Milli-scale structure and micro-scale structure effect on pool boiling

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1. Introduction

Critical Heat Flux (CHF) is the limitation of available heat flux in the industries due to the melt down of the material. For this reason, many researchers have studied to increase not only CHF, but also heat transfer coefficient (HTC) that means efficiency of the system below CHF.

Many researchers reported about surface modification to enhance CHF [1-5]. However, these techniques were not applied to industries because nano- or micro-structure is not enough robust in the real operating condition. In this research, milli-structure and micro-structure were examined to identify boiling performance with expectation of reliability in applications.

2. Experiments

Pool boiling was conducted at saturated temperature under atmospheric pressure using DI water.

2.1 Pool setup

The pool boiling facilities are depicted in Fig 1. The pool consists of aluminum frame which has visualization window to see the boiling surface. Above test surface, there exists cartridge heater for making saturated temperature, and reflux condenser is on the top cover to sustain water level from evaporation during experiment.

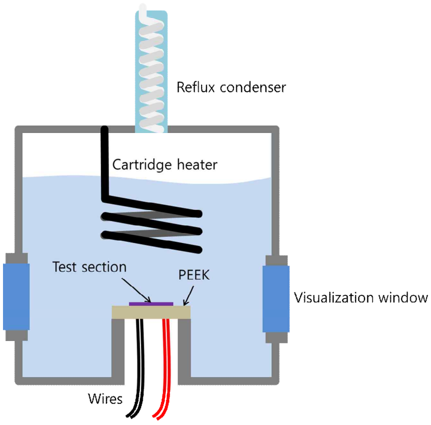


Fig 1. Schematic image of pool boiling

2.2 Heater design

The heater was fabricated using MEMS technique. Platinum thin heater, which has 1200Å thickness, was patterned on the backside for heating and temperature measurement. The effective heating area is 10mm x 15mm, and two wires were soldered at each electrode. To investigate effect of the structures on boiling, area ratio was controlled by changing diameter and pitch. The milli-scale and micro-scale structure, which is cylindrical shape, were made on the topside surface. Fig 2. shows its design and Table 1. shows the size of the structures for diameter and pitch. The structures consisted of two different diameters, and each diameter has two different pitches. Each structure was named from A to D as area ratio decreases. In this research, totally four structures were examined.

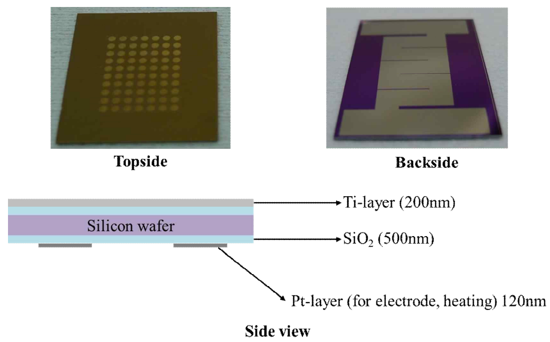
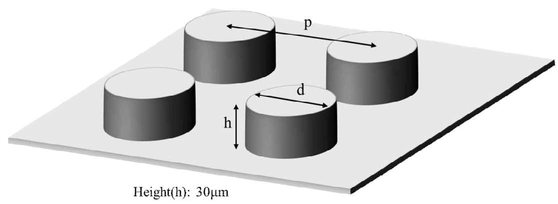


Fig 2. Silicon heater design



Name	Dia. (mm)	Pitch (mm)	# of posts	Area ratio
A	0.1	0.15	100x67	1.70
B	0.1	0.4	38x25	1.10
C	1	1.5	10x7	1.07
D	1	4	4x3	1.01

Table 1. Structure matrix

Before experiments, static contact angles were measured to check wettability of the structures and results are in Table 2. A DI water droplet of 5μl was dropped on each structure at the same condition.

Surface	Contact angle
Flat	91˚
A	62 ˚
B	75 ˚

C	73 °
D	63 °

Table 2. Contact angle for each surface

2.3 Experimental steps

Before experiment, the water was degassed using cartridge heater for one hour, and maintained saturated condition during experiment. The heat flux was increased stepwise, and every step keeps its heat flux for 120 seconds to make steady-state condition. At CHF, the power supply shut down when abrupt temperature increase showed. Then CHF was defined as a heat flux right before abrupt temperature increase.

3. Result

The purpose of this research is to examine the effect of milli-structure and micro-structure on pool boiling, specially about CHF and HTC with changing area ratio which is defined as total area to projection area.

Fig 3. shows CHF value with increasing area ratio. These points have a trend of enhancing CHF as area ratio increases. Even though milli-scale structure has a good reliability, its effect on boiling in this research is slight; D: 740kW/m^2, C: 943kW/m^2. In contrast to milli-scale structure, micro-scale structure has large CHF enhancement; B: 1113kW/m2, A: 1508kW/m^2. All surfaces make the first bubble at 30~35kW/m^2, which is starting point of nucleate boiling region.

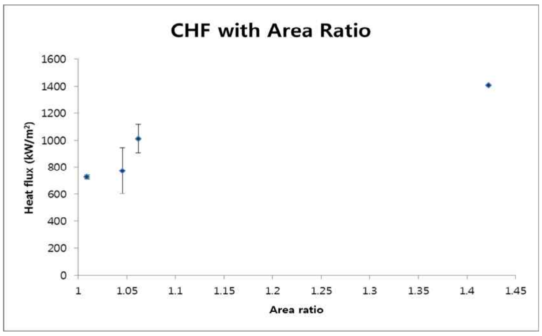


Fig 3. CHF with area ratio

HTC also increases with increasing area ratio. HTC increased as temperature increased, so two values for each structure were presented. The first one is HTC_max, which is the maximum HTC regardless of its temperature at CHF point. The other is the HTC at the same heat flux, 500kW/m^2. The highest area ratio structure has the largest HTC. The boiling performance was represented by only area ratio although each structure has different diameter and pitch.

For analysis, wettability is an important parameter having effects on the boiling [2]. However, there was no trend for static contact angle in Table 2. unlike its boiling characteristics with increasing area ratio. It means that the static contact angle is not sufficient to explain the enhancement of CHF and HTC.

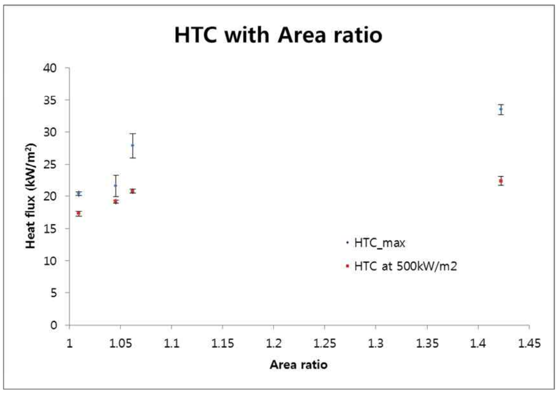


Fig 4. HTC with area ratio

4. Conclusion

Although milli-scale structure is more reliable than nano- or micro-scale structure, its boiling performance has slight improvement and static contact angle doesn't explain results. There are different approaches which consider dynamic situation for explaining boiling phenomena [4]. It means that additional plans to examine wettability in dynamic situation are needed. In addition, the milli-scale structure has also micro-scale height due to limitation of the substrate. For the future work, full milli-scale structure will be studied. Furthermore, to understand mechanisms of CHF and of HTC enhancement, boiling phenomenon study should be followed using high-speed camera.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (No. NRF-2012M2A7A1052459).

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