Pumpless Liquid Transport through Wettability Patterning: Applications in Dropwise Condensation and Jet Impingement Cooling

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Rapid transport of liquid on open surfaces is important for many engineering applications, ranging from phase-change heat transfer, electronic chip cooling to lab-on-chip devices. We use facile, scalable, surface-wettability engineering approaches to fabricate patterned substrate containing superhydrophilic domains on superhydrophobic backgrounds. The large difference in energy between the hydrophilic-hydrophobic surface facilitates accelerated movement of liquid droplets through hemiwicking and Laplace pressure condition.

We introduce a bio-inspired design to show the suitability of our approach for enhanced dropwise condensation (DWC) heat transfer. In this approach, alternate strips of hydrophilic and superhydrophilic regions are patterned to spatially control condensate nucleation and maximize droplet size along with facilitating pump-less condensate drainage from the surface. An optimized design effectively reduces the maximum diameter of condensate droplets departing from the condenser surface. The corresponding condensation heat transfer rate in vapor/air atmosphere is increased by 35% as compared to un-patterned DWC surfaces.

We have used similar type of approach for jet impingement cooling. With growing number of miniaturized devices there is a compelling reason to have advanced techniques that can effectively and quickly remove internal heat. Different types of jet impingement are used widely for effective cooling in these systems. Here, we employ a wettability-patterning approach that diverts an orthogonally-impinging laminar water jet onto a pre-determined location at the target surface. Superhydrophilic tracks on a superhydrophobic background provide the means to re-direct the impinging jet and enable spatially-selective cooling on the heated surface. Since this approach facilitates prolonged contact with the underlying heated surface through thin liquid film spreading, evaporative cooling is also promoted. By comparing with other jet impingement cooling approaches, the present approach provides roughly four times more efficient cooling by using less amount of coolant.

Short Bio

Dr. Sinha Mahapatra received his Ph.D. in Fluid/Thermal Sciences from Jadavpur University in 2014. He did his bachelors in Mechanical Engineering from Jadavpur University in 2007. He worked as Senior Project Officer at the Indian Institute of Technology Madras, Chennai (May-September, 2014) and is currently working as postdoctoral researcher at University of Illinois at Chicago, Chicago (October 2014-present). He received the CSIR senior research fellowship and on the spot (OTS) programmer award from Infosys. He has published about 16 journal papers, 22 conference papers and 2 provisional patents. His current research interests focus on fluid/particle transport, heat transfer enhancement, multifunctional coatings relevant to point of care diagnostics.