Then we will introduce WirelessLLM as a new framework to apply LLMs to wireless communications, illustrated with use cases including spectrum sensing, power control, and protocol understanding. Furthermore, we will present an AI agent for wireless networks, named as WirelessAgent, which can automatically assist network management and optimization. Finally, we will discuss a roadmap towards developing multi-modality wireless foundation models.

Bio:

Jun Zhang received his Ph.D. degree in Electrical and Computer Engineering from the University of Texas at Austin. He is an IEEE Fellow and an IEEE ComSoc Distinguished Lecturer. He is an Associate Professor in the Department of Electronic and Computer Engineering at the Hong Kong University of Science and Technology. His research interests include wireless communications and networking, mobile edge computing and edge AI, and cooperative AI. He is a co-recipient of several best paper awards, including the 2021 Best Survey Paper Award of IEEE Communications Society, the 2019 IEEE Communications Society & Information Theory Society Joint Paper Award, and the 2016 Marconi Prize Paper Award in Wireless Communications. He also received the 2016 IEEE ComSoc Asia-Pacific Best Young Researcher Award. He is an Area Editor of IEEE Transactions on Wireless Communications and IEEE Transactions on Machine Learning in Communications and Networking.



Toward Sustainable and Safe Batteries

Atsuo Yamada
The University of Tokyo

Rechargeable batteries have ushered the wireless revolution over last two decades and are now matured to enable green automobiles. The current generation Li-ion batteries employ oxides such as $Li(Ni,Mn,Co)O_2$ and olivine $LiFePO_4$ as cathodes. However, the growing concern on scarcity and large-scale applications of Li-resources have steered effort to realize sustainable sodium-ion batteries, Na and Fe being abundant and low cost charge-carrier and redox center. In this pursuit, numerous Fe-based cathode compounds capable of efficient Na (de)insertion have been reported. However, their performance is limited owing to low operating voltage and sluggish kinetics. We have identified a hitherto-unknown $Na_2Fe_2(SO_4)_3$ with Alluaudite structure, registering the highest ever Fe^{3+}/Fe^{2+} redox potential at 3.8 V (vs. Na) along with very fast rate kinetics, leading to competitive energy density with lithium battery with $LiFePO_4$ cathodes.

The increasing energy density and size requirements has necessitated establishing reliable safety technologies for rechargeable batteries. In particular, understanding and controlling thermal runaway, an uncontrollable heat generation from continuous exothermic reactions in batteries, is essential to develop high-safety batteries. However, comprehensive safety evaluations at the full-cell level are limited by size requirements (greater than the ampere-hour scale) for performing accelerating rate calorimetry (ARC) tests that can provide critical information on heat generation during thermal runaway. Further, efficient safety screening is difficult because of the use of substantial quantities of battery materials and costly manufacturing processes. In this study, we designed cylindrical-pouch-type small batteries (~21 mAh, ~0.1 g of cathode active materials) that are highly susceptible to heat generation, thus allowing to perform full-cell-level ARC tests on a laboratory scale. This enables rapid safety screening and early-stage feedback for battery design, which can help accelerate the development of high-safety batteries.

Intelligent Sensor/Actuator for Human-Machine Interfaces

Liwei Lin
James Marshall Wells Distinguished Professor, Department of Mechanical Engineering
Co-Director, Berkeley Sensor and Actuator Center (BSAC)
University of California
Berkeley, California 94720 USA
E-mail: lwlin@berkeley.edu

Leveraging from core MEMS (Microelectromechanical Systems) techniques in microfabrication and nanotechnology, my group has been working on micro/nano sensors and actuators toward practical applications. In this talk, I will present 6 main research results related to for human-machine interfaces. In the area of personalized health by wearable systems, a piezoelectric pulse detector is developed to sense human pulse for health monitoring which emulates the concept of traditional Chinese Medicine practices. In the second area, I will discuss our efforts in using graphene to make a transistor for gas detection in cell phone applications. The third topic is the development of flexible mechanical actuators as haptic feedback stimulations in applications such as AR/VR and robotics. Forth, I will discuss the development of piezoelectric micromachined ultrasonic transducers (pMUTs) with various applications, such as sensing temperature, flow, blood pressure … In the fifth area, my group has been working on microfluidic devices and some of the biomedical applications will be introduced. The sixth topic is energy generation and storage systems, such as energy harvesters, supercapacitors, and batteries. Finally, I will also introduce some fun robotics projects, such as an ultra-robust and fast moving piezoelectric robot similar to those of cockroaches and the smallest untethered flying robot driving in a magnetic field.

Biographical Sketch

Professor Liwei Lin is the James Marshall Wells Distinguished Professor at the Mechanical Engineering Department and Co-Director at Berkeley Sensor and Actuator Center (BSAC) at UC Berkeley. His research interests are in design, modeling, and fabrication of micro/nano structures; sensors and actuators; as well as mechanical issues in micro/nano systems including heat transfer, solid/fluid mechanics, and dynamics. Dr. Lin is the recipient of the 1998 NSF CAREER Award for research in MEMS Packaging and the 1999 ASME Journal of Heat Transfer best paper award for his work on micro scale bubble formation. He led the effort to establish the MEMS division in ASME and served as the founding Chairman of the Executive Committee from 2004~2005. He is an ASME Fellow and has 23 issued US patents in MEMS. He was the general co-chair of the 24th IEEE international conference on Micro Electro Mechanical Systems at Cancun, Mexico. He serves as associate editor for Microsystems & Nanoengineering published by the Nature group.

Detection of virus aerosols via air sampling and PCR analysis, for the post-COVID-19 era

Jungho Hwang

School of Mechanical Engineering, Yonsei University, Korea

Jungho Hwang is a Professor at the School of Mechanical Engineering, Yonsei University, Korea. He received the BS degree and MS degree in the Department of Mechanical Engineering of the Seoul National University, Seoul, Korea, in 1983 and 1985, respectively, and the PhD degree in ME Dept. of the University of California, Berkeley in 1991. He worked at the CU (University of Colorado, Boulder) combustion research center as a researcher from Feb. 1989 to Feb. 1993. He then joined the Yonsei University in March 1993, where he is currently a professor of the School of Mechanical Engineering.

He has been served as Editor of Aerosol and Air Quality (AAQR) Journal, Editor of J. Mechanical Science and Technology (JMST), and Editorial Board Member of J. Aerosol Science (JAS). He has been a member of The Korean Academy of Science and Technology (KAST) and was the President of Korean Association for Particle and Aerosol Research (KAPAR).

His research interests include a variety of aerosol technologies such as fabrication and deposition control of functional nanoparticles, real-time detection and inactivation of bio-aerosols. He is also interested in non-thermal plasma technology for air cleaning and fuel reforming.

Abstract

Viruses (20-150 nm) can be suspended in the air longer than three hours. The airborne transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been officially recognized by the WHO and the US CDC in enclosed indoor spaces occupied by a large number of people, particularly in the absence of ventilation and air filtration. The airborne viruses also directly affect the infectious diseases of animals, such as avian and swine flu that lead enormous socioeconomic losses worldwide.

For on-site rapid detection as a point-of-care testing, airborne viruses need be collected in liquid medium (*i.e.*, **aero-to-hydro sampling**) for molecular analysis-level diagnostics. However, the concentrations of the viruses in the air are usually too low to be detected, although they can cause human infection through respiratory transmission even at that concentration. Viruses in the ambient air are usually suspended with concentrations lower than concentrations in pandemics (10^3–10^4 viral genome copies (GC) per 1 m^3 of air) which are close to the limit-of-detection (10^3 GC/mL) for the polymerase chain reaction (PCR)-based diagnostics if they are collected in 1 mL of liquid medium.

To PCR analysis to work, a long-term, high-volume, and gentle air sampling is required to secure readable signals. These challenges can be addressed through electrostatic air sampling, which not only results in high virus collection efficiency but also maintains high air flow rate, therefore, enables to achieve a PCR-detectable sample within a short time. In addition, encapsulation of virus particles collected on a sampler surface via a single water droplet will be introduced to obtain a highly enriched sample for PCR detection.

To reduce the time required for PCR analysis, plasmonic quantitative PCR (qPCR) technology that uses the photothermal energy conversion of plasmonic nanostructures (such as gold) will be a solution. Unlike conventional PCR, which relies on Peltier heating, plasmonic PCR enables ultrafast thermocycling, significantly reducing the reaction time to a few minutes. In addition to qPCR, digital PCR (dPCR) can be applied for precise virus quantification. qPCR allows real-time monitoring of amplification through fluorescence-based detection, enabling the quantification of viral genome copies in collected samples. Meanwhile, dPCR provides an absolute quantification method by partitioning the sample into numerous nanoliter-sized reactions, improving the accuracy and sensitivity of virus detection even at extremely low concentrations. By integrating plasmonic thermocycling with dPCR, it is possible to achieve rapid, sensitive, and quantitative detection of airborne viruses, making it a promising approach for pandemic surveillance and bioaerosol monitoring.

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02
Invited Lectures

Bioelectronics (1)

Reinforced biomaterials for tissue regeneration, stem cell fate commitment, and wound healing

Author: Shabir Hassan

Affiliations: Khalifa University, UAE

Purpose/Objectives: The effects of self-oxygenation biomaterials on different aspects of regenerative medicine such as healing of the myocardium after MI or stem cell fate in cellularized hydrogels have not yet been studied. Additionally, although decellularized hydrogels-based research is gaining attention, however, very little is known about their burn wound healing properties.

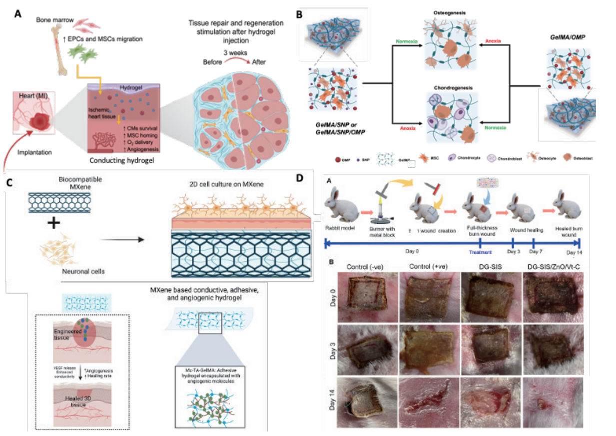

Figure 1. A). Schematics showing for myocardial infarction (MI) healing process by oxygenating and cardioprotective tissue adhesive tyramine conjugated alginate and silk fibroin (TSF) hydrogels encapsulated with oxygen releasing microparticles (OMPs) and stromal differentiation factor (SDF) B). Depiction of the effect of OMP, SNP, and OMP+SNP on the differentiation fate of hMSCs toward osteogenesis or chondrogenesis under normoxia and anoxia, respectively. C) Application of 2D material for spinal injury. D) Complete healing of a burn wound in rabbits through decellularized biomaterials.

Methodology: Biomaterials were reinforced to give them oxygenating, antioxidative, and tissue-adhesive properties for three different applications: 1.) Better tissue regeneration in MI, 2.) Stem cell fate commitment for regenerative medicine such as bone regeneration, and 3) Complete healing of burn wounds (**Figure 1**). Calcium peroxide as the source of oxygen was encapsulated in polycaprolactone to produce oxygenating microparticles with prolonged oxygen release profile. These oxygen-generating microparticles were incorporated into bioadhesive silk-alginate or gelatin methacryloyl (GelMA) based hydrogels with or without mesenchymal stem cells (MSCs), for MI and osteochondral differentiation, respectively. For MI, these hydrogels were conjugated with stromal cell derived factor (SDF) to orchestrate chemotaxis and angiogenesis and generate oxygen via oxygenating microparticles (OMPs) to alleviate the cytotoxic anoxic environment. Silk fibroin (SF) was explored to endow elasticity and resilience to the injectable hydrogel. Additionally, tyramine (TA) was conjugated to alginate (TA-Alg) and SF, producing a mechanically robust and tissue adhesive hybrid hydrogel (TSF) that encourages tissue adhesion and enhances the injectability of the hydrogels. For stem cell fate commitment for bone tissue engineering applications, oxygen-generating microparticles were incorporated into GelMA hydrogels in the presence/absence of osteoinductive silicate nanoparticles (SNPs). A comparative study revealed the osteogenic fate of hMSCs in the designed hydrogels under normoxic (the gold standard for in vitro cultures) and anoxic (common in large bone defects; <0.1% oxygen) conditions. Additionally, hydrogels from decellularized caprine small intestine submucosa (DG-SIS) were reinforced with vitamin C (Vt-C) and ZnO NPs for complete burn wound healing in rabbits. This study demonstrated a synergistic effect of ZnO/Vt-C in the bioactive gel as an effective therapeutic approach for full-thickness burn wound treatment.

Results and Conclusion: The hydrogel was shown to continuously release SDF and oxygen for MI applications. The subsequent combinational and synergistic effect results in a significant improvement in vascularization, increasing the cardiomyocyte survival by 30% cardiomyocyte survival and reducing the fibrotic scar formation in an MI animal rodent model. To study the role of oxygenating biomaterials in driving fate commitment in MSCs, in line with the literature, under standard laboratory conditions (normoxia), stem cells exposed to osteoinductive SNPs most effectively were differentiated into bone-forming osteoblasts. Bulk RNA-sequencing confirmed that OMPs possessed a stronger expression of osteogenic gene transcript fingerprint than SNPs or SNPs in combination with OMPs. The addition of OMP also increased the number of vessels and potentially increased vessel diameter and thus vessel maturation. Decellularized caprine scaffolds encapsulating vitamin C and ZnO nanoparticles showed complete healing of a burn wound in a rabbit. Taken together, we present innovations in biomaterials in their oxygenating capacity, bioadhesion, and antioxidating and wound healing properties to treat a wide variety of medical conditions in small and bigger animal models.

Wearable Electrochemical Biosensor Interfaces for Health Monitoring Applications

Jayoung Kim
Department of Medical Engineering, Yonsei University College of Medicine)
jayoungkim@yonsei.ac.kr

Abstract: Wearable Electrochemical biosensors represent a promising opportunity to monitor human physiology through dynamic measurements of (bio)chemical markers in bio-fluids such as sweat, tears, saliva, and interstitial fluid in continuous and non-invasive way. Such new platforms can thus offer real-time (bio)chemical information toward a more comprehensive view of a wearer's health, performance, or stress at the molecular level in daily life. Continuous biomonitoring addresses the limitations of traditional invasive blood testing and provides the opportunity for early diagnostic and therapeutic interventions. My talk will focus on developing wearable electrochemical biosensor interfaces towards non-invasive health monitoring opportunities and evaluating the potential impact of such wearable and point-of-care devices on our daily life and clinical settings. Lastly, the talk will also cover the recent interdisciplinary approaches to overcome the existing limitations of wearable biosensor field by developing new class of artificial receptors and new smart featured interface materials for health monitoring applications.

Ultrasoft nanomesh electronics for on-skin applications

Sunghoon Lee[1,2,3]
[1]Thin-Film Devices Laboratory, RIKEN, Tokyo, Japan
[2]CEMS, RIKEN, Tokyo, Japan
[3]EEIS, The University of Tokyo, Tokyo, Japan

Abstract: An ultimate goal of biological measurement is to monitor the states of a living body in a non-invasive, continuous, and accurate manner without disturbing the natural functions or activities of the living body. Because sensors in direct contact with biological tissues are inevitably exposed to physical disturbances caused by physical contact, considerable efforts have been made to minimize the effects of sensors. In temperature measurement, for example, it is preferable to reduce the heat capacity or thermal conductance of a sensor in order to suppress the effect of heat transfer from the object to the sensor. Furthermore, mechanical compliance with electronics is extremely important for biological objects. The skin is soft and has a three-dimensional structure. Flexible and/or stretchable sensors have been proposed to reduce the effects of modulus differences between the skin and the electronics.

In this talk, I will introduce skin-attachable nanomesh electronics to further improve biocompatibility by introducing an extremely soft, thin, and porous structure. They electrically functionalize the skin while allowing its inherent functionalities. The nanomesh electrode having sufficiently high gas-permeability can be attached to the skin without additional adhesives [1]. It results in a continuous attachment to the skin for a week without any skin inflammation issues. Furthermore, the nanomesh pressure sensor enables the monitoring of finger manipulation without interfering with the inherent skin sensation, although the sensor is directly applied to the highly sensitive fingertip [2]. Finally, we demonstrate the monitoring of skin deformation under mechanically harsh conditions, such as when the fingertip comes into contact with a ball during a pitching motion [3].

Refs. [1] A. Miyamoto, et al., *Nat. Nanotechnol.* **12**, 907 (2017). [2] S. Lee, et al., *Science* **370**, 966 (2020). [3] S. Lee, et al., *Device* (online) (2024).

Title: How to Maximize Your Success in Scientific Publishing – An Advanced Perspective

Speaker: Haeryung Lee
- Affiliation: Wiley
- E-mail: halee@wiley.com

Abstract

Greetings from Wiley! It's my pleasure to have this talk in Yonsei Engineering Symposium 2025. This presentation will provide a brief overview of Wiley journals, current trends and challenges in scientific publishing, some ethical considerations, how publishers and authors interact and influence each other, and how the publishing arena is being transformed. Tips will be presented on how to select an appropriate journal for your paper, what aspects of preparation and presentation to focus on from an editor's and referee's perspective, and hints for increasing the discoverability of your paper after publication.

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02
Invited Lectures

Bioelectronics (2)

Advancing Digital Health through Soft Optical and Mechano-Acoustic Sensors

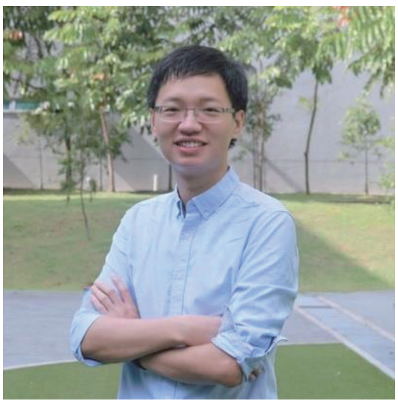
Wu Changsheng
National University of Singapore

Abstract

The rapid ageing of populations and the global impact of the COVID-19 pandemic have exposed critical shortcomings in medical resources and healthcare systems, underscoring the urgent need for innovative biomedical technologies. Traditional centralized healthcare remains predominantly offline and reactive, with physiological monitoring occurring intermittently at clinical facilities. In contrast, recent advancements in smart materials, wearable technologies, wireless communication, artificial intelligence, and the Internet of Things are paving the way for a paradigm shift toward continuous, pervasive, and personalized digital health solutions. However, significant challenges persist in achieving advanced monitoring modalities and ensuring long-term wearability.

This talk will present our recent progress in developing soft optical and mechano-acoustic sensors for ambulatory monitoring of deep-tissue signals. We will introduce wireless, flexible near-infrared spectroscopy (NIRS) devices capable of measuring local hemodynamics and tissue oxygenation. These devices employ multi-photodiode arrays for simultaneous monitoring of systemic and local biomarkers through multiwavelength reflectance-mode photoplethysmography and functional NIRS. Additionally, we will discuss mechano-acoustic sensing technologies that use skin-mounted accelerometer arrays to decode tissue mechanics. This system enables calibration-free, depth-sensitive assessments of tissue stiffness, validated through bi-layer phantom studies and dynamic muscle monitoring during exercise. These innovations represent a step toward accessible, cost-effective, and continuous health monitoring, addressing diverse needs such as pediatric care and rehabilitation, and paving the way for smarter healthcare systems.

Brief Biodata cum with a Photo



Changsheng Wu is a Presidential Young Professor in the Department of Materials Science and Engineering (MSE) at the National University of Singapore (NUS). He is also an assistant professor by courtesy in Electrical and Computer Engineering and a PI in the Institute for Health Innovation and Technology and the N.1 Institute for Health, NUS. He received his PhD in MSE from Georgia Tech and carried out postdoctoral research in the Querrey Simpson Institute for Bioelectronics at Northwestern University. His research focuses on developing wireless wearables and intelligent robots for energy harvesting, biosensing and therapeutic applications, leveraging bioelectronics, materials science, and advanced manufacturing to create solutions for sustainable living and environment. He has been recognized by international awards including MRS Early Career Distinguished Presenter, Asia Pacific Biomedical Engineering Consortium (APBEC) Young Scholar Award, NGPT Young Investigator Award, TechConnect Innovation Award, and has been listed in the World's Top 2% Scientists by Stanford University for 2021-2024.

Soft Materials for Bioresorbable Medical Devices

Yeonsik Choi

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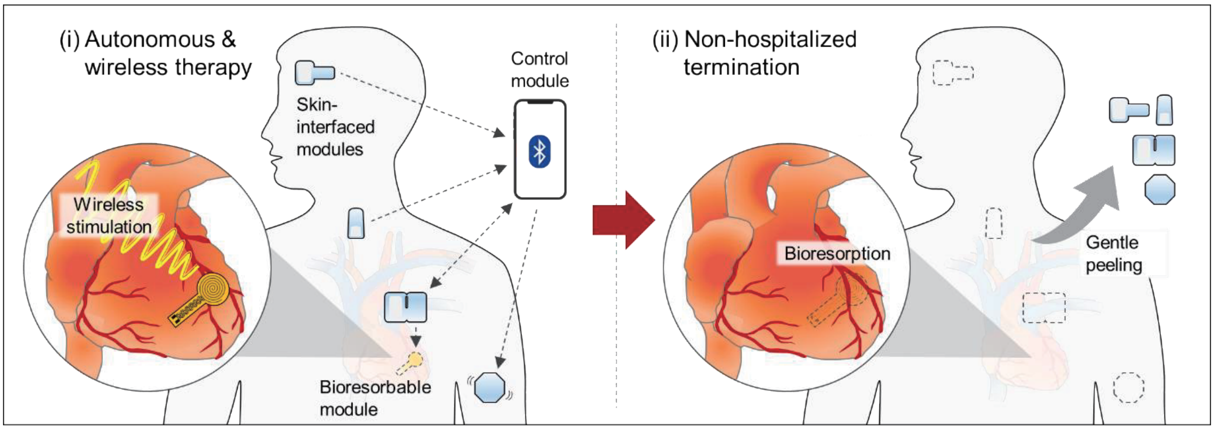
Advancements in integrated circuit technology have traditionally emphasized stability and reliability, prioritizing materials that remain unchanged over time. However, a new field of electronic materials is emerging, centered on transient devices capable of dissolving, disintegrating, or disappearing at predetermined rates. These water-soluble transient electronics have significant potential for bioresorbable medical implants that are designed to dissolve safely within the human body.

In this presentation, I will explore the chemistry and materials science behind soft materials used in bioresorbable medical devices, with a focus on energy efficiency and wireless power transfer. I will discuss the integration of inductive coupling mechanisms for wireless energy transfer, which allows for non-invasive powering of temporary medical implants. This approach eliminates the need for conventional batteries, reducing the device footprint and enhancing patient safety. As a case study, I will present the design of bioresorbable wireless electronic stimulators for the treatment of temporary bradycardia, demonstrating how innovative materials and energy transfer technologies can transform medical treatment options and patient care.



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Wearable and implantable bioelectronics

Sanggil Han

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Remarkable advances in medicine and biology have been made possible with bioelectronics - devices that bridge and connect the worlds of living systems and electronics. Our recent work on miniaturized sensors with exceptionally high performance allows fabrication of biosensors in various formats such as wearables and implantables[1-4], which branches out to different fields of application. In this talk, I will introduce a state-of-the-art biosensor technology and its broad applications, ranging from wearable medical devices to neuroscience and Plantronics. In wearable devices, I will introduce wearable patch for fitness monitoring. In brain-machine interfaces, I will talk about the latest technology for recording brain electrophysiology[5]. Lastly, in Plantronics, I will share our recent work on potassium ion recording not only from extracted sap[6] but also directly inside xylem, which I believe would pave the way for real-time plant physiology, plant healthcare as well as advanced precision agriculture.

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Keywords
Bioelectronics, Biosensors, Plantronics

Liquid-Metal Neural Interfaces for Precision Neural Stimulation and Recording

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Recent advancements in optoelectronic devices for wearable bioelectronics demand superior mechanical deformability to enable versatile applications in daily life. In parallel, rapid progress in neurotechnology has made it possible to establish bidirectional communication between the nervous system and engineered devices. This capability is crucial for precise recording and stimulation of specific target neurons, unlocking revolutionary medical applications such as diagnosing and treating neurological disorders. Thus, a thorough understanding of the electronic devices and their biological interfaces is essential.

This talk introduces fundamental concepts of neural signaling, recording, and stimulation, leading to the development of advanced neural interfaces integrated with wearable electronic systems. We will discuss key material considerations, focusing on the unique properties of liquid metals—especially Ga-based liquid metal alloys—that are highly biocompatible and offer low modulus, minimizing tissue damage upon implantation. High-resolution 3D printing of these materials enables the fabrication of precise neural interfaces for measuring neural signals and delivering electrical stimulation to specific neural targets. In this talk, we will present results from recent studies demonstrating the stimulation of neural tissues such as the retina, brain, and spinal cord using these liquid metal interfaces. Finally, we will address the challenges and future directions for next-generation neural interfaces, highlighting how innovative materials and fabrication techniques may shape the future of neurotechnology.

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02
Invited Lectures

Bio-mechanics

High-Resolution 3D Surface Measurement with Structured Light

Jae-Sang Hyun
Department of Mechanical Engineering, Yonsei University

Abstract: Structured light illumination is widely utilized in fields such as medicine, manufacturing, and entertainment for 3D reconstruction. It offers advantages over other active illumination methods, particularly in capturing high-resolution geometry of objects with precision.

This presentation will discuss the development of algorithms that improve phase map quality in 3D reconstruction and introduce a new approach to acquiring 3D models through mechanical means. These advancements provide a foundation for further research and application in high-accuracy 3D modeling, showcasing the potential of structured light in various industrial applications.

Attendees will explore recent algorithmic improvements and mechanical techniques in structured light applications, understanding their impact on the accuracy and resolution of 3D modeling.

Bio

Jae-Sang Hyun is an assistant professor in the school of mechanical engineering at Yonsei University. He was a research scientist at ORBBEC 3D Technology in the U.S. and led the projects related to the structured light 3D scanning system. He received Ph.D. in the School of Mechanical Engineering at Purdue University in 2020 and B.S. at Yonsei University (South Korea) in 2015. The focus of his research includes high-speed optical sensing to measure fast moving objects in 3-D and SLAM (Simultaneous Localization and Mapping) with 3D sensing technologies.

Advances in Focused Jets and Cavitation: Measurement Techniques and Emerging Applications

Professor Yoshiyuki Tagawa

Tokyo University of Agriculture and Technology

Understanding and controlling fluid dynamics at micro and macro scales is crucial for advancing engineering applications across diverse fields, from biomedical engineering to industrial processes. This talk will focus on recent advances in focused jets and cavitation phenomena, with an emphasis on cutting-edge measurement techniques such as background-oriented schlieren (BOS) and photoelastic measurement. These methods enable high-resolution visualization and quantitative analysis of fluid stress fields and pressure fluctuations, providing new insights into the dynamic behavior of fluids under extreme conditions [1][2]. Building on our recent work, we will discuss novel approaches for optimizing jet penetration and velocity control, leveraging explainable artificial intelligence for enhanced interpretation of experimental data [3]. The talk will also explore the interplay between cavitation dynamics and microjet formation, highlighting its implications for applications such as needle-free injection, material processing, and microfluidics [4]. In addition to established research, we will introduce an emerging project on strong 4D printing and fluid stress measurement using jet-based techniques, offering a glimpse into the future of fluid science-driven innovations. The integration of advanced experimental techniques with computational and machine learning approaches holds promise for unlocking new functionalities and enhancing performance across various engineering disciplines [5][6]. This talk seeks to encourage collaboration across disciplines, connecting mechanical, chemical, and materials engineering to explore new possibilities and advancements in fluid science applications.

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AI-Driven Innovations in Microfluidics: From Coating Optimization to Droplet Generation

Prof. Jinkee Lee

Microfluidics Convergence Laboratory

School of Mechanical Engineering

Sungkyunkwan University, Suwon, Rep. of Korea

This presentation highlights recent advancements in integrating artificial intelligence (AI) and machine learning into microfluidic applications conducted at MiCon Lab, SKKU Mechanical Engineering. The research focuses on two key areas: coating optimization and droplet microfluidics. For coating, a physics-informed neural network (PINN) was developed to predict optimal coating conditions by leveraging physical parameters, improving accuracy compared to standard neural networks. In droplet microfluidics, the lab introduced a 3D-printed device for measuring green algae concentration using a microfluidic droplet generator and transfer learning with pre-trained deep learning models. Additionally, an autonomous control system for droplet generation was established using Bayesian optimization, requiring minimal training data and enabling flexibility across different channel geometries and fluids. The team also developed an AI-driven automated double emulsion droplet library generator, employing a fine-tuned convolutional neural network (CNN) for object detection and real-time feedback control. These innovations aim to enhance accessibility, precision, and efficiency in microfluidics, addressing challenges like manual intervention and system sensitivity, while paving the way for broader applications in research and industry.

Additive Manufacturing of Functional Materials Integrated Smart Structures for Sensing Applications

Hoe Joon Kim (김회준)

Department of Robotics and Mechatronics Engineering, DGIST

Additive manufacturing has advanced the current state of manufacturing, device technology, and healthcare. Novel printable materials led to additional functions to the printed systems, thus allowing the emergence of 4D printing. 4D printed structures and devices possess various additional functionalities, such as sensing, to already advanced and complex structures. This talk introduces various multifunctional sensors based on 4D printing technology. First, we introduce the direct printing of MWCNT-PLA composite using the FDM method. Using the dual-printing nozzles, the conductive composites are patterned to form multi-axis pressure sensing and temperature compensation simultaneously. The fabricated pressure-temperature hybrid sensor system is used for step monitoring and gripper applications. In addition, we introduce the conformal integration of carbon black nanoparticles on 3D printed mechanical metamaterial, a gyroid structure, to develop a durable and high-operating range pressure sensor. Lastly, the talk introduces the direct printing of PZT-PDMS composites to fabricate flexible piezoelectric nanogenerators and self-powered physical sensing.

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02

Invited Lectures

Communication Technology

Fractional Programming for Signal Processing and Machine Learning

Kaiming Shen

The Chinese University of Hong Kong

Abstract: Fractional programming (FP) is an invaluable optimization tool for communications and signal processing because many problems in these fields are fractionally structured, e.g., the signal-to-interference-plus-noise ratio (SINR) maximization for wireless transmission, the normalized cut maximization for graph clustering, the Cram₩'{e}r-Rao bound (CRB) minimization for radar signal processing, the mean square error minimization for pilot signal processing, the margin maximization for support vector machine (SVM), and the age of information (AoI) minimization for sensor networks, etc. This talk gives a general introduction of the FP theory and methods upon which some latest advances in signal processing and machine learning are based. After briefly reviewing the classic FP theory, the talk focuses on a recently developed state-of-the-art technique termed the quadratic transform. We start with the basic quadratic transform for the sum-of-ratios FP, and then extend it to the other types of FP. We further explore the connections of the quadratic transform to the conventional optimization methods including the fixed-point iteration, the weighted minimum mean square error (WMMSE) method, the majorization-minimization (MM) method, and the gradient projection. Moreover, as performance analysis, we examine the condition for the quadratic transform to converge, and further quantify the convergence rate.

Bio: Kaiming Shen received the B.Eng. degree in information security and the B.Sc. degree in mathematics from Shanghai Jiao Tong University, China in 2011, and then the M.A.Sc. degree in electrical and computer engineering from the University of Toronto, Canada in 2013. After working at a tech startup in Ottawa for one year, he returned to the University of Toronto and received the Ph.D. degree in electrical and computer engineering in early 2020. Dr. Shen has been with the School of Science and Engineering at The Chinese University of Hong Kong (CUHK), Shenzhen, China as a tenure-track assistant professor since 2020. His research interests include optimization, wireless communications, information theory, and machine learning. Dr. Shen received the IEEE Signal Processing Society Young Author Best Paper Award in 2021, the University Teaching Achievement Award in 2023, and the Frontiers of Science Award in 2024. Dr. Shen is a senior member of IEEE and currently serves as an Editor for IEEE Transactions on Wireless Communications.

Paradigm Shifts in Massive MIMO Channel Acquisition – From Estimation To Prediction

Jeonghun Park
Yonsei University

Abstract: A critical hindrance in realizing massive multi-input multi-output (MIMO) systems is the overhead associated with the downlink (DL) channel state information at the transmitter (CSIT) acquisition. To address this, numerous CSIT acquisition methods have been studied. In this talk, we classify these methods into two categories: channel estimation and channel prediction. In addition, we introduce a novel framework that eliminates the need for CSI feedback, while achieving robust sum spectral efficiency (SE). Specifically, by leveraging partial frequency invariance of channel parameters, we reconstruct the DL CSIT using uplink (UL) pilots with the 2D-Newtonized orthogonal matching pursuit (2D-NOMP) algorithm. In frequency division duplex (FDD) systems, however, due to discrepancies between the two disjoint bands, however, perfect DL CSIT acquisition is infeasible; resulting in multi-user interference (MUI). To account for this, we reformulate the sum SE maximization problem using the reconstructed channel and its error covariance matrix (ECM). Then, we propose an ECM estimation method based on the observed Fisher information matrix and introduce a robust precoder optimization technique.

Bio: Jeonghun Park (S'13-M'17) is currently working as an assistant professor in School of Electrical and Electronic Engineering at Yonsei University, Seoul, South Korea. Prior to joining Yonsei, he worked in Qualcomm wireless R&D, San Diego, USA and Kyungpook National University, Daegu, South Korea. He received his B.S. and M.S. degrees in Electrical and Electronic Engineering from Yonsei University, Seoul, South Korea, in 2010 and 2012, respectively. He also received his Ph.D. degree in Electrical and Computer Engineering at The University of Texas at Austin, TX, USA, in 2017. He served as an associated editor of the IEEE WIRELESS COMMUNICATIONS LETTERS. His main research interest is developing and analyzing future wireless communication systems using tools of optimization, information theory, and machine learning.

MIMO Precoding in Power-limited Systems for 6G Frontiers

Jinseok Choi
KAIST

Abstract: As wireless networks evolve towards 6G, the challenge of managing power consumption while maximizing spectral efficiency becomes increasingly critical. This research presents novel approaches to MIMO precoding optimization specifically designed for power-limited systems in emerging 6G applications. We introduce an adaptive precoding framework that dynamically balances energy efficiency and system performance through intelligent power allocation strategies. Our solution incorporates machine learning techniques to predict optimal precoding matrices based on channel state information and power constraints, achieving up to 40% improvement in energy efficiency compared to conventional methods. The proposed framework demonstrates remarkable resilience in various challenging scenarios, including ultra-massive MIMO configurations and millimeter-wave frequencies. Extensive simulations reveal that our approach maintains high throughput even under strict power limitations, making it particularly suitable for battery-operated and energy-harvesting devices in future 6G networks. Furthermore, we present a comprehensive analysis of the trade-offs between computational complexity and precoding performance, offering practical insights for real-world implementations. The results indicate that our proposed method can serve as a foundational building block for sustainable and efficient 6G communication systems, particularly in scenarios where power efficiency is paramount. This work not only addresses current challenges in MIMO precoding but also paves the way for future research in power-aware wireless communications.

Facing to Information Aging for Goal-oriented Communications in 6G

Jemin Lee

Associate Professor
Department of Electrical and Electronic Engineering, Yonsei University
(Email: jemin.lee@yonsei.ac.kr)

Abstract:
For the advances in 5G technology, the latency has been considered as a key metric for addressing the requirements of real-time communications. As wireless system evolves towards 6G, those requirements become more stringent to catering to the real-time and autonomous communications and decision-making for emerging mission-critical interactive systems. Accordingly, the latency becomes insufficient to parameterize those requirements, which brings large attention to the information freshness, measured by the age of information. In this talk, with focusing on this information freshness, we will explore how to face to the information aging for goal-oriented communications in 6G, specifically for wireless monitoring networks, edge computing-enabled networks, and the blockchain-enabled networks. Finally, we discuss the potential and the challenges associated with this promising avenue of research.

Biography:
Jemin Lee is an Associate Professor at the Department of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea. She received the Ph.D. degrees in Electrical and Electronic Engineering from Yonsei University, Seoul, Korea, in 2010. Her current research interests include wireless communications, wireless security, intelligent networking, and blockchain technology. Dr. Lee is currently an Area Editor for IEEE Transactions on Machine Learning in Communications and Networking, and an Editor for the IEEE Transactions on Communications, the IEEE Transactions on Mobile Computing, and the IEEE Communications Magazine. She served as a Chair for the IEEE Communication Society (ComSoc) Radio Communications Technical Committee for 2021-2022. She received the Haedong Young Engineering Researcher Award in 2020, the IEEE ComSoc Young Author Best Paper Award in 2020, the IEEE ComSoc AP Outstanding Paper Award in 2017, the IEEE ComSoc AP Outstanding Young Researcher Award in 2014, the Temasek Research Fellowship in 2013, and the Chun-Gang Outstanding Research Award in 2011.

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02
Invited Lectures

Environmental and Membranes

Prof. Zhiping Lai

Highly Crystalline and Oriented 2D Covalent Organic Framework Membranes for Molecular and Ionic Separations

Zhiping Lai
Center of Excellence for Renewable Energy and Storage Technologies (CREST), Chemistry program, Division of Physical Science and Engineering, King Abdullah University of Science and Technology (KAUST), Thuwal, 23955-6900, Saudi Arabia
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Abstract

Membrane-based separation processes are crucial for sustainable applications such as water purification, gas separation, and energy storage. Two two-dimensional (2D) covalent organic frameworks (COFs) have recently garnered significant attention due to their highly tunable pore architectures and exceptional stability. Constructed from covalently linked organic building blocks, 2D COFs offer precise control over pore size, shape, and surface functionality, enabling the design of membranes that achieve both high selectivity and permeability. Their inherent modularity allows for the customization of molecular or ionic interactions through tailored pore environments and surface modifications, while their layered structure provides short, direct transport pathways that enhance flux and reduce fouling. Additionally, the robust chemical and thermal stability of these frameworks makes them well-suited for harsh operational conditions.

Despite these promising features, several challenges remain. Fabricating large-area, defect-free COF membranes with consistent crystallinity is difficult, as imperfections can lead to non-selective transport. Moreover, ensuring the mechanical integrity of these ultrathin membranes under operational stress and scaling up production without compromising quality are significant hurdles that must be overcome to fully harness the potential of 2D COF membranes in advanced separation technologies.

Over the past decade, we have developed multiple synthesis approaches to prepare ultrathin COF membranes with enhanced crystallinity. Notably, an innovative electrochemical synthesis method now enables the rapid fabrication of large-scale, highly crystalline COF membranes, paving the way for their practical application. In this work, we discuss the use of our COF membranes in a range of applications—including ion separations, osmotic energy harvesting, organic solvent nanofiltration, and oil separation—and detail how the exceptional structure of COFs leads to superior membrane performance.

Brief Biography

Dr. Prof. Zhiping Lai is a full professor in the Chemistry and Chemical Engineering program at King Abdullah University of Science and Technology (KAUST), with a B.E. and M.S. from Tsinghua University and a Ph.D. from the University of Massachusetts Amherst. He then conducted postdoctoral research at the University of Minnesota Twin Cities and served as an Assistant Professor at Nanyang Technological University before joining KAUST as a founding faculty member.

Prof. Dae Woo Kim

Multilayer Nanoporous Graphene Membrane for Ultrafast Organic Solvent Nanofiltration

Dae Woo Kim

Department of Chemical and Biomolecular Engineering, YONSEI University

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Graphene-based materials have potentially been utilized for organic solvent nanofiltration (OSN) membranes due to their interlayer structure and excellent mechanical and chemical stability, which enables precise molecular sieving in harsh conditions, e.g. in toxic organic solvents. Pore generation on graphene techniques has been applied to enhance the solvent flux because the activated nanopores with appropriate size can accelerate the transport of solvent molecules while maintaining high selectivity. In this talk, several post-pore activation methods for nanoporous graphene will be discussed with applications as high-performance OSN membranes. The nanopores could be generated on the basal plane of graphene by the thermal or chemical treatment of GO. In particular, sp2 carbon domains were additionally recovered from amorphous sp3 carbon structures through microwave-assisted reduction. The resulting multilayer nanoporous graphene membranes are capable of ultrafast organic solvent filtration with precise molecular sieving. Furthermore, the membranes were feasible for the separation of multiple mixed solutes in various organic solvents. I will also discuss the solvent flow mechanism through the porous multilayer graphene, particularly focusing on the critical pore size and interlayer spacing for ultrafast solvent flow.

Prof. Dae Woo Kim currently holds the position of Associate Professor in the Department of Chemical and Biomolecular Engineering at Yonsei University. He has a record of more than 130 publications in esteemed international journals and serves as an early career editorial board member for the Journal of Membrane Science. His ongoing research focuses on the structure of nanomaterials and their applications in various sectors associated with energy and the environment. This includes areas such as membrane separation, energy devices, and catalysis. More details about Dr. Kim’s research can be found on his group homepage: hni.yonsei.ac.kr.

Prof. Tae-Hyun Bae

Engineering hypercrosslinked porous polymers for advanced CO_2 separation

Tae-Hyun Bae
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Abstract
Development of cost-effective gas separation processes is critical to reducing energy consumption in chemical industries as well as producing clean energy that causes minimal environmental problems. For example, CO_2 separation processes are widely used in many energy and environmental technologies such as CO_2 capture in power plants, hydrogen purification, biogas recovery and natural gas treatment. While current gas separation processes including absorptions and distillations that consume a large amount of energy are too costly due to their energy consumption, adsorption and membrane-based gas separations have demonstrated a potential toward reducing cost and improving performance. I will introduce most recent studies conducted, including amine-appended porous organic polymers and their processing into 3-D monolithic structure and membranes. Besides, porous organic polymers can provide various advantages as the filler material of mixed-matrix membranes, namely high surface area and pore volume, excellent chemical stability, and tunable functionality leading to a high CO_2 separation performance. In this talk, the strategies explored to tailor the CO_2 separation performance will be discussed. In addition, I will introduce our novel approach to designing a polymeric molecular sieve membrane that achieves remarkable CO_2 separation performance without compromising mechanical stability.

Dr. Tae-Hyun Bae is an Associate Professor at the KAIST CBE Department (joined in May 2019). Tae-Hyun Bae received his Ph.D. in Chemical Engineering at Georgia Institute of Technology in 2010. Following a postdoctoral experience at the University of California, Berkeley, he had worked at Nanyang Technological University, Singapore, from 2013 to 2019 as an Assistant Professor of Chemical Engineering. Dr. Bae has extensive research experience in nanoporous materials and membrane technology used in various chemical and environmental engineering processes. He is now serving as an editor of Journal of Membrane Science and has published about 130 research papers that have been cited more than 17000 times (Google Scholar).

Prof. Jong Suk Lee

Tailoring Microporous Membranes for Condensable Gas Separation: Defect Engineering and Cross-Linking

Jong Suk Lee
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Abstract
Purification and separation processes account for approximately 10-15% of global energy consumption. To achieve net-zero emissions by 2050, the global energy sector must reduce its carbon footprint and lower energy costs. Membrane-based gas separation techniques offer a promising alternative to traditional thermally-driven separation methods due to their high energy efficiency and compact design. However, most polymeric membranes face inherent challenges, such as the permeability-selectivity trade-off that limits separation performance and plasticization-induced reductions in selectivity at high feed pressures of condensable gases. This presentation will delve into molecular engineering strategies for microporous membranes, which are recognized as next-generation materials for achieving superior separation performance and enhanced resistance to plasticization. In particular, defect engineering has emerged as a facile and efficient method to tailor the interfacial morphology between metal-organic frameworks and polymers, addressing key challenges in separation efficiency. Additionally, cross-linking techniques offer another practical avenue to improve gas flux and plasticization resistance. These advancements underscore the potential of molecularly tailored microporous membranes to drive sustainable innovations in gas separation, paving the way for transformative solutions in energy-efficient industrial applications.

Brief Biography
Jong Suk Lee received his Ph.D. in Chemical Engineering in 2011 from the Georgia Institute of Technology. Following his postdoctoral work, he worked as a senior researcher at the Korea Institute of Science and Technology for four years. In 2016, he joined the Department of Chemical and Biomolecular Engineering at Sogang University, where he is now an associate professor. Prof. Lee serves as an editor for the *Journal of Industrial and Engineering Chemistry* and as an associate editor for the *Korean Journal of Chemical Engineering*. His research focuses on gas separation and water purification, with expertise in designing advanced materials, such as polymers, metal–organic frameworks, carbon molecular sieves, and composite systems.

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02
Invited Lectures

Energy Storage (1)

Modulating the electrical double layer to tune battery corrosion film chemistry

Yuzhang Li
UCLA

Abstract: Battery performance is strongly influenced by the solid electrolyte interphase (SEI) that forms from electrolyte decomposition and remains a key target for engineering design. Whereas traditional approaches to tune the SEI have focused on electrolyte chemistry, we show that manipulating the electric field offers a novel approach. Here, we change the electrical double layer (EDL) composition by either applying or removing the local electric field, which directly controls SEI formation. Surprisingly, the solvent-derived SEI known to form in a conventional electrolyte exhibits anion-enhanced chemistry when the electric field is removed, which is attributed to the Coulombic interaction between the electric field and free anions. With the electric field control, we produce an anion-enhanced SEI in conventional electrolytes that demonstrates improved battery cycling and corrosion resistance. Together, our findings highlight the importance of EDL composition and demonstrate electric field strength as a new parameter to tune SEI structure and chemistry.

Prof. Kyung-Wan Nam

Exploring Structure-Ionic Conductivity Links in New Solid Electrolyte Materials Using Synchrotron X-ray Analysis

Kyung-Wan Nam
Department of Energy and Materials Engineering, Dongguk University, Seoul 04620, South Korea
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Abstract

There have been enormously increasing demands for developing next-generation Li-ion batteries with enhanced energy, power density, and safety features compared with the current state-of-the-art LIB technology. Such advances necessitate successfully developing and implementing the new cathode, anode, and (solid) electrolyte materials. In this regard, understanding the structure-property correlation of advanced battery materials has become a central aspect of battery research.

Developing highly conductive and (electro) chemically stable inorganic solid-electrolytes (SEs) using cost-effective materials is critical to enabling all-solid-state batteries(ASSBs). A key challenge in this field is understanding the complex relationship between SE material's atomic structure and ionic conductivity. In this study, we explore the (interfacial) structure-ionic conductivity correlations in new solid electrolyte materials (sulfide and halide-based SEs) using a combination of various synchrotron X-ray techniques, including X-ray diffraction (XRD), X-ray absorption spectroscopy (XAS), and x-ray pair distribution function (PDF) analysis. Notably, as the PDF analysis can provide valuable multi-scale atomic structural information, this tool becomes critical to unveil the correlation between local atomic structure changes (e.g., site disordering and interphase/interfacial conduction) and ionic conductivity of new halide-based SEs. By probing these materials' atomic-scale arrangements and disorder, we aim to uncover the structural features that govern ionic transport.

Kyung-Wan Nam is a professor at the Department of Energy and Materials Engineering, Dongguk University-Seoul, South Korea. He received his B.S. (1998),M.S. (2000), and Ph.D. (2005) in Metallurgical Engineering from Yonsei University, South Korea. In 2006, he joined the Chemistry Department of Brookhaven National Laboratory as a research associate and worked as a staff scientist from 2009 until 2014. His research focuses on materials for advanced Li- and Na-ion batteries, all-solid-state batteries, supercapacitors, and developing new in situ characterization tools using synchrotron-based X-ray techniques.

Directing Lithium Metal Dodecahedra Formation via Copper Current Collector

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The diffusion-limited mass transport in electrolytes is commonly considered the origin of Li dendritic growth. This process begins when metallic Li formation is initiated by charge transfer on a Cu current collector, disrupting the local distribution of Li ions within the liquid electrolyte from its equilibrium and creating a concentration gradient. At the point where the concentration of Li^+ approaches zero, a steep local gradient of Li ions in the electrolytes is formed, which eventually triggers dendritic Li growth. This phenomenon is often discussed in terms of Sand's equation. Although many previous studies have attempted to reduce this concentration gradient of Li ions in the electrolyte including highly concentrated electrolytes, modified electrodes with lithiophilic property, and metallic alloying with heteroatoms, these studies have mainly focused on Li adsorption and ignored the surface migration of Li atoms that can occur directly after Li adsorption.

In this work, I will present that Li plating is a collective motion of Li adatoms influenced by the crystallographic orientation of the Cu substrate and that Li adatoms can be redistributed by interacting with individual Cu grains through surface migration. By comparing centimeter-sized single-crystal Cu(111) and Cu(410) foils, we show that Cu(111) foil inhibits dendritic growth of metallic Li, likely due to the near-zero migration barrier of Li adatoms according to our modeling. This insight into Li adatom surface-migration behavior proposes a new avenue for developing high-performance, anode-free Li batteries.

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Techno-economic and life-cycle analysis of combined pyro- and hydrometallurgical process based on roasting pretreatment for lithium-ion battery recycling system

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Conventional pyrometallurgical and hydrometallurgical processes for lithium-ion battery (LIB) recycling face significant challenges, including prolonged leaching times, wastewater pollution, and high energy consumption. To overcome these limitations, a combined pyro- and hydrometallurgical process using a roasting-based pretreatment has garnered increasing attention. However, due to the low technology maturity, research is needed on the design, economic, and environmental impacts of recycling systems at an industrial scale. This study provides a comprehensive assessment of these impacts through process modeling, techno-economic analysis (TEA), and life cycle assessment (LCA). Process modeling was conducted for three representative roasting pretreatment methods: carbothermic reduction, sulfation, and chlorination-based roasting, and sensitivity analysis was conducted on the TEA and LCA results. The results showed that carbothermic reduction roasting had the lowest levelized cost of recycling (LCOR) of 2.53 $/kg due to its low water and chemical consumption while fully recovering the valuable metals. In addition, carbothermic reduction roasting is the only one of the three processes to recover Li in the form of LiOH and recycle the waste graphite generated during the process, making it the most environmentally friendly system. Thus, the system, TEA, and LCA results presented in this study can be used as design and operational guidelines for selecting appropriate roasting technologies and for commercializing battery recycling systems beyond the lab-scale to industrial scale.

Keywords: Lithium-ion battery, Battery recycling, Roasting, Process simulation, Techno-economic analysis, Life-cycle assessment

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02

Invited Lectures

Energy Storage (2)

New layer-structured cathode materials for sodium-ion batteries and their sodium storage mechanisms

CV of Yong-Ning Zhou

Yong-Ning Zhou is a Professor in Department of Materials Science at Fudan University, China. He received his Ph.D. in Materials Physics and Chemistry from Fudan University in 2010, then he worked as a Research Associate in Brookhaven National Laboratory, USA until 2015. His research interests are associated with advanced materials for electrochemical energy storage, mainly focused on the cathode materials for lithium- and sodium-ion batteries, as well as advanced in situ characterization techniques for energy storage materials. He has authored about 160 research papers and obtained 12 authorized patents.

Abstract

Sodium-ion batteries (SIBs) are promising energy storage devices as lithium battery alternatives due to their abundant Na resource, potential low cost and high safety. Recently, high energy density layer-structured cathode materials with anionic redox chemistry in SIBs has attracted great attentions in this field. The working potential of oxygen redox chemistry in layered transition metal oxide cathodes is about 4.2 V (vs. Na^+/Na) which can not only increase the battery potential, but also provide extra capacity. Thus, reasonable utilization the oxygen redox chemistry can drastically increase the energy density of SIBs. However, the irreversible phase transition and crystal distortion resulted from oxygen redox chemistry usually result in severe capacity fading and voltage decay of the cathodes. Thus, it is of great significance to balance the oxygen redox activity and cycling stability of the cathodes.

In this talk, we developed a series of layer-structured cathode materials for SIBs. By controlling the synthesis condition, intrinsic vacancies are introduced into the TM layer of P2 structured cathode materials, and Mg ions are introduced into Na sites successfully. Intrinsic vacancies in the TM layer create the local configurations of "□-O-□", "Na-O-□" and "Mg-O-□" to trigger oxygen redox in the whole voltage range of charge and discharge. Mg ions in the Na layer sever as "pillars" to stabilize the layered structure during electrochemical cycling. The orphaned electrons in the nonbonding 2p orbitals of O that point toward TM vacancy sites are responsible for the reversible oxygen redox, and Mg ions in Na sites suppress oxygen release effectively. This rational design expands the voltage region for reversible anion redox in layer-structured cathode materials and is expected to open new fields for cathode material design.

Tender X-ray Absorption Spectroscopy and Fluorescence Imaging Studies on Next-Generation Batteries

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Over the past few decades, significant advancements in synchrotron-based X-ray techniques have provided transformative opportunities to study the mechanisms of emerging functional materials, including energy storage systems, catalysts, ferroelectrics, and nanomaterials. By integrating scattering, spectroscopy, and imaging methods, researchers have tackled complex challenges associated with material operation, addressing chemical and physical phenomena across multiple length scales.

This presentation will emphasize the application of tender X-ray techniques with spatial resolution, offering critical insights into battery chemistries. Specifically, spatially resolved X-ray fluorescence (XRF) imaging and absorption spectroscopy (XAS) will be showcased for investigating sulfur-based chemical species in Li-S batteries. These techniques enable detailed mapping of elemental distributions and chemical states, providing a deeper understanding of reaction pathways, cycling performance, and failure mechanisms.

Our recent studies demonstrate that combining tender X-ray spectroscopy and imaging offers powerful insights into interfaces and transport dynamics, particularly in solid-state batteries. By resolving microscale heterogeneities and chemical gradients, these approaches reveal the critical roles of interfacial stability and ion transport in determining battery performance and longevity. Such findings guide the development of more robust and efficient energy storage systems.

This presentation highlights the transformative potential of tender X-ray techniques for uncovering fundamental mechanisms that drive battery performance and degradation. These insights contribute to accelerating advancements in next-generation battery technologies and sustainable energy storage solutions. Finally, a perspective will explore how synchrotron techniques can continue to impact the future development of advanced battery chemistries.

Keywords *:Lithium ion batteries, Synchrotron X-ray characterization, X-ray absorption spectroscopy, X-ray imaging*

Digital Twin Battery Modeling and Simulations

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Digital twin battery modeling gathers much attraction in unraveling veiled behaviors or parameters of various battery systems. Once 3D structures are created with reasonable resolution, they can be utilized to analyze structural, electrochemical, and mechanical behaviors during calendering process or electrochemical testing. However, the first hurdle is how to generate 3D structures as precisely as possible through reconstructing the actual electrodes or creating virtual electrodes with limitedly provided information. Furthermore, depending on available time and computing resources, we must choose the best method for specific system.
In this presentation, we will first introduce how the digital-twin 3D modeling has been utilized for all-solid-state battery studies: visualizing the microstructures of composite electrodes; quantifying specific contact area between electrode components; calculating effective electronic or ionic conductivity; and simulating voltage profiles, overpotentials, and lithium-ion concentrations during cycling. And then, we will present that mechanical behaviors of single electrode particle can be also simulated successfully with digital-twin-driven 3D structure during charging and discharging process. Furthermore, dynamic simulations on structural deformation of composite electrodes are introduced during calendering process.

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Accelerating the Development of Electrolytes for Lithium Batteries with Self-Driving Labs

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The development of functional electrolytes for lithium batteries requires the optimization of various combinations of salts, solvents, and additives, a process that is traditionally time- and resource-intensive. To accelerate this, computational methods are employed to pre-select candidate combinations, and efforts are underway to utilize self-driving labs (SDLs) powered by AI and robotic automation to efficiently explore optimal electrolyte formulations. By automating electrolyte preparation, battery assembly, and electrochemical analysis, SDLs can rapidly identify optimal combinations with fewer experiments. In this talk, I will introduce the **A**utomated **L**i-ion **BA**ttery **T**esting **RO**bot **S**ystem (ALBATROSS), which allows us to explore new electrolytes by autonomously formulating combinations of salts, solvents, and additives, assembling coin cells, and testing their performance using battery cycling and electrochemical impedance spectroscopy (EIS), all without human intervention. I will also discuss the challenges that must be addressed for the practical implementation of SDLs in the development of battery materials.

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02
Invited Lectures

Medical-mechanics

MAP in Medicine for enhanced pathway beyond skin

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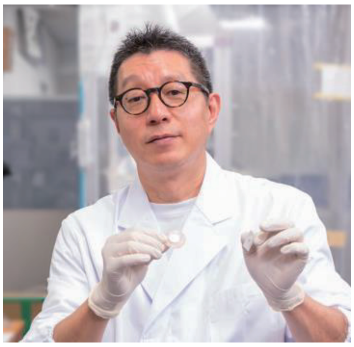
Abstract

Recently, in the transdermal drug delivery methods, the microneedle-mediated drug delivery system (DDS) has been developed to replace the hypodermic injection-mediated DDS, to provide painless self-administration of biological drug with patient friendly manner. Dissoluble microneedles have attracted much attention because they have several advantages, such as no needle-related risks. We have developed new fabrication methods for biodegradable microneedle array patches (MAPs) that are different from conventional fabrication methods such as the stepwise casting method. Here, a new transdermal drug delivery system using a dissoluble microneedle patch was introduced.

We also developed several aspects of bio-sensor components to accomplish portable point-of-care diagnostic devices, which are disposable, user-friendly, low-cost, and highly sensitive. We fabricated a porous microneedle on a paper substrate to develop a novel platform for direct integration of sensors. The device painlessly monitors fluid in the skin within seconds. In contrast, we developed a medical device based on optical microneedle (MN) patches that can deliver both photosensitizer (PS) and light deep into the lesions. This combination of microneedle devices and photodynamic therapy (PDT) will allow transcutaneous administration of active PS for the treatment of infiltrative and nodular skin cancer cells.

Additionally, considering cosmetic and skin troublesome applications, dissoluble MAPs have been commercially available in the last ten years. Now, we collaborate with industrial partners for efficient skin care, especially to design micro sponge spicules to dramatically increase skin permeability in a painless and intuitive manner.

Biography



Beomjoon Kim is a Professor of Institute of Industrial Science, the University of Tokyo, Japan. He is currently a director of LIMMS-KIKO and the Center for Research on Engineering in Medicine and Biology (CREMeB) at the University of Tokyo. He received his B.E. degree from Seoul National University, Department of Mechanical Design and Production Eng., Korea, in 1993, and M.S. and Ph.D. degrees in Precision Engineering, from the University of Tokyo, Japan, in 1995 and 1998, respectively. He was a CNRS Associate Researcher in LPMO, Besancon, France (1998-99), and worked at the MESA+ Research Institute, University of Twente (1999-2000). He was an associate professor at the University of Tokyo (2000-2013), and a co-director at the CIRMM/CNRS Paris office (2001-2003). He investigated several aspects of bio-sensor components to accomplish portable point-of-care diagnostic devices, which are disposable, user-friendly, low-cost, and highly sensitive. Moreover, he is interested in developing self-powered, energy-harvesting microsensors, as well as smart monitoring systems. Recently, the main research topic has been the study of new transdermal drug delivery systems using dissoluble micro needle patches. He has published 121 peer-reviewed journal papers, 252 international conference papers, 226 domestic conference papers, tens of patents, and book publications.

Intelligent Photonics: A Disruptive Technology to Shape the Present and Redefine the Future

Liangcai Cao
Department of Precision Instruments
Tsinghua University

In 2024, the Nobel Prizes in Physics and Chemistry were awarded for advancements in artificial intelligence (AI), which has made breathtaking progress in recent years, evolving into a strategic technology for pioneering the future. The growing demand for computing power—especially in demanding inference tasks, exemplified by generative AI models such as ChatGPT—poses challenges for conventional electronic computing systems. Advances in photonics technology have ignited interest in investigating photonic computing as a promising AI computing modality. Through the profound fusion of AI and photonics technologies, intelligent photonics is developing as an emerging interdisciplinary field with significant potential to revolutionize practical applications. Deep learning, as a subset of AI, presents efficient avenues for optimizing photonic design, developing intelligent optical systems, and performing optical data processing and analysis. Employing AI in photonics can empower applications such as smartphone cameras, biomedical microscopy, and virtual and augmented reality displays. Conversely, leveraging photonics-based devices and systems for the physical implementation of neural networks enables high speed and low energy consumption. Applying photonics technology in AI computing is expected to have a transformative impact on diverse fields, including optical communications, automatic driving, and astronomical observation. In this talk, recent advances in intelligent photonics are introduced from the perspective of the synergy between deep learning and metaphotonics, holography, and quantum photonics. This talk will also spotlight relevant applications and offer insights into challenges and prospects.

Liangcai Cao received his BS/MS and PhD degrees from Harbin Institute of Technology and Tsinghua University, in 1999/2001 and 2005, respectively.

Then he became an assistant professor at the Department of Precision Instruments, Tsinghua University. He is now tenured professor and director of the Institute of Opto-electronic Engineering, Tsinghua University. He was a visiting scholar at UC Santa Cruz and MIT in 2009 and 2014, respectively. His research interests are holographic imaging and holographic display. He is a Fellow of the Optica and the SPIE.

Bridging Perception with Robot Manipulation

Sungwook Yang
KIST

Abstract

The convergence of robotic perception and manipulation has the potential to transform how systems interact with the world, spanning fields from industrial automation to complex human-robot collaboration. Despite significant advancements, many robotic platforms still face challenges in achieving the necessary precision and adaptability due to limitations in sensory integration and real-time control. This presentation will explore advanced methodologies that bridge the gap between robotic perception and manipulation, leveraging state-of-the-art techniques in control and imaging. Key research developments will be highlighted, including the use of handheld robots for visual servoing and the implementation of hybrid force/vision control strategies that enable precise and safe manipulation. In the area of brain tumor therapy, we introduce a system that employs real-time imaging and SLAM-based light therapy to support minimally invasive procedures. Additionally, our work toward a fully automated COVID-19 sampling robot will be discussed, showcasing image-based control for multi-degree-of-freedom manipulators and force sensor-driven control to enhance safe and effective sample collection. Finally, we delve into the application of Vision Language Models (VLM) to extract semantic information from visual data, enabling intuitive, intent-driven control of multi-fingered robotic hands and broadening the scope of applications across both structured and unstructured environments. These contributions highlight the growing synergy between perception and manipulation, paving the way for more responsive and intelligent robotic systems across medical and industrial applications.

Liquid Metal Fiber Mat for Permeable Electronic Skins

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Abstract:
Soft electronics plays an important role in the realization of health monitoring and rehabilitation, Internet of Things (IoTs), and soft robotics. In the past two decades, the research focuses have been devoted to developing soft electronics based on thin film materials and architectures that are non-permeable to air, moisture, and liquid. It is recently found that permeability is essential to the chronic biocompatibility of these soft devices, especially those closely attached on soft skins and tissues. This short talk will discuss our recent research effort on developing liquid metal based soft and permeable electronics for wearable, skin-attached, and implantable applications. In particular, we will introduce how to fabricate stretchable and permeable electronics using liquid metal based material platform, how to address the interfacial mismatches, how to achieve high resolution patterning toward functional stretchable and permeable electronic devices and systems, and how to integrate into 3D permeable circuits.

Biography:
Prof. Zijian Zheng is currently Chair Professor of Soft Materials and Devices at the Department of Applied Biology and Chemical Technology, Director of PolyU-Daya Bay Research of Associate Director of Research Institute for Intelligent Wearable Systems at The Hong Kong Polytechnic University (PolyU). His research interests include surface and polymer science, nanofabrication, flexible and wearable electronics, energy conversion and storage. Prof. Zheng received his B. Eng. in Chemical Engineering at Tsinghua University in 2003, PhD in Chemistry at University of Cambridge in 2007, and postdoctoral training at Northwestern University in 2008-2009. He joined PolyU as Assistant Professor in 2009, and was promoted to tenured Associate Professor in 2013 and then Professor in 2017. He has published more than 200 papers in journals such as *Science*, *Nat. Mater.*, *Nat. Comm.*, *Adv. Mate.*, *JACS*, *Angew. Chem.*. He also files more than 40 patents and is recipient of more than 20 academic awards. He serves as Editor-in-Chief of *EcoMat* (impact factor: 10.7), a flagship open-access journal in green energy and environment published by Wiley. He is Founding Member of The Young Academy of Sciences of Hong Kong (2018), Chang Jiang Chair Professor by the Ministry of Education of China (2020), Senior Research Fellow of the University Grant

Commission of Hong Kong (2021), Fellow of International Association of Advanced Materials (FIAAM, 2021), Fellow of the Royal Society of Chemistry (FRSC, 2022), and Young Fellow of the Hong Kong Academy of Engineering Science (YFHKEng, 2024). He is awardee of the inaugural Hong Kong Engineering Science and Technology Award.

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02
Invited Lectures

Nanoelectronics

Prof. Sang-Hoon Bae

2D and 3D nanomembrane-based materials innovation: From artificial heterostructures to monolithic 3D integration

Sang-Hoon Bae
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Abstract
Thin film technology involves the deposition of thin layers of materials, typically ranging from a few nanometers to several micrometers, onto a substrate. These films serve critical functions in fields such as electronics, optics, and optoelectronics. While silicon has historically dominated thin-film advancements due to its well-established processing techniques, the growing demand for enhanced performance and novel functionalities has accelerated the exploration of alternative materials. Freestanding nanomembranes—such as 2D materials and ultrathin 3D nanomembranes—stand out as transformative innovations, offering unique properties that enable the creation of cutting-edge devices and the discovery of new physical phenomena.
Our team is at the forefront of this innovation, specializing in the development of freestanding 2D and 3D nanomembranes. We have pioneered novel fabrication methods to produce these materials, which are characterized by their exceptional thinness, low stiffness, and minimal internal stress. These properties make them ideal for vertical stacking and monolithic 3D integration, unlocking new opportunities for exploring physical phenomena and designing advanced device architectures through artificial heterostructures. In this presentation, I will outline the core principles behind the fabrication of these nanomembranes and discuss their significant potential in artificial heterostructures and monolithic 3D integrated applications such as in-sensor computors and AI hardware.

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Brief Biography
Sang-Hoon Bae is an assistant professor at Washington University in St. Louis since 2021. He received his Ph.D. degree in the Department of Materials Science and Engineering from UCLA and was then a postdoctoral research associate at MIT. He is a recipient of multiple honorous awards such as breakthrough of the year from Falling Walls Foundation award (2024), finalist for Rising Stars of Light from Light Science and Applications (2023), Hanwha Junior Faculty Award, (2023), SAMSUNG Global Research Outreach Award (2022), EMA early career researcher's contribution (2022). He has published over 100 papers (citations >10,000 and an h-index >50) .

Prof. Han Wang

Van der Waals Material Devices for Logic, Memory and Computing

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In this talk, I will discuss the recent academic and industrial development of van der Waals material based devices for advanced logic, memory and computing technologies. Two-dimensional (2D) transition metal dichalcogenides materials are promising candidates for advanced logic transistor applications. It however still faces difficulties towards practical commercialization due to challenges in device contact resistance, gate dielectric technology, integration process development, as well as its reliability and yield. In the first part of the talk, I will discuss our recent work in addressing some of these issues. Moreover, the unique physical properties of 2D materials also offer opportunities for developing novel memory and computing device technologies that can result in substantial performance improvement over traditional semiconductor devices as well as enabling new device and circuit functionalities difficult to achieve using conventional technologies. In the second part of the talk, I will discuss our work in developing such new semiconductor devices including 2D material based ferroelectric tunneling junction memory and stochastic computing devices for efficiently solving combinatorial optimization problems. I will conclude with remarks on how van der Waals material devices are expected to benefit the next-generation electronics systems and the remaining roadblocks that need to be overcome.

Han Wang is Professor of Electrical and Electronic Engineering at University of Hong Kong (HKU). He also serves as the Director of the Center for Advanced Semiconductors and Integrated Circuits at HKU. Before joining HKU in 2023, he worked at IBM T. J. Watson Research Center (2013-2014), and the University of Southern California (2014-2023), first as Assistant Professor and then as tenured Associate Professor. In 2021-2023, he also served as the head of the new material and device research department at Taiwan Semiconductor Manufacturing Company (TSMC) Corporate Research. His research interests include advanced microelectronics technology based on emerging semiconductor materials. He is recipient of US Army-ECASE Award, IEEE Nanotechnology Council Early Career Award, US Army Research Office Young Investigator Award, US NSF CAREER Award and the Roger A. Haken Best Paper Award in IEEE International Electron Device Meeting (IEDM). He is the IEEE Nanotechnology Council Distinguished Lecturer (2020-2021). He served on the IEDM technical program committee (2022-2023), and he currently serves as Chair of the IEEE Electron Device Society Neuromorphics Technical Committee and Chair of the IEEE ED/SSC Hong Kong Joint Chapter.

Prof. Youngmin You

How Do Organic Compounds Degrade in Electronic Devices?

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Dipolar and multi-resonance thermally activated delayed fluorescence (TADF) molecules have emerged as indispensable components in high-efficiency organic electroluminescence devices. However, accumulated research has indicated that devices based on TADF materials suffer short operational lifetime. My group has focused on mechanistic understanding of how the TADF materials degrade. We employed a variety of experimental techniques to identify the key intermediates for intrinsic degradation. We found that the excitonic stability is governed primarily by conformational distributions. Our studies also revealed that radical cation (positive polaron) of TADF compounds are more susceptible to intrinsic degradation than excitons. We quantified Faradaic yields for degradation of polarons which are order of magnitude greater than quantum yields for degradation of excitons. This finding was supported by operational lifetime of devices involving the TADF materials. Finally, we investigated effects of host materials on the stability of a TADF molecule. Heterobimolecular electron transfer was identified as the key degradation mechanism. Spectroscopic experiments revealed that host excitons were reduced with ground-state TADF dopants to form radical ion pairs that underwent rapid polaronic degradation. We established a numerical model for the electron-transfer degradation which could simulate the operational lifetime of devices. These understanding will be instrumental toward designing organic compounds with high operational stabilities.

Youngmin You earned his bachelor and MS degrees in Chemical Engineering from Seoul National University. He then decided to move to the Department of Materials Science and Engineering of Seoul National University for his Ph.D. study under supervision of Soo Young Park. Youngmin stayed at Massachusetts Institute of Technology as a Postdoctoral Fellow, where he learned bioinorganic chemistry under guidance of Stephen J. Lippard. He is currently Professor of the Department of Chemical and Biomolecular Engineering at Yonsei University. His research group focuses on the design, syntheses, and spectroscopic investigations of photoactive molecules for photonic applications, including electroluminescence and photoredoxcatalysis.

Prof. Sooyeon Cho

Accelerating Sensor Development through the Engineering of Nanoparticle Corona

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To tackle the challenges posed by rapidly evolving biochemical phenomena and emerging unknown diseases in life sciences, it is essential to develop sensing materials and devices capable of specifically targeting analytes and biomarkers with diverse, distinct, and previously uncharacterized molecular structures. While the typical sensor construct offers selective and sensitive detection, a significant limitation is that the systems are based on a single type of biological receptor, rendering them non-effective for detecting new diseases or adapting to antigen mutations with different molecular structures. Thus, there is an immediate need for a high-throughput sensor development technology that can rapidly design and produce sensors responding to totally different or unknown molecular structures, without relying on a synthesis of new biological receptors and their functionalization.

In this talk, we introduce an accelerated design workflow for biochemical sensing materials that completely eliminates the need for time-consuming biological receptor design. We have developed label-free sensor constructs based on a corona phase molecular recognition (CoPhMoRe), utilizing near-infrared (nIR) fluorescent single-walled carbon nanotubes (SWCNTs). We engineered versatile three-dimensional corona interfaces on SWCNTs through non-covalent functionalization using a diverse library of soft materials, such as DNA and PEG-phospholipids, enabling access to a wide spectrum of chemical and physical properties. The precisely tailored morphology and nanoscale dimensions of these interfaces facilitate robust and selective molecular recognition of various biomarkers, detected via nIR signal modulation. Through automated high-throughput screening and a combination of molecular dynamics and docking computations, we have established a sensor design rule that facilitates the identification of optimal nanosensor constructs. Selected examples highlight the versatility in creating fluorescent sensors for various pandemic viruses and biomarker proteins in human biofluids. The resulting label-free sensors have proven their efficacy even in complex biofluids and on-site diagnostic form factors that we designed, with a non-biological origin construct demonstrating remarkable stability.

Sooyeon Cho has been an associate professor in the School of Chemical Engineering at Sungkyunkwan University (SKKU) since March 2025, having previously served as an assistant professor from 2022 to 2025. He received a B.S. and Ph.D. from the KAIST in Chemical Engineering (2019). Prior to joining SKKU, Prof. Cho was a postdoctoral associate in the Department of Chemical Engineering at the MIT from 2019 to 2022. He was a visiting scholar in the Department of Electrical Engineering and Computer Science at the University of California, Berkeley in 2016.

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03
Poster Session

Chemical & Biomolecular Engineering

Organooxotin complexes for Extreme UV Photolithography

Jihye Baek,[1] Sihyun Woo,[2] Chawon Koh,[3,4] Tsunehiro Nishi,[3] and Youngmin You[1]*
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Transition metal complexes, such as those involving Sn, are considered promising candidates for negative-tone photoresists (PRs) for extreme ultraviolet lithography (EUVL). To fully exploit the EUVL potential of the metal complexes, it is imperative to improve their EUV sensitivity and thermal and storage stabilities. To meet these requirements, we have developed eight organooxotin complexes with ditopic bis(pyrazolecarboxylate) ligands wherein the two pyrazole units were linked through differed alkyl bridges.[1] We found that the complex with a propylene linker contain the tetranuclear planar stannoxane having vertical butyl ligands. The unique ligand disposition enabled the formation of the layer-ordered supramolecular structure of Sn complexes. The Sn complex exhibited the high lithographic performance for producing well-defined 20 nm line/space patterns under 1200 μC cm^{-2} e-beam and 221 mJ cm^{-2} EUV exposure. Chemical investigations based on thermogravimetric analyses and $^{119}Sn\{^{1}H\}$ NMR spectroscopy indicated high thermal and moisture stabilities of the complex.

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Large-Scale Lithium Metal Powder Electrodes with a Tailored Adhesive-Conductive Interlayer for Interface Stabilization in High-Energy-Density Batteries

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Keyword: Li Metal Batteries, Li Metal Powder Electrodes, Adhesive-Conductive Polymer Interlayer, Structural Stability, large-dimensional Li Anode

A slurry-based coating method utilizing lithium metal powder (LMP) has been developed as an alternative to traditional extrusion and pressing processes for lithium (Li) metal electrode production, enabling the fabrication of ultra-thin and broad-width Li electrodes through coating condition optimization. LMP electrodes, however, face significant challenges including delamination of the LMP composite layer from the copper current collector (Cu CC) due to electrolyte infiltration at the interface, and degradation of interfacial connectivity during charge-discharge cycles. To resolve these limitations, an adhesive-conductive polymer (AC-polymer) interlayer, composed of poly(3,4-ethylenedioxythiophene) and poly(styrene sulfonate-co-acrylic acid), was introduced between the LMP composite layer and Cu CC for enhanced interfacial stability. Implementation of the AC-polymer interlayer resulted in a reduction of Li stripping overpotential from 89.8 mV to 35.8 mV (60% decrease) and improved cycling stability, demonstrating 91% capacity retention at 4 mA cm^{-2} discharging rate after 150 cycles in carbonate-based electrolyte. The successful fabrication of a 300 mm-wide and 20 μm-thick slurry-coated AC-LMP electrode demonstrates the potential for practical application in Li metal batteries.

Tailoring ZIF-8 Morphology: High-Aspect Ratio Nanoplates and Twinned Structures for Enhanced Hydrocarbon Separation

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Keywords: Mixed matrix membrane; Gas separation; High aspect ratio; Zeolitic imidazolate framework-8; Morphology control

Membrane technology offers a cost-effective, energy-efficient alternative to distillation for gas separation. Although polymer membranes are widely used, they often exhibit a compromise between permeability and selectivity. To address this issue, integrating selective fillers into polymer matrices to form mixed matrix membranes (MMMs) has proven to be an effective strategy. Conventional MMMs using isotropic metal-organic framework (MOF) particles have demonstrated robust performance; however, further improvements in gas separation can be achieved through refined morphology control and enhanced interfacial interactions. In our work, we have systematically overcome these challenges by engineering the morphology of MOF fillers. Utilizing a $Zn_5(NO_3)_2(OH)_8$ template, we optimized synthesis parameters to produce ZIF-8 nanoplates (NZIF-8) with a high aspect ratio and superior alignment compared to conventional ZIF-8s. Furthermore, by adopting a twin-growth process using a ZIF-L template, we developed twinned ZIF-8 (TZIF-8) structures that introduce additional vertical channels within the nanoplates, thereby enhancing the selective transport of gases. These morphology-engineered fillers were uniformly incorporated into the 6FDA-DAM polymer matrix *via* scalable bar coating techniques to fabricate MMMs. Gas permeation tests revealed that the high aspect ratio ZIF-8 nanoplates, with their expansive lateral dimensions and minimal thickness, create a more tortuous pathway that selectively impedes larger molecules while allowing smaller ones to pass rapidly, also contributing to improved hydrogen extraction efficiency during propane dehydrogenation. In addition, introducing twin structures further enhances the separation of propylene from propane by providing extra vertical pathways. Our study demonstrates that the precise morphology control of MOF fillers, transitioning from conventional isotropic particles to high aspect ratio nanoplates and twinned structures, is key to achieving high-performance MMMs. The findings provide clear insights into the structure–property relationships governing gas separation and lay the groundwork for next-generation membrane technologies with significant industrial application potential in hydrocarbon separation and hydrogen extraction.

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Development of a Catalyst Cost Guideline Model for Green Ammonia

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Green ammonia is an attractive hydrogen carrier due to its many advantages, including high energy, relatively mild liquefaction conditions, and use of existing infrastructure. Catalysts are used in ammonia synthesis and decomposition processes to utilize green ammonia, and experimental catalysis studies are focused on developing catalyst materials with improved performance under mild temperature and pressure conditions. Although a variety of ammonia catalysts have been developed, there are challenges in bridging lab-scale catalyst performance to industrial-scale performance and quantifying it into economic value. Therefore, this study performed multi-scale modelling of green ammonia catalyst kinetics and the processes of synthesis and decomposition. In addition, the economics of each catalyst under optimal conditions were evaluated and compared to existing catalysts. Thus, it can provide catalyst developers with cost guidelines to determine from the lab-scale performance of their catalysts to industrial-scale production economics.

Keywords: Green ammonia, Catalyst, Ammonia synthesis, Ammonia decomposition, Economic analysis, Catalyst cost

Orthogonal photopatterning of two-dimensional percolated network films for wafer-scale heterostructures

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ABSTRACT: Molecular intercalation based electrochemical exfoliation of two-dimensional (2D) materials can be used to create van der Waals heterostructures. However, the scalable assembly of vertical heterostructures typically requires the use of various chemical solvents for photolithography and subsequent transfer, which can leave behind chemical residues and limit patterning resolution. Here, we show that patterned van der Waals heterostructures can be fabricated from electrochemically exfoliated 2D flakes using a photoreactive cross-linker. When a 2D van der Waals percolated network with the cross-linker is exposed to ultraviolet light, the network junctions form covalent bonds, thereby enabling improved charge transport and orthogonal patterning of vertically stacked van der Waals thin-film networks without affecting the underlying prepatterned layers. Our approach can be used to create wafer-scale arrays of photopatterned field-effect transistors based on different 2D materials. The field-effect transistors exhibit high spatial uniformity and can be used to create logic gates, including NOT, NAND, and NOR gates.

Exosome Isolation for Cancer Diagnosis and Monitoring using Microfluidic Chip

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Exosomes have received considerable attention as potential biomarkers for liquid biopsies due to their unique biological functions and rich biological information. However, the heterogeneity of exosomes and non-standardized isolation methods may interfere with clearly determining the patient's condition. Therefore, two microfluidic chip-based systems were developed for the diagnosis and monitoring of HER2-overexpressing cancers. The first system, called the magnetically labeled exosome isolation system (MEIS-chip), uses different magnetic nanoclusters and antibodies to immunoaffinity capture HER2-overexpressing and non-target (common) exosomes. The MEIS-chip efficiently separated HER2-overexpressing exosomes from *in vitro* and *in vivo* samples, providing a means of analyzing high-purity HER2-overexpressing exosomes while minimizing the contribution of abundant common exosomes in the sample. In addition, common exosomes isolated simultaneously with HER2-overexpressing exosomes served as a negative control for monitoring real-time changes in HER2 expression. The second system, a microfluidic chip (nanochip) in which a three-dimensional nanostructure is implanted in a herringbone pattern, captures exosomes using a nanoporous structure composed of silica particles attached with antibodies to isolate exosomes. The Nano-chip induces micromixing through the herringbone structure and reduces the hydrodynamic surface resistance through the nanoporous structure, thereby improving the contact and interaction between the exosome and the nanostructure. In addition, the dual Nano-chip system, which was fabricated by connecting nanochips with different antibodies, simultaneously isolated HER2-positive exosomes and common exosomes from *in vitro* and *in vivo* samples without pretreatment, demonstrating its applicability for disease diagnosis and monitoring. These microfluidic chip-based systems have potential applications in the development of biosensors to isolate and detect exosomes from body fluids for disease diagnosis and monitoring.

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Promoting Granular Lithium Sulfide Growth by Soft Acidic–Hard Basic Ionomer Binder for Lithium–Sulfur Batteries

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Key words: Li–S batteries, Hard soft–acid base theory, Ionomer binders, Damköhler number, Electrode passivation, S utilization

Electrode passivation limits the reversibility of lithium–sulfur (Li–S) batteries. Pivoting from the prevailing approaches that focus on electrode active materials and electrolytes, herein, we introduce a class of S electrode binders based on soft acidic–hard basic (SAHB) ionomers. The SAHB binder contains a soft cation (tetraallyl ammonium ion, TA^+) paired with a hard counter anion (nitrate, NO_3^-), allowing matched interactions with Li polysulfides (LiPS) via soft acid–soft base (TA^+–S_x^{2-}) and hard base–hard acid (NO_3^-–Li^+) pairings. This intermolecular coupling retards LiPS diffusion, promoting three-dimensional granular Li sulfide (Li_2S) growth, guided by a high Damköhler number (*Da*). Consequently, the SAHB binder enables a Li–S cell to achieve a high specific capacity of 1545 mAh g_{sulfur}^{-1} (corresponding to 92.3% S utilization) and stable capacity retention (71.5% after 300 cycles at a current density of 1 C), outperforming previously reported S electrode binders.

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03
Poster Session

Electrical & Electronic Engineering

Large Language Model Empowered Hierarchical Intelligent Control for O-RAN

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Abstract

Recent advancements in large language models (LLMs) have led to a significant interest in deploying LLM-empowered algorithms for wireless communication networks. Pre-trained on diverse datasets, LLMs acquire general knowledge applicable across various scenarios. Meanwhile, open radio access network (O-RAN) techniques offer unprecedented flexibility, with the non-real-time radio access network intelligent controller (non-RT RIC) and near-real-time RIC (near-RT RIC) components enabling intelligent resource management across different time scales. This paper proposes the hierarchical LLM-RL RIC (HLR-RIC) framework, which integrates LLM with reinforcement learning (RL) for efficient network resource management. In this framework, LLMs function as rApps in the non-RT RIC, providing strategic guidance and high-level policies based on environmental context. Concurrently, RL agents serve as xApps in the near-RT RIC, performing low-latency tasks based on strategic guidance and local near-RT observation. Finally, we evaluate the HLR-RIC framework in an integrated access and backhaul (IAB) network, optimizing backhaul power allocation for maximum throughput. Simulation results highlight the framework's superior performance, underscoring its potential to advance intelligent wireless communication systems.

Nanomesh-based RRAM with Percoltaed Nanoparticle Networks

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Keywords: Silver selenide, Nanoparticles, Nanomesh, RRAM

Resistive random access memory (RRAM) stands out as a leading next-generation non-volatile memory, offering simplicity in operation and fabrication, thus making it suitable for wearable and skin-attachable devices. However, the insulating layer used in conventional RRAM, typically composed of inorganic materials, possesses high mechanical strength due to strong chemical bonding and crystalline structure, making it challenging to integrate into flexible components. Organic semiconductors like Musin and Pentacene have been proposed as alternatives, but their memory characteristics (endurance, chemical stability, durability, etc.) are inferior to those based on inorganic materials. Additionally, applying non-porous structures to wearable and skin-attachable devices often leads to discomfort and skin irritation due to poor breathability. Therefore, developing flexible and porous structure components based on inorganic materials is essential for applying RRAM components to wearable and skin-attachable devices. Herein, we present sliver selenide (Ag_2Se) embedded nanomesh-based RRAM devices, which possess flexibility and breathability. Silver (Ag) nanoparticles are patterned on flexible and breathable nanomesh. Furthermore, we seek to form silver selenide (Ag_2Se) inorganic semiconductor material by reacting with selenium precursor solution, followed by depositing aluminum (Al) to achieve a flexible and breathable Metal-Insulator-Metal (MIM) structure. The Ag_2Se nanoparticles embedded nanomesh-based RRAM presents outstanding switching characteristics ($I_{on}/I_{off} > 10^6$, and retention time $>10^6$ s). This study suggests the possibility of further application for memory devices of wearable and skin-attachable devices.

Authors' background

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Sungjoon Cho	Mr.	Wearable electronics	-
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Bussgang Meets Kalman in Neural Networks: State Estimation with 1-Bit Observations and Imperfect Models

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Yonsei University

State estimation from noisy observations is a fundamental problem in many applications of signal processing. Traditional methods, such as Extended Kalman Filter (EKF), work well under fully known Gaussian models, while recent studies on hybrid deep learning frameworks, combining model-based and data-driven approaches, can also handle partially known models and non-Gaussian noise. However, the existing work commonly assumes no quantization distortion, which is inevitable especially in non-ideal analog-to-digital converter. One-bit quantization causes significant quantization distortion and severe information loss, rendering conventional state estimation strategies unsuitable. To address this, inspired from the Bussgang decomposition technique, assuming perfectly known models, we first develop the Bussgang-aided Kalman Filter (BKF), wherein the quantization distortion is properly captured into the state estimation process. Further, to deal with partially known models, we also propose a deep learning based method by exploiting the principle of our BKF. In this work, accurate estimation with low computational complexity is enabled by the process of dithering using state prediction, which provides error covariance of observations. Through simulation on the Lorenz-Attractor model and the NCLT dataset, we demonstrate that our proposed method achieves accurate state estimation performance even in highly nonlinear and mismatched conditions.

Hybrid Semantic Communication with Complementary Shannon Transmission

Hyelin Nam
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A generative model-based semantic communication (GSC) system transmits key feature information of an image, enabling the reconstruction of perceptually similar images with reduced transmission overhead. However, the performance of GSC is fundamentally constrained by the generative capability of models trained on large-scale image datasets, limiting the accurate reconstruction of fine details even with increased semantic transmission. To address this limitation, we propose the Hybrid Semantic Communication (HSC) system, an extension of GSC that incorporates additional '*Complementary information*' within a conventional Shannon transmission framework. This approach enhances the reconstruction of fine details, achieving a higher fidelity approximation of the original image. The proposed system provides a flexible trade-off between transmission efficiency and reconstruction accuracy. Theoretical analysis validates its effectiveness, while experimental results with various generative models, including variational autoencoders (VAEs) and diffusion models, demonstrate that increasing the additional transmission reduces reconstruction error. Notably, HSC achieves lossless reconstruction with a lower transmission rate than conventional methods.

A Wireless Wearable Sensor System based on a Silver Nanowire-decorated Silicon Nanomembrane for Precise and Continuous Hazardous Gas Monitoring

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Abstract

Wearable wireless gas sensors have attracted enormous interest due to precise, real-time healthcare and environmental monitoring without temporal and spatial limitations. Among various toxic gases, detecting ammonia (NH_3) is crucial because of its highly hazardous nature and applicability as a noninvasive biomarker for diagnosing health conditions. In this study, silver nanowires-decorated silicon nanomembrane (AgNW-SiNM) chemiresistive gas sensor with high selectivity to ammonia was fully integrated with an ultrathin flexible Joule heater and wireless communication system to fabricate wearable wireless real-time toxic gas monitoring system. The sensor exhibited improved performance to NH_3 gas, attributed to heating-induced changes in adsorption/desorption rates, along with electronic and chemical sensitization facilitated by AgNW decoration. The gas sensing system exhibited stable and high responses of ~1.83, 1.47, and 1.19 on the NH_3 exposure at concentrations of 10, 5, and 1 ppm even under mechanical deformations. The real-time dynamic response of the sensor was wirelessly transmitted to portable electronics and displayed on the screen. Moreover, the system alerts the users in advance through the integrated haptic interface when exposed to dangerous gas environments for early evacuation. The system paves the way for timely warnings from hazardous gas and more accurate noninvasive medical diagnosis related to respiratory disorders.

Exosome Isolation for Cancer Diagnosis and Monitoring using Microfluidic Chip

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Exosomes have received considerable attention as potential biomarkers for liquid biopsies due to their unique biological functions and rich biological information. However, the heterogeneity of exosomes and non-standardized isolation methods may interfere with clearly determining the patient's condition. Therefore, two microfluidic chip-based systems were developed for the diagnosis and monitoring of HER2-overexpressing cancers. The first system, called the magnetically labeled exosome isolation system (MEIS-chip), uses different magnetic nanoclusters and antibodies to immunoaffinity capture HER2-overexpressing and non-target (common) exosomes. The MEIS-chip efficiently separated HER2-overexpressing exosomes from *in vitro* and *in vivo* samples, providing a means of analyzing high-purity HER2-overexpressing exosomes while minimizing the contribution of abundant common exosomes in the sample. In addition, common exosomes isolated simultaneously with HER2-overexpressing exosomes served as a negative control for monitoring real-time changes in HER2 expression. The second system, a microfluidic chip (nanochip) in which a three-dimensional nanostructure is implanted in a herringbone pattern, captures exosomes using a nanoporous structure composed of silica particles attached with antibodies to isolate exosomes. The Nano-chip induces micromixing through the herringbone structure and reduces the hydrodynamic surface resistance through the nanoporous structure, thereby improving the contact and interaction between the exosome and the nanostructure. In addition, the dual Nano-chip system, which was fabricated by connecting nanochips with different antibodies, simultaneously isolated HER2-positive exosomes and common exosomes from *in vitro* and *in vivo* samples without pretreatment, demonstrating its applicability for disease diagnosis and monitoring. These microfluidic chip-based systems have potential applications in the development of biosensors to isolate and detect exosomes from body fluids for disease diagnosis and monitoring.

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A Tough and Hemostatic Hydrogel for Wound Healing and Closure: Syringe-Injectable and Patch Type with Strong Tissue Adhesion

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Abstract

Failure to promptly control bleeding can lead to several complications, including scar formation, bacterial infections, and sepsis. In particular, a simple and rapid hemostatic method must be established to effectively manage massive bleeding in emergencies, such as surgical procedures and wartime injuries. In this study, we developed a hemostatic hydrogel with strong tissue adhesion, high mechanical strength, self-healing ability (within 10 seconds), and antibacterial properties. The hydrogel was formulated using polyvinyl alcohol (PVA), dopamine-grafted sodium alginate (SA-DOPA), and tannic acid (TA), with borax as a crosslinking agent. SA-DOPA is known for its superior adhesion even in moisture conditions. The hydrogel demonstrated superior adhesion with porcine skin (shear strength ≈ 275 kPa). Additionally, TA contributed to both antibacterial activity and hemostasis. The hemostatic and wound-healing efficacy of the hydrogel was validated through a series of *in vitro* and *in vivo* experiments. In a liver puncture mouse model, the hydrogel achieved complete hemostasis within 5 seconds. Furthermore, its shear-thinning properties and strong tissue adhesion enabled effective sutureless wound closure. These findings demonstrate the hydrogel's potential as an effective wound dressing for emergency and surgical applications.

Keywords: Hemostasis hydrogel, Strong tissue adhesion, Sutureless wound closure

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03

Poster Session

Materials Science and Engineering

Cation-eutaxy-enabled III-V-derived Van Der Waals Crystals as Gate-tunable Memristor

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Novel two-dimensional semiconductor crystals offer diverse physical properties beyond their intrinsic semiconducting characteristics, highlighting their significance in advanced material research. Memristive behaviors, frequently observed in wide-bandgap materials, present a challenge when combined with semiconducting properties to achieve functional memtransistors. A new class of semiconducting van der Waals crystals, denoted as $H_xA_{1-x}BX$, was synthesized, exhibiting both memristive and semiconductive properties. To identify suitable materials, a systematic high-throughput screening process was employed, resulting in 44 promising III–V compounds. Among these, ten materials, including nitrides, phosphides, arsenides, and antimonides, were successfully synthesized. These compounds demonstrated unique features such as electrochemical polarization and memristive phenomena while maintaining their semiconductor functionality. Single-gate memtransistors fabricated using these materials exhibited gate-tunable synaptic and logic functions, harnessing the interplay between their semiconducting and memristive attributes. This study provides a pathway for discovering van der Waals materials with unconventional crystal symmetries and multifunctional properties.

Liquid-metal-based Three-dimensional Microelectrodes Integrated with Flexible Phototransistors Arrays for Vision Restoration

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Inherited retinal degenerative diseases cause photoreceptor cell loss, leading to vision impairment or blindness. However, inner retinal neurons are often preserved, prompting efforts to restore vision by stimulating these cells. Electronic retinal prostheses, which electrically stimulate inner retinal neurons using photo-responsive devices, have progressed to clinical trials but are limited by low visual acuity. A key challenge is poor proximity between the implant and retina, increasing the electrode-to-cell distance and causing imprecise stimulation, which can inadvertently activate RGC axons and generate irregular visual perceptions.

To address this, we present an artificial retina integrating flexible ultrathin phototransistors with 3D liquid-metal microelectrodes. This design enables conformal contact with the retina, where phototransistors convert light into electrical stimuli delivered via soft 3D electrodes. These pillar-shaped electrodes improve proximity to target cells, selectively stimulate local regions, and minimize damage due to their low Young's modulus. Platinum (Pt) nanoclusters on the electrode tips reduce impedance and enhance charge injection. Additionally, unsupervised machine learning confirms selective stimulation of the RGC somas, and in-vivo experiments in a retinal degeneration mouse model demonstrate localized retinal responses under targeted light exposure, suggesting potential for vision restoration.

Piezoelectric Power Generation of Amorphous Perovskite Oxide Thin Films

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Thin-film piezoelectric energy harvesters have been based on crystalline ferroelectric oxide thin films deposited on rigid substrates. These films necessitate high-temperature processing, usually above 700°C, and are commonly designed to utilize vibrational input sources. For flexible harvesters, however, the high-temperature crystallization process is unsuitable because it is incompatible with most polymer-based substrates. Herein, a flexible energy harvester using amorphous perovskite $CaCu_3Ti_4O_{12}$ (CCTO) thin films on a plastic substrate is introduced as a highly competitive power generator. Sputtering CCTO thin films at room temperature with controlled pO_2 ratios enables the use of plastic substrates and allows for defect engineering within the amorphous films. Surprisingly, the resultant amorphous nature of the films resulted in an output voltage and power density of ~38.7 V and ~2.8×10^6 μW cm^{-3}, respectively, which far exceed previously reported typical performance. The origin of this outstanding power-generating performance is attributed to the localized permanent dipoles of TiO_6 octahedra and the lowered dielectric constant in the amorphous state, depending on the stoichiometry and defect states of the sputtered CCTO thin films.

Complementary Moisture-induced and Triboelectric Energy Harvesting Enabled by Resilient MXene/Organo-ionic Hydrogel Foam

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The rising demand for renewable energy highlights the significance of moisture-induced electric generators (MEGs) and triboelectric nanogenerators (TENGs). Herein, we present a complementary energy harvester, simultaneously generating MEG and TENG power in a single device. Our harvester was comprised as melamine foam coated with 2-dimensional conductive MXene ($Ti_3C_2T_x$) nanosheets and partly covered with organo-ionic hydrogel. This results in the MEG outputting a DC voltage of 310 mV and delivering a current density of 877 μA cm^{-2}. The robust foam withstands repeated mechanical contact, yielding a TENG that generates a high AC voltage of 80 V. When this MEG is integrated with triboelectric effects, the combined device exhibits an impressive electrical power output of 83 μW cm^{-2}. This distinct combination of DC and AC power outputs paves the way for a groundbreaking emergency guidance system, in which a MEG-driven light is enhanced by a self-sustaining TENG during emergency situations.

Stimuli-responsive Polyurethanes for Bioresorbable Medical Device

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Yonsei University

Recent advancements in transient devices have led to the development of bioresorbable medical devices, eliminating the need for explant surgeries and reducing the risk of infection. However, conventional polymeric encapsulations often face premature device failure or prolonged residual presence due to their hydrolysis-based “passive” degradation. Here, we introduce a novel stimuli-responsive polyurethane designed for the “active” degradation of electronic medicine. This material, called bioresorbable glutathione-responsive polyurethane (b-GrPU), employs disulfide bonds to trigger degradation in the presence of the biological antioxidant glutathione. Studies demonstrate the stimuli-responsive characteristics of b-GrPU through its mechanical and chemical properties. Systematic tests as an encapsulation material for medical devices show its ability to sustain operation with controllable durations ranging from a few hours to a week while immersed in aqueous solutions.

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03

Poster Session

Mechanical Engineering

Thermo-Galvanic Based Contact Heat Flux Sensing

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Temperature is a fundamental physical parameter that plays a crucial role in various fields, including industrial process control, health monitoring, building energy management, cold chain monitoring, and electronic cooling. The ongoing development of temperature-sensing technologies is driven by the increasing need for precise and reliable monitoring. However, temperature measurements alone do not always provide a complete picture of thermal behavior, as heat flux is also essential in understanding energy transfer processes. This necessitates the use of transient heat flux sensors in many applications.

While significant advancements have been made in high heat flux sensors, such as thermopiles, challenges remain—particularly in terms of sensitivity. Sensitivity is influenced by the sensor's thermal conductivity, thickness, and by the thermoelectric Seebeck coefficient, which as indicated by recent studies, is typically in the range of a few hundred $\mu V\ K^{-1}$. A promising alternative involves the use of thermo-galvanic cells that leverage the Soret effect, as they exhibit a high ionic Seebeck coefficient, potentially enabling the development of high-performance thermoelectric (TE) devices. However, while ionic liquids can achieve higher sensitivity than conventional TE materials, they pose stability issues due to the risk of leakage in stretchable ionic conductors under large deformation or prolonged storage, leading to performance degradation and potential hazards. Consequently, the development of quasi-solid or solid-state, liquid-free stretchable ionic conductors is a key objective in this field.

Additionally, low-grade thermal energy (<100 °C) is widely available in everyday environments, industrial processes, and even the human body, presenting vast opportunities for energy harvesting. In recent years, thermogenic cells that function based on temperature gradients have garnered considerable attention for their potential in utilizing low-grade thermal energy. Advancing high-performance, stable, and stretchable ionic thermoelectric materials is therefore critical for enabling new applications in waste heat recovery and body heat harvesting, ultimately contributing to sustainable energy solutions and self-powered wearable technologies.

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Flexible Woven-Based Radiative-Convective Cooling Heat Sink

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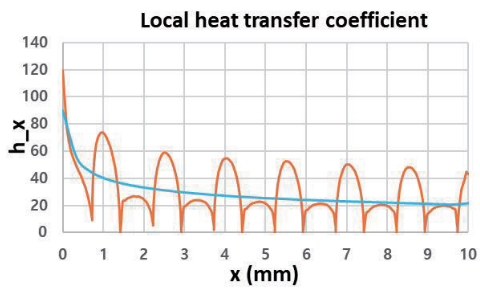
Radiative cooling heat sinks, due to their ability to achieve passive cooling without requiring external energy, are widely utilized in fields such as solar power generation, building temperature regulation, and thermoelectric power generation. The core principle of this technology lies in efficient spectral regulation. These devices typically exhibit a high solar reflectance to minimize the absorption of solar radiation while maintaining a high infrared emissivity, allowing surface heat to be dissipated into outer space through the 8–14μm atmospheric infrared transparency window. This mechanism effectively lowers the system temperature, enhancing overall energy efficiency and providing crucial technological support for sustainable thermal management.

In general, daytime radiative cooling heat sinks lower temperatures below ambient levels, which can reduce cooling performance due to convective heat transfer occurring in the reverse temperature gradient. However, when the temperature rises above the surrounding atmosphere due to heat generation, maximizing heat dissipation through both convection and radiation becomes essential. Therefore, this study designs and evaluates a structure that maximizes the synergy between convective and radiative cooling.

The proposed heat sink adopts a periodic wavy surface structure to promote airflow separation and reattachment, thereby enhancing convective heat transfer performance. A porous Poly (vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) membrane is integrated with the woven fabric to form a structured surface with regular undulations. As a result, the device achieves a solar reflectance of 93.58% and demonstrates exceptionally high infrared emissivity in the 8–14μm wavelength range. Under wind conditions of 1 m/s, the average surface convective heat transfer coefficient of this heat sink increased by 19.4% compared to a smooth surface.



Key words: daytime radiative cooling, convective heat transfer coefficient, heat sink

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Soft Electronics and Beyond

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Soft electronics technology is gaining attention as a key enabler for next-generation wearable devices, smart healthcare, neural interfaces, and AI-driven electronic systems. Conventional rigid electronics face limitations in mechanically dynamic environments and biocompatibility, restricting their integration with flexible components. To address these challenges, this study integrates mechanical, electronic, materials, and biomedical engineering to develop stretchable and flexible electronic devices that maintain high electrical performance and mechanical durability. This research focuses on stretchable electrodes and neuromorphic semiconductor devices to enable stable neuromorphic computing under mechanical deformation and energy-efficient real-time signal processing. High-resolution gold nanosheet (AuNS)-based stretchable electrodes form a two-dimensional percolation network, patterned via photolithography and lift-off processes, ensuring both stretchability and conductivity for neuromorphic and wearable sensor applications. Stretchable semiconductor and sensor development are essential for soft electronics, requiring materials and device designs that sustain electrical stability under strain. Polymer-composite-based semiconductors enhance charge transport, enabling stretchable circuits and neuromorphic artificial neural devices. Photoresponsive materials further expand functionality for bio-signal detection, neuromorphic computing, and wearable sensing. Additionally, inkjet printing technology is employed for precise patterning and uniform thin-film formation. Optimized ink composition and surface energy enable stable jetting and deposition, facilitating stretchable electrode and semiconductor fabrication for next-generation displays and flexible electronics. Beyond individual device improvements, this research enables multi-sensor integration and optimized signal processing, paving the way for high-reliability intelligent systems. The developed technology supports real-time bio-signal monitoring, low-power neuromorphic computing, and long-term stability in flexible devices, driving advancements in wearable AI, IoT-based smart sensors, and neural interfaces.

Contact Line Dynamics of Gallium-Based Liquid Metals

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Gallium-based liquid metals (GBLMs) have both high fluidity and electrical conductivity and have recently raised great hopes with the promise of realizing soft machines and electronics. However, a nanometer-thick oxide skin forms on the GBLM surface, introducing distinctive interfacial behaviors. Although the oxide skin is a key factor for controlling the motions of GBLM at a microscale, the interfacial physics of oxide-coated GBLM has been little explored. Here, we present the results of a combined experimental and theoretical investigation of the contact line motions of eutectic gallium-indium (EGaIn) with the surface oxide layer (Fig. 1). Our study provides not only a theoretical framework for handling GBLM but also new insights into the manufacturing techniques of GBLM for various applications such as soft electronics, robotics, microfluidics.

Figure 1. Investigation of contact line motions of oxide-coated EGaIn droplet. (a) Schematics of an experimental setup. (b) Typical contact line motion with metallic residue. (c) Instance of contact line motion without residue.

Microelectromechanical Resonance Computing Device for High-Temperature Operation

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This work demonstrates a robust and reconfigurable microelectromechanical (MEM) computing device capable of performing logic operations in extreme environments. The MEMS computing device, which is actuated electrostatically, integrates an electromagnetic inductor and a frequency-tunable torsional resonator with two independent comb-drives. These comb-drives enable precise adjustment of the resonant frequency. By applying individual DC bias voltages to each comb-drive, the resonant frequency can be dynamically tuned, allowing programmable transitions between on-resonance (logic "1") and off-resonance (logic "0") states. This reconfigurability allows the device to successfully perform 2-bit NOR logic operation, demonstrating its potential as a fundamental component for more complex mechanical logic systems. The proposed device also exhibits exceptional thermal reliability. It operates stably at high temperatures up to 250°C in air, surpassing the limitations of conventional complementary metal-oxide-semiconductor-based logic devices. As a result, it is highly suitable for harsh environments such as aerospace and industrial applications, where thermal reliability is critical.

Enhancing the Performance of 3D Printed Bio-photoelectrochemical Cells Through Multi-objective Bayesian Optimization

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Attaching thylakoid Membranes (TM) on bio-photo-electro-chemical cells (BPEC) enables energy harvesting through photoelectrode extraction. However, the attachment methods rely on thin coating methods such as dip-coating, drop-casting, or electrospray deposition. We herein demonstrate the use of direct ink writing in coating TM on BPEC cells, aiming for rapid prototyping and mass production of BPEC cells. As photoelectron extraction through high TM loadings is not feasible, we investigate previously reported conducting materials to be used in mixture with TM. The conductive TM composite ink, referred to as BPEC ink in this study, is optimized through multi-objective Bayesian optimization (MOBO) with the two objectives of maximizing current density and maximizing printability. 14 initial searches were taken, followed by 15 MOBO searches. We confirm that after MOBO, current density and printability enhanced by 162% and 149%, respectively. Using the optimized BPEC ink, we demonstrate the 3D printing of fully integrated BPEC cells arranged in series.

High-Speed Fourier Ptychography with Integrated Lenslet LED Illuminator for Stitching-Free and Photon-Efficient Imaging

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Abstract:

Fourier ptychographic microscopy (FPM) is a computational imaging modality that enables high-resolution, large-area imaging of thin specimens. However, these appealing features come at the cost of temporal resolution rendering it unsuitable for dynamic imaging studies. The primary challenges contributing to this low temporal resolution are the large number of images required for computational phase retrieval and extended exposure times, particularly for dark-field (DF) imaging.

Here, we propose a high-throughput FPM approach termed PEH-FPM, which incorporates a photon-efficient lenslet-array LED illuminator and a hybrid illumination-multiplexing method. Our illuminator provides uniform, high-intensity illumination without vignetting, dramatically reducing DF image acquisition times to just a few milliseconds. Our novel illumination-multiplexing further minimizes the number of required measurements, achieving a 0.52 NA resolution across a 4.1 mm^2 field of view with a total acquisition time of <40 msec using a 4x 0.13 NA objective.

We demonstrate the capabilities of PEH-FPM through simulations and experiments, including the imaging of resolution targets and dynamic red blood cells (RBCs) in microfluidic channels. The system offers high-throughput imaging, making it a promising tool for applications in fields such as cellular biology, pathology, and quantitative phase imaging.

Ultra Low Power Generation Cost of Thermoelectric Device

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The rapid growth in technology and industry has led to an increase in demand for more energy. However, the increase in electrical energy generation leads to an increase in thermal energy wasted into the environment. Thermoelectric generators are suitable for recovering the waste heat as they can generate electrical power wherever there is a stable heat source. However, their high power generation cost is a major factor that prevents their widespread application and commercialization. This work presents a method to alter the structure of thermoelectric generators to achieve an ultra low power generation cost. A thermoelectric generator with the proposed structure is fabricated and its performance is experimentally evaluated. Results revealed that the new device is capable of reducing the power generation cost of thermoelectric devices by about 80 %. This results shows a promising future for the commercialization of thermoelectric generators in various fields.