Saturday, December 14, 2019

Plenary Lectures

PRTEC-2PL01

9:00 – 9:40 (Monarchy 4) Chairperson: Sumanta Acharya (Illinois Institute of Technology, USA)

Prof. John K. Eaton, Stanford University, USA

Turbulent Thermal Transport: MRI Experiments, Large-Eddy Simulation, and Machine-Learning Models

Turbulent scalar mixing is the controlling process in many thermal systems including boundary-layer heat transfer, buoyant plumes, and discrete-hole film cooling. In simple flows, turbulent transport is calculated accurately by direct numerical simulations, but lower fidelity models used for practical computations are not predictive. Magnetic Resonance Imaging (MRI) techniques to measure velocity and scalar concentration fields provide new insight into thermal transport in complex flows, particularly for film cooling flows where we have focused our attention. For example, full-field measurements of isolated film-cooling jets reveal important regions with negative scalar diffusivity. Wall resolved large eddy simulations (LES) accurately reproduce the MRI measurements and are used to explore these unexplained phenomena. We are developing new scalar transport models for Reynolds-Averaged Navier-Stokes computations using physics-informed, machine learning (ML) techniques. The goal is accurate representation of the turbulent diffusivity leading to improved temperature field predictions. ML models trained using high fidelity simulations provide significantly better scalar transport predictions than conventional turbulence models. Interpretation of the ML models leads to new understanding of the flow features that cause failure of conventional models.

PRTEC-2PL02

9:40 – 10:20 (Monarchy 4) Chairperson: Yong Tae Kang (Korea Univ., Korea)

Prof. Min Soo Kim, Seoul National University, Korea

Hydrogen Economy and Fuel Cell Technology

Hydrogen economy can be one of possible solutions to the global warming and air pollution problems. The air pollution due to the use of fossil fuel will be even more serious in the future. By this reason, hydrogen is considered as an eco-friendly energy source and related fuel cell technology gains a great attention. As a kind of fuel cells, polymer electrolyte membrane fuel cell (PEMFC) attracts the limelight as a future power generation system in automotive, household and industrial applications. However, some problems still exist to be solved to meet the needs of current industries, that is, to enhance the performance of the fuel cell. In our research, high performance of fuel cell is achieved when locally non-uniform porous flow field design is applied, which enables us to realize more compact and efficient fuel cell systems. Next, with the elevation of fuel cell performance, heat dissipation rate also increases especially when the power generation rate is great. Therefore, application of flow boiling into fuel cell thermal management system is tried, and we achieved uniform temperature distribution over the fuel cell stack at a reasonable temperature level. Fault detection and diagnosis logic for the fuel cell system to improve its durability and reliability is very important for a commercialization of fuel cell systems. System parameter variations for possible faults are carefully reviewed for early detection of faults and neural network approach was applied for diagnosing the faults.

Keynote Lectures

PRTEC-2KL01

15:20 – 15:50 (Monarchy 4) Chairperson: Hiroshi Takamatsu (Kyushu Univ., Japan)

Prof. Osamu Nakabeppu, Meiji University, Japan

MEMS Sensor for Cooling Loss Study of IC Engine

PRTEC-2KL02

15:20 – 15:50 (Monarchy 2) Chairperson: John Lienhard (MIT, USA)

Prof. Ying Sun, Drexel University, USA

Probing the Temperature Profile across a Liquid-Vapor Interface during Phase Change

PRTEC-2KL03

15:20 – 15:50 (Monarchy 3) Chairperson: Jungho Lee (KIMM, Korea)

Prof. Yong Tae Kang, Korea University, Korea

Development of Core Refrigeration Technologies with Low GWP Refrigerants

PRTEC-2KL04

15:55 – 16:25 (Monarchy 4) Chairperson: Taku Ohara (Tohoku Univ., Japan)

Prof. Kenji Yasuoka, Keio University, Japan

Acceleration and Analysis of Molecular Dynamics Simulation with Machine Learning

PRTEC-2KL05

15:55 – 16:25 (Monarchy 2) Chairperson: Ji Hwan Jeong (Pusan Natl. Univ., Korea)

Dr. Jungho Lee, KIMM, Korea

Role of Microporous Coating on Boiling Heat Transfer Enhancement in Thermosyphon and Thermal Ground Plane

PRTEC-2KL06

15:55 – 16:25 (Monarchy 3) Chairperson: Yogesh Jaluria (Rutgers Univ., USA)

Prof. Dereje Agonafer, University of Texas Arlington, USA

Thermal and Control Design for Dynamic Air and Liquid Cooling in Data Centers

Panel Discussion 1: “Emerging Topics in Nanoscale Thermal Transport”

13:20 – 15:00 (Monarchy 4) Moderator: Xiulin Ruan (Purdue University, USA) [See, Panel Discussions page (Page 18) for details.]

Sunday, December 15, 2019

Plenary Lectures

PRTEC-2PL03

8:30 – 9:10 (Monarchy 4) Chairperson: Yasuyuki Takata (Kyushu Univ., Japan)

Prof. Chi-Chuan Wang, National Chiao Tung University, Taiwan

Recent Progress of Novel Air-Cooled Heat Sinks for Electronic Cooling

This study provides an overview regarding enhancement of an air-cooled heat sink applicable for electronic cooling. The augmentations upon air-cooled heat sinks are normally via incorporating more surfaces, surface modifications such as interrupted, dimple, groove, vortex generator, porous surface, or compound combinations, and manipulating effective temperature difference. Some novel designs to facilitate the aforementioned means are discussed in the present overview. Fin configuration plays essential role in the air-cooled heat sinks. Normally interrupted surfaces offer higher heat transfer performance than dimple/groove surface. Vortex generator or dimple/groove surfaces provide lower pressure drop penalty but also contains a comparatively low heat transfer performance. More surface may yield higher pressure drop with lower fin efficiency. The ineffectiveness of low fin efficiency is especially severe when porous structure is employed. To tailor the low efficiency problem, incorporating the non-uniform fin design or some supporting solid plate can appreciably remedy the weak point. Manipulating effective temperature difference is also quite useful in fine tuning the performance with least expenses. In some cases, the performance can be maintained or slightly improved with smaller surface area, thereby mass reduction and a lower cost can be achieved.

PRTEC-2PL04

9:10 – 9:50 (Monarchy 4) Chairperson: Mamoru Tanahashi (Tokyo Inst. Tech., Japan)

Prof. Taku Ohara, Tohoku University, Japan

Thermal Energy Transfer in Liquids, Soft Matters and over the Interfaces: A Molecular View

Why does this material have this value of thermophysical properties? How will be the value of thermophysical properties when this imaginary material is realized? Can we design new molecules to build a new material that has desired thermophysical properties? Molecular dynamics (MD) analysis has a potential to answer these questions. It may be the only way especially for liquids, soft matters and their interfaces where no useful theory is available unlike solids and gases. Here we present our systematic study on thermal energy transfer in liquids and soft matters. To analyze heat conduction, our unique approach of the heat flux decomposition has been applied where contribution of the typical atomic groups in the molecules to macroscopic heat flux is evaluated. Bulk liquids including liquids of long chain molecules that transfer thermal energy via deformation, associated liquids with long-range electrostatic intermolecular forces, and soft matters with some orientation of polymer molecules which exhibit anisotropic heat conduction have been analyzed. The concept of analysis for these bulk materials are now being extended to thermal energy transfer over solid-liquid/soft matter interfaces, which seeks reduction of thermal boundary resistance by using surface modification and thermal interface materials (TIMs) that are required for high-density heat generation devices such as modern power modules.

General Information

13:30 – 17:00 Round Table on Future of Thermal Engineering

Monday, December 16, 2019

Plenary Lectures

PRTEC-2PL05

8:30 – 9:10 (Monarchy 4) Chairperson: Kaoru Maruta (Tohoku Univ., Japan)

Prof. Yuji Suzuki, The University of Tokyo, Japan

Electret-based Thermal and Kinetic Energy Harvesting for Wearable Devices

Recently, thermal and kinetic energy harvesting devices attract much attention for their use in powering IoT/wearable devices, and various electret-based energy harvesters have been developed. Electret is analogue to magnet, by which a permanent electrostatic field is formed. However, since the first development of electret using Carnauba wax in 1925, electret materials have been developed by heuristic approach, and no guide principle for their improvement exists. In this talk, our recent study of high-performance amorphous fluorinated polymer electret based on quantum chemical analysis is discussed. Density functional theory is adopted to analyse the electron affinity of fluorinated polymers with different end groups. In analysis of CYTOP series with different end groups, it is found that the amide bond at the end of CYTOP chain attracts electrons, leading to high electron affinity of the molecule. Based on the DFT results, a new electret material has been developed. With a 15 um-thick film, a record-high surface charge density of -4 mC/m^2 has been obtained. It is also found from the thermally stimulated discharge experiment that the electrons trapped in this new material are stable even above the glass transition temperature of the polymer.

In the latter part of this talk, our recent prototypes of electret-based thermal and kinetic energy harvesters will be introduced. A novel low-profile rotational electret energy harvester (EH) is prototyped for capturing power from low-frequency vibration, such as human arm swing. CYTOP is employed to realize high surface potential over 800 V. Thanks to cost-effective flexible print circuit boards, the thickness of the rotational part is as thin as 2.8 mm, which is at least less than half of the previous rotational EHs. Output power up to 200 uW has been obtained at a low rotational speed of 1 rps. Attempts of electret-based thermal energy harvesters using unsteady temperature change will also be discussed.

PRTEC-2PL06

9:10 – 9:50 (Monarchy 4) Chairperson: Yong Tao (Cleveland State Univ., USA)

Prof. Andrei G. Fedorov, Georgia Institute of Technology, USA

Thermal Dissipation at Extremes using Confined Evaporating Liquid Films with Streaming Gas/vapor Flows

I will present recent advances in fundamental understanding of ultra-thin liquid film evaporation subjected to high velocity streaming gas/vapor flow, which allows for simultaneous reduction of convective/conductive heat transfer resistance across the liquid film and rapid removal of vapor from an evaporating liquid interface. This unique environment for observing evaporative heat and mass transfer dynamics is enabled by use of two complimentary thermal management schemes and testbeds: (1) ultra-small (<10 um) microgaps, with and without pin fins, for convective boiling in confined quasi-2D domains, and (2) nanoelectrospray impingement for controlled topology (<1 um) liquid film formation coupled to an entrained gas jet. The test sections are batch micromachined in silicon and instrumented with thin-film resistive thermometry to enable quantitative assessment of the capability for dissipating extreme heat fluxes up to multiple kW/cm^2. These experimental systems and test parameters constitute extreme values in terms of geometry, film thickness, mass fluxes, and heat fluxes. New flow regimes for convective flow boiling and thin film evaporation will be identified and discussed, as a function of increasing heat flux and film confinement. Dominant mechanism(s) of two-phase heat transfer responsible for each regime are postulated based first principle heat/mass transfer modeling and flow visualization correlated with pressure drop, mass flux and thermal resistance measurements.

Keynote Lectures

PRTEC-2KL07

13:10 – 13:40 (Monarchy 4) Chairperson: Ji Hwan Jeong (Pusan Natl. Univ., Korea)

Prof. Jae Dong Chung, Sejong University, Korea

Adsorption Refrigeration: Numerical Approaches for System Analysis

PRTEC-2KL08

13:10 – 13:40 (Monarchy 2) Chairperson: James Klausner (Michigan State Univ., USA)

Prof. Joerg Petrasch, Michigan State University, USA

Heat Transfer Challenges in Thermochemical Grid-level Storage of Electricity Using Metal/metal Oxide Redox Systems

PRTEC-2KL09

13:10 – 13:40 (Monarchy 3) Chairperson: Satoshi Kadowaki (Nagaoka Univ. Tech., Japan)

Prof. Hiroshi Kawanabe, Kyoto University, Japan

Structure and Combustion Process of a Diesel Spray

PRTEC-2KL10

13:45 – 14:15 (Monarchy 4) Chairperson: Kazuhiko Suga (Osaka Pref. Univ., Japan)

Prof. Hiroshi Suzuki, Kobe University, Japan

Low Carbon Society Realization by using Hard-shell Microcapsules with Phase Change Materials

PRTEC-2KL11

13:45 – 14:15 (Monarchy 2) Chairperson: Yogesh Jaluria (Rutgers Univ., USA)

Prof. Wilson K. S. Chiu, University of Connecticut, USA

Three-dimensional Heat and Species Transport in Energy Materials

PRTEC-2KL12

13:45 – 14:15 (Monarchy 3) Chairperson: Jae Dong Chung (Sejong Univ., Korea)

Prof Ji Hwan Jeong, Pusan National University, Korea

Inducing Drop-wise Condensation of Steam on Metallic Surfaces Used for Heat Exchangers

Panel Discussion 2: "Response of Thermal Engineering to Global Challenges"

10:10 – 11:50 (Monarchy 4) Moderator: Yogesh Jaluria (Rutgers University of Piscataway, USA) [See, Panel Discussions page (Page 18) for details.]

Tuesday, December 17, 2019

Plenary Lectures

PRTEC-2PL07

9:05 – 9:45 (Monarchy 4) Chairperson: Tong Seop Kim (Inha Univ., Korea)

Prof. Sung Jin Kim, KAIST, Korea

Journey Toward Flexible Thermal Superconductor

This talk is intended to provide a perspective and review of a journey toward a flexible thermal superconductor, which can be bent or twisted, to control heat transfer in heat generating devices of various shapes. The thermal superconductor exploits recent advances in micro pulsating heat pipes, which consists of a liquid-vapor slug-train unit oscillating within a microchannel. Its thermal conductivity is 1000 W/mK, 5 times higher than aluminum, and 5000 times higher than current flexible materials, and its thickness is less than 1 mm. Compared to conventional pulsating heat pipes, micro pulsating heat pipes with hydraulic diameters of less than 1 mm have interesting features including orientation independent performance. In addition, several new ideas for thermal performance enhancement in the micro pulsating heat pipes will be presented. This talk will conclude with an overview of ongoing research activities associated with a prestigious 9 year grant by Korea's Creative Research Initiative to develop Flexible and Thin Thermal Superconductors.

Keynote Lectures

PRTEC-2KL13

9:50 – 10:20 (Monarchy 4) Chairperson: Sung Jin Kim (KAIST, Korea)

Prof. Tong Seop Kim, Inha University, Korea

Achieving a Very High Efficiency Using Synergistic Cycle Combination Technologies in Power Plant Engineering

PRTEC-2KL14

9:50 – 10:20 (Monarchy 2) Chairperson: Takaharu Tsuruta (Kyushu Inst. Tech., Japan)

Prof. Akio Miyara, Saga University, Japan

Measurement of Local Heat Transfer Characteristics and Flow Behavior of Two Phase Flow in a Complex Channel

PRTEC-2KL15

9:50 – 10:20 (Monarchy 3) Chairperson: Xiulin Ruan (Purdue Univ., USA)

Prof. Asegun Henry, Massachusetts Institute of Technology, USA

Rethinking Problems in Thermal Science and Engineering - From Atoms to Applications