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Effects of Wettability Patterns on Multiphase Flow and Heat Transfer in Mini/Microscale

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Abstract - Surface wettability is an ability of a liquid to maintain contact with a solid surface. In mini/microscale, many fluid flow and heat transfer systems become smaller, governing forces change from a body force to a surface force. Specifically, the feature in the micrometric scale multiphase flows and heat transfer is that the interfacial force becomes predominant comparing to inertia and buoyancy forces. Because most of multiphase heat transfer systems are considered that of intermediate fluid and gas on a solid surface, the wettability plays a critical role in the two-phase boiling heat transfer and fluid flow in mini/microspaces, because the surface wettability affects the triple contact lines, i.e., the inter-connected lines for all three phases; liquid, gas, and solid. It was also found that the wettability patterned surface can generate vortex flow at the intersection lines of different surface wettabilities (Zhang and Qiu 2008). The triple contact lines can be expanded, shrunken, moved and balanced dynamically during phase change heat transfer with or without an external forced convection. Therefore, the fluid flow and dynamic contact are governed by surface wettability patterns.

Recently, a novel technique that enhance both the heat transfer and the critical heat flux using the hydrophobic and hydrophilic patterned surfaces has been reported by Betz et al. (2010). Various flow control and heat transfer applications related with wettability patterned surfaces are accelerated by new micro/nano structured surface fabrication techniques, because the surface wettability can be modified by different surface material coating/deposition (Phan *et al*., 2009, Sun *et al.* 2013).

This work will conduct a review on the challenges and opportunities that surfaces with micro/nanostructure patterned wettabilities. Bubble dynamics, fluid flow and heat transfer caused by the micro/nanostructure patterned surfaces will be discussed. The effects of micro/nanostructure patterned surfaces on flow generation under a vapour bubble in a microchannel under very low Reynolds number will be demonstrated. The effects of wettability patterned surfaces on nucleation pool boiling and flow boiling heat transfer processes will be described. Bubble formation, breakup and departure will be visualized and measured. Different microchannels are fabricated by micro fabrication technology in conjunction with oxidation layer deposition and Octadecyltrichlorosilane/Teflon coating as hydrophilic and hydrophobic patterns. The vortex flows generated by monolayer hydrophilic/hydrophobic surface patterns were investigated utilizing micro resolution particle image velocimetry (µPIV). Because bubble dynamics is very important for fluid flow and heat transfer in microchannels, especially for bubble formation, departure and breakup at hydrophobic microdots, bubble dynamics and two-phase flow pattern were measured utilizing high speed camera visualization and micro resolution PIV. The critical vapour velocity on smooth and flat surfaces combining hydrophilic and hydrophobic patterns may trigger Helmoltz instabilities and enhance two-phase flow heat transfer. Different networks combining hydrophilic and hydrophobic regions are characterized. The pressure drops with different surface patterns in microchannels were evaluated by a differential pressure transducer to establish the correlation between two-phase flow and boiling heat transfer parameters. Microbubble nucleation, formation, breakup and departure are measured quantitatively utilizing novel optical techniques. According to our study, the wettability patterns on the chip do enhance the critical heat flux (CHF) and heat transfer coefficient

(HTC). The mechanisms on how the patterns can increase the HTC by increase the active nucleation sites, decrease the bubble departure diameter, shorten the bubble departure time and activate more bubble interactions will be presented. Patterns increase the CHF by moderating the Helmholtz instabilities so as to preventing the formation of an insulating vapor layer will be discussed in details.

References

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