Pool boiling heat transfer on heterogeneous wetting surface with hydrophobic dots

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1. Introduction

The boiling heat transfer mechanism of pool boiling is fundamental phenomena for understanding the phase change nature. Of many surface characteristics, the effects of wettability of heating surface is focused on as the dominant parameter for bubble dynamics and boiling heat transfer [xx]. In this study, highly controlled heating surfaces via MEMs technique were used for understanding the boiling heat transfer of heterogeneous wetting surfaces mixed by hydrophobic dots and a hydrophilic substrate. The diameter of hydrophobic dots and area ratio of phobic dots to heating area were regulated. The range of phobic dot diameter and area ratio were 50~1000um and 18.33~54.3%, respectively. The performance of boiling heat transfer of each surface were evaluated by comparing with a wholly hydrophilic surface. It will contribute to understand the mechanism and criterion of enhanced heating surface condition by modified surface treatment procedure.

2. Methods and Results

2.1 Experimental apparatus and sample

The experimental facility and sample were designed for pool boiling joule heating experiment with silicon wafer heater which were modified by MEMs technique. The aluminum pool and PID immersion heater were set up to maintain atmospheric saturated condition of water.

As a heating surface, a silicon wafer was used. On the one side of wafer, the platinum was deposited by E-beam process to be used as heater. And on the other side of wafer, Teflon hydrophobic dots were fabricated by lift-off process for a heterogeneous wetting heating surface. By coating and patterning of hydrophobic dots onto a hydrophilic bare substrate, the heterogeneous wetting surface was fabricated. The apparent contact angle of Teflon and hydrophilic bare substrate with distilled water were 54^o and 123^o, respectively. At that time, the difference of height between coated Teflon dots and a hydrophilic bare substrate were checked by measuring roughness via 3D-profiler. The roughness(Rt) of Teflon dots were ~52.76nm. It indicated that the roughness of fabricated surfaces does not possess a micro structure which can affect the boiling phenomena. So, we can only focus on the effect of wettability for boiling heat transfer without considering the effect of surface structure [xx].

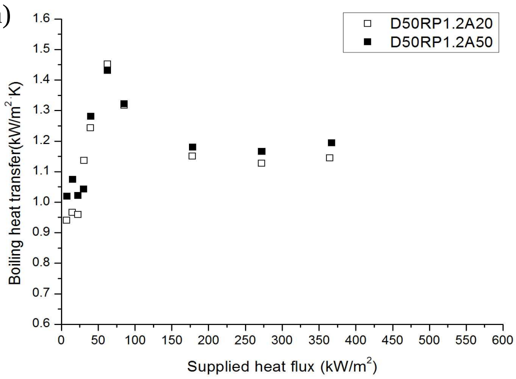
Of the parameter of a heterogeneous wetting surface, the diameter of hydrophobic dots and the ratio of phobic area to total heating area were adjusted for understanding the relation of boiling heat transfer performance and heating surface conditions. The used diameter of hydrophobic dots were 50, 100, 1000um and range of used area ratio was 18.33~54.3%. The pitch distance between dots were fixed by considering the ratio between the pitch distance and dot diameter to cover various used diameter range. Finally, determined ratio between the pitch distance and dot diameter was 1.2. Detailed information of used heterogeneous wetting surfaces is given in Table 1.

Table I: Detail information of used heterogeneous surfaces

Index	Diameter (um)	Pitch (um)	Number of dots	Area ratio (%)
D50RP1.2A20	50	60	15000	19.6
D50RP1.2A50	50	60	41500	54.3
D100RP1.2A20	100	120	3750	19.6
D100RP1.2A50	100	120	10375	54.3
D1000RP1.2A20	1000	1200	35	18.3
D1000RP1.2A40	1000	1200	72	37.7

2.2 Experimental results and Discussion

Based on calculated heat flux by considering supplied heat flux and computed heat loss and measured wall temperature, the boiling heat transfer performance was evaluated. Figure 1 and 2 show the experimental result on various heterogeneous wetting conditions. The experimental results were sorted in the different diameter and different area ratio of area of phobic dots to total heating area.

(a)


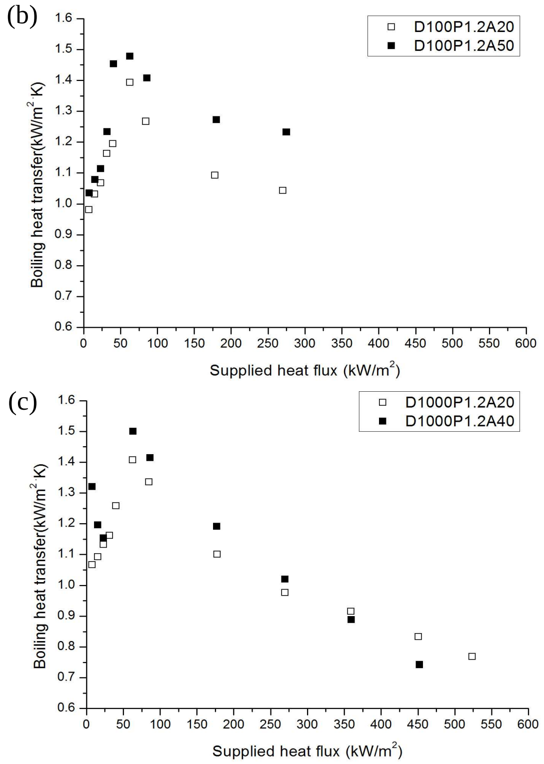


Fig. 1. Boiling heat transfer as heat flux increase on (a) 50um dot cases, (b) 100um dot cases, (c) 1000um dot cases

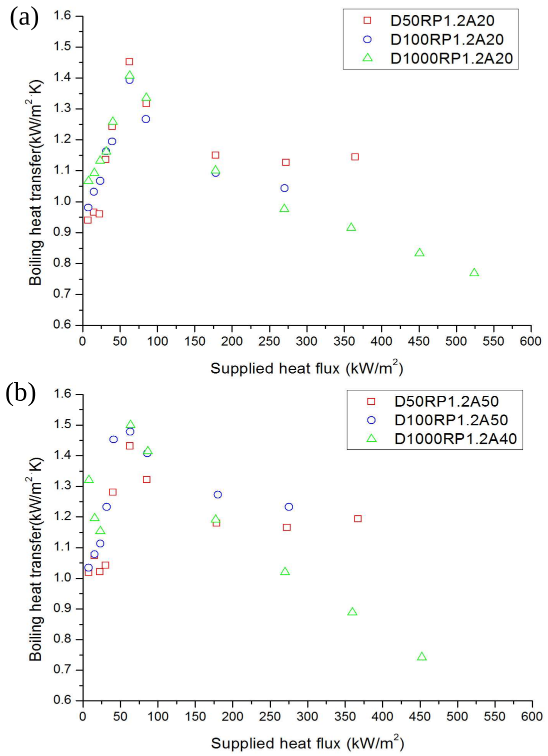


Fig. 2. Boiling heat transfer as heat flux increase on (a) area ratio is around 20% cases, and (b) area ratio is around 40~50%

All comparisons of heat transfer on heterogeneous wetting surfaces were conducted with bare hydrophilic surface before CHF occurrence. First of all, we can find the effect of number of phobic dots which could be indicated the area ratio of phobic area. As the number of phobic dots increase, the boiling heat transfer is improved as shown in Fig. 1 (b) and (c). However, after over the certain number like 50um dot cases(Fig. (a), number of dots on each case = 15000 and 41500), the boiling heat transfer showed saturation that means no more increase even though the number of phobic dots increase. This phenomena could be elucidated by connecting the activated number density of vapor because the phobic dots contribute to bubble nucleation[xx]. The plateau phenomena reported in this study over the certain number also indicated that, because there were so many nucleated site density by many Teflon dots, the condition of fabricated surface could not contribute more enhancing boiling heat transfer.

Secondly, we can show the effect of diameter of phobic dots in Fig. 2. Generally, 50um and 100um diameter cases are in almost same trend. When we consider the effect of number of phobic dots in Fig. 2, the difference between 50um and 100um will be more reduced. But, 1000um showed obviously different trend compared with the others that is boiling heat transfer decrement in high heat flux regime. Based on bubble dynamics on hydrophobic dots, the generated diameter could be fixed by the diameter of phobic dots. So there are too many induced large bubble on 1000um dots in high heat flux regime to transfer heat efficiently and it caused heat transfer decrement.

3. Conclusions

We can find the effect of number density and diameter of phobic dots. It is strongly related with bubble dynamics. And by this study, we can conjecture the boiling heat transfer saturation phenomena on many activated sites. We expected that the analysis of such phenomena will contribute to understand the basic mechanism of boiling heat transfer.

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