中国科学院长春光机所
CIOMP

KSME

GPL

2024 China-Korea Advanced Optics and Thermal Engineering Seminar

Seminar Program

2024/07/01

Changchun

Contents

1. Seminar Information

Time :

2024/07/01

Place :

Academic Exchange Center

(学术交流中心报告厅)

Chair :

Wei Li, Professor, CIOMP

Longnan Li, Professor, CIOMP

Organizing Institute :

Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences

Organizing Department :

GPL Photonics Laboratory

1. Seminar Information

The "2024 China-Korea Advanced Optics and Thermal Engineering Seminar" will be held on July 1, 2024, at the Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), Chinese Academy of Sciences (CAS). The seminar is hosted by CIOMP and will invite the Thermal Engineering Division (TED) of the Korean Society of Mechanical Engineers (KSME). Members of the KSME-TED Board, including the President, Academy of Korean Sciences members, and other board members, will attend.

The seminar will bring together over 10 top scientists in the fields of optics and thermal engineering for academic exchange and discussion, focusing on the topic of "Optics and Thermal Engineering Frontier Intersections". The seminar will delve into important research advancements in the following areas:

- Nanophotonics
- Thermal Radiation
- Micro/nanoscale Phase Change Heat Transfer
- High-power Electronics Cooling
- Micro and nano scale heat transfer
- High-efficiency cooling systems

In addition to these topics, the seminar will explore new applications of thermal science in the field of optics and fundamental theoretical issues that need resolution. It will also discuss relevant technical issues related to major projects undertaken by the seminar organizers under the National Natural Science Foundation of China. Participants will visit key laboratories, the optoelectronic industrial park, and the International Laboratory for Micro and Nano Photonics and Materials at CIOMP. The seminar will primarily be an in-person event, highlighting its high level of professionalism and expertise, conducted through a combination of academic reports and discussions.

This seminar will focus on the future prospects of thermal science, foster broad academic exchange and cooperation with CIOMP and KSME-TED, provide a high-level academic exchange platform for outstanding scientists, promote research collaboration, lead academic research directions, explore industry development, and support continuous innovation and development in the fields of optics and thermal engineering.

2. Seminar Schedule

2024 China-Korea Advanced Optics and Thermal Engineering Seminar		
Time	**Contents**	**Chair**
June, 30th, Reception		
July, 1st - CIOMP, Seminar		
08:50-09:00	Opening Ceremony（Greeting from CIOMP、Photo time）	Wei Li
09:00-10:30	Session 1	Longnan Li
09:00-09:05	**Seong Hyuk Lee** Professor, Chung-ang University, South Korea PIFI Visiting Scientist **Greeting**	
09:05-09:15	**Lingtong Zhang** Director of Division of International Collaboration, CIOMP, CAS **Title：Introduction for CIOMP**	
09:15-09:25	**Jungho Lee** Professor, Ajou University, South Korea President of KSME-TED **Title: Introduction of KSME-TED**	
09:25-09:55	**Yong Tae Kang** Professor, Korea University, South Korea Member of Academy of Korean Sciences **Title: Sorption Thermal Battery for Plus Energy Building Application**	
09:55-10:25	**Wei Li** Professor, CIOMP, CAS Director of GPL Photonics Laboratory **Title: Directional Control of Photons: Thermal Radiation and Detection**	

10:25-10:55	**Taesung Kim** Professor, Sungkyunkwan University, South Korea **Title: Thermal Effect and Process Variation in Copper Chemical Mechanical Polishing**	
10:55-11:10	Coffee Break	
11:10-12:15	Session 2	Longnan Li
11:10-11:40	**Si-Cong Tian** Professor, CIOMP, CAS **Title: Heat Dissipation Improvement by Multi-Hole-Aperture Vertical-Cavity Surface-Emitting Lasers**	
11:40-12:10	**Youngsuk Nam** Associate Professor, Korea Advanced Institute of Science & Technology, South Korea **Title: Liquid-Metal Based Thermal Packaging**	
12:10-12:40	**Jianxun Bao** Associate Professor, CIOMP, CAS **Title: Silicon Carbide and its Composites for Optics and Precision Structures**	
13:00-17:00	Lunch, Tour	

3.Introduction for Speakers

Seong Hyuk Lee

Professor, Chung-Ang University, South Korea

PIFI Visiting Scientist

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Biography: Seong Hyuk Lee is currently a full professor at the School of Mechanical Engineering at Chung-Ang University in South Korea. He has served as the Dean of the School of Mechanical Engineering at Chung-Ang University and the Director of the Next Generation Energy Security Research Institute at Chung-Ang University. He is currently the Director of the Multi-dimensional Battery Research Institute at Chung-Ang University, Vice President (and President for the year 2025) of the Korean Society of Mechanical Engineers' Thermal Fluid Engineering Division (TED), and Vice President of the Korean Society for Liquid Atomization and Spray Systems (ILASS).He has long been engaged in the research of phase change heat transfer phenomena such as evaporation, condensation, and frosting, with a particular focus on the development of visualization techniques for phase change processes. He has made significant research achievements in capturing high-resolution evaporation, condensation, and frosting processes using surface plasmon resonance (SPR) imaging methods, earning considerable international influence and recognition as a distinguished scholar in this field. Professor Lee has published over 180 papers in international journals such as Nano Energy, International Journal of Heat and Mass Transfer, and ACS Applied Materials and Interfaces. He has received numerous awards, including the Namheon Academic Award from the Korean Society of Mechanical Engineers, the Outstanding Contribution Award from the Journal of Mechanical Science and Technology, and the Outstanding Contribution Award from the Korean Society of Air-Conditioning and Refrigeration Engineers, as well as several best paper and best poster awards from various international and Korean academic societies. Professor Lee currently serves as an associate editor for journals such as the Journal of Mechanical Science and Technology, Journal of Mechanical Science and Technology Advances, and the International Journal of Air-Conditioning and Refrigeration.

Jungho Lee

Professor, Ajou University, South Korea

President of the KSME-TED

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Biography: Jungho Lee is a professor at the Department of Mechanical Engineering of Ajou University, Suwon, Korea. He received his M.S. (1994) and Ph.D. (1999) in Mechanical Engineering from the Pohang University of Science and Technology (POSTECH), Pohang, Korea. Currently, he serves as a president of the thermal engineering division (TED) of the Korean Society of Mechanical Engineers (KSME) and a vice president of the Korean Society for Fluid Machinery (KSFM). He is also a member of ASME, ASM, IEEE, and AUTSE. His research interests focus on convective heat transfer enhancement, phase-change heat transfer (boiling and condensation), thermal management for the high heat dissipation of electronic devices, and development in the phase-change heat transfer devices (heat pipes, vapor chambers, and thermal ground planes). He wrote more than 100 peer-reviewed journal papers related to heat transfer.

Yong Tae Kang

Professor, Korea University, South Korea

Fellow of The Korean Academy of Science and Technology.

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Biography: He received his BS and MS at Department of Mechanical Eng., Seoul National University in 1987 and 1989, respectively, and PhD at Department of Mechanical Eng, The Ohio State University in 1994. After spending two years at the OSU as a postdoctoral researcher, he joined JST as a special researcher and TUAT, Tokyo, Japan as a visiting professor in 1997. After spending three years at JST and TUAT, he joined the faculty at Kyung Hee University, Korea in 2000, and moved to Korea University in 2014. His research focuses on thermal energy systems including absorption heat pumps, heat exchanger design, refrigeration systems, nanofluids, CO2 capture using nanoabsorbents and sorption thermal battery. He published more than 200 international and domestic journals and more than 250 conference papers. He is now a member of ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers), KSME (Korean Society of Mechanical Engineers), IIR (International Institute of Refrigeration), JSHRAE (Japanese Society of Heating, Refrigeration, and Air-Conditioning Engineers) and SAREK (Society of Air-Conditioning and Refrigeration Engineers of Korea). In 2010, his lab. was designated as a National Research Lab. by the Ministry of Science and Technology. In 2012, he served as a vice president of graduate school, Kyung Hee University. In 2015, he received the Asian Academic Award jointly from SAREK/CAR/JSRAE. In 2017, He received the best research award from Korea University. In 2018, he was elected as a fellow of The Korean Academy of Science and Technology. He was also elected as a fellow of National Academy of Engineering of Korea in 2020. He served as a director of BK21 plus center for creative research engineers of convergence mechanical systems, School of Mechanical Engineering, Korea University. He is a former president of SAREK in 2022 and now fellow of SAREK and AUTSE. Now he is a director of Research Center for Plus Energy Building Innovative Technology (ERC) sponsored by Korea Government.

Title: **Sorption thermal battery for plus energy building application**

Abstract: A key strategy to realize the plus-energy building beyond the net-zero energy building is to employ the renewable energy so that the amount of generated energy is larger than that of energy consumption. It is inevitable to apply the high-performance energy storage system for the effective usage of renewable energy due to the mismatch between the supply and demand. This study suggests a daily sorption thermal battery to store the thermal energy in the form of the chemical potential difference, which can compensate the incompatibility of the renewable thermal energy. The sorption thermal battery involves van der Waals interaction between the sorbent and the sorbate. If the sorbate obtains sufficient momentum to overcome

the bonds with the sorbent, the sorbate changes its phase so that the thermal storage is achieved by separating the sorbate from the sorbent, which is called “charging process”. The discharge of the sorption thermal battery provides the useful energy for application when the sorbate undergoes the phase change that releases heat upon contact with the sorbent. This type of the thermal energy storage system doesn’t require the thermal insulation to prevent the heat loss of the storage tanks and has an advantage of the small volume with high energy storage density. There are two strategies suggested in this study to apply the daily sorption thermal battery for plus-energy building: one is an absorption thermal battery using the H2O-LiBr as working fluid, the other is an adsorption thermal battery employing the composite adsorbent consisting of LiOH salt hydrate impregnated into Zeolite 13X and H2O as a sorbate. The absorption thermal battery can supply the cooling output to relieve the cooling demand that can operate repeatedly with the same performance without any additional manipulation. The numerical investigation is conducted to optimize the discharging process of absorption thermal battery in the aspect of the mass flow rate and the total charge amount of the LiBr solution, in which the optimized point derives the minimum value of difference between the cooling output of absorption thermal battery and the cooling demand of the building. The optimum solution charge and solution flow rate are quantified based on the four different building types (residential, hotel, hospital, and office) and the most suitable cooling load response is observed in the case of the hotel. The building cooling demand can be relieved as much as 91.31% with optimized absorption thermal battery and the energy storage density is estimated as 101.99 kWh/m3 under the solution charge of 1440 kg and the solution flow rate of 0.51 kg/s. The maximum COP and energy storage density are estimated as 0.74 and 207.73 kWh/m3 with the solution charge of 1440 kg and the solution flow rate of 1.0 kg/s. The adsorption thermal battery with composite adsorbent of LiOH salt hydrate and Zeolite 13X can serve the hot water supply with temperature of 55 □ to the plus-energy building and it achieves the energy storage density of 2219.21 kJ/kg by measuring with the simultaneous thermogravimetric analyzer. This result should be applicable to the reactor-scale. However, since adsorption only takes place on the surface of the adsorbent, the adsorbent with a large ratio of surface area to volume will assist to maximize the amount of the water vapor adsorbed. The hydrodynamic resistance is also considered to guarantee the inner surfaces of the composite adsorbent to be accessible for the water vapor, which means a large specific volume, sufficient passages between the composite adsorbent, and a large amount of heat released. The experimental investigation is conducted with cylindrical reactor filling with composite adsorbent to observe the breakthrough curve and temperature distribution of the reactor. The breakthrough curve is also predicted with the numerical investigation by varying the length of the reactor, the velocity of the water vapor flow, and the relative humidity of the inlet water vapor so that the appropriate charging time and length of the reactor for the daily adsorption thermal battery can be estimated.

Wei Li

Professor, CIOMP, CAS

Director of GPL Photonics Laboratory

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Biography: Wei Li is a professor at Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), Chinese Academy of Sciences (CAS). He also serves as the Director of GPL Photonics Laboratory at CIOMP and Deputy Head of State Key Laboratory of Luminescence and Technology. Before joining CAS, he did his Ph.D. and postdoc at Vanderbilt University and Stanford University, respectively. His research interests include thermal photonics, nanophotonics, and their applications in next-generation energy and information technologies. He is a Highly Cited Researcher (Clarivate) and the recipient of MIT Technology Review Innovator Under 35 (TR35 Asia Pacific), Key Program PI (National Natural Science Foundation of China), and others. He is the associate editor of npj Nanophotonics and the faculty advisor of IEEE Student Chapter and the Optica Student Chapter at CIOMP, CAS.

Title: **Directional Control of Photons: Thermal Radiation and Detection**

Taesung Kim

Professor, Sungkyunkwan University, South Korea

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Biography: Dr. Taesung Kim received his Bachelor degree in Mechanical Engineering from Seoul National University, Korea in 1994. He received his Master's, and Ph. D. in Mechanical Engineering from University of Minnesota, USA in 1998 and 2002, respectively. He joined Seagate Technology in 2002 and worked as Sr./Staff Engineer in Recording Head R&D. Since 2005 Dr. Kim has been a professor in the School of Mechanical Engineering and SKKU Advanced Institute of Nanotechnology (SAINT), Sungkyunkwan University in Suwon, Korea. In 2014, he was appointed as SKKU Young Fellow and started working for SKKU Research & Business Foundation as a Vice President. During 2019 and 2020, he worked as a Vice President of Admission and he is currently a dean of College of Engineering starting 2023. His research interests include 2-D material synthesis using plasma process, optical fiber sensors, semiconductor fabrication process (CMP, cleaning and contamination control), and atmospheric/indoor aerosol control.

Title: **Thermal Effect and Process Variation in Copper Chemical Mechanical Polishing**

Abstract: Chemical mechanical polishing (CMP) is a crucial process in semiconductor manufacturing, responsible for removing over-deposited materials and achieving both local and global planarization. Temperature plays a pivotal role in the CMP process. Recently, the latest commercial polishers have incorporated steam heating and gas cooling systems to regulate the polishing pad temperature. Understanding the temperature variation and its impact on different consumables throughout the polishing process is essential for optimizing the polishing protocol. Various metrology methods have shown that the pad surface temperature increases significantly within the first 60 seconds, peaking at approximately 55°C. The slurry flow rate and pad-wafer contact behavior are fundamental factors influencing the pad surface temperature, with the latter having a more pronounced effect. As the temperature rises, slurry viscosity and pad hardness decrease, while colloidal silica particles tend to aggregate into larger clusters. During polishing, compression and shear forces flatten the pad surface; however, the asperities tend to revert to their original shape at high temperatures due to the shape-memory properties of polyurethane. Experiments with different slurry temperatures were conducted to polish amorphous silicon dioxide and copper films. The removal rate of amorphous silicon dioxide remained constant regardless of slurry temperature. In contrast, the removal rate for copper polishing with 60°C slurry was 71.35% higher on average compared to polishing with 23°C slurry.

Si-Cong Tian

Professor, CIOMP, CAS

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Biography: Si-Cong Tian was born in Changchun, China, in 1984. He received his B. Sc. and Ph. D. degrees in Physics from Jilin University, China, in 2007 and 2012, respectively. From 2016-2017 he studied at Arkansas University, US, as a visiting scholar. Currently, he is a Professor at Bimberg Chinese-German Center for Green Photonics, Changchun Institute of Optics Fine Mechanics and Physics, Chinese Academy of Sciences, China. His research interests include high-speed vertical-cavity surface-emitting lasers and high-brightness semiconductor lasers..

Title: **Heat Dissipation Improvement by Multi-Hole-Aperture Vertical-Cavity Surface-Emitting Lasers**

Abstract: Large bit-rate Vertical-Cavity Surface-Emitting Lasers (VCSEL) are one of the backbones of fiber-based data communication. Their performance is limited by the small volume of the active region leading to heat accumulating, and in turn to fast saturation e.g. of their output power and cut-off frequency with increasing current. To alleviate the impact of thermal effects, this paper proposes a Multi-Hole Aperture (MuHA) approach which strongly improves heat dissipation by etching holes from the top mesa surface down to the top of the aperture and then filling them with metal. Simulations of MuHA VCSELs show a lower temperature in the active region, a smaller wavelength shift, and better heat dissipation compared to classical VCSELs. The first experimental results presented also here validate the predictions.

Youngsuk Nam

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Biography: Prof. Youngsuk Nam is an associate professor in the Department of Mechanical Engineering at Korea Advanced Institute of Science and Technology (KAIST). Prior to joining KAIST, he served as a full, associate, and assistant professor at Kyung Hee University, and as a postdoctoral associate at the Massachusetts Institute of Technology (MIT). He earned his Ph.D. in Mechanical Engineering from the University of California, Los Angeles (UCLA), in 2010, and his M.S. and B.S. from Seoul National University (SNU). His research interests focus on understanding micro/nanoscale phase change physics and transport phenomena, developing novel thermal materials, and integrating them to introduce innovative thermal solutions. He has received several awards, including the KAIST CGCL Lab, LG Yonam Foundation International Scholar Award, Kyung Hee Outstanding Research Award, KSME Young Thermal Scientist Award, and outstanding paper awards from several international conferences including ECTC, ISGE, ISMP.

Title: **Liquid-Metal Based Thermal Packaging**

Abstract: Due to the recent surge in demand for artificial intelligence and next-generation mobility, the integration density of semiconductor devices has been rapidly increasing, and the range of platforms to which they are applied is also expanding quickly. In this study, we propose the use of gallium-based liquid metals as thermal interfacial materials (TIM) and phase change materials (PCM) and examine their application in thermal management.

GaInSn-TIM: Conventional silicone-based TIMs, which are widely used, suffer from low thermal conductivity and poor temperature stability, while solder-based TIMs have issues with high application temperatures and microcracking. To address these problems, we developed a process to prevent the formation of an oxide layer within GaInSn and create a copper nanoparticle network, investigating its potential as a TIM. The developed GaInSn-based TIM provided a high thermal conductivity of approximately 63 W/mK and excellent thermal stability, even with a low copper nanoparticle volume ratio of 4%. Additionally, unlike solder, it was confirmed that a high-quality interface with a silicon substrate could be formed without the need for separate metal layer deposition.

Ga-PCM: Phase change-based thermal storage materials have been examined for dynamic thermal management in various energy systems such as semiconductors, batteries, and buildings. Previous studies on organic PCMs have identified issues like low thermal conductivity, limited latent heat per unit volume, and stability, which restrict their application areas. Gallium (Ga) liquid metal, on the other hand, offers advantages such as a phase transition

temperature near room temperature (~29.8°C), high latent heat per unit volume (473 J/cm^3), and high thermal conductivity (~33.6 W/mK). However, its application has been limited due to supercooling characteristics that delay the phase change from liquid to solid below the phase transition temperature. In this study, we developed a PCM heat absorption layer composed of porous copper-gallium-PDMS and significantly improved the supercooling characteristics by activating heterogeneous nucleation at the copper-gallium interface. The developed heat absorption layer induced the liquid-to-solid phase transition of Ga at approximately 20°C, enhancing the applicability of gallium-based thermal absorption materials in thermal management fields.

Jian-xun Bao

Associate Professor, CIOMP, CAS

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Biography: Jian-xun Bao serving as an associate professor at Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), Chinese Academy of Sciences (CAS). Specialized in the development of silicon carbide ceramic composites and their components for optics and precision structures. As a leader or a main technical developer, he has worked in the projects of the Jilin Province innovation and entrepreneurship talent plan, the CIOMP innovation fund for the SiC additive manufacturing and the fabrication of series of high performance SiC mirror blanks and structural components for spaceborne payloads, including those for Tianwen-1 Martian probe, Jilin-1 satellite constellation.

Title: **Silicon carbide and its composites for optics and precision structures**

Abstract: Silicon carbide ceramics have outstanding thermomechanical comprehensive properties. The components made of them are lightweight, highly rigid and highly dimensional stable when applied in the optomechanical system manufacturing and functioning, especially for the aerospace payloads. Focusing on the technical difficulties in fabricating silicon carbide component blanks with large sizes and high structural complexity, the presentation demonstrates the study in the preparation of reaction bonded silicon carbide ceramics, including the progress in the new tech development of silicon carbide additive manufacturing. In order to improve the thermal performance of precision structures, the research team began to explore issues such as structural optimization, material composition and microstructure optimization and structure-function integration.