SINGLE-PHASE AND FLOW BOILING HEAT TRANSFER OF JET IMPINGEMENT ON SMOOTH AND ENHANCED MICRO STRUCTURED SURFACES

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ABSTRACT

In this study, we investigate the use of jet impingement on smooth and enhanced surfaces for high heat flux electronics cooling. Using water and R134a, a comprehensive experimental single-phase and two-phase study has been carried out for a single jet ($D = 2.0\ mm$) impinging on a $2 \times 2\ mm$ micro-heater over a wide range of jet velocities. Several micro pin fin geometries (e.g., circular, elliptical, hydrofoil, square, rectangular) with hydraulic diameters ranging from 75 to 125 μm were investigated. The effects of saturation pressure, heat flux, jet velocities, pin fin geometry, and pin fin array configuration on the single-phase and flow boiling heat transfer characteristics are investigated and presented.

For a smooth surface (plane heater), the single-phase experimental Nusselt numbers were underpredicted by the stagnation zone heat transfer correlations available in the literature. Significant enhancement of the single-phase heat transfer coefficients has been observed as a result of the presence of the micro pin fins on the impingement surface; the enhancement was larger than the area enhancement. Enhancement factors as high as 3.03 or about 200% increase in the heat transfer coefficients were observed when the area enhancement was 2.44. Single-phase heat transfer enhancement was also shown to increase with increasing jet velocity. Experimental results for flow boiling jet impingement on smooth surfaces are largely characterized by significant temperature overshoot (boiling hysteresis). Both the onset of nucleate boiling and fully-developed flow boiling heat transfer coefficients have been found to increase with increasing jet velocity. Increasing the jet velocity and saturation pressure caused a decrease in the temperature overshoot. Surface condition was also found to have significant effects on the fully developed boiling regime with the boiling curves significantly shifting as a result of surface aging. Flow boiling jet impingement on micro pin fins displayed significant enhancement in the heat transfer coefficients relative to a smooth surface. Flow boiling heat transfer coefficients exceeding $110,000\ W/m^2 - K$ were observed at a relatively low veloc-

ity of 2.7 m/s with the large ($D = 125\ \mu m$) circular micro pin fins using R134a as the working fluid. The boiling characteristiccs of jet impingement on micro pin fins were interestingly characterized by the suppression of boiling hysteresis, largely attributed to the increase in nucleation site density. The effects of heat flux on the boiling heat transfer coefficients suggest that the heat transfer mechanisms are dominated by nucleate boiling.