Bubble Behavior and Heat Transfer of Nucleate pool boiling on Micro-Pin-Finned Surface in Microgravity

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Nucleate pool boiling heat transfer of micro-pin-fined surface structure is proposed for efficiently cooling electronic components with high heat flux in microgravity, and verified by experiments performed utilizing the drop tower Beijing. Micro-pin-fins with the dimensions of 50 μm × 120 μm (thickness × height) (denoted as Chip PF50-120) and the space of 50μm were fabricated on the chip surface by dry etching technique. FC-72 was used as working fluid. Nucleate pool boiling on a smooth surface was also tested for comparison. Experiments were conducted in terrestrial gravity before the release of the drop capsule and in short-term microgravity during the free falling in the drop tower Beijing. The facility satisfied the safety criteria to expose the apparatus in the drop capsule to different gravitational environments varying between microgravity (μg) (10^{-2}-10^{-3} g_0, g_0=9.81 m/s^2) in the free falling period and high-g level in the deceleration recovery system (16 g_0).

Figure 1 and 2 show the transitions of vapor bubble behaviors and the mean surface temperature of chip PF50-120, responding to the variations of gravity level for the heating voltage of 64 V (corresponding to a heat flux of 34.24 W/cm^2). The positions of Figure 2(a)-2(d) are marked on the curves of the mean temperature of chip PF50-120. The liquid subcooling is about 30 K. The bubbles generate and departure continuously from the heating surface caused by buoyancy forces before entering the microgravity condition as shown in Figure 2(a). However, the bubbles number is much larger than that for the smooth chip, indicating that micro-pin-finned surface can provide a large number of nucleate sites for enhancing boiling heat transfer performance. At about 0.12 s after entering the microgravity condition, the vapor bubbles coalesce with each other to form a large bubble as shown in Figure 2(b). With increasing time, the bubbles coalesce to form a very large spherical bubble as shown in Fig. 2(c) and only cause a little increase of wall temperature at a high heat flux, as shown in Fig. 1. The performance of high efficient heat transfer on micro-pin-finned surface is independent of the gravity, which stems from the sufficient supply of fresh liquid to the heater surface due to the capillary forces.

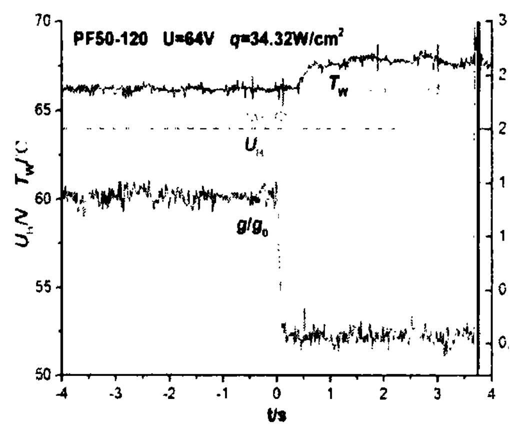

Fig. 1 Variations of surface temperature, heating voltage and gravity for chip PF50-120.

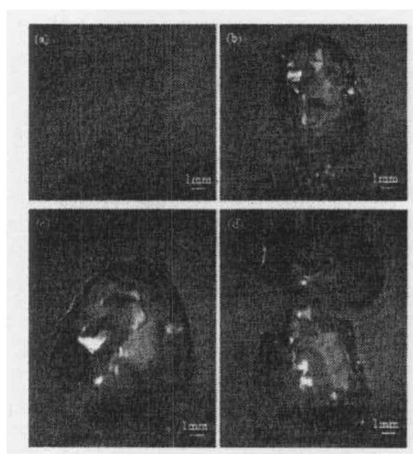

Fig. 2 Bubble behaviors on chip PF50-120 of 34.32W/cm^2. a)-0.5 s, b)0.12 s, c)1.8 s, d)3.0 s.

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