COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
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ME Department Seminar

A New Framework for Heterogeneous Boiling Incipience on Smooth Surfaces

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Abstract

In recent years there have been numerous research investigations that have observed low superheat incipience of nucleate boiling over nano-smooth surfaces with highly wetting and moderately wetting fluids. Incipience due to a vapor trapping mechanism has been precluded due to the small surface features, which are on the order of tens of nanometers. Measurements of heterogeneous incipient superheat with a high degree of accuracy over three different nano-smooth Si, Ti and Al surfaces using a highly wetting fluid, FC-72. Have recently been made. For all three surfaces, incipience occurs at approximately 30% of the homogeneous superheat limit of the working fluid, and the contact angles range between 13 and 20 degrees. A theoretical framework based on a homogeneous-like theory and the macroscopic contact angle is proposed to estimate the ***minimum*** incipient wall superheat for heterogeneous nucleation over smooth surfaces in the absence of any vapor trapping cavities. The Clausius inequality is used to derive a theoretical model for predicting the minimum incipience superheat for a given system pressure and contact angle. The proposed theory is applicable to slow heating rates and is not kinetically limited. While the model is consistent with qualitatively observed trends, a comprehensive experimental investigation of vapor bubble incipience over a wide range of contact angles is needed to fully validate the model.

Bio

Dr. James Klausner is an MSU Foundation Professor and Chair of the Mechanical Engineering Department at Michigan State University. He serves on the board of directors for the International Titanium Association Foundation. For the past three years he served as a Program Director at the U.S. Department of Energy Advanced Research Projects Agency-Energy (ARPA-E). While at ARPA-E he ran research programs totaling over $100 M in thermal energy storage, efficient light metals manufacturing, dry power plant cooling, and carbon capture. Prior to that he served as the Newton C. Ebaugh Professor of Mechanical and Aerospace Engineering at the University of Florida. He received his Ph.D. degree in 1989 from the University of Illinois, Urbana-Champaign. His research interests include high temperature solar thermochemical conversion, waste heat and solar driven desalination, and high heat flux phase-change heat transfer. Dr. Klausner has authored more than 150 refereed publications, and his theoretical work on bubble dynamics is included in the Handbook of Heat Transfer. His work on thermal lattice Boltzmann simulations was one of the top downloaded articles in the Journal of Computational Physics in 2013. He is a Fellow of the American Society of Mechanical Engineering, and he has served as Chair of the ASME Heat Transfer Division. He is a recipient of the ASME Heat Transfer Division 75th Anniversary Award.