Computational Analysis of Evaporation in Tailored Microchannel Evaporators

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Abstract

The rapid increase in power densities of integrated circuits has induced a significant interest in new reliable and high heat flux cooling technologies. The implication of such growth is the increased need for more efficient and more compact cooling mechanisms. Promising research has been conducted in the area of MEMS cooling devices, taking advantage of the increased heat transfer characteristics in microfabricated structures. While significant advances in microchannels can be found in the literature, little work is being done to develop microchannels with non-uniform cross sections that can evaporate fluid without the presence of the bubbles at the exit flow [1]. The design and modeling approach, microfabrication process and the full testing of the tailored micro-evaporators was a part of the author's earlier work. The qualitative nature of the two-phase flow along the shaped channels is observed through the glass cover wafer, for different flow rates and wall temperatures and the onset of phase change successfully fixed at a prescribed location, while achieving evaporation from a meniscus, separating the liquid from the vapor, without the presence of the bubbles exiting the microchannel [2]. In microscale, as the surface area to volume ratio increases with the decrease of the system feature size of microdevices, some physical phenomena which are insignificant in the macro domain become prominent in the micro domain. Some of the tried and tested macroscale theory and experimental results no longer show similar trends in the microscale. Hence dealing with simultaneously widely differing physics becomes too complicated in the microscale which include microfluidics. Finite element analysis simulation will be a powerful tool to study the microfluidic flow behavior and guide and further the microchannel device design and characterization. This work combines mathematical modeling with engineering design and evaluation of tailored microchannel evaporators. A deeper understanding of the two-phase flow in micron scale and temperature distribution in microchannels with non-uniform boundary conditions will be obtained, which provides further guidance to the design and development of tailored microchannel evaporators. The results of simulations will be compared with the results of experimental investigations. Once the models are validated against the observed behavior of two phase flow, the same models can be used to predict behavior in a larger set of potential microchannel designs. This will allow fast identification of "winning" designs which can then be fabricated for targeted applications.

Reference

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