International Symposium of Heat Transfer and Heat Powered Cycle 2016
27-29 June 2016, University of Nottingham, University Park, Nottingham. NG7 2RD, UK.

Flow Boiling in Small to Micro Diameter Tubes and Microchannels

Tassos G.Karayiannis[1] and Mohamed M. Mahmoud[1,2]

[1]College of Engineering, Design and Physical Sciences, Brunel University London,

Uxbridge, UB8 3PH, UK

[2]Faculty of Engineering, Zagazig University, Egypt

The demand for removing high heat fluxes from electronic equipment is increasing and in certain cases has become the limiting factor in further development for the electronics industry. The use of flow-boiling in micro passages is currently considered as one of the most effective methods for cooling these devices. Other applications include small scale refrigeration systems, cooling fuel cells, cooling solar photovoltaic panels, cooling electronics in electric vehicles, cooling energy storage devices and cooling of magnetrons [1-4]. In such equipment the heat flux values can be as high as 10 MW/m^2, e.g. for defence electronics [4], such as radar systems If we consider the possible "hot spots" that can be 6 – 10 times the chip average power [5] and the predictions of the average chip power given by [6] as more than 800 W per a single chip, the heat flux can reach 27 – 45 MW/m^2 by 2026. In addition to the possible high heat flux rates, when employing flow boiling as the cooling method the temperature of the substrate or medium to be cooled can remain fairly constant due to the evaporation process. This reduces thermal stress in these high heat flux equipment and possible failure.

The presentation will cover work carried out at Brunel University London in flow boiling both in single and multichannel small and micro scale metallic tubes and rectangular passages. The fundamental issues that require classification will be discussed. These include the differentiation of the macro and micro passages, the changes in flow patterns as the diameter diminishes and the heat transfer mechanisms.

Other parameters that require consideration include the effect of surface characteristics and heated length on the flow patterns, heat transfer rates and pressure drop. Instabilities and flow reversal in single passage systems where compressibility is present or in multichannel systems is also important and can affect local and average heat transfer rates.

Detailed analysis of pressure drop and heat transfer results will be presented along with the development of correlations that can be used to predict the heat transfer coefficients and assist in the design of these micro evaporators and subsequently overall thermal systems for high heat flux devices. Such systems require not only the design of an evaporator but also a small scale condenser and the appropriate operational integration of the system. The construction, commissioning and operation of such a system using HEE-7100 and copper micro evaporator and condenser will also be presented.

References

[1] W. Yuan, B. Wang, Y. Yang, K. Ren, J. Xu, Y. Liao, Development and experimental study of the characteristics of a prototype miniature vapour compression refrigerator, Applied Energy, 143, pp. 47 – 57, 2015.

[2] K. S. Reddy, S. Lokeswaran, Pulkit Agarwal, Tapas K. Mallick, Numerical investigation of microchannel-based active module cooling for solar CPV system, Energy Procedia 54, 400 – 416, 2014.

[3] Mudawar, I. Two phase microchannel heat sinks: theory, applications and limitations, J. of Electronic Packaging, Vol. 133, 041002:1 – 31, 2011.

[4] M. Cozzini, Solar cell cooling and heat recovery in a concentrated photovoltaic system, Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan.

[5] J. Lee and I. Mudawar, Low-temperature two-phase microchannel cooling for high-heat-flux thermal management of defence electronics, IEEE Transactions on Components and Packaging Technologies, 32, 2, June 2009.

[6] C. Bachmann and A. Bar-Cohen, Hotspot remediation with anisotropic thermal interface materials, 11th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems, 28 – 31 May, Orlando, FL, USA, 2008.

[7] International Technology Roadmap of Semiconductors, 2011.