PHYSICAL MATHEMATICS SEMINAR

Nanoengineered Surfaces for Enhanced Thermal-Fluid Transport: Studies on Dynamic Wetting and Phase Change Phenomena

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ABSTRACT

Thermal-fluid-surface interactions are ubiquitous in multiple industries including Energy, Water, Agriculture, Transportation, Electronics Cooling, Buildings, etc. Over the years, these systems have been designed for increasingly higher efficiency using incremental engineering approaches that utilize system-level design trade-offs. These system-level approaches are, however, bound by the fundamental constraint of the nature of the thermal-fluid-surface interactions, where the largest inefficiencies occur. In this talk, we show how surface/interface morphology and chemistry can be engineered to fundamentally alter these interactions in a wide range of processes involving fluid, heat and mass transport processes including, droplet impact, condensation, boiling, and freezing. We study the dynamics of wetting hysteresis of droplets in an Environmental SEM (ESEM) as a function of surface texture and surface energy and establish various wetting regimes and conditions for wetting transitions. We extend these concepts to dynamic wetting and establish optimal design space for droplet shedding and impact resistance. We show for droplets bouncing off of non-wetting superhydrophobic surfaces that their contact time can be reduced below the inertial-capillary time scale by introducing macroscale features that counter-intuitively enhance rather than attenuate surface interactions. We then present the behavior of surfaces under phase change, such as condensation, and freezing at both macroscale and microscale (using ESEM) and find their non-wetting properties can be compromised due to nucleation of water or frost within texture features. Based on these insights we introduce lubricant-impregnated surfaces that can result in two to three orders of magnitude reductions in ice adhesion and promote dropwise condensation. We discuss the unconventional contact line morphology, thermodynamics and dynamics of droplet shedding on these surfaces and show how even complex fluids like ketchup, mayonnaise, and jelly slide off the surface easily. Finally, we discuss the influence of electronic structure on interfacial wetting interactions and use these insights to develop new class of ceramic materials that are intrinsically hydrophobic. Robust materials, and applications of nanoengineered surfaces in various energy, water, and transportation systems including oil & gas (flow assurance and energy efficiency), turbines, power and desalination plants, and electronics cooling will be highlighted.

Bio

Kripa Varanasi is a Doherty Associate Professor in the Department of Mechanical Engineering at MIT. He received his B.Tech from IIT, Madras, India and his MS (ME and EECS) and Ph.D from MIT. Prior to joining MIT, Dr. Varanasi was a lead research scientist and project leader in the Energy & Propulsion and Nanotechnology programs at the GE Global Research Center, Niskayuna, NY, and was the PI for the DARPA Advanced Electronics Cooling program. The primary focus of his research is in the development of nano-engineered surface, interface, and coating technologies that can dramatically enhance performance in energy, water, agriculture, transportation, buildings, and electronics cooling systems. He is enabling this approach via highly interdisciplinary research focused on a nanoengineered surfaces and interfaces, thermal-fluid science and new materials discovery combined with scalable nanomanufacturing. His work spans various thermal-fluid and interfacial phenomena including phase transitions (condensation, boiling, freezing), nanoscale thermal transport, separation, wetting, catalysis, flow assurance in oil and gas, nanofabrication, and synthesis of inorganic bulk and nanoscale materials guided via computational materials design. Dr. Varanasi has filed more than 50 patents in this area. He was awarded the First Prize at the 2008 ASME Nanotechnology Symposium and won several awards at GE Research Labs including Technology Project of the Year, Best Patent Award, Inventor Award, and Leadership Award. He has received the MIT Energy Initiative award, 2010 IEEE-ASME ITherm best paper award, NSF Career Award and DARPA Young Faculty Award. He is commercializing some of the slippery coating technology under LiquiGlide for which his team received the audience choice award at the MIT 100K and 100K Diamond prize at MassChallenge Entrepreneurship competitions. Time Magazine and Forbes Magazine have named his invention LiquiGlide one of the Best Inventions of the Year. He was most recently awarded the 2013 Outstanding Young Manufacturing Engineer award by the Society of Manufacturing Engineers.

TUESDAY, MARCH 19, 2013
2:30 PM
Building 56, Room 180

Reception following in Building 2, Room 290
(Math Dept. Common Room)

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