

**The 9th  
Micro & Nanoscale  
Heat Transfer and  
Energy Workshop**

**MNHTE  
2023**

**12.05 Tue.**

**In NCUT  
Taichung City,  
Taiwan**

**| Conference  
Proceedings**

**2023 The 9th Micro & Nanoscale Heat Transfer and Energy Workshop**

**Table of Contents**

Committee ..... 1  
Guidelines ..... 2  
Location..... 4  
Program Schedule ..... 6  
Topics ..... 10  
Poster Competition Abstract ..... 22

## **2023 The 9th Micro & Nanoscale Heat Transfer and Energy Workshop Committee**

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Ming-Tsang Lee, National Tsing Hua University, TAIWAN

Yao-Hsien Liu, National Yang Ming Chiao Tung University, TAIWAN

Yu-Bin Chen, National Tsing Hua University, TAIWAN

### **Keynote Speaker / Sorted by First Name**

Chi-Chuan Wang, National Yang Ming Chiao Tung University

Ming-Chang Lu, National Taiwan University

Sebastian Volz, University of Tokyo

Sheng Shen, Carnegie Mellon University

Zuan-kai Wang, Hong Kong Polytechnic University

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Tian-Shiang Yang, National Cheng Kung University, TAIWAN

Win-Jet Luo, National Chin-Yi University of Technology, TAIWAN

Yu-Lieh Wu, National Chin-Yi University of Technology, TAIWAN

## Guidelines

### 1. Official Language

The official language of the 9<sup>th</sup> MNHTE is English.

Guideline for Participants

#### (1) Time Schedule

09:20-17:20, Tuesday, Dec. 5th, 2023 (Qing-Yong Building 6F Jing-Syuan Hall)

09:20-09:50 for registration

#### (2) Taiwan High Speed Rail Taichung Station Pick up

- Pick up time: Estimated departure at 08:30
- Pick-up location: Exit 6

#### (3) Workshop Kit

A workshop kit which contains a workshop brochure and a name badge will be provided to participants at the registration/information desk.

### 2. Guideline for Poster Submission

Please use "Abstract" to submit your manuscript

\* Online submission

Please send your submission file to [ksyang@gm.ncut.edu.tw](mailto:ksyang@gm.ncut.edu.tw)

\* Notes

- File format : Word file, limited to 1 pages, abstract sample as below.

### [Abstract Sample File \(Click this\)](#)

- Full-text file data : less than 5MB.
- Full-text file name : **MNHTE2023\_Poster\_author\_title.docx**
- Subject of the letter : **MNHTE2023\_Poster\_author\_title**
- If the submitted paper is the result of a National Science and Technology Council funding program, please indicate the program number.
- Preliminary finalists should make posters according to the format and post them at the venue by themselves. (9:20~13:00, Tuesday, Dec. 5th, 2023)
- Poster format: 59.4 cm ( W ) x 84.1 cm ( H ), straight A1 size.
- The conference reserves the right of final interpretation.

For unexpected events that cannot be handled on the spot, you may make a direct notification to the registration/information desk.

### 3. Registration

General Registration / At least one person must register for each abstract.

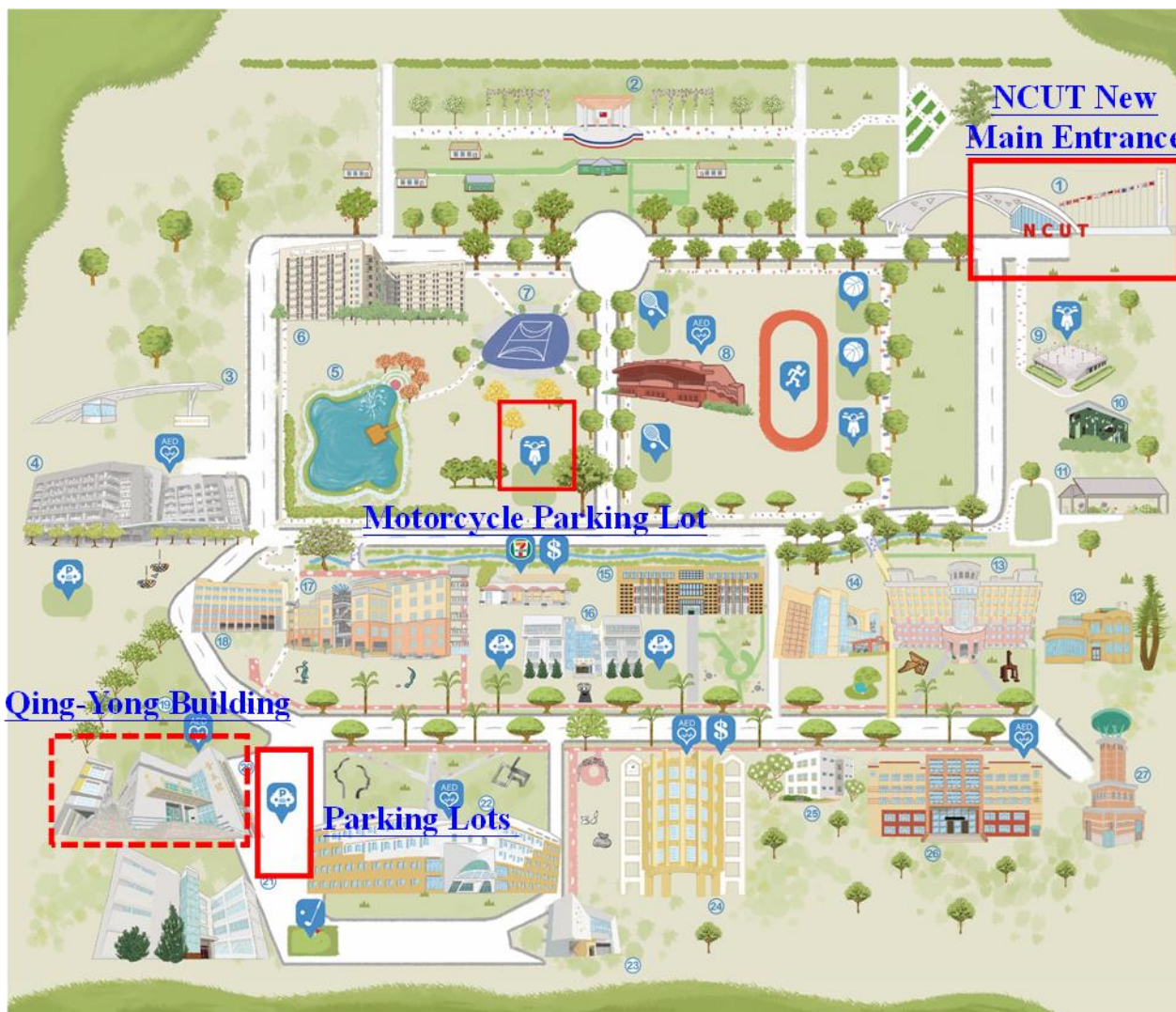
- General Registration (HMTST Member) NT\$ 4,000 / before November 30, 2023
- General Registration (Non-HMTST Member) NT\$ 5,500 / before November 30, 2023

[Online Registration \(Click this\)](#)




On-Site Registration

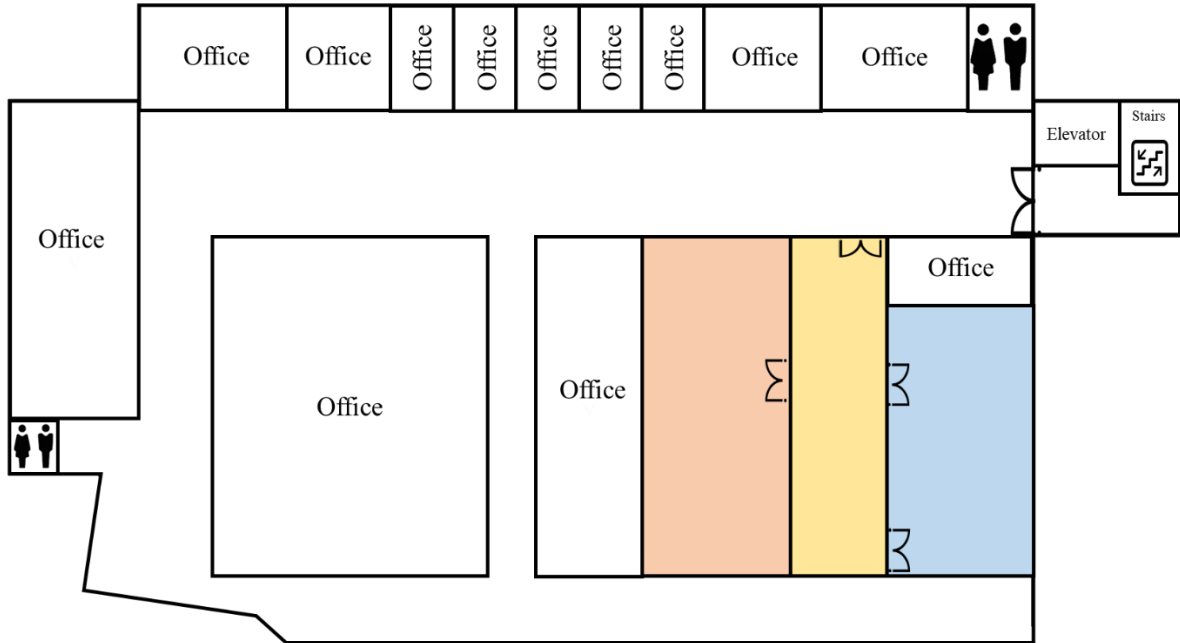
- On-site Registration (HMTST Member) NT\$ 4,500
- On-Site Registration (Non-HMTST Member) NT\$ 6,000

# Location



# Qing-Yong Building 6F

 Membership Meeting Location  Registration, Post and Lounge Area  Keynote Speech



**【NCUT Qing-Yong Building 6F】**

## 2023 The 9th Micro & Nanoscale Heat Transfer and Energy Workshop Program Schedule

2023.12.05 (Tuesday)

Time	Agenda	Venue
09:20-09:50	Registration	Qing-Yong Building 6F Jing-Syuan Hall
09:50-10:10	Opening Ceremony Moderator: Prof. Win-Jet, Luo	Qing-Yong Building 6F Cai-Fong Hall
10:10-10:55	Keynote Speech I Speaker: Professor Zuankai Wang/ Hong Kong Polytechnic University Title: Nature-inspired surfaces for water-energy nexus Moderator: Prof. Win-Jet Luo	Qing-Yong Building 6F Cai-Fong Hall
10:55-11:15	Coffee Break	Qing-Yong Building 6F Jing-Syuan Hall
11:15-12:00	Keynote Speech II Speaker: Professor Sheng Shen / Carnegie Mellon University Title: Engineered Nanostructured Materials for Advanced Thermal Management, Rectification, and Encryption Moderator: Prof. Ming-Chang Lu	Qing-Yong Building 6F Cai-Fong Hall
12:00-13:00	Lunch Break	Qing-Yong Building 6F Jing-Syuan Hall
	Membership Meeting	Qing-Yong Building 6F Meeting Room
13:00-13:45	Keynote Speech III Speaker: Professor Ming-Chang Lu / National Taiwan University Title: Magnon Thermal Transport in Individual Nickel Nanowires Moderator: Prof. Ming-Tsang Lee	Qing-Yong Building 6F Cai-Fong Hall
13:45-14:30	Keynote Speech IV Speaker: Dr. Sebastian Volz / The University of Tokyo Title: Polaritons Guided Thermal Radiation Moderator: Prof. Yu-Bin Chen	Qing-Yong Building 6F Cai-Fong Hall
14:30-14:50	Coffee Break	Qing-Yong Building 6F Jing-Syuan Hall
14:50-15:35	Keynote Speech V Speaker: Professor Chi-Chuan Wang / National Yang Ming Chiao Tung University Title: Stability Control of Two-phase Microchannel Cold Plate Moderator: Prof. Yao-Hsien Liu	Qing-Yong Building 6F Cai-Fong Hall
15:35-16:35	Post Competition	Qing-Yong Building 6F Jing-Syuan Hall
16:35-17:20	Awards ceremony	Qing-Yong Building 6F Cai-Fong Hall
17:20	Take the shuttle bus to Taichung High Speed Rail Station	

Student Poster Competition	
Micro & Nanoscale Heat Transfer and Energy Poster Sessions	
P-01	Enhancing pool boiling heat transfer on helical wires array surface (Chen-Kuang Wang, You-De Ren, Hua-Yi Hsu, and Ching-Wen Lo)
P-02	Numerical simulation of seawater temperature and burial depth effect on the maximum operating current of submarine cables (Li-Wei Hu, and Ben-Ran Fu)
P-03	Effect of Chamber design on the Flow Field in Atomic Layer Deposition Process (Chen-Yang Hsieh, Yuan-Chun Tseng, and Yao-Hsien Liu)
P-04	Anti-icing/deicing on suspended nanofiber membrane surfaces (Ching-Wen Lo, Kai-Yu Wang, Kuan-Lun Hsu, and Ming-Chang Lu)
P-05	Length-dependent thermal transport measurements on various nanowires (Po-Yen Huang, Jiun-Hung Yi, Yi-An Li, Ming-Chang Lu, and Chih-Wei Chang)
P-06	Temperature visualization on a Tesla turbine by using stroboscopy and liquid crystal technique (Chien-Lun Lee, Szu-Chi Huang, and Yao-Hsien Liu)
P-07	Pool Boiling Heat Transfer on the Single Reentrant Micro-pillar Arrays (Qi-Jun Chen, Saumyadwip Bandyopadhyay, and Ming-Chang Lu)
P-08	Heat Transfer and Pressure Drop of Ice Slurry Refrigerant (Yeu-Shaw Lin, Ching-Wen Lo, and Ming-Chang Lu)
P-09	Explore the Heat Transfer Properties of the Lignin-reduced Graphene Oxide films (Ming-Chang Lu)
P-10	Experimental and Theoretical Investigations on the Thermal Conductivity and Electrical Resistivity of Single Nickel Nanowire (Wei-Tsu Peng, Jiun-Hung Yi, Kuan-Ju Yu, Tien-Kan Chung, and Ming-Chang Lu)
P-11	Effect of the Twisted Ribs on Flow Field and Heat Transfer in Water Jet Impingement (Wu Feng Yang, Yu-Chin Chien, and Wen-Ren Jong)
P-12	Dip coating of ceramic on additively manufactured porous structure for transpiration cooling (Pei-Wen Zhou, Yong-Huang Lin, Hui-Ci Weng, Yao-Hsien Liu, and E-Wen Huang)
P-13	Magnetic nanofluid pool boiling heat transfer on hydrophilic/hydrophobic surface (Huei-Chu Weng, and Zi-Xuan Huang)
P-14	Standardization and quantification of backscattered electron imaging using atomic number electron microscopy (Hih-Ming Wang, Yu-Cheng Chiu, Yu-Hsin Wu, Bo-Yi Chen, I-Ling Chang, and Chih-Wei Chang)
P-15	Indoor Photovoltaic Energy Harvester for Volatile Organic Compound Sensor Node (C. Bambang Dwi Kuncoro, Swami Nath Maurya, and Maria Mahardini Sakanti)
P-16	A PDMS-nanocomposite microfluidic layer for adaptive thermal control of windows (Arjun Lochen, Della Monica, Nella Nadya Lumban Tobing, and Bivas Panigrahi)

P-17	Performance Optimization of Radiative Cooling of Recyclable Material by Taguchi Method (Sanjay Kumar Samudi, San-Tian Liew, Yen Ting Hsu, and Jui-Yung Chang)
P-18	Powering Point-of-Care Testing: Energy Harvesting with TENG-Enabled Digital Microfluidics (Ta-Jen Yang, Zong-Hong Lin, and Yen-Wen Lu)
P-19	Coherent thermal absorption in coupled localized plasmon resonance (Bo-Yi Chen, Hsuen-Li Chen, and Chih-Wei Chang )
P-20	Performance of passive direct formate fuel cells using metal foam as anode diffusion layer (Jin-Cherng Shyu, Jie An He, and Jia-Jun Hong )
P-21	The capacity evaluation of CO <sub>2</sub> -EGS based on the porous thermal-hydraulic model (David T.W. Lin, and Kevin C.T. Tang)
P-22	Investigation on thermal emissivity and optical constants spectra of Ge-Sb-Te in three phases (Yi-Hua Yang, Jui-Yung Chang, Dong-Han Wu, and Yu-Bin Chen)
P-23	Thermal Error Analysis and Control of a 3-axis Machining Center using an Intelligent and Adaptive Thermal Balance Control Methodology (Chuan-Feng Lee, Chun-Han Shih, Chang-Chuan Yeh, and Ming-Tsang Lee)
P-24	Performance Study of Dowtherm-A and Naphthalene Heat Pipe (Jie-Mou Jhang, Jui-Ching Hsieh, Xian-Da Cai, and Shi-Yan Hu)
P-25	A Numerical Study of Solar Steam-Methanol Micro-reformer (Yu-Ting Chuang, Chen-Yu Chiang, and Ming-Tsang Lee)
P-26	Homogenization Simulation and Optimization of Pin Fin Array in Cooling Channel for High Power Module Applications (Jun-Yang Liao, Wei-Lin Liao, Shen-Chi Kuo, Min-Kuang Chen, and Ming-Tsang Lee)
P-27	Effect of Ammonia Enriched Gaseous Co-flow on Soot Formation in Droplet Combustion. (Atul Kumar, Shouyin Yang, M Aldi Nugroho, and Muhamad Bahrul Ulum)
P-28	The frosting effects on superhydrophobic vertical plate surface (Jia-Wei Zheng, Po-Che Pan, Yu-Sheng Xie, Yu-Lieh Wu, and Kai-Shing Yang)
P-29	Using Intelligent IoT Programming Control in Energy-saving Monitoring and Measurement for Lighting and Aviation Refrigerated Containers Case Study (Chih-Neng Hsu, Teng-Jen Hu, and Wen-Kai Lo)
P-30	Experimental Analysis of Titanium Felt in Proton Exchange Membrane Fuel Cells under Varying Relative Humidity Conditions and Hydrophobic Coating (Chin-Hsi Huang, Chong-Kai Wang, Ming-Yuan Shen , Tain-Fu Yang, and Yean-Der Kuan)
P-31	Reliability Research of Machine Tool Cooling System (Chun-Hao Chen, and Kun-Ying Li)
P-32	Simulation of Solid Oxide Fuel Cell Hydrogen Power Generation System (Ping-Hao Liu, and Jenn-Kun Kuo)

P-33	Effect of temperature difference on salinity-gradient power generation across graphene oxide nanochannel membranes (Chih-Chang Chang, Wei-Hao Huang, Yi-Hsuan Li, Ruey-Jen Yang)
P-34	Optimization of thermal battery performance through the development of geometry structures and composite phase change materials: A comparative analysis (Muhammad Naufal Ramz, Yean-Der Kuan, and Tien-Fu Yang)

## Topics Keynote Speaker

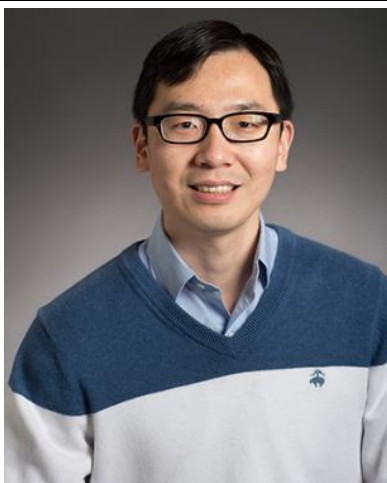
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**Keynote Speech I**



**Prof. Zuankai Wang**

**Keynote Speech II**



**Prof. Sheng Shen**

**Keynote Speech III**



**Prof. Ming-Chang Lu**

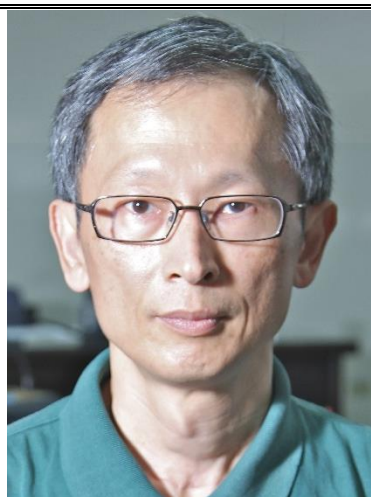
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**Keynote Speech IV**



**Dr. Sebastian Volz**

**Keynote Speech V**



**Prof. Chi-Chuan Wang**

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## Keynote Speech I

### **Prof. Zuankai Wang**

Hong Kong Polytechnic University

#### **Research Area:**

Nature-inspired engineering

Surface & interface

Thermal-fluid

Droplets & Bubbles

Microfluidics and nanofluidics

#### **Biography**

Prof. Zuankai Wang is currently Chair Professor of Nature-Inspired Engineering in the Department of Mechanical Engineering at The Hong Kong Polytechnic University (PolyU) and concurrently serves as Associate Vice President (Research & Innovation). Professor Wang received his Ph.D. degree from Rensselaer Polytechnic Institute in 2008. After a one-year postdoctoral training at Columbia University, he joined the City University of Hong Kong (CityU) as Assistant Professor in 2009 and was promoted to Chair Professor in 2021. He is currently the Executive Editor-in-Chief of Droplet journal (Wiley).

Professor Wang is a founding member of the Hong Kong Young Academy of Sciences, Croucher Senior Research Fellow (2023), RGC Senior Research Fellow (2022), Highly Cited Researcher (Cross-field) recognized by Clarivate (2022), Fellow of the International Society of Bionic Engineering, and Changjiang Chair Professor conferred by Ministry of Education of China (2016). His work has been recognized by the Guinness Book of World Records and two inventions have won the International Exhibition of Inventions of Geneva Gold Medal and Gold Medal with Congratulations of Jury, respectively. He has received many awards including the Falling Walls Science Breakthroughs of The Year 2023 (Engineering and Technology), BOCHK Science and Technology Innovation Prize (2022), Green Tech Award (2021), Xplorer Prize (2020), Hall of Fame (Advanced Engineering Materials, 2019), 35th World Cultural Council Special Recognition Award (2018).

## **Nature-inspired surfaces for water-energy nexus**

### **Abstract**

The outbreak of Coronavirus disease 2019 (COVID-19) recalls for the paramount importance of harmonious co-existence between humans and nature. Instead of fighting nature, we can learn from nature's endless strategies and inspiration for better living. Indeed, honed by billion years of evolution, nature has developed extraordinary principles that are characterized by green energy and resilience. This talk focuses on how learning from nature's principles creates unconventional wisdoms and surprises, which help to address the grand challenges such as water and energy.

In the basic research, I will first describe our efforts in answering three fundamental questions in surface science. i.e. what's the physical limit of solid/liquid contact time since the first observation of droplet dynamics in 1876, how to enable liquids to select their spreading direction since the first study of liquid spreading in 19th century, and how to achieve the spontaneous, directional, rapid liquid flow. In the applied research, I will discuss our recent efforts in developing robust, scalable, multifunctional surfaces/coatings as well as exploring their applications in water collection, energy harvesting, and thermal cooling including suppressing the Leidenfrost effect that was observed in 1756.

## Keynote Speech II

### **Prof. Sheng Shen**

Carnegie Mellon University

#### **Research Area:**

Nanoscale heat transfer

Nanostructured materials for energy applications

Nanophotonics and metamaterials

#### **Biography**

Sheng Shen is a professor in the Mechanical Engineering Department of Carnegie Mellon University (CMU). He also holds courtesy appointments in both the Electrical and Computer Engineering and the Materials Science and Engineering Departments at CMU. He received his Ph.D. degree from the Mechanical Engineering Department at MIT, and BS and MS degrees from Huazhong University of Science and Technology in China. Prior to joining CMU in 2011, he conducted his postdoctoral research at UC-Berkeley. His research focuses on nanophotonics, nanoscale energy transport and conversion, nanofabrication and advanced manufacturing, and their applications in thermal management, light sources and devices, thermal emission control, solar or thermal energy conversion, infrared sensing and detection, multifunctional materials, and others.

# **Engineered Nanostructured Materials for Advanced Thermal Management, Rectification, and Encryption**

## **Abstract**

In this talk, I will give three examples about utilizing specially engineered nanostructured materials to develop advanced thermal applications. First, I will demonstrate nanostructured thermal interface materials that have ultralow thermal resistance and polymer-like compliance. They also exhibit exceptional long-term reliability with  $>1,000$  thermal cycles over a wide temperature range. Second, I will report an ultra-high-contrast and reversible nanoscale thermal switch based on the structural phase transition in crystalline polymer nanofibers, which enables a  $\sim 10X$  thermal switching ratio. By fabricating a heterogeneous “irradiated-crystalline nanofiber junction”, we also demonstrated a high-performance solid-state nanoscale thermal diode with a rectification factor as high as  $\sim 54\%$ , which exceeds any existing solid-state nanoscale thermal diodes. Finally, I will present the design and fabrication of bio-inspired brochosome structures, which appear visually similar under the visible light but have distinct emissivity profiles. Such a property allows us to encode physical information with brochosome arrays that can only be decoded under infrared signals, which is potentially useful in the areas of thermal encryption, infrared holograph, and data storage.

## Keynote Speech III

**Prof. Ming-Chang Lu**

National Taiwan University

**Research Area:**

Micro/nanoscale heat transfer

Phase-change heat transfer

**Biography**

Prof. Ming-Chang Lu received his Ph.D. degree in Mechanical Engineering from the University of California at Berkeley in 2010. He worked at National Chiao Tung University from 2010 to 2019. He joined the National Taiwan University in August 2019. He is currently a Professor in the Mechanical Engineering department at National Taiwan University. He was elected as a Fellow of the International Association of Advanced Materials (FIAAM) in 2022. He also received the Distinguished Young Scholar award from the Society of Theoretical and Applied Mechanics of the Republic of China in 2015 and the 2015 Ta-You Wu Memorial (Distinguished Young Scholar) Award from Taiwan's Ministry of Science and Technology. His research interests lie in micro/nanoscale heat transfer, phase-change heat transfer, anti-icing, and the Leidenfrost effect.

# Magnon Thermal Transport in Individual Nickel Nanowires

## Abstract

Spintronic devices have drawn great attention in recent years for their prosperous future in achieving highly efficient artificial intelligence (AI) learning and quantum computing. While improving their performance through size shrinking, the thermal issues accompany them. To validate the heat dissipation ability of spintronic devices, the physical properties of nanoscale ferromagnetic materials should be re-examined, and the importance of the energy carriers in heat dissipation, including electrons, phonons, and magnons, should be revisited.

Thus, in this study, the thermal conductivity and electrical resistivity of individual nickel nanowires (NiNWs) were investigated. The experimental results showed that the magnetic field had little effect on the electrical transport and gave an ordinary magnetoresistance ratio of 2%. On the contrary, a large reduction in the thermal conductivity of NiNWs was observed when a magnetic field was applied, and the reduction increased with the magnetic field. This field-dependent reduction is considered the magnon-contributed thermal conductivity, which is generally negligible compared to the contributions of electrons and phonons. Nevertheless, the magnon thermal conductivity exhibited an astonishing 30% of the total thermal conductivity of NiNWs. Theoretical modeling based on the Boltzmann transport equation was conducted to further elucidate the heat transfer mechanism. The modeling revealed that magnon-boundary scattering limited the magnon mean free path (MFP). The magnon MFP decreased with the magnetic field, which resulted from a stronger inhibition of long wavelength magnons as the magnetic field increased. The findings in this paper enrich the knowledge of magnon transport behavior and open a window for novel designs of spintronic devices.

## **Keynote Speech IV**

**Dr. Sebastian Volz**

University of Tokyo

**Research Area:**

Nanoscale Heat Transfer

Polaritons

Fundamental Thermal Physics

**Biography**

Dr. Sebastian Volz has been developing direct simulations and characterizations to understand the role of phonons, electrons and photons in the thermal behaviour of micro and nano-structures. His group was involved in large european projects on thermoelectric micro-modules and thermal interface materials. Sebastian Volz has led the european Thermal NanoSciences and NanoEngineering network of the CNRS for 17 years (Springer, Topics in Applied Physics series, n° 107 and 118) and is now the director of the CNRS Laboratory for Integrated Micro-Mechatronic Systems (LIMMS, UMI CNRS 2820).

# Polaritons Guided Thermal Radiation

## Abstract

Phonons are the quasiparticles of lattice vibrations and represent the primary heat carriers in bulk dielectric materials. The thermal conductivity of dielectric membranes is thus typically driven by acoustic phonons that is usually assimilated to a gas of particles, and generally reduces with the membrane thickness due to the increasing frequency of surface scattering events [1]. In the light of the ever-increasing miniaturization of devices with enhanced rates of operation, this reduction in the thermal conductivity causes overheating, low reliability, and reduced lifetime of electronic components [2–4]. Yet, while the thermal transport via acoustic phonons might be at the limit, the heat dissipation might be enhanced via optical phonons coupled with surface electromagnetic waves.

Over the past decade, substantial research efforts have been devoted to the study of these surface waves, because the surface effects predominate over the volumetric ones in nanostructures with high surface-to-volume ratio. Some types of surface electromagnetic waves may even carry heat [5] and thus improve the thermal performance and stability of nanoscale devices.

One type of such surface waves is the surface phonon-polaritons (SPhPs), which occurs as a hybrid of optical phonons and surface electromagnetic waves. The SPhPs are essentially evanescent waves that propagate along the surface of polar dielectric membranes [6,7].

We will first demonstrate the existence and the properties of those SPhPs in thin SiO<sub>2</sub> films and especially uncover that the propagation lengths of those waves reach the range of hundreds of micrometers [8], which is orders of magnitude longer than the typical mean free path of acoustic phonons. Theoretical models predict that such a long propagation length enables SPhPs to conduct more thermal energy than phonons when the membrane thickness is reduced below 100 nm.

We will then corroborate the significant contribution of SPhPs to heat flux in silica membranes [9], in a restricted temperature range and also, in a wide temperature range, in silicon nitride membranes where SPhP thermal conductivity becomes predominant at 800K [10]. An additional confirmation was finally provided by showing the size dependence of thermal conductivity due to the ballistic contribution of SPhP.

## **References:**

- [1] P. Nath, K. L. Chopra, Thermal conductivity of amorphous vs crystalline Ge and GeTe films. *Jpn. J. Appl. Phys.* 13, 781 (1974).
- [2] S. Volz, J. Shiomi, M. Nomura, K. Miyazaki, Heat conduction in nanostructured materials. *J. Therm. Sci. Technol.* 11, JTST0001 (2016).
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- T. Dekorsy, F. Alzina, B. Graczykowski, E. Chavez-Angel, J. S. Reparaz, M. R. Wagner, C. M. Sotomayor-Torres, S. Xiong, S. Neogi, D. Donadio, Nanophononics: State of the art and perspectives. *Eur. Phys. J. B* 89, 15 (2016).
- [4] M. Nomura, J. Shiomi, T. Shiga, R. Anufriev, Thermal phonon engineering by tailored nanostructures. *Jpn. J. Appl. Phys.* 57, 080101 (2018).
- [5] K. Joulain, J.-P. Mulet, F. Marquier, R. Carminati, J.-J. Greffet, Surface electromagnetic waves thermally excited: Radiative heat transfer, coherence properties and Casimir forces revisited in the near field. *Surf. Sci. Rep.* 57, 59–112 (2005).
- [6] D.-Z. A. Chen, A. Narayanaswamy, G. Chen, Surface phonon-polariton mediated thermal conductivity enhancement of amorphous thin films. *Phys. Rev. B* 72, 155435 (2005).
- [7] J. Ordonez-Miranda, L. Tranchant, T. Tokunaga, B. Kim, B. Palpant, Y. Chalopin, T. Antoni, S. Volz, Anomalous thermal conductivity by surface phonon-polaritons of polar nano thin films due to their asymmetric surrounding media. *J. Appl. Phys.* 113, 084311 (2013).
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- [9] L. Tranchant, S. Hamamura, J. Ordonez-Miranda, T. Yabuki, A. Vega-Flick, F. Cervantes-Alvarez, J. J. Alvarado-Gil, S. Volz, K. Miyazaki, Two-dimensional phonon polariton heat transport. *Nano Lett.* 19, 6924–6930 (2019).
- [10] Y. Wu, J. Ordonez-Miranda, S. Gluchko, R. Anufriev, D. De Sousa Meneses, L. Del Campo, S. Volz, and M. Nomura, Enhanced thermal conduction by surface phonon-polaritons, *Science Advances* 6(40):eabb4461, (2020).
- [11] Y Wu, J Ordonez-Miranda, L Jalabert, S Tachikawa, R Anufriev, H Fujita, S Volz, M Nomura, Observation of heat transport mediated by the propagation distance of surface phonon-polaritons over hundreds of micrometers, *Applied Physics Letters* 121 (11), 112203, (2022).

## Keynote Speech V

### **Prof. Chi-Chuan Wang**

National Yang Ming Chiao Tung University

#### **Research Area:**

Electronic cooling

Cloud computing energy management

Seawater desalination

Development and application of machineries for non-traditional fluid

Refrigeration and air conditioning

Supercritical fluid systems and heat exchangers (soft and hardware)

LED heat dissipation

Micro-channel heat flow design (single and two-phase flow applications)

#### **Biography**

Prof. Chi-Chuan Wang is currently a distinguished professor in the Department of Mechanical Engineering, National Yang Ming Chiao Tung University. He received his B.S., M.S., and Ph.D. from the Department of Mechanical Engineering of National Chiao Tung University, Hsinchu, Taiwan during 1978-1989. He then joined the Energy and Environment Research Lab., Industrial Technology Research Institute (ITRI), Hsinchu, Taiwan for about twenty years (1989.10-2010.1) conducting researches related to electronic cooling (liquid-cooling, air-cooling, heat pipe technology, immersion cooling, two-phase high performance cold plate, data center cooling...) enhanced heat transfer, electronic cooling, multiphase system, micro-scale heat transfer, membrane separation, and HVAC&R technology. He joined National Chiao Tung University in 2010 as a professor, working on all aspects of thermal energy systems and heat transfer processes. His editorial services include a regional editor of the Journal of Enhanced Heat Transfer, an associate editor of Heat Transfer Engineering, and an editor of Int. J. of Air-conditioning and Refrigeration. He has been authors or co-authors of more than 360 international journal articles with accumulated google citations above 15500, and a h-index of 62. He is also a co-inventor of 35 Taiwan Invent Patents and 5 US Patents, and authored three books in association with heat exchanger design and heat transfer. He is also an elected Fellow of ASME and ASHRAE. He was a member of the Assembly of the World Conference (AWC) on Experimental Heat Transfer, Fluid Mechanics, and Thermodynamics (2009-2017) and a member of the scientific council of the International Centre for Heat and Mass Transfer (2017~2022).

# Stability Control of Two-phase Microchannel Cold Plate

## Abstract

The present study examines the feasibility of using inlet contraction and gap design above microchannel to ease the two-phase instability in straight fin microchannels for the cold plate by using refrigerant R-134a or dielectric fluid. The presentation first gives an overview about the current available designs in literature, and discusses their applicability. Subsequently, experimental results for our designs are elaborated in details. The mass flux ranges from 25 to 425 kg/m<sup>2</sup>·s while the heat flux spans from 60 to 300 kW/m<sup>2</sup>. The inlet flow conditions can be either a fully liquid inlet or with vapor qualities (from 0.1 to 0.45). Improved flow distribution is found with the introduction of the contraction. Based on the mass flux and irrespective of the inlet conditions, the test results indicated that the heat transfer performance of the proposed designs are superior to conventional designs with lower pressure drop penalty. Flow visualizations were performed, and it was found that the designs are free from flow reversal, and the fluctuations in temperature or pressure drop are much less pronounced.

# **Poster Competition Abstract**

## Enhancing pool boiling heat transfer on helical wires array surface

Chen-Kuang Wang<sup>1</sup>, You-De Ren<sup>1</sup>, Hua-Yi Hsu<sup>2</sup>, and Ching-Wen Lo<sup>1,\*</sup>

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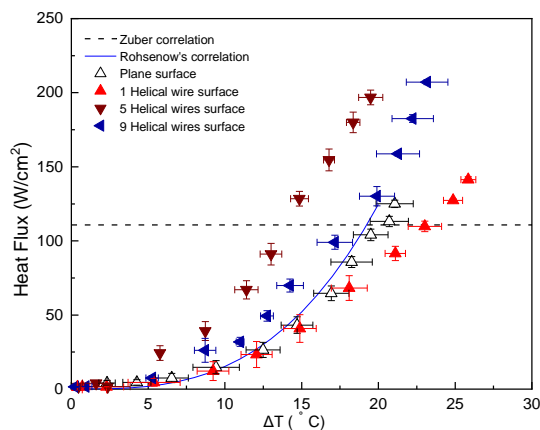
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**ABSTRACT:** Pool boiling is known for its exceptional heat transfer capabilities and its widespread application in high-power-density thermal devices. In recent decades, researchers have employed engineered surfaces to improve critical heat flux (CHF) and heat transfer coefficient (HTC) in pool boiling. These enhancements involve modifying surface wettability, increasing surface roughness, and refining liquid-vapor separation strategies for effective cooling. The focus has primarily been on optimizing liquid delivery to prevent surface dry-out, especially under high heat flux conditions. However, flow instability above the boiling surface remains a challenge for liquid supply mechanisms. To mitigate this instability, we propose a novel approach to manage liquid supply and vapor flow above the surface. Here, we introduced 1, 5, and 9 helical wires on a flat surface to enhance pool boiling heat transfer by simultaneously manipulating liquid and vapor flow. Our findings indicate that compared to the flat surface, the CHF increased by 166% with the 9 helical wires and the HTC increased by 154% with the 5 helical wires. This improvement can be attributed to the Laplace pressure exceeding the pressure drop when vapor flows within the helical wires, restricting vapor primarily within the wires and extending the liquid-vapor phase separation mechanism above the surface. This reduces the impact of Kelvin-Helmholtz instability. Additionally, the confined vapor flow area increases vapor release velocity and creates a local negative pressure, enhancing the liquid supply from the side walls of the helical wires. In conclusion, the approach to managing vapor and liquid flow above the surface presents a promising method to significantly enhance pool boiling heat transfer in the field of thermal engineering, offering a potential solution to the challenges posed by flow instability.

**KEYWORDS:** Helical wires, Pool boiling, Critical heat flux, Heat transfer coefficient, Liquid-vapor separation.



# Numerical simulation of seawater temperature and burial depth effect on the maximum operating current of submarine cables

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**ABSTRACT:** With the development of offshore wind power, submarine cables play a crucial role in connecting the onshore electrical grid. The higher ampacity of submarine cables, the more electricity can be transported; however, it would also increase the temperature of the conductor,  $T_c$ . Typical insulation material of cables is cross-linked polyethylene having maximum allowable operating temperature ( $T_{max}$ ) of  $90^{\circ}\text{C}$ . To ensure the safety and extend the service life of submarine cables during operation, understanding the maximum temperature of the cables under different environmental conditions and operating currents is essential. Therefore, this study utilizes ANSYS FLUENT to create a two-dimensional steady-state heat transfer model of a three-core submarine cable to investigate the temperature distribution of the cable under varying conditions of seawater temperatures ( $T_w$ ), burial depths ( $D$ ) and operating currents ( $I$ ). Fig. 1(a) shows the conductor temperature under different seawater temperatures with a burial depth of 3 m while operating current increases from 200 A to 1000 A. The results indicate that the conductor temperature significantly increases with the rise in the current. In addition, for every  $5^{\circ}\text{C}$  decrease in the seawater temperature, the conductor temperature decreases by approximately  $2^{\circ}\text{C}$ . Fig. 1(b) indicates that burial depth is a crucial factor affecting the maximum operating current of submarine cables. As the burial depth increases, the maximum operating current ( $I_{max}$ ) significant decreases. For instance, at a seawater temperature of  $10^{\circ}\text{C}$ , the maximum operating current decreases from 777 A at a burial depth of 1 m to 678 A at a burial depth of 4 m, decreasing approximately 100 A.

**KEYWORDS:** Submarine cable, Maximum operating current, Temperature distribution

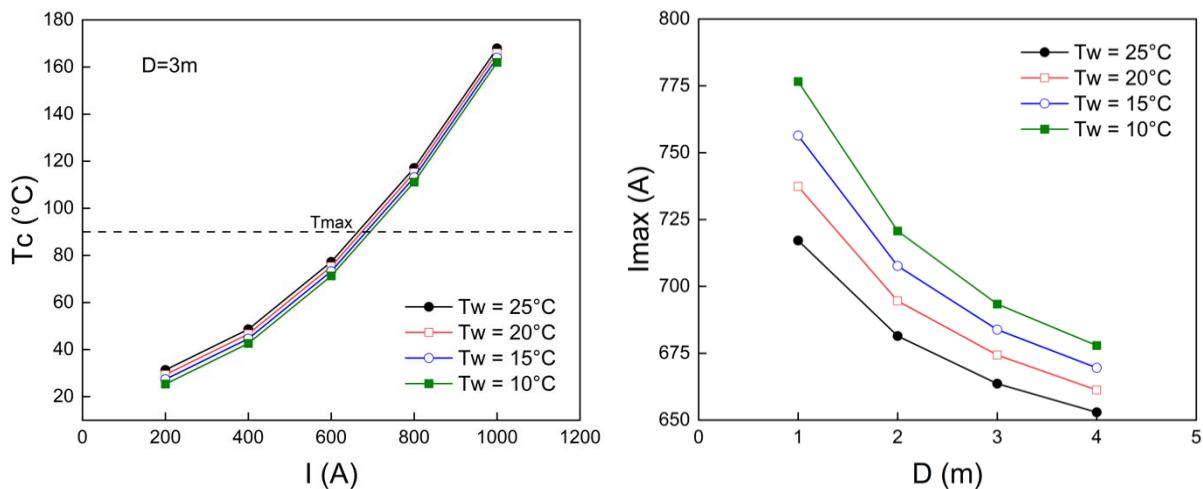


Fig.1 (a) Conductor temperature and (b) maximum operating current under different conditions.

# Effect of Chamber design on the Flow Field in Atomic Layer Deposition Process

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**ABSTRACT:** Atomic layer deposition (ALD) can produce high-quality, conformal thin films with precise control over thickness. However, the main drawbacks of the ALD process are its extremely low deposition rate and low gas dosage efficiency. By reducing the reaction time for a single cycle and minimizing gas consumption, it is possible to save time and material costs in the multiple cycles of gas inlet and purging steps in ALD processes, thereby improving semiconductor production efficiency. This study adopts a showerhead-type reaction chamber for three-dimensional transient simulations to optimize the ALD process in terms of time and gas dosage. The focus is on optimizing parameters such as chamber design, including nozzle diameter, number of nozzle holes, and chamber height. This involves a series of validations including grid independence testing, time step independence testing, and chemical model validation. The goal is to complete the ALD process reaction within the shortest possible time and with minimal precursor gas usage to reduce process costs. After optimizing the chamber design, modifications are made to the parameters of both the chamber and showerhead compared to the original reference chamber resulting in significant improvements. Trimethylaluminum (TMA) gas consumption can be reduced by up to 64.1%, while saving up to 63.3% of time.

**KEYWORDS:** atomic layer deposition, chamber design, precursor, optimization of ALD Process, process cost

## Anti-icing/deicing on suspended nanofiber membrane surfaces

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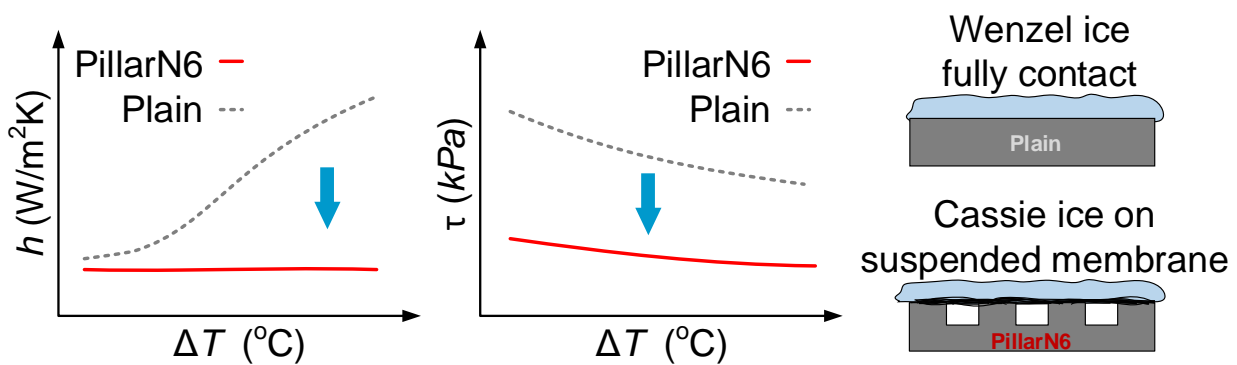
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**ABSTRACT:** Ice accumulation disrupts industrial systems, posing economic and safety risks. Ice formation processes involve phase transitions from gas to liquid and from liquid to solid. The superhydrophobic or superhydrophilic surfaces have been investigated for their anti-icing properties, while the potential of hygroscopic surfaces remains underexplored. This study explores the application of nylon-6 nanofiber membranes, known for their cost-effectiveness, lightweight, and water-absorbing qualities, in anti-icing. We propose a Si micropillar array coated with a nylon-6 nanofiber membrane as an anti-icing surface. The suspended nanofiber membrane absorbs liquid water molecular, potentially inhibiting the formation of Wenzel ice, while the micropillar array supports the nanofiber membrane, reducing the heat transfer area and ice adhesion. Anti-icing performance was evaluated on a flat Si surface (plain surface), and the micropillar array coated with the nylon-6 nanofiber membrane (PillarN6 surface). Results indicate that the coated micropillar array exhibited a lower heat transfer coefficient, attributed to the water-absorbing properties of the nylon-6 membrane, which facilitates the formation of Cassie ice. In contrast, the plain surface had a higher heat transfer coefficient due to better contact of Wenzel ice. The presence of air pockets between the micropillars with high thermal resistance serves to hinder the growth of ice layers, thereby guaranteeing efficient anti-icing properties. Besides, ice adhesion stress is a key deicing indicator, with lower values indicating better deicing performance. Our result demonstrates an obvious reduction in ice adhesion stress on PillarN6 surface compared to the plain surface. Thus, the PillarN6 surface offers superior anti-icing and deicing capabilities.

**KEYWORDS:** nylon-6, nanofiber membrane, micropillar, anti-icing, deicing, adhesion



# Length-dependent thermal transport measurements on various nanowires

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**ABSTRACT:** In recent times, numerous experimental techniques have emerged for measurements of temperatures at nanoscale levels. Nonetheless, it remain uncertain whether these methods would produce consistent results, especially when the contact thermal resistance cannot be separated from the total thermal resistance. In this study, we invent an experimental approach utilizing a scanning electron microscope (SEM) to determine the local temperature at different position of individual nanowires and the associated transport properties, particularly for silicon carbide (SiC) and nickel (Ni) nanowires. We obtained consistent results using two different analytical methods, confirming the feasibility of this approach. We can also determine the difference in the thermal conductance between the two measurement pads, which can be as much as 16%. Furthermore, we found that applying the electron-beam-induced deposition method to the contact points can improve the contact thermal resistance, with a maximum enhancement of up to 546%. The results show that all nanowires exhibit diffusive transport, and the best contact thermal resistance is  $56 \text{ MWm}^{-2}\text{K}^{-1}$ , which is approximately equivalent to interfacial thermal conductance of Rh/AL<sub>2</sub>O<sub>3</sub>.

**KEYWORDS:** Nanowire, Local temperature, Thermal conductivity, Contact thermal resistance

# Temperature visualization on a Tesla turbine by using stroboscopy and liquid crystal technique

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**ABSTRACT:** In this experiment, stroboscopy and thermochromic liquid crystals were employed to explore the heat transfer distribution on the rotating disc of a Tesla turbine. The Tesla turbine was renowned for its competitiveness in recovering low to medium-temperature waste heat and harvesting energy. Since the operating principle of the Tesla turbine was based on the boundary layer effect of the fluid, and temperature was one of the factors that affect fluid viscosity, therefore, by analyzing the temperature distribution on the turbine blades, we can identify the key parameters for improving the efficiency of the Tesla turbine. First, a calibration test was conducted to mitigate the uncertainty caused from high rotational speeds and establish the correlation between hue values and temperature. This research employed air as the working fluid and investigated various parameters, including disc rotational speeds from 0 to 10000 rpm, numbering of disc (5, 7, and 9 discs), and output voltage generation at 10000 rpm, expected to be approximate 85 volts. The pitch between discs was also examined for its impact on system performance. This study aimed to establish the relationship between mass flow rate, temperature distribution on the disc, and rotational Reynolds number with the efficiency of the Tesla turbine.

**KEYWORDS:** Tesla turbine, Thermochromic Liquid Crystal, Stroboscopy, Heat transfer, rotating disc

## Pool Boiling Heat Transfer on the Single Reentrant Micro-pillar Arrays

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**ABSTRACT:** Thermal management in the electronics industry is crucial as the power density surges with the increased functionality of electronic devices. Such a high power density can only be managed through phase-change heat transfer. Pool boiling among various phase-change systems is the most straightforward approach for cooling electronic devices. However, the maximum power dissipation in pool boiling is limited by the critical heat flux (CHF) of pool boiling. The hydrodynamic instability model has proven to be the closest approximation to the experimentally observed CHF. Premised on this model, the research community has focused on surface engineering to obtain higher CHF values. A recent study has shown that the one-dimensional (grooved) single reentrant (SR) structures can increase the CHF among several micro-structured surfaces. However, the pertaining physics remains undisclosed. This has motivated us to study the mechanism of CHF on the two-dimensional SR structured surfaces on silicon substrates, the most commonly used material in the semiconductor industry. In this work, we have carried out a comparative study of pool boiling on a pillar, a single reentrant (SR), and a Teflon-coating single reentrant (SRT) surface, with a control experiment on a flat SiO<sub>2</sub> sample, as shown in Figures 1(a) to 1(d). The vapor coverage ratios are directly observed by using Infrared imaging, as shown in Figures 1(e) to 1(g). In these figures, the darker spots correspond to the bubble regions, while the brighter spots correspond to the wetted parts. Our observations reveal that the pillar and SR surfaces have smaller bubble diameters than the flat surface. This is attributed to the design of the water channels on the two surfaces, which reduces the resistance to the flow and limits the diameter of the departing bubble. Due to this, the CHF increases by 33% on the

pillar surface compared to that on the flat SiO<sub>2</sub> surface. Furthermore, an increment of 22% in the CHF was observed on the SR and SRT surfaces over the pillar surface. This is attributed to the strong anchoring effect of the SR structures. Figures 1(h) and 1(i) show the comparison of vapor-covered areas (under a bubble) on pillar and SR surfaces. From the figures, it can be observed that the pillar surface is dry, whereas the SR surface is wet in the regions covered with structures. The strong adherence of water to the SR results in a two-way enhancement of the CHF. First, the anchored water results in a delayed dry-out phenomenon. Second, due to intermittent vapor-liquid interface, the bubble adherence to the solid surface reduces, further limiting the departing bubble diameter. Moreover, the

SRT surface depicted a 1% reduction in the CHF due to additional heterogeneity at the bubble contact line; however, due to the early onset of nucleation boiling typical to hydrophobic surfaces, the SRT surface exhibited a higher heat transfer coefficient as compared to the SR surface. In addition to the enhanced CHF, it is noteworthy that the results obtained are in good agreement with the CHF model based on hydrodynamic instability. **KEYWORDS:** Pool Boiling, Single-Reentrant Structure, Hydrophilicity, Critical Heat Flux, Heat Transfer Coefficient, Nucleation Density, Vapor Coverage Area Ratio.

**KEYWORDS:** Pool Boiling, Single-Reentrant Structure, Hydrophilicity, Critical Heat Flux, Heat Transfer Coefficient, Nucleation Density, Vapor Coverage Area Ratio.

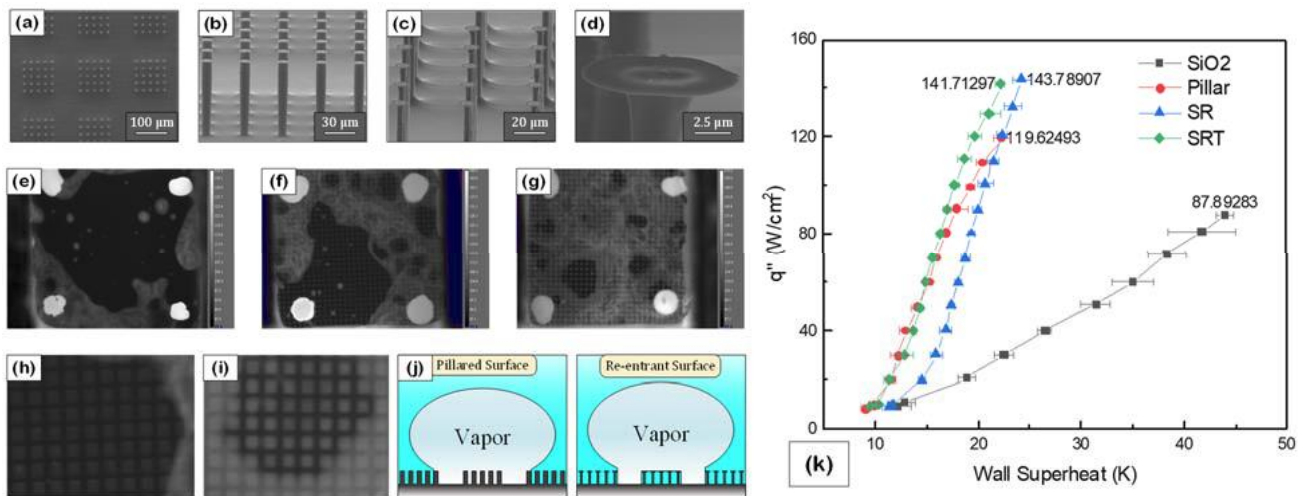


Figure 1 (a) Top view of a pillared sample, (b) front view of a pillared sample, (c) front view of a single reentrant (SR) structures, (d) enlarged view of the overhang on a SR sample, (e) IR image of a flat SiO<sub>2</sub> sample at CHF, (f) IR image of a pillared sample at 110W/cm<sup>2</sup>, (g) IR image of an SR sample at 110W/cm<sup>2</sup>, (h) enlarged IR image of a pillared sample at 110W/cm<sup>2</sup> under a bubble region, (i) enlarged IR image of an SR sample at 110W/cm<sup>2</sup> under a bubble region, (j) schematic of a comparison between bubble formation on a pillared and an SR sample, and (k) the boiling curves as obtained on different surface types.

## Heat Transfer and Pressure Drop of Ice Slurry Refrigerant

Yeu-Shaw Lin, Ching-Wen Lo, and Ming-Chang Lu\*

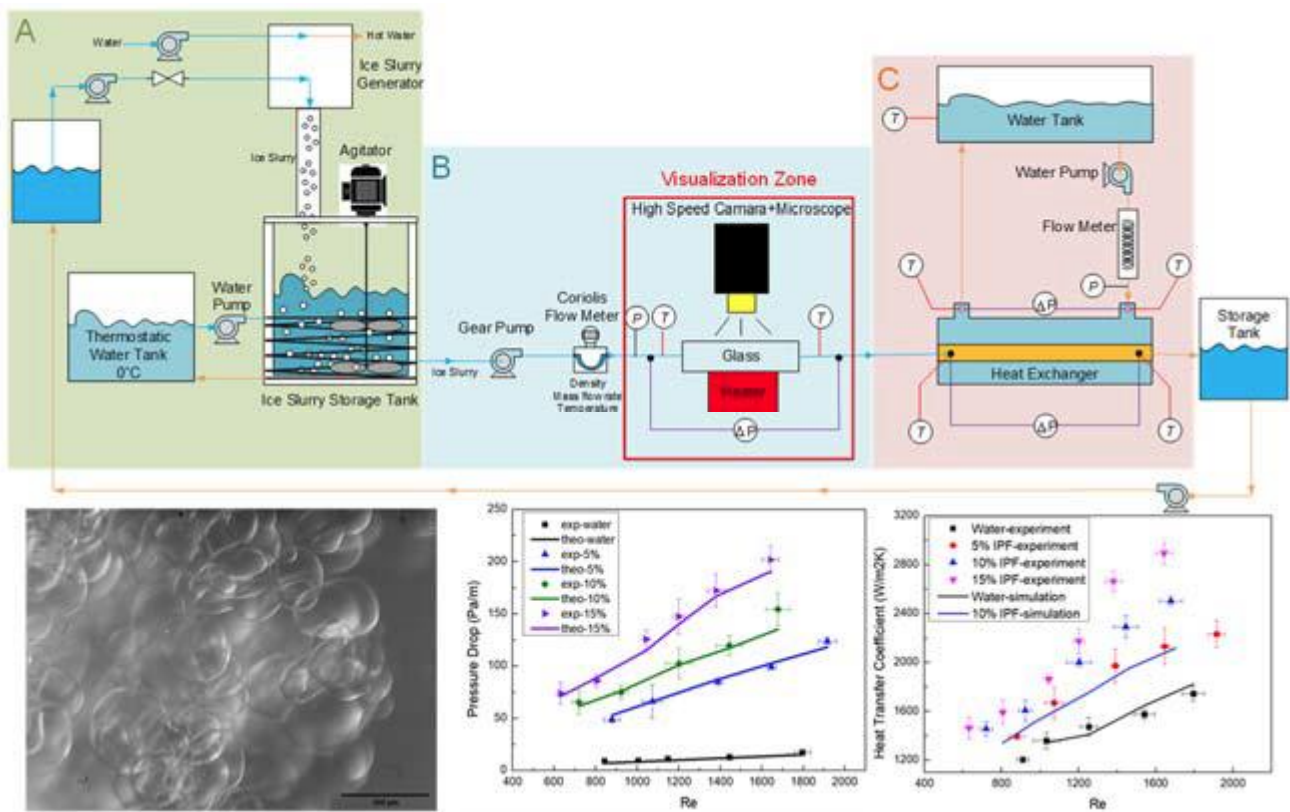
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**ABSTRACT:** The robust economic growth and the surge in electricity demand have caused summer peak power demand to be a significant global challenge. Air conditioning accounts for over 40% of a building's total energy consumption. Ice storage air conditioning has emerged as an important approach to reduce peak power demand and energy consumption in buildings. It utilizes non-peak electricity to produce and store ice, which can be used as a cooling source during peak hours. Ice slurry, a two-phase mixture of small ice particles and carrier liquid, is the working fluid for ice storage air conditioning. It has several advantages over conventional refrigerants, such as being free of CFCs, excellent energy storage capabilities, and superior heat transfer characteristics. However, the application of ice slurry in cooling systems is still limited by the lack of understanding of its flow and thermal behavior. Therefore, this study aims to establish an ice slurry system and investigate its pressure drop and heat transfer properties under different operating conditions. The ice slurries in this work use 5% ethylene glycol as the carrier liquid and consist of various ice packing factors (IPFs). The average ice particle size is approximately 200  $\mu\text{m}$ . Our findings indicate that when the IPF is below 15%, the flow behavior of ice slurry resembles that of a Newtonian fluid. Additionally, the heat transfer coefficient of ice slurry is approximately 1.5 times higher than that of single-phase water, and it increases with rising IPF.

**KEYWORDS:** Ice slurry, Heat transfer Coefficient, Ice packing factor.



# Explore the Heat Transfer Properties of the Lignin-reduced Graphene Oxide films

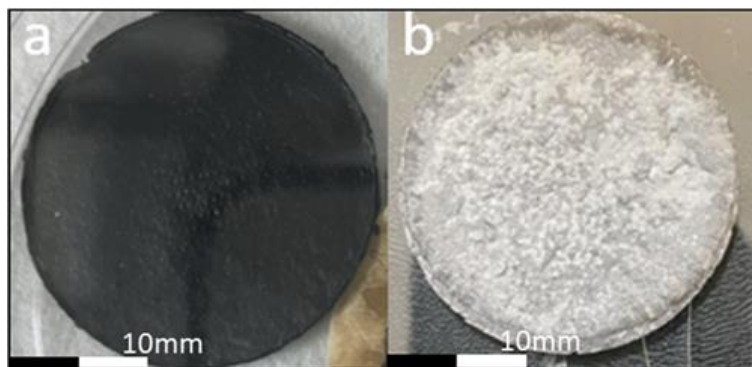
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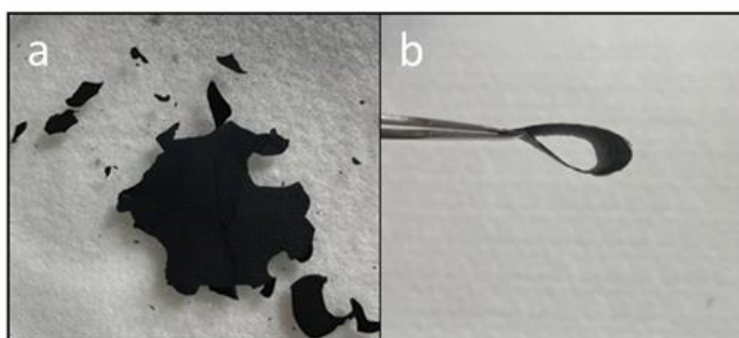
**Grant Number:** NSTC 112-2223-E-002-013

**ABSTRACT:** The pursuit of high performance in electronic products inevitably leads to increased power density of chips, with current power densities reaching up to 300 W/cm<sup>2</sup>. Therefore, efficient heat dissipation becomes crucial. A typical thermal agriculture consists of a heat spreader to spread heat from the chip, and the heat is eventually dumped into the environment through heat convection. Single-layer graphene membranes with a superior thermal conductivity ( $k$ ) of approximately 5000 W/m-K are a promising candidate as the heat spreader. However, the  $k$  of graphene membranes decreases with increased thickness, and the production of highly pure graphene membranes is costly. In contrast, reduced graphene oxide (rGO) films have  $k$  comparable to graphene and can be easily prepared from graphene oxide (GO) through a cost-effective reduction process. Traditional reducing agents used for rGO synthesis are harmful to the environment. In an effort to promote a green circular economy and sustainable development, In this study, lignin was used as a reducing agent. Lignin exhibits excellent reduction capability. The results of the study showed the successful synthesis of reduced graphene oxide (L-rGO) films using lignin, as shown in Fig. 1(a). The L-rGO film was thermally annealed at 1400 °C to enhance its heat transfer, as shown in Fig. 1(b). The L-rGO film has a low elastic modulus, which makes it easily to be broken under external stress, as shown in Fig. 2(a). In contrast, the high-temperature annealing treatment gives the film flexibility, as shown in Fig. 2(b). The study also measured the in-plane  $k$  of the L-rGO films. As shown in Fig. 3(a), the obtained in-plane  $k$  of L-rGO film is 3.32 W/m-K. However, through annealing, its  $k$  can be increased to 50-60 W/m-K. Additionally, the LrGO films were bonded to a Si chip to evaluate their efficacy in reducing the thermal resistance of a Si chip with a power density of approximately 1000 W/cm<sup>2</sup>. The thermal resistance of the chip was reduced from ~11 K/W to ~5 K/W by bonding the annealed L-rGO films.

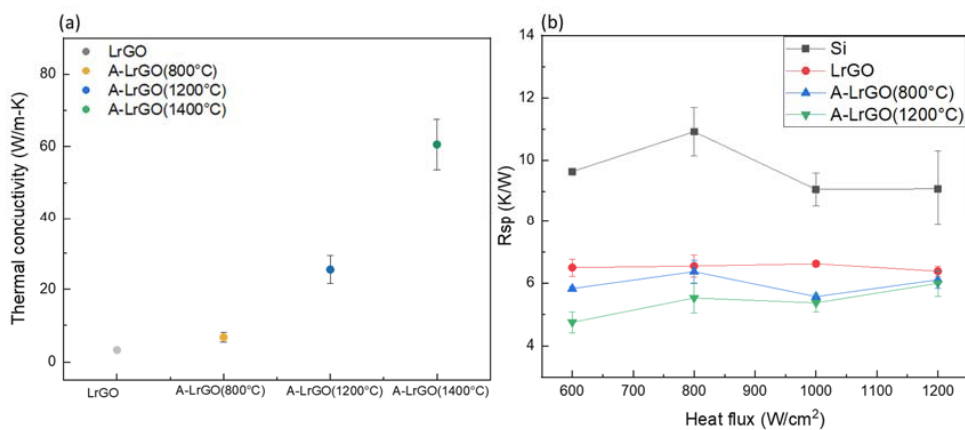
**KEYWORDS:** Lignin, Reduced Graphene Oxide, Thermal Conductivity, Thermal Resistance.



**Figure 1.** Reduced Graphene Oxide images: (a) L-rGO reduced with lignin, and (b) A-LrGO after annealing.



**Figure 2.** (a) Image of LrGO under stress., and (b) Image of the annealed LrGO under stress.



**Figure 3.** (a) In-plane thermal conductivity of L-rGO, (b) Thermal spreading resistance of LrGO bounded with a Si chip.

# Experimental and Theoretical Investigations on the Thermal Conductivity and Electrical Resistivity of Single Nickel Nanowire

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**ABSTRACT:** Nickel is a ferromagnetic material commonly used in spintronic devices, which manipulate spins as an additional degree of freedom for data processing by means of a magnetic field. Spintronic device has versatile applications, including sensors and detectors, memory technology, artificial synapses, quantum computing, and others. These applications are not only a foundation of contemporary electronic devices but also represent the cutting-edge technologies to renovate the future. Reducing the line width improves the performance of spintronic devices, yet the inherent increasing power density results in severe heat accumulation, which deteriorates the functionality of spintronic devices. Therefore, it is crucial to investigate the transport properties of nanoscale ferromagnetic material, as well as the influence of magnetic field on transport properties.

In this study, nickel nanowires (NiNWs) were fabricated through electrodeposition using porous anodic aluminum oxide (AAO) membranes as templates. The morphology, crystallography, element composition, and magnetic properties of NiNWs were thoroughly characterized. The results show that the NiNWs were polycrystalline with a face-center cubic (FCC) crystal structure, and their grain size was approximately 23 nm. In addition, its magnetization increased as the magnetic field elevated and reached saturation at around 3 kOe. Meanwhile, the NiNW's magnetic domain shifted from a multi-domain distribution to a single domain at the saturated magnetization. The experimental results showed that the magnetic field had a remarkable influence on the thermal conductivity of NiNWs yet little influence on their electrical resistivity. When the magnetic field is exerted, a 1.6% increment in electrical resistivity and an approximately 15% decrement in thermal conductivity of NiNWs were observed at room temperature under the saturated magnetization. This indicates that the magnetic field predominates the magnon transport, compared to electron transport. To apprehend the anomalous thermal behavior, a theoretical model derived from the Boltzmann transport equation was established. The model incorporates four scattering sources, including boundary scattering, defect scattering, magnon-magnon scattering, and magnon-phonon scattering. Through theoretical modeling, boundary and defect scatterings were found crucial in magnon transport. Moreover, it revealed that the field-induced degradation of the magnon mean free path is responsible for the reduction of NiNWs' thermal conductivity as the magnetic field increases.

**KEYWORDS:** nickel nanowire, electrical resistivity, thermal conductivity, magnon, mean free path

# Effect of the Twisted Ribs on Flow Field and Heat Transfer in Water Jet Impingement

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**ABSTRACT:** With the development trend of high-speed computing, a large amount of waste heat will be accumulated on the system, resulting in a decrease in overall performance. In order to effectively remove waste heat, jet impingement cooling technology is widely used in the industrial field[1]. The main purpose of this study is to investigate the flow field and heat transfer behavior of a swirl jet impinging on a heated surface. As shown in figure 1, a swirl jet is generated through a nozzle with the twisted ribs. Simulations are carried out with a certain nozzle-target spacing for the rib swirl angle varying from 0o to 45o at Reynolds number varying from 825 to 41,292[2]. The results show that the heat transfer performance increases with the increase of rib swirl angle and Reynolds number.

**KEYWORDS:** Jet impingement, Twisted ribs, Computational fluid dynamics, Flow structure, Heat transfer

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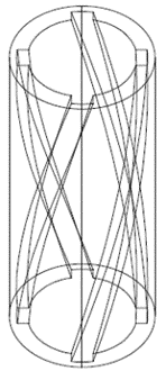


Fig. 1 Geometry of the new nozzle.

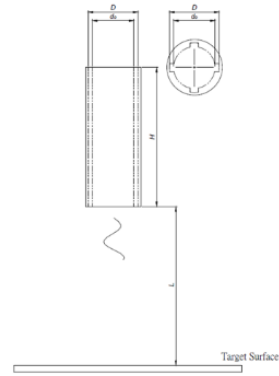


Fig. 2 Schematic diagram of the computational model.

## Dip coating of ceramic on additively manufactured porous structure for transpiration cooling

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**ABSTRACT:** Transpiration is widely used for cooling high temperature combustion chambers, rocket nose cones, and turbine blades. Additive manufacturing minimizes material wastage and is commonly used for prototyping and customized product fabrication. In this study, we investigated the porous structure near the leading edge of the rocket engine for transpiration cooling. Different unit cells were employed to propose the porous structure. The pore size ranged from 300-600 $\mu\text{m}$ , and its performance was studied using computational fluid dynamics. We selected a 3D printed porous structure made of Ti6Al4V material. Since metal parts typically have a high temperature limit and inferior mechanical properties at high temperatures, ceramic coating was added to the additively manufactured porous structure. The dip coating process was chosen as the coating method, and we studied the effect of ceramic solution and removal speed on it. An optical microscope was used to observe the microstructures of ceramic in the porous region. It can be observed that successful coating of ceramic occurred on both external and internal surfaces within the porous part. Although there are grains of ceramic distributed on the surface in microscope images along with cracks and uneven morphology, primary flow channels within each unit cell remain unblocked without any noticeable changes in their geometry.

**KEYWORDS:** Transpiration cooling, Dip coating, Ceramic coating, Porous structure

# Magnetic nanofluid pool boiling heat transfer on hydrophilic/hydrophobic surface

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**ABSTRACT:** When a fluidic device gets smaller, the heat transfer would become a more important issue. The heat removal technology with pool boiling heat transfer of fluids with particles could be one of the candidates. Fluids with magnetic nanoparticles (nanofluids) could be designed to exhibit improved or tunable properties against magnetic field. Magnetic nanofluids on a modified wall surface in a magnetic field may lead to significant pool boiling heat transfer enhancement [1-3]. In this presentation, the pool boiling heat transfer problem for a magnetic nanofluid on hydrophilic and hydrophobic wall surfaces under an external applied magnetic field will be shown, and the surface wettability effect will be investigated. Magnetite nanoparticles were synthesized via chemical coprecipitation technique. Oleic acid was used as a surfactant, capped on the surface of nanoparticles via sol-gel technique. A hydrophilic surface of copper hydroxide (Cu(OH)<sub>2</sub>) was provided by etching technique on a copper substrate. A hydrophobic surface was provided by soaking the copper hydroxide substrate in myristic acid which was dissolved in ethanol. An external magnetic field gradient was set, so that we can investigate the influence of a magnetic force on the pool boiling heat transfer performance of the magnetic nanofluid on hydrophilic and hydrophobic surfaces. The magnetic force generated by a magnetic field gradient will facilitate the bubbles to leave the surface and thus reduce the excess temperature for a fixed heat flux. The largest reduction is about 80% for hydrophilic case and 60% for hydrophobic case. For smaller heat fluxes, hydrophobic surfaces provide a better choice for lower excess temperatures; however, for greater heat fluxes, hydrophilic surfaces provide a relatively better choice. Such a surface effect is relatively insignificant when the magnetic force is applied.

**KEYWORDS:** Nanofluid, pool boiling, heat transfer, critical heat flux, magnetic field gradient.

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# Standardization and quantification of backscattered electron imaging using atomic number electron microscopy

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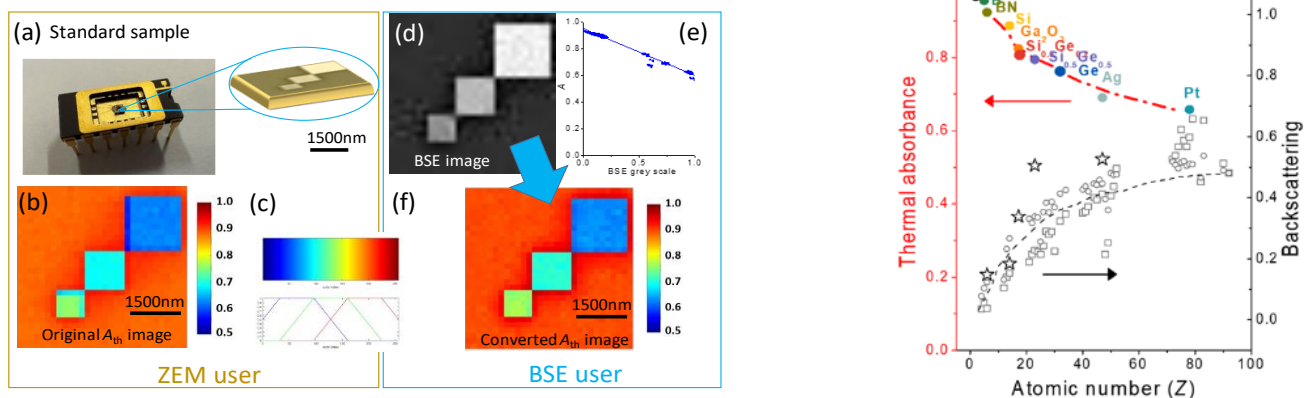
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**ABSTRACT:** Scanning electron microscopy (SEM) coupled with backscattered electron (BSE) imaging stands as a widely employed tool in the scientific and industrial realms. Nevertheless, achieving consistent standards and precise quantification in BSE images has proven to be a long-standing challenge. Previous SEM standardization methods incorporating dedicated calibration processes and Monte Carlo simulations have still posed practical limitations for widespread adoption. Our innovation lies in the introduction of a pioneering bolometer platform designed to directly measure the thermal energy absorbed of the electron beam by a sample. This platform, as demonstrated in our study, significantly contributes to the analysis of the atomic number ( $Z$ ) of the samples under investigation, thereby giving rise to Atomic Number Electron Microscopy (ZEM). ZEM's foundation lies in the conservation of energy principles and it can serve as a nearly ideal BSE detector. Our approach integrates the strengths of both BSE and ZEM detectors, simplifying quantitative analysis for samples of various shapes and sizes. Moreover, the complementary nature of the ZEM and BSE signals enhances the detection of light elements and compounds, making it more accessible than existing microanalysis techniques. This innovation holds great promise for elevating the precision and versatility of SEM-based imaging and analysis, offering a universal methodology in the field with implications for diverse scientific and industrial applications.



**KEYWORDS:** Scanning electron microscopy, Backscattered electron imaging, Atomic Number Electron Microscopy, Detection of light elements, Quantitative analysis

# Indoor Photovoltaic Energy Harvester for Volatile Organic Compound Sensor Node

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Grant Number: NSTC 110-2222-E-167-003-MY3

**ABSTRACT:** This study aims the develop of energy harvester module for volatile organic compounds sensor node based on the indoor solar cell. The developed sensor node utilizes a low-power strategy to enable autonomous operation in monitoring indoor air quality. A low-power algorithm was applied to the proposed smart sensor achieving a total power consumption of 924mW per operational cycle, taking a total time of 63s. A comprehensive performance testing shows the highest power consumption, amounting to 419mW, occurred during the data transmit process, which took approximately 1.646s. However, employing a low power strategy significantly mitigated power consumption, as it reduced it to only 152mW with a time interval of 60s. During this interval, the smart sensor operated in sleep mode, reactivating to perform initialization processes, read sensors, transmit data, and return to sleep mode. This study explores the potential of micro energy harvesting from the indoor environment to extend the lifespan of the developed sensor node. Amorphous silicon thin film measuring 2 × (114mm × 74mm) were employed to connect with the smart sensors. By utilizing indoor photovoltaics, the operating time of the smart sensor can be increased from 16 hours and 30 minutes to 19 hours (at 500 lx), or even further to 21 hours and 30 minutes (at 750 lx).

**KEYWORDS:** VOC, Smart Sensor, Low Power, IPV.



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# A PDMS-nanocomposite microfluidic layer for adaptive thermal control of windows

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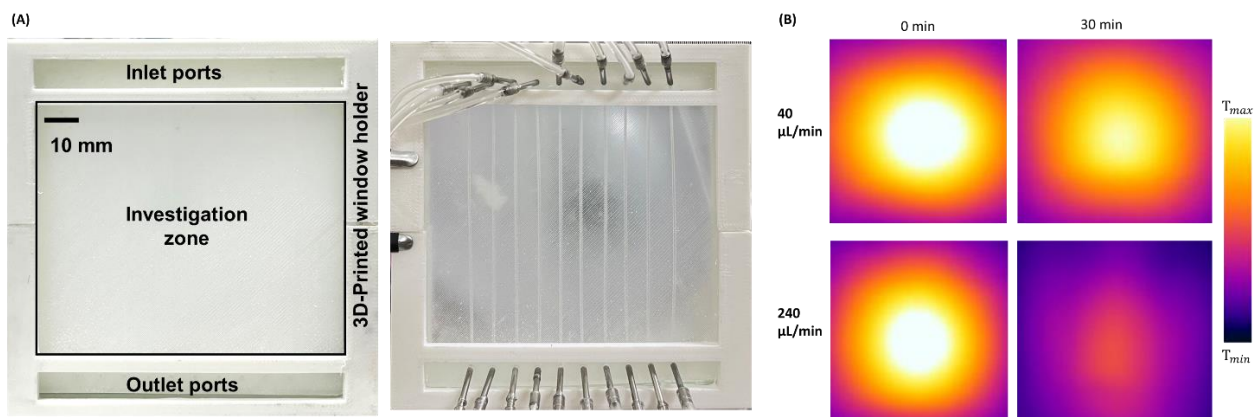
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Grant Number: NSTC 111- 111-2221-E-167 -016

**ABSTRACT:** Building's windows and facades are the major sources of energy inefficiency in modern buildings that account for 40% of the entire building's energy cost due to the thermal energy loss during both the summer and winter in terms of heat gain and heat loss. It is realized that the window can be used as a heat exchanger system towards reducing overall heat gain and heat loss meanwhile collecting solar energy towards a better thermal management. The fluidic window concept, where multiple laminated glass bolted through manual glazing technology to create a cavity in order to carry heat exchanging fluid for the collection and conversion of solar heat radiation to reusable energy source, is considered efficient in terms of reducing carbon footprint and on top of that it is transparent to visible light. Using additive manufacturing, this work proposes microfluidic layers based on Paraffin–polydimethylsiloxane composites that can be tailored for tunable transparency and integrated with existing window structures for thermal management and energy harvesting applications. The preliminary results suggested using DI water at room temperature as working fluid and with a flow rate tuning 240  $\mu\text{L}/\text{min}$ , the average temperature of a  $10\times 10\text{ cm}^2$  window model can be reduced by approximately 10–15  $^{\circ}\text{C}$ .

**KEYWORDS:** Fluidic window, microfluidics, PDMS-paraffin nanocomposite, CFD.



**Figure 1.** A . PDMS-nanocomposite microfluidic layer prior to exposure of light source (left), post exposure to light (right) demonstrating optical tunability capability corresponding to incoming light. **B.** IR images of window for different flow rate of 40 and 240  $\mu\text{L}/\text{min}$  describing the hydrodynamic influence of thermal management

# Performance Optimization of Radiative Cooling of Recyclable Material by Taguchi Method

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Grant Number:

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**ABSTRACT:** In recent years, rapid advancements in technology and industry have led to a continuous rise in atmospheric temperatures, resulting in an increasing demand for effective passive cooling techniques that are non-dependent on additional energy sources. [1] Radiative cooling is one of them, which allows thermal radiation to pass through the atmosphere to achieve the cooling effect. Therefore, this study selects an environmentally friendly material, polylactic acid (PLA), and measures its optical properties, revealing excellent infrared emissivity while approaching zero reflectivity in the visible range. To address the issue of low reflectivity in the infrared region, this research transforms PLA into fibers and stacks them to form a fibrous membrane, thereby enhancing its reflectivity. [2] This study uses melt electrospinning techniques to produce microscale fibers. By controlling the parameters to stack fibers with different diameters, and combining them with PLA sheets, a multilayer structured fibrous membrane with radiative cooling effects is created. This durability-enhanced structure of a single material (PLA) type facilitates the recycling and dissolution of the entire sample with ease. The Taguchi method was used to design an optical parameter experiment and selected with the voltage difference of 300 V, 0.4 mm of PLA sheet thickness with 4 layers of stacking, and 1.5 minutes of spinning time per layer. This experimental study produced a single-material cooler with an average reflectance of 44.53% and a maximum reflectance of 57.63%. To conclude, the temperature of the sample remained 6.5°C below the ambient temperature during the solar irradiation experiment and hence this PLA fibrous material successfully achieved the passive radiative cooling technique.

**KEYWORDS:** melt electrospinning, polylactic acid, Taguchi method, multi-layer structure, radiative cooling

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# Powering Point-of-Care Testing: Energy Harvesting with TENG-Enabled Digital Microfluidics

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**ABSTRACT:** Our recent study unveils a novel Digital Microfluidic (DMF) system, energized by a self-generated power source using a Triboelectric Nanogenerator (TENG). This cutting-edge combination heralds a new era in microfluidic platforms, particularly for sample preparation in biochemical assays and lab-on-chip technologies.

Traditionally, DMF operations rely on external power sources for supplying the necessary actuation voltage. This dependence has been a barrier to the system's portability, thus limiting its extensive use in on-site diagnostic tests, such as point-of-care testing (POCT). Our new approach employs a TENG, a device renowned for its distinctive features, including its ability to generate high voltage with low current output, which aligns perfectly with the requirements for Electrowetting on Dielectric (EWOD) based DMF systems.

The integration of TENG, specifically a manually-rotated Disk-TENG, into the DMF device marks a significant milestone. For the first time, we demonstrate fundamental droplet operations like moving, splitting, merging, dispensing, and even stretching the droplets to mimic the shapes of alphabetical electrodes, all powered solely by a TENG. Beyond these basic manipulations, we successfully executed complex biochemical processes. These include the mixing of samples and reagents and carrying out chemical reactions such as nucleic acid amplification and the phenol red test directly on the DMF chip's programmed electrode patterns.

This breakthrough indicates that the Disk-TENG can reliably supply power to DMF chips for POCT applications, thus significantly enhancing their practicality and scope of use in various field-based diagnostic settings.

**KEYWORDS:** TENG, Electrowetting

## Coherent thermal absorption in coupled localized plasmon resonance

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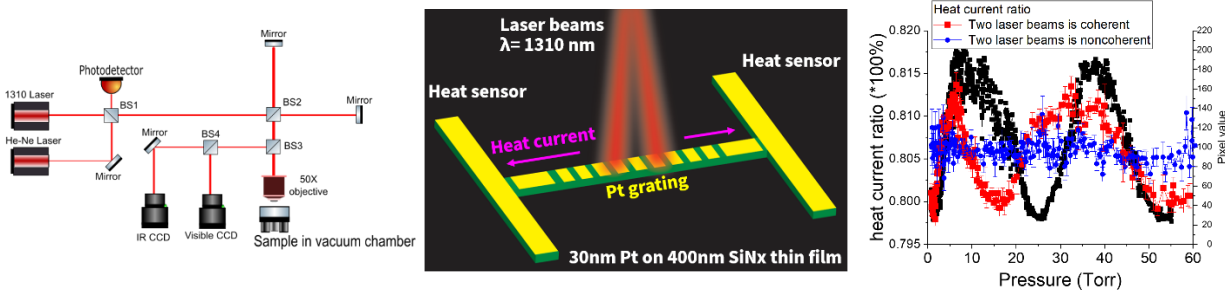
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**ABSTRACT:** Thermal radiation is usually a temporally incoherent light source. Thus, coherent thermal emission arising from the spatial correlation of surface phonon polaritons (SPhPs) wave has caught much attention due to its highly directional thermal emission with small angular divergence. Kirchhoff's law states there is an equality between the emissivity and absorption of objects under thermal equilibrium. However, very few papers investigate the coherent nature of the absorption counterpart inferred from Kirchhoff's law. Here, we experimentally demonstrated the coherent thermal absorption using coupled localized surface plasmon resonance (LSPR) on suspended Pt grating. We shone two laser beams with modulated phase differences on the Pt grating and subsequently measured the heat current by resistive Pt thin film sensor. By determining the heat current ratios derived from simultaneous and independent of these two laser irradiations, we were able to unveil the phase correlation associated with thermal absorption. The results showed that the thermal absorption of two coupled LSPR oscillations over a distance greater than 20 $\mu\text{m}$  could be modulated by altering the phase difference of two exciting lasers. It could be attributed to the phase correlation between two LSPR oscillations which leads to the coherent thermal absorption. The coherent control on thermal absorption over long-range distance has great potential in absorption-based plasmonic switches, modulators, solar cells, and light-harvesting devices.



**KEYWORDS:** Coherent thermal absorption, Localized surface plasmon resonance, Kirchhoff's law

## Performance of passive direct formate fuel cells using metal foam as anode diffusion layer

Jin-Cherng Shyu<sup>\*</sup>, Jie An He, and Jia-Jun Hong

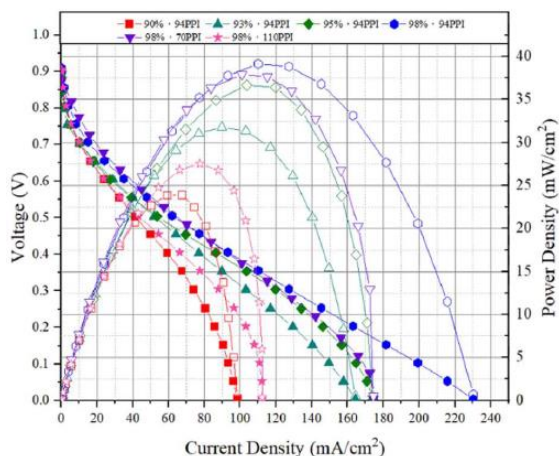
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Grant Number: NSTC 111- 2622-E-992-018

**ABSTRACT:** Because of the regular large pore structure and high permeability, metal foam has considered as one of the potential electrode structures that can increase the electrochemical active surface area (ECSA) and enhance the reactant transport towards the catalyst layer for direct liquid fuel cells. In this study, Ni foam was used as the anode diffusion layer in passive, direct potassium formate fuel cells (passive DFFCs). Palladium was coated on a 0.9-mm-thick gold-plated nickel foam using dip coating technique with a given loading of 2 mg/cm<sup>2</sup> to serve as the anode, while commercially available carbon paper gas diffusion electrode with a catalyst loading of 2 mg/cm<sup>2</sup> was employed as the cathode. Polarization curves of those passive DFFCs having Ni foam of different porosities (90%, 93%, 95%, 98%) and pore densities (70 PPI, 94 PPI, 110 PPI) were measured. According to the correlation published in the literature, permeability of those Ni foam was estimated to investigate the catalyst morphology on those Ni foams exhibited by SEM images. Meanwhile, cyclic voltammetry (CV), and electrochemical impedance spectroscopy (EIS) were measured of those fuel cells with different anode diffusion layer to investigate the effect of Ni foam structural parameters on the performance of the passive DFFCs. The SEM images showed that the pores of the Ni foam with permeability lower than 10<sup>-7</sup> m<sup>2</sup> would be blocked while coating catalyst ink. Besides, measured results indicated that the appropriate porosity and pore density of Ni foam can both notably enhance the ECSA of anode, and enhance the fuel transport to the catalyst. However, the drawback of using metal foam as anode diffusion layer is the risk of cathode flooded by the anolyte since the Ni foam diffusion layer is about 4 orders of magnitude higher than the traditional diffusion layer such as carbon cloth and carbon paper. In this study, the highest maximum power density of the tested passive DFFCs reached 39.14 mW/cm<sup>2</sup> when the Ni foam of the tested passive DFFC with porosity of 98% and pore density of 94 PPI

**KEYWORDS:** Formate, Ni foam, cyclic voltammetry, electrochemical impedance spectroscopy



V-I curves and P-I curves of the tested passive DFFCs with Ni foam as anode diffusion layer

# The capacity evaluation of CO<sub>2</sub>-EGS based on the porous thermal-hydraulic model

David T.W. Lin<sup>1\*</sup> and Kevin C.T. Tang<sup>2</sup>

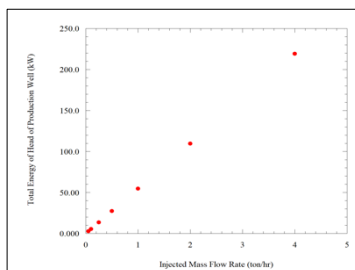
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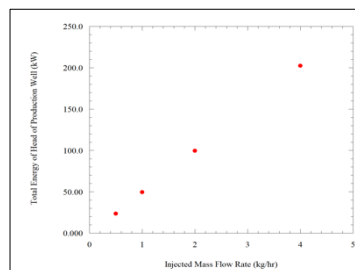
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Grant Number: NSTC 112-2221-E-024-001-

**ABSTRACT:** This study was to evaluate the feasibility of CO<sub>2</sub> enhanced geothermal systems (CO<sub>2</sub>-EGS) based on the geothermal well No. 2 Hong Cha Lin (HCL-2) and Jie Yuan (JY-1), ILan, Taiwan. A porous-fracture thermal-hydraulic model combined the fracture network, porous heat transfer model and Darcy's Law was established by finite element analysis. The phenomena of heat extraction of the supercritical CO<sub>2</sub> injected were discussed. The temperature variation of the reservoir under different injected conditions and the total geothermal capacity of CO<sub>2</sub>-EGS were discussed. Two group of injected mass flow rate were discussed here, one was the larger mass flow rate as 0.5 ton/hr, 1 ton/hr, 2 ton/hr and 4 ton/hr, the other was the smaller mass flow rate as 0.0005 ton/hr, 0.001 ton/hr, 0.002 ton/hr, 0.004 ton/hr. The exit temperature of the production well of CO<sub>2</sub>-EGS increased about 21.5% and the specific capacity increased from 511.28 kJ/kg to 571.4 kJ/kg about 11.8% when the injected mass flow rate was from 0.0005 ton/hr to 4 ton/hr. The temperature difference of the production well decreased as the injected mass flow rate increased. The total capacity increased from 27.4MW to 219MW as the injected mass flow rate was from 0.5 ton/hr to 4 ton/hr and from 23.6 kW to 202.37kW as the injected mass flow rate was from 0.0005 ton/hr to 0.004 ton/hr as figure 1. The temperature decreased from 372.5 K at the bottom of the well to 371.96 K at the exit of the production well as the injected temperature is 293.15 K. However, the temperature increased about 0.01 K as the injected temperature increased from 293.15 K to 303.15 K. The reservoir temperature distribution could be affected by the injected fluid temperature slightly as figure 2. An evaluated model of CO<sub>2</sub>-EGS was built in this study. The effect of porous thermal-hydraulic conjugation was modelled. In future, the porous thermal-hydraulic-mechanical will be developed based on this study.



(a)



(b)

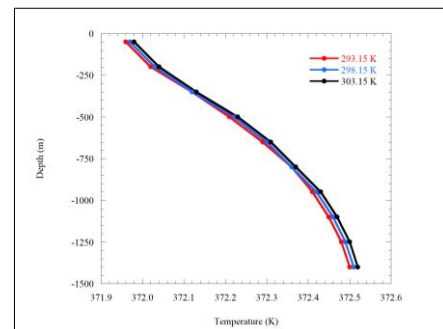


Fig. 1 Total energy of EGS (a) the larger injected mass flow rate, (b) the smaller injected mass flow rate

Fig. 2 The temperature distribution along the production well with different injected temperature

**KEYWORDS:** CO<sub>2</sub>-EGS, Supercritical CO<sub>2</sub>, Darcy model, Porous medium, Porous TH model

# Investigation on thermal emissivity and optical constants spectra of Ge-Sb-Te in three phases

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Grant Number: MOST 110-2221-E-007-044-MY2

**ABSTRACT:** In recent years, research and development on applications of thermal radiation have gained significant attention, such as tunable emitters and infrared camouflage, etc., and phase change materials are often used in this field of research. This type of material changes its phase with temperature, and the radiative properties will change significantly. When doing the research of thermal radiation, it is necessary to simulate the radiative properties of materials, including absorptivity, reflectivity, transmissivity and emissivity. Parameters such as optical constants (refractive index and extinction coefficient), thickness, and radiation angle are used for the simulation, but most of the literature does not provide the optical constants of phase change materials at different phase states, and different temperatures. Therefore, the germanium-antimony-tellurium( $\text{Ge}_2\text{Sb}_2\text{Te}_5$ , GST) three-phase change film was selected as the research sample in this study, and a calculation model for the optical constants of the GST film will be established. Through this model, the optical constants of the three-phases GST film (amorphous, FCC and HCP) in the infrared wavelength range ( $4\ \mu\text{m} \sim 18\ \mu\text{m}$ ) at temperature of  $100^\circ\text{C} \sim 400^\circ\text{C}$  will be obtained.

**KEYWORDS:** Emissivity, Ge-Sb-Te, Optical constants, Phase change material, Thermal radiation

# Thermal Error Analysis and Control of a 3-axis Machining Center using an Intelligent and Adaptive Thermal Balance Control

## Methodology

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Grant Number: NSTC 112-2218-E-003-001

**ABSTRACT:** The thermal deformation caused by uneven temperature distribution and the thermal elongation caused by temperature rise in the structure are the main reasons for inadequate precision in manufacturing and, as a result, the process of remaking often leads to waste of electricity and material. The complexity of thermal deformation due to bending typically cannot be resolved by compensation alone. This research developed a novel intelligent and Adaptive Thermal Balance (ATB) control methodology, combing experimental results, multi-physics coupling simulation, neural network modelling and parameter optimization, to predict the thermal errors induced in the tool cutting point (TCP) and dynamically control key temperature of the structure, thus simplifying thermal errors to elongation only. The error prediction model utilized Long-Short Term Memory (LSTM), a time-dependent neural network solution to account for the time-delay deformation response relative to temperature. Model inputs are ordered based on correlation between the temperature and the displacement at the TCP. Singular Value Decomposition (SVD) method is used to analyze collinearity between the selected temperature to minimize the number of inputs. According to the experimental results, under the operating condition of randomly changing spindle speed and without environmental temperature control, the ATB control methodology can reduce to, and control, the Y-axis thermal deflection( $\Delta Y$ ) to within  $\pm 1\mu\text{m}$ . Th result proves that the ATB control methodology not only effectively reduces the thermal error timely without the necessity for remodification of the tool structure, but also improves the overall manufacturing efficiency, and thus achieves the purpose of sustainable manufacturing. This research uses a 3-axis machining center.

**KEYWORDS:** Adaptive thermal balance, Thermal error prediction, Thermal deformation, Sustainable manufacturing, Ultra-high precision manufacturing

## Performance Study of Dowtherm-A and Naphthalene Heat Pipe

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Grant Number: NSTC 111-2221-E-167 -017 -MY3

**ABSTRACT:** Industrial waste heat is generated from various industrial processes but often remains unused, lost, and discharged into the environment [1]. This waste heat represents an opportunity for recovery through different technologies, serving as valuable energy sources and contributing to overall energy consumption reduction. Among these technologies, heat pipe heat exchangers are known for their high heat transfer efficiency and capability to prevent contamination from the mixing of hot and cold fluids [2]. However, most existing literature focuses on high and low-temperature heat pipes primarily used in nuclear and electronic applications. This research investigates the performance of Dowtherm-A and naphthalene heat pipes by adjusting parameters such as fill ratio, inclination angle, and evaporator and condenser section length ratio. The study utilized heat pipes with an 8mm diameter titanium shell and 480 mm length, equipped with a single-layer stainless steel mesh wick having 150 meshes. Surface temperatures of the heat pipe were measured using 11 J-type thermocouples. The experiment maintained a constant total length for the heat pipe while adjusting the evaporator and condenser length ratios. Case 1 featured a 3:1 ratio, Case 2 a 1:1 ratio, and Case 3 a 1:3 ratio with a constant 280 mm adiabatic section length for all cases. Inclination angles 90° with a 15% filling ratio showed higher thermal resistance for Dowtherm-A and naphthalene heat pipes (1.577K/W and 2.217K/W, respectively) due to insufficient fluid recirculation resulting from low working fluid levels. However, increasing the filling ratio to 30% reduced thermal resistance to 0.93 K/W and 0.961 K/W, respectively. At a 35% filling ratio, increased working fluid levels resulted in vapor bubbles adhering to the evaporator wall, causing local overheating and increased thermal resistances (1.077 K/W and 1.075 K/W). Experiments with a 30% filling ratio and 0° inclination angles showed slower backflow leading to evaporator overheating, whereas 90° inclination angles reduced thermal resistance to 0.93 K/W and 0.961 K/W, respectively. The optimal performance was identified in Case 2 (0.93 K/W and 0.961 K/W) at a 90° inclination angle and 30% filling ratio. By adjusting the fill ratio, inclination angle, and length ratio, heat pipes can be optimized for industrial waste heat recovery within specific parameters.

**KEYWORDS:** Heat pipe, Dowtherm-A, Naphthalene, Length ratio

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## A Numerical Study of Solar Steam-Methanol Micro-reformer

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**ABSTRACT:** Steam-methanol reforming (SMR) for hydrogen production is an endothermic reaction that requires the supply of heat. In this study, sunlight was converted as the heat source to enhance the efficiency and sustainability of the SMR system, effectively transforming it into a sustainable energy conversion system. The primary objective of this research is to evaluate the performance of solar thermal reformers at a variety of water-methanol mixture flowrates and considering the reformer's geometry. Microreactors have several advantages, including enhanced heat and mass transfer, and a reduction in heat loss due to convection owing to the compact system dimensions. The reformer is divided into two regions: the evaporation region and the reformer region. The evaporation region comprises a serpentine microchannel with a hot plate at the bottom. A gradually expanding serpentine flow channel is chosen to assist stabilizing the uneven flow rate distribution observed in a single-width serpentine flow channel during the evaporator section. In the reformer region, a nanocatalyst matrix with an average thickness of 100 nm is fabricated and placed at the bottom of the channel. The catalytic matrix is exposed to solar simulator at an intensity corresponding 1 sun. The momentum, heat, and mass transfer within the solar thermal reformer were investigated through numerical simulations.

**KEYWORDS:** Steam-methanol reformer, Microreactor, Solar hydrogen

# Homogenization Simulation and Optimization of Pin Fin Array in Cooling Channel for High Power Module Applications

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**ABSTRACT:** In this study, a modified homogenized simulation approach based on porous medium approximation is proposed and developed. This method physically converges a 3-dimensional power module with pin fin array into an equivalent 2-dimensional model by using theoretically derived flow velocity and temperature profiles, as well as applying integral average method. The pin-to-cover plate clearance has been considered corresponding to real cooling channel for the target power module, thus flow velocity and temperature distribution between fin region and clearance was included in the modified homogenized model. In addition, a modified porous media equivalent model was derived for high Reynold number scenario. The modified homogenized model yields improved accuracy on pressure drop and heat transfer performance analysis comparing with the referenced original homogenized model. Another great advantage of the developed model is significantly reduced calculation cost, typically from few hours to less than one minutes for a standard pin fin array simulation. This allows a feasible physics model based optimization. By using topology optimization with minimum objective function that adjust the height of each pin fin, an optimized results with reduced baseplate maximum temperature of 1.4 degree and pressure drop by 56% compared to the original design was reached. The optimized pin fin array from this 2-dimensional homogenized model was converted into 3-dimensional geometry, followed by 3D simulation for validation. From the results, it is evident that the modified homogenized model in conjunction with the topology optimization can serve as a reliable pin-fin array optimization tool single with great computation efficiency.

**KEYWORDS:** Pin fin array, Heat transfer model optimization, Homogenized model

# Effect of Ammonia Enriched Gaseous Co-flow on Soot Formation in Droplet Combustion

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**ABSTRACT:** Due to issues surrounding carbon dioxide emissions, there is growing interest in ammonia (NH<sub>3</sub>) as an alternative combustion fuel. The present study examined the effect of ammonia injection in fuel combustion soot production. Ammonia is injected as 5%, 10% and 15% in air flow around the droplet combustion. Results show that up to 10% the diffusion flame is stable, but at 15% ammonia dual flame nature takes over as in diffusion flame at the Centre and ammonia flame surrounding it. This takes Place due to the flammability of ammonia is 14.8% to 33.5% in air. This dual Flame forces the stable combustion towards Instability due to hydro dynamic instability. The results also show, with increment in the ammonia concentration flame length and diffusion area increases. This change in flame nature is due to the buoyancy effect which results from hydrogen in enrichment through ammonia decomposition. Results shows that more than 15% ammonia injection, droplet does not ignite cause ammonia flame and diffusion becomes dominant. So at 15% ammonia duel flame is observed. The soot production rate lowers effectively with the injection of ammonia from 5-15% for all the fuels. The reduction in soot is because of the hydrogen enrichment through ammonia.

**KEYWORDS:** Laser Extinction Imaging, Dual Flame, Natural Convection, Soot

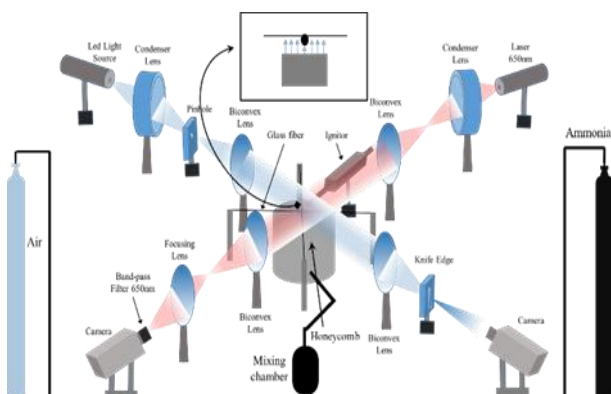


Figure 1. Laser extinction setup with ammonia injection mechanism.

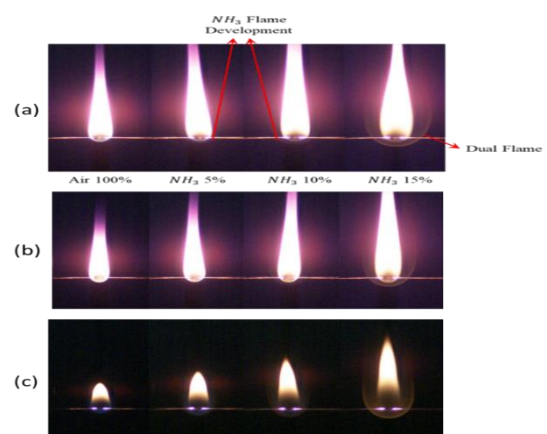


Figure 2. Direct imaging results for (a) Kerosene, (b) Diesel and (c) Butanol for 0-15% ammonia injection.

## The frosting effects on superhydrophobic vertical plate surface

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**ABSTRACT:** The primary objective of this study is to investigate the influence of chemical surface modification designs on frost formation in a vertical cold plate. Superhydrophobic surface were fabricated through a chemical spray method, and these surfaces were placed within an environmental chamber. During the experiments, various velocity conditions were tested, and camera observation equipment was utilized to monitor frost formation times under different conditions. The image analysis was performed to categorize frost crystal shapes, which include ice droplets, needle-like structures, feather-like formations, stacked feather-like patterns, and irregular shapes. The Image analysis revealed that prior to 40 minutes into the experiment, variations in velocity had a minimal impact on the surface characteristics of the samples, indicating a high degree of similarity. However, after 40 minutes, differences in surface characteristics became increasingly prominent due to the influence of velocity. The Fig.1 below demonstrates that a velocity of  $1.5 \text{ m s}^{-1}$  serves as a threshold; the superhydrophobic surfaces exposed to velocities exceeding this threshold exhibited faster accumulation of frost layers, while surfaces exposed to velocities below this threshold experienced slower frost layer build-up compared to regular surfaces. However, it's important to note that changes in velocity did not significantly affect the initial formation and development of frost on the superhydrophobic surfaces.

**KEYWORDS:** Superhydrophobic surface, Frost branch shape, Frost thickness, Delayed frosting

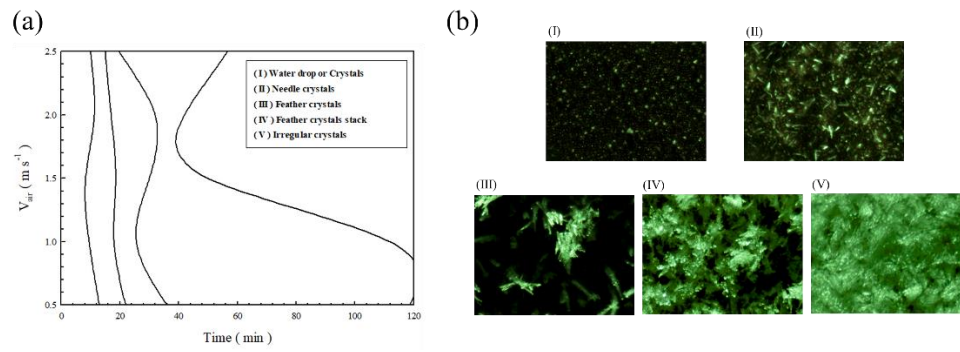


Fig. 1 (a) time distribution of frosting stages for different velocities ( $T_s = -20^\circ\text{C}$ ) (b) Frosting process ( $V_{\text{air}} = 2.5 \text{ m/s}$ )

# Using Intelligent IoT Programming Control in Energy-saving Monitoring and Measurement for Lighting and Aviation Refrigerated Containers Case Study

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**ABSTRACT:** An application of the intelligent internet of things in automotive lighting and aviation refrigerated storage container system with utilizes hardware platforms such as ESP32, Raspberry Pi, DPM8608 programmable power module, sensing module, and LoRa wireless transmission technology, combined with Node-Red monitoring software, to achieve intelligent monitoring and control of advanced white-light lighting and aviation refrigerated containers system temperature. Therefore, we have developed an accurate set of advanced white-light lighting measurements for vehicles, and use the IoT technology to implement real-time monitoring and data collection of lighting, then to improve the quality and reliability of lighting system. In terms of application research on the refrigeration system of aviation refrigerated storage container, the monitoring performance of intelligent internet of things technology in aviation refrigerated containers (temperature, relative humidity, images, and other parameters) is verified. Data is collected using temperature modules and transmitted to remote monitoring centers through LoRa wireless transmission technology. At the same time, user can use data as real-time through the internet cloud or the video software platform in the aviation refrigerated storage cabinet. Then, an integrated intelligent internet of things technology to monitor the practical energy-saving solutions of the system or as an improvement in real-time, feasibility, and performance of the system.

**KEYWORDS:** Intelligent internet of things, advanced white-light lighting, aviation refrigerated storage cabinet.

# Experimental Analysis of Titanium Felt in Proton Exchange Membrane Fuel Cells under Varying Relative Humidity Conditions and Hydrophobic Coating.

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**ABSTRACT:** In Proton Exchange Membrane Fuel Cells (PEMFC), the Bipolar Plates(BPs) are commonly made of metals and graphite, with engraved circular holes or serpentine channels serving as pathways for fuel supply. This study explores the performance of a porous Titanium Felt(TF) (Figure 1) as the PEMFC BPs under different relative humidity(RH) conditions at the cathode and anode (Table 1). The experiments involved testing a closed PEMFC system with pure hydrogen and pure oxygen gases, and fuel RH levels of no humidification, 0.25/0.5/0.75. According to the experimental results (Figure 2), the titanium metal fiber felt exhibits superior overall performance due to its excellent conductivity. However, the fiber's structure leads to the condensation of water vapor from the fuel, adhering to the substrate and impeding the fuel supply. Therefore, performance is significantly affected by humidity, with optimum performance observed when the RH=50%, achieving a maximum power density of 111mW/cm<sup>2</sup> for Case 3. Based on the significant impact of relative humidity observed in the previous experiments, the next step involved coating carbon nanotubes (CNT) with different weight percentages and degrees for hydrophobic treatment. The stability test results, shown in Figure 3, illustrate performance variations.

**KEYWORDS:** PEMFC, Titanium felt, Relative Humidity, Hydrophobic coating, Gas distribution.

Table 1 Case1 – Case4 channel type.

Channel type	Case No.			
	Case 1	Case 2	Case 3	Case 4
Anode	TF	Traditional graphite	TF	Traditional graphite
Cathode	TF	TF	Traditional graphite	Traditional graphite

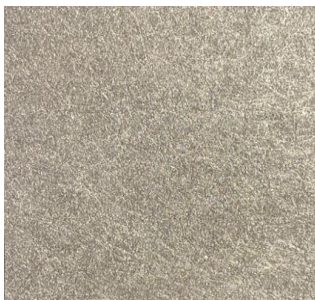


Fig.1.TF sample image.

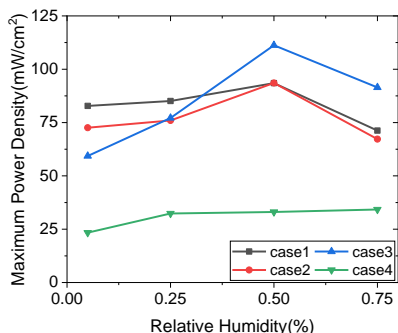


Fig.2. Case1-4 relationship chart between different RH and P<sub>max</sub> points.

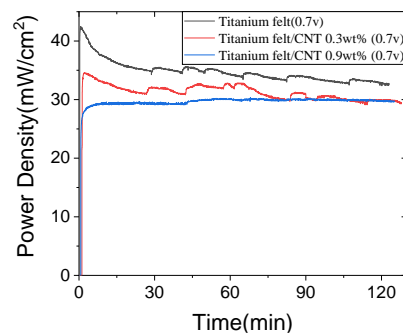


Fig.3. Performance curves of coated CNT at various wt%.

**Reference:**

[1] Z. M. Wan, Y. Sun, C. Yang, X. Z. Kong, H. Z. Yan, X. Chen, T. M. Huang and X. D. Wang, Experimental performance investigation on the arrangement of metal foam as flow distributors in proton exchange membrane fuel cell, Energy Conversion and Management, Vol.231, pp.113846, 2021.

## Reliability Research of Machine Tool Cooling System

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**ABSTRACT:** The thermal error of a machine tool can be regarded as an important index of machining accuracy. Such an error is reproducible and stable, meaning that machine tools can be easily maintained by thermal compensation, ensuring a long-term good machining quality. In this study, reliability engineering was applied to increase the mean time between failures (MTBF) of a cooling system to maintain the structure temperature and accuracy, and the MTBF was increased. In addition, the Taguchi method was used with the finite element method and multivariate regression analysis to obtain the optimal cooling conditions to reduce thermal deformation and stabilize the structure temperature.

**KEYWORDS:** reliability, MTBF, machine tool, cooling system

# Simulation of Solid Oxide Fuel Cell Hydrogen Power Generation System

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**ABSTRACT:** Solid Oxide Fuel Cells (SOFCs) are extensively employed in distributed power generation due to their reliable performance, low environmental impact, minimal noise, ease of operation, and adaptability. Hydrogen, with its high energy content, stands out as an ideal, environmentally friendly choice for fueling fuel cells to generate electricity. Nevertheless, the cost of hydrogen production is relatively high, and its transportation entails substantial safety risks. When it comes to distributed power generation with SOFCs, the storage and transportation of hydrogen necessitate stringent safety measures, whereas SOFCs demonstrate a high tolerance for fuel impurities.

Hydrogen-rich gas derived from external reforming processes like methanol, natural gas, gasoline, and ammonia, along with a minor degree of steam reforming within the SOFC at high temperatures, can serve as fuel for SOFCs. This study's primary aim is to create a simulation and conduct a performance analysis of a hydrogen power generation system utilizing solid oxide fuel cells. This entails converting the electrochemical reactions and energy generation-consumption processes in the fuel cell into a series of mathematical equations to simulate various characteristics and efficiencies of the fuel cell system. Employing simulations enables the prediction of performance and experimental outcomes before actual experiments, effectively reducing costs and time associated with experimental testing. Moreover, comparing optimal parameter values obtained from simulations with real system results facilitates the optimization of system performance and the development of an optimized model design.

In this study, a model of a 10 kW solid oxide fuel cell single-cell system is established, encompassing the fuel cell power generation system and its components. Due to the high operating temperature of SOFC reactions, serially connecting multiple stacks of cells not only allows for heat recycling to elevate the temperature of input fuel gases and reduce heat loss rates but also enhances overall efficiency. The inclusion of a gas separator and heat exchanger enables the collection of unreacted gas in the anode and the separation of gases such as water vapor and hydrogen. The recovered hydrogen can be reutilized, improving the fuel utilization efficiency of the SOFC system. Furthermore, the heat recovered via the heat exchanger contributes to the overall efficiency.

**KEYWORDS:** Hydrogen energy, fuel cell system simulation, solid oxide fuel cell, Reformer, Heat Exchanger.

# Effect of temperature difference on salinity-gradient power generation across graphene oxide nanochannel membranes

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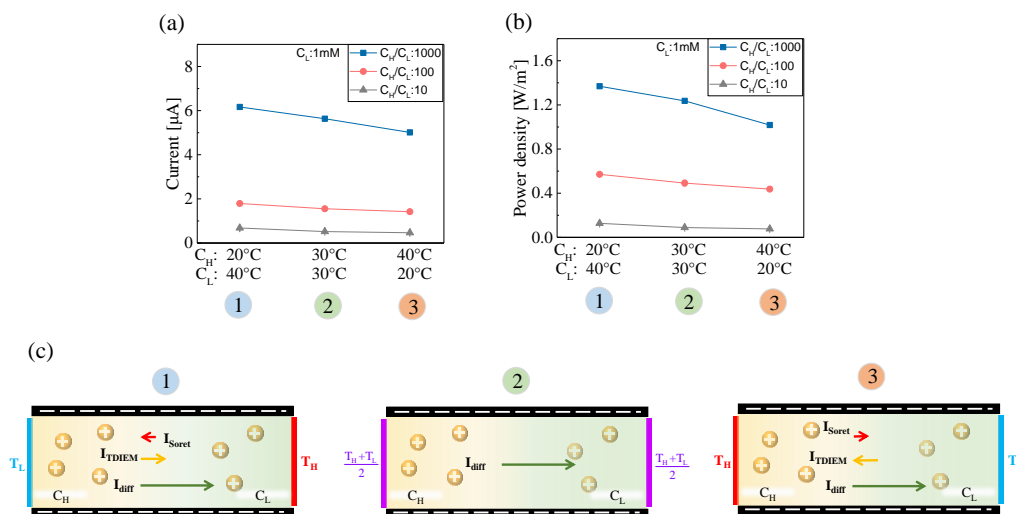
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**ABSTRACT:** In this study, we conducted both experimental and numerical investigations into the thermal effects on salinity-gradient power generation in graphene oxide nanochannel membranes. The experimental results revealed that a higher output power density is achieved when the temperature gradient is opposite to the salinity gradient, whereas a lower power density is observed when the temperature gradient aligns with the salinity gradient, as illustrated in Figure 1. According to the theory of ionic thermoelectricity in nanoconfined electrolytes, we infer that the temperature-dependent ion electrophoretic mobility (TDIEM) plays an crucial role in non-isothermal salinity-gradient power generation. When the temperature gradient opposes to the salinity gradient, the thermally induced current due to TDIEM aligns with the diffusion current, thereby increasing the short-circuit current. This, in turn, leading to an increase in the maximum power density. This experimental trend is qualitatively consistent with the numerical results obtained from the non-isothermal Poisson-Nernst-Planck (PNP) model. We believe that our findings provide valuable insights for the development of non-isothermal salinity-gradient energy harvesting.

**KEYWORDS:** Ionic thermoelectricity, Salinity-gradient power, Electrical double layer Nanochannel, Graphene oxide



**Figure 1** (a) Short-circuit current, (b) maximum power density, and (c) mechanism illustration.

# Optimization of thermal battery performance through the development of geometry structures and composite phase change materials: A comparative analysis

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**ABSTRACT:** Lithium-ion batteries have an important role as one of the technologies and energy storage media. The application and utilization of lithium-ion batteries in various household and industrial sectors that are increasingly rapid make many methods in the use of these batteries. To enhance and optimize battery performance, a special method namely the Battery Thermal Management System (BTMS) was created. BTMS is a method created to maintain battery performance while operating which focuses on maintaining the optimum temperature range allowed. One method in BTMS is to use Phase Change Material (PCM). PCM is a renewable solution that is compact and can be integrated with various battery pack geometry structures. This research aims to study and analyze the cooling effect on the battery by using Composite Phase Change Material (CPCM) combined with the geometry structure developed in the battery pack. After comparing the PCM variations used at high level battery operating conditions with computational simulation methods using COMSOL software. The results show that by using CPCM expanded graphite with a fraction mass of 30% integrated with the new and developed battery pack geometry structure, the maximum temperature of the battery can be controlled below 40°C, the maximum temperature of the battery obtained was 38.78°C while the average temperature of the battery pack as a whole was 36.86°C. The results of this simulation show that a good and appropriate combination of CPCM as a cooling medium for batteries with varying fraction masses can optimize the cooling process in the battery and prevent thermal runaway in the battery so that the life cycle and battery operation can be maintained in optimal conditions.

**KEYWORDS:** Lithium-ion batteries, battery thermal management system, composite phase change material, thermal runaway

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