TWO-PHASE FLOW ACROSS A BANK OF MICRO PIN FINS

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ABSTRACT

With the continuous miniaturization of integrated circuit chips over the last decade, there has been a steady increase in power density of electronic devices giving rise to the need for aggressive and affective cooling systems. Simultaneously, the rapid growth of microfabrication technology has led to the development of microelectromechanical system (MEMS) based microchannels, which can be used as miniaturized heat exchangers capable of cooling high power electronic devices. Micro pin fins entrenched inside microchannels have been proposed as a candidate for second generation heat sinks. Microchannel entrenched with micro pin fins are advantageous compared to plain microchannels due to their enhanced heat transfer rates for practically the same manufacturing cost. Effective implementation of pin fins in heat transfer systems requires a thorough understanding of both single-phase and two-phase fluid dynamics and heat transfer mechanisms. The existing scientific knowledge on similar flow configurations in conventional scale systems can aid tremendously in understanding the governing phenomenon in micro-scale systems. The aim of this research is to extend the current fundamental knowledge of two-phase flow to the micro-scale pin fin heat sinks. In this study, micro devices have been fabricated and adiabatic and diabatic experiments have been conducted to study the two-phase flow across a bank of micro pin fins entrenched inside microchannels.

Hydrodynamic studies were performed by conducting adiabatic gas-liquid flow experiments across circular staggered micro pin fins to elucidate the flow patterns, measure the two-phase pressure drop, and the void fraction. It was found that existing conventional scale correlations and flow maps did not predict well the corresponding characteristics in micro-scale systems, and thus, new correlations and flow maps have been developed. Furthermore, a parametric study of size scale and surface tension effects were conducted and the effect of these parameters on flow patterns and their transition lines, void fraction, and pressure drop were quantified.

Flow boiling of DI water across a bank of micro pin fins was investigated to elucidate the heat transfer mechanisms in micro domains with pin fins. The local heat transfer coefficient characteristics and flow visualization revealed the dominance of convective boiling in such systems. A mechanistic correlation was developed using the frictional multiplier correlation obtained from the adiabatic studies. Further, nucleate boiling in micro pin fins entrenched inside a microchannel was also studied using coolant HFE 7000. The local heat transfer coefficients revealed significant enhancement during nucleate boiling which was attributed to bubble agitation and boundary layer perturbation caused by the presence of bubbles on the surface. A thermal performance evaluation study with a plain microchannel revealed that the channel with the micro pin fins considerably enhanced the heat transfer.