TWO-PHASE FLOW OVER FLOODED MICRO-PILLAR STRUCTURES WITH ENGINEERED WETTABILTY

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ABSTRACT

Flooding caused by excessive droplet feeding on heat dissipation areas periodically occurs for droplet-based thermal management. The conventional highly wettable texture of target surfaces, which is designed for thin film evaporation, has negligible effect on improving thermal performance during flooding. This work examines a combination of micro-pillar structures and engineered wettability that aims to improve the liquid-vapor phase change intensity and heat dissipation rate during flooding. Numerical simulation has been made to investigate the thermal and dynamic impact of the proposed combination structure on boiling and evaporation. A transient 3-D volume-of-fluid (VOF) model has been developed to analyze behaviors of bubble growth, coalescence, and departure processes. Parameters including volumetric liquid-vapor mass transfer rate, heat source temperature and heat transfer coefficient are examined. It has been demonstrated that surface wettability gradient in the pillar height direction can effectively facilitate the bubble departure and removal within the pillar forest. Thus smaller bubble size and a lower thermal resistance in the fluid domain can be achieved. The structured surface with higher pillars and denser pillar array is desirable for heat dissipation. The factor of pillar height has more impact on cooling enhancement than pillar array density when the solid-liquid interface area was kept the same. For wettability texture on the micro-pillar structure, the resulting heat transfer performance is determined by a trade-off between the bubble departure improvement within the pillar forest and the bubble pinning at hydrophobic pillar tops.