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Flow boiling enhancement of FC-72 from microporous surfaces in minichannels

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ABSTRACT

The microporous coatings can remarkably enhance the liquid boiling heat transfer. Therefore, they are promising to be introduced into minichannels in the design of the cooling system of high-power microchips. However, the flow boiling heat transfer characteristics from microporous surfaces in the minichannels have not been extensively studied, and the pertinent knowledge is rather fragmentary. The present research is an experimental investigation on flow boiling of a dielectric fluid FC-72 from microporous coating surfaces in horizontal, rectangular minichannels of 0.49, 0.93 and 1.26 mm hydraulic diameter. Effects of coating structural parameters, such as the particle diameter and coating thickness, were investigated to identify the optimum microporous coating for heat transfer enhancement. All microporous surfaces in this paper were found to significantly enhance FC-72 flow boiling heat transfer in minichannels. With the optimum coating, the heat transfer coefficients could be 7–10 times those of the uncoated surface, and the boiling wall temperature was reduced by about 10 K. The flow boiling phenomena in the present minichannels were distinctly different from those in conventional-sized channels, due to the wall confinement effect on vapor bubbles. The confinement effect was evaluated by taking the contributions of the liquid mass flux and channel size into consideration. It was found that the very strong confinement effect was unfavorable with respect to flow boiling enhancement of the microporous coatings in the minichannels.

1. Introduction

With the remarkable development of the integrated circuits technology, the heat dissipation of electronic devices is constantly increasing and hence the cooling systems for microelectronic chips, especially for the advanced microprocessors, are facing the challenge to remove a great deal of thermal power in confined spaces. Flow boiling in minichannels is a promising option, since flow boiling is associated with high heat transfer rate, and minichannels are characterized by their compactness and low pressure drop.

Numerous investigations were carried out on flow boiling in minichannels. Sumith et al. investigated water flow boiling in a vertical 1.45 mm diameter tube [1]. They found that small diameter tube produced a remarkable heat transfer enhancement and existing flow boiling correlations largely underpredicted the heat transfer coefficient, especially for a low heat flux condition. Martin-Callizo et al. [2] found that smaller channel diameter led to a higher subcooled flow boiling heat transfer rate of R-134a in a vertical small tube (diameter 0.83–1.70 mm). Jang et al. [3] found that FC-72 saturated flow boiling heat transfer coefficients of the small tube of 2 mm diameter were 30.6% higher on average than those of the 4 mm diameter tube. In recent years, many attempts have been made to understand the distinct two-phase heat transfer mechanism within mini- or microchannels [4,5] and to establish the criterion for the macro-to-microscale transition [6,7].

Methods of heat transfer enhancement can be easily introduced into the minichannels to guarantee superior heat transfer performance in a confined space. In order to significantly intensify boiling heat transfer, micro-structured surfaces containing reentrant cavity geometries are often employed [8]. These surfaces manufactured industrially are of two categories, those made by finning and/or knurling the tube surface (such as Thermoexcel series of Hitachi, Turbo-B of Wolverine and Gewa series of Wieland–Werke) or by covering the surface with capillary-porous structures sintered or deposited on the surface (such as High Flux of UOP) [9]. In general, sintered or deposited microporous surfaces are more favorable in the cooling systems, because their relatively small pores are suitable for boiling enhancement of refrigerants or dielectric liquids.

A number of experimental researches on pool boiling from the sintered microporous surfaces have shown that these surfaces provide excellent boiling enhancement. Sintered microporous surfaces exhibited excellent capability to enhance the pool boiling heat transfer, with the heat transfer coefficients increased by 7–9 times [10,11]. Marto and Lepere [12] declared that the High Flux porous surfaces provided higher enhancement than the Thermoexcel-E and Gewa-T surfaces in their experiments of refrigerants pool boiling.

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