SEMINAR SERIES

International Institute for Carbon-Neutral Energy Research
Kyushu University

Title Two-Phase Flows and Heat Transfer in Microscale

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Abstract

Whether it is the transition to fly-by-wire in aeronautics or development of advanced nuclear reactors, the use of flow boiling heat transfer and its impact on the economy and climate is significant. More specifically, flow boiling in microchannels, while very promising as a cooling technology in numerous thermal management applications, is still a subject that requires further investigation Before applying this technology for the next generation of chips, aerospace industry, power electronics and advanced nuclear reactors, challenging issues such as fully understanding boiling mechanisms in confined spaces, extending and stabilising nucleate boiling regime, suppressing flow boiling instabilities, maintaining uniform flow distribution among microchannels, have to be addressed. If flow boiling is to be used as a thermal management method for high heat flux applications it is necessary to understand the behaviour of a non-uniform heat distribution, which is typically the case observed in a real operating chips. In this study, flow boiling of deionised water in a silicon microchannel heat sink under uniform and non-uniform heating has been investigated with particular attention to flow boiling instabilities. An experimental system was designed and constructed to carry out the experimental investigations. The experimental heat sink consisting of forty parallel rectangular microchannels with 194 µm hydraulic diameter together with integrated inlet and outlet manifold was fabricated on a silicon wafer using inductive coupled plasma dry etching, in conjunction with photolithographic techniques. A design with integrated temperature sensors made from a thin nickel film allows local temperature measurements with a much faster response time and smaller thermal resistance as compared to temperature measurements using thermocouples. The integrated heater was designed to enable either uniform or non-uniform heating (hotspot investigation) with a low thermal resistance between the heater and the channels. Numerical simulations for single phase flow in adiabatic conditions were used to assist the design of the manifold geometry in the microchannels heat sink. Microfabricated temperature sensors were used together with simultaneous high speed imaging in order to obtain a better insight related to temperature fluctuations caused by two-phase flow instabilities under uniform and non-uniform heating. Two types of two-phase instabilities with flow reversal were identified and classified into flow stability maps. The effect of inlet water temperature on flow boiling instabilities was experimentally studied, with the influence of different subcooling conditions on the magnitude of temperatures as well as the influence on temperature uniformity over the heat sink being assessed. The effect of various hotspot locations on flow boiling instabilities has been investigated, with hotspots located in different positions along the heat sink. Bubble growth and departure size have been experimentally investigated. The results of this study demonstrate that bubble growth in microchannels is different from that in macroscale channels. Furthermore, the effects of bubble dynamics on flow instabilities and heat transfer coefficient have been investigated and discussed.

About the Speaker

Professor Khellil Sefiane, *H.D.R.* from *ENS*, Paris, *D.E.A.* and *PhD* from Marseille, France, is Professor of thermophysical engineering in the School of Engineering at the University of Edinburgh, United Kingdom. He is also head of the Research Institute for Materials and Processes (IMP) in Edinburgh. K. Sefiane is Adjunct professor at the University of Toronto, Canada, 2008-2014. He is associate editor of the International Journal for Multiphase Flows, Elsevier and Heat Transfer Research, *Begell* House Inc. He has been recipient of the prestigious Institute of Physics (*IoP*) award (2009) for his work on wetting and evaporation. K. Sefiane is Fellow of the Royal Society of Chemistry, Cambridge, UK and corresponding member of the European Academy for Sciences, Literature and Art. K. Sefiane is currently leading a European Union funded international project involving, Edinburgh (UK), Shanghai (China), EPFL Lausane (Switzerland), Nottingham (UK) and Maryland (US) to imvestigate two-phase flows in micro-systems. He holds an ExxonMobil fellowship awarded by the Royal Academy of Engineering, London in 2000 and is a member of the British *EPSRC* Peer Review College. K. Sefiane is a member of numerous international scientific committees. Professor K. Sefiane has published more than 110 research papers in prestigious international journals and 10 contributions to monographs.

Host: Professor Yasuyuki Takata

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