I²CNER Seminar Series

International Institute for Carbon-Neutral Energy Research (WPI-I²CNER)
Kyushu University

Title **Phase Change Dynamics of Supercooled Water Droplets**

Speaker ***Professor Shuhuai Yao***

Department of Mechanical and Aerospace Engineering,
The Hong Kong University of Science and Technology, Hong Kong, China

Time & Date 3:00 PM (JST), Wednesday, March 4th, 2026

Venue Hybrid format (I²CNER Hall C, I²CNER Bldg. 1, Ito Campus, Zoom)

Abstract

The phase change of water under extreme conditions is pivotal in energy-related and aerospace processes. The vaporization of sensible water droplets under vacuum involves a complex interplay of states that challenges conventional understanding. Unlike direct cooling, in a low-pressure environment, droplet temperatures rapidly decrease to supercooled levels due to intense evaporative cooling at the liquid-gas interface. In our study, we investigate the intriguing phase change dynamics and transport phenomena of supercooled freezing droplets on various surfaces at low pressures (~ 100 Pa). First, we reveal a significant counteractive momentum, termed vaporization momentum, resulting from the progressive recalescence of the droplets. Through a combination of experimental visualization and theoretical analysis, we demonstrate that this momentum can cause droplet deformation and subsequent self-propelled jumping from superhydrophobic surfaces. We unravel the complex physics involving vaporization, freezing recalescence, and liquid-solid interactions, and quantify the vaporization momentum to predict droplet freezing and jumping dynamics. Second, we show that adding glycerol to a water droplet can transform these disruptive behaviors into more controllable rhythms. Instead of typical breakup or rapid self-propulsion, freezing glycerol-water droplets enter a state of gentle, cyclic levitation, repeatedly undergoing "dwelling, liftoff, flight, and impact". The tunability of glycerol enables a cyclic droplet motion driven by self-sustaining thermal oscillation. Third, we demonstrate that using a non-volatile oil-infused surface can enhance ice sublimation flux by approximately 10X compared to pure water. The ultra-fast sublimation of frozen droplets is accompanied by self-rolling, which is attributed to the disruption of cloaking oil caused by the stirring mechanism during the supercooled stage, as well as the heat conduction from the relatively high-temperature oil film. Our findings illuminate the role of supercooling and low-pressure mediated phase change in shaping fluid transport dynamics, paving the way for the design of water-surface interaction systems applicable to anti-freezing coatings, sublimation cooling, flash distillation, aerospace and deep-space exploration initiatives.

About the Speaker

Prof. Shuhuai YAO is a Professor in the Department of Mechanical and Aerospace Engineering and a joint faculty member in the Department of Chemical and Biological Engineering at the Hong Kong University of Science and Technology. She obtained her B.S. degree in Engineering Mechanics from Tsinghua University and both her M.S. and Ph.D. degrees in Mechanical Engineering from Stanford University. Following her doctoral studies, she completed postdoctoral training at Lawrence Livermore National Laboratory. Prof Yao's research focuses on the exploration of micro-/nano-scale fluid dynamics and heat transfer phenomena, with a particular interest in integrating theory and experiments to develop innovative technologies for instrumentation. Prof. Yao has published in top journals such as Naure, Nature Energy, Nature Physics, Nature Communications, Physical Review Letters, etc, and holds ten granted patents and has filed more than forty patent applications, three of which have been licensed to HKUST spin-off startups. In addition, Prof. Yao co-founded two startup companies based on her patented microfluidic technologies developed at HKUST.

Registration **https://forms.office.com/r/y3bbmf62fT**

Host Prof. Qinyi Li

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Register here!!

I^{2}CNER Seminar Series

International Institute for Carbon-Neutral Energy Research (WPI-I^{2}CNER)
Kyushu University

Title **Coupled Behavior in Solid State Ionic Materials for Electrochemical Energy Applications**

Speaker ***Professor Nicola Helen Perry***
Department of Materials Science and Engineering, University of Illinois, Urbana-Champaign, US

Time & Date 4:00 PM (JST), Wednesday, March 4th, 2026

Venue Hybrid format (I^{2}CNER Hall C, I^{2}CNER Bldg. 1, Ito Campus, Zoom)

Abstract

Links between dynamic chemical, mechanical, electrical, and optical properties of solid-state ionic materials can be leveraged to monitor or control behavior relevant for energy applications (fuel cells, electrolyzers, batteries, etc.). In this talk I will describe recent results that highlight two types of coupled behaviors: "photo-ionics" and "chemo-mechanics."

Regarding photo-ionics, time-dependent light absorption can be used to monitor changes in defect populations, for example surface exchange reaction kinetics that govern efficiency of electrodes in fuel and electrolysis cells. In this case the relevant gas partial pressure (pO_2 or pH_2O) is stepped around a thin film electrode material and its optical relaxation over time is fit to determine a surface exchange coefficient. I will describe our recent extension of this method to evaluate oxygen exchange kinetics of combinatorial libraries and proton exchange kinetics of new triple conducting oxides. However, light absorption is also a means to control ion fluxes in materials; I will provide an example of how shining UV light onto electrode thin films can induce oxygen surface exchange and oxygen incorporation at intermediate temperatures. Understanding and leveraging such phenomena lays the foundation for a new generation of opto-ionic technologies and lies at the heart of the UIUC MRSEC Interdisciplinary Research Group on photo-ionics – the first center-wide effort in the world dedicated to this topic.

Regarding chemo-mechanics, strains/stresses accompanying defect concentration changes can be deleterious for device lifetime. To improve electrolyte and electrode stability we have been uncovering descriptors for near-zero-strain materials. Our previous work focused on crystal chemical design principles for low-strain perovskites, while our latest efforts have instead turned to the role of morphology in other crystal structures. I will discuss the effects of nanostructuring on chemical expansivity of fluorite-structured electrode candidates, where modifications to defect chemistry in the proximity of interfaces alter the macroscopic chemical strains and transport behavior. Stress/strain can also be leveraged to modify ion dynamics; one example from our work is mechano-electro-chemically driven exsolution of catalytic nanoparticles on electrode surfaces to improve fuel electrode activity and device efficiency in all-fluorite cells.

About the Speaker

Nicola H. Perry received her Ph.D. in Materials Science and Engineering from Northwestern University in 2009, for investigating interfacial transport behavior in nano-ionics with Thomas O. Mason. After this she joined the Energy Frontier Research Center for Inverse Design as a postdoctoral fellow developing p-type transparent conducting oxides and synthesizing missing materials. From 2012-2014 she was a postdoctoral researcher at the International Institute for Carbon-Neutral Energy Research (I^{2}CNER) at Kyushu University, Japan, and a visiting scholar at MIT, working with Harry L. Tuller. From 2014-2017 she served as a World Premier Initiative Assistant Professor in I^{2}CNER and as a Research Affiliate at MIT, where her research focused on mixed ionic and electronic conducting oxides for high temperature electrochemical energy conversion and storage. She joined UIUC in January 2018, where she leads a group in tailoring and understanding point defect-mediated properties in electro-chemo-mechanically active oxides and halides. Her research has been recognized with a NSF CAREER Award, DOE Early Career Award, JSPS Kakenhi Awards, UIUC Dean's Award for Excellence in Research, IUMRS Award for Encouragement of Research, J. Bruce Wagner Jr. Award from the Electrochemical Society, Principal Investigator Development in Sustainability Award from the American Chemical Society, and the Edward C. Henry and Richard M. Fulrath Awards from the American Ceramic Society.

Registration https://forms.office.com/r/y3bbmf62fT

Host Prof. Tatsumi Ishihara

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