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Pool boiling experiments on modified heterogeneous wetting surfaces with Teflon dots

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1. Introduction

Boiling phenomena has been used as a main heat transfer mechanism to transfer heat energy in many heat transfer systems and apparatuses. In boiling phenomena, there are two important performance parameters: Boiling heat transfer (BHT) and critical heat flux (CHF). Of two parameters, CHF, which is directly related with the safety of systems, will be mainly studied in this article.

Via challengeable recent boiling experiments, the effect of heating surface was focused in boiling mechanism [1-3]. In this regard, we conducted the pool boiling experimental study by using the modified surfaces with locally treated heterogeneous wetting surfaces to understand the basic mechanism between the occurrence of CHF and local heating surface condition.

2. Methods and Results

2.1. Experimental apparatus and sample

The test apparatus is designed for a pool boiling experiment under atmospheric pressure with electronic joule heating method. It consists of a test sample jig, a main test pool, and a lid with an immersion heater and a condenser to sustain the 1atm saturated condition. [4].

The platinum thin film heater was embedded as a heater part at the one side of oxidized silicon wafer, and the other side of wafer was modified as a heating surface with mixed Teflon pattern technique. The total size of specimen and the size of heated area were 25mm x 20mm and 15mm x 10mm, respectively. The heat loss was calculated by using COMSOL CFD simulation.

The mixed wettability surface consist of two parts: 1. Teflon coated surface, which is the hydrophobic part in this article, 2. Oxidized silicon wafer surface, which is the hydrophilic part in this letter. The size and pitch distance of Teflon dots and the ratio of phobic area to total heating area were controlled to find the relation between the occurrence of CHF and local heating surface condition.

In this article, the characteristic of modified surface was represented as two parameters: 1. Apparent contact angle, 2. Surface roughness. The static contact angle of the oxidized silicon wafer, which contains the 5000Å oxidation layer, is 54^o. The exact angle made by the Teflon coated surface is 123^o in the present condition. And we confirm that the patterning procedure didn't change the contact angle of each surface.

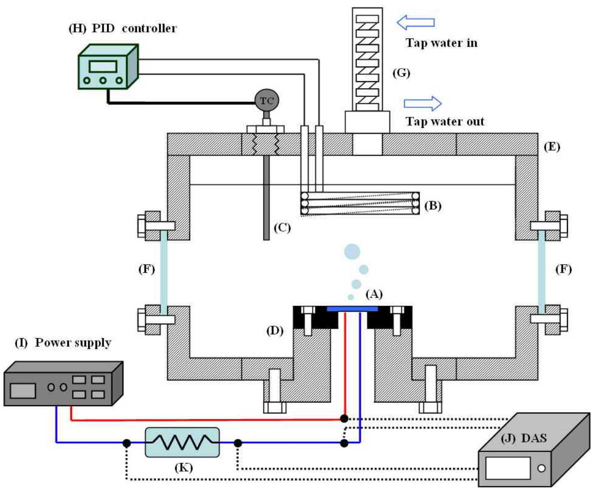

Figure 1 Experimental apparatus: (A) test section, (B) immersion pre-heater, (C) thermocouple, (D) sample jig, (E) pool, (F) visualization window, (G) reflux condenser, (H) PID controller, (I) power supply, (J) data acquisition system, and (K) reference resistance in constant temperature pool diagram of pool boiling facility

By using 3D profiler, the roughness of bare surface (oxidized silicon surface), Teflon coated surface, and pattern surface is measured. As a result, the roughness of each surface is less than sub-micron level. It is also confirmed by the 3D profiler that the Teflon dot does not possess a micro structure which can affect the boiling phenomena. Table 1 contains the surface information.

Property		Bare	Teflon	Mixed surface
Contact Angle (^{o})		54	123	Each value is preserved
Roughness (nm)	Ra	1.75	1.55	4.38
	Rt	17	27.04	52.76

Table 1 Information of surface characteristic

2.2. Result and discussion

Figure 2 shows the results of experiments conducted on uniform hydrophobic and hydrophilic surfaces to re-establish baselines. According to this result, the hydrophilic had higher CHF than the hydrophobic surface. However, the hydrophobic showed earlier ONB than the hydrophilic surface. Furthermore, according to visualization results, the hydrophobic case had more generated bubbles on heating surface than the hydrophilic case. Such tendency on uniform wettability surface coincides with previous reports, which studied about boiling performance and bubble dynamics on different wettability heating surfaces [4-6].

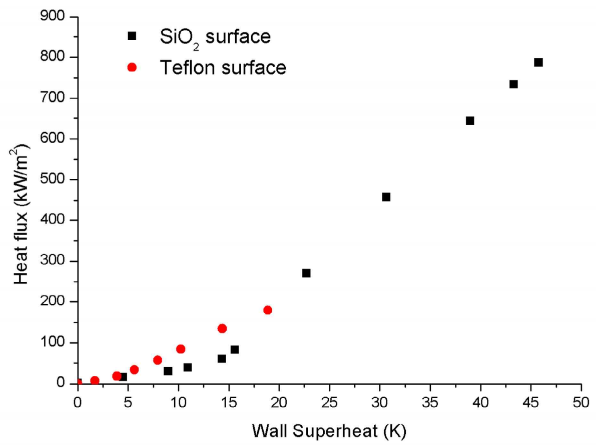

Figure 2 Experimental reproducibility

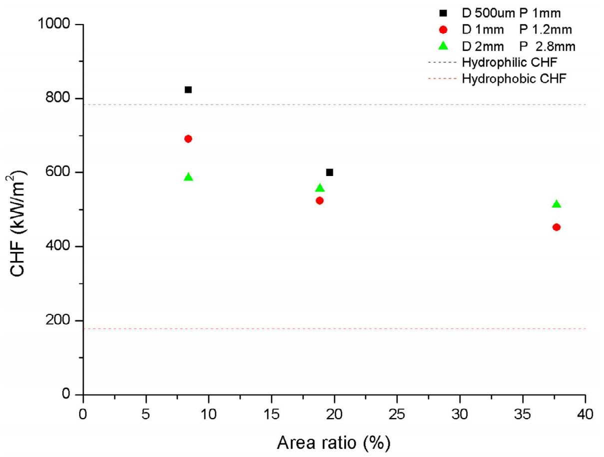

Figure 3 Boiling curve on several heterogeneous wetting surfaces

Figure 3 shows the occurrence of CHF on uniform and patterned heterogeneous wetting surfaces. Each patterned conditions was controlled to know the effect of surface parameters, so we can recognize the effect of local surface characteristic to CHF by analyzing the tendency on Figure 3. First, the effect of different ratio of hydrophobic area to total heating area was significantly shown, independent of their diameter or pitch distance. The CHF on patterned surface decreased as the ratio increased. Secondly, there is the effect of patterned diameter. It more dominated in low area ratio region than in high area ratio region. In low area ratio, the smaller the diameter of Teflon dot is, the higher CHF occur. However, in high ratio region, the effect of size of Teflon dots could be neglected.

To understand such phenomena, we should attend the role of Teflon dots. According to previous studies and visualization results, hydrophobic surfaces and patterned hydrophobic dots were favored to make bubble on their surface and, after once bubble generated on the hydrophobic dot, the pattern could not be wetted by liquid like irreversible dry spots [7]. So the experiment result could be interpreted by the CHF mechanism of hot and dry spots [8]. Still more experimental cases are needed to understand the relation between CHF and local surface characteristics but it is expected that this study will contribute as a first step to develop the new CHF model, which includes the effect of locally modified surface characteristics.

3. Acknowledgments

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