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Critical Heat Flux of Finite Shape TiO_2 Sputtered Surface

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1. Introduction

In order to clarify the relationship between CHF and wettability of the boiling surface, very ideal experiments were conducted. DC plasma sputtering method was applied to establish wettability controlled surface without any formation of porous structure. Pool boiling CHF experiments were conducted on the heaters with various contact angles and CHFs on wettability enhanced surfaces were compared with that of bare surface.

2. Experimental Apparatus and Procedures

In this section the experimental methods and techniques are briefly described. DC plasma sputtering method for modifying the surface wettability and experimental apparatus was introduced.

2.1 Pool Boiling Test Rig & Experimental Procedure

The test pool was shown in Fig. 1. It was composed of (a) the external chamber (32×42.5×29.5cm) and (b) the internal chamber (19.5×29.5×27cm) with tempered glass. Two heaters with 0.3 kW power were installed in the internal chamber to keep the saturation temperature during the experiment. Two brass rods of 20 mm diameter were connected to the PCB test heater and rods were mounted at the Teflon cover (f) which was installed on top of the internal chamber.

The power supply (l) which has the control range of 0~330A current and 0~20V voltage was connected with the brass rods. The output of power supply was automatically controlled with the programmed increment rate. For the data acquisition, 34970A HP Agilent was used. Current was measured by using DC shunt resistor made by manganin.

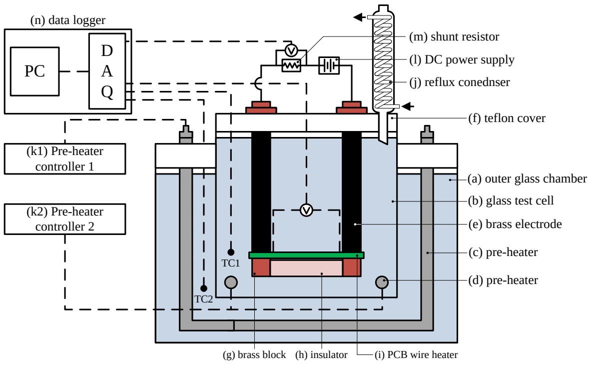


Fig. 1. Figure of pool boiling test rig

2.2 Heater Implemented on the PCB

As shown in Fig. 2, a thin and long plate heater was constructed on a printed circuit board (PCB) (of which dimension was 150 mm × 25 mm× 2 mm). The heater geometry was babel shape which focuses Joule heating on the test section at middle side. The heater was made of copper (17.5μm thick) coated with nickel (5.5μm thick). The bare heater surface used in this study showed typical contact angle (81.6˚). Two terminals were prepared to measure the voltage drop across the heater to measure the surface temperature and supplied power.

To minimize the backside heat loss of PCB, 1 mm thick silicon pad and 16 mm thick bakelite plate were attached. The longitudinal length l of test section was 100 mm and the width *w* was 4 mm.

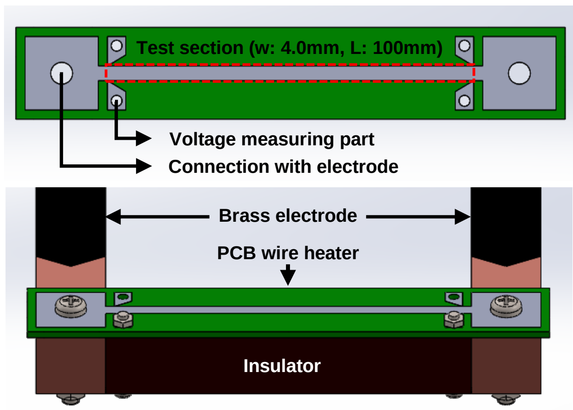


Fig. 2. Heater implemented on the PCB

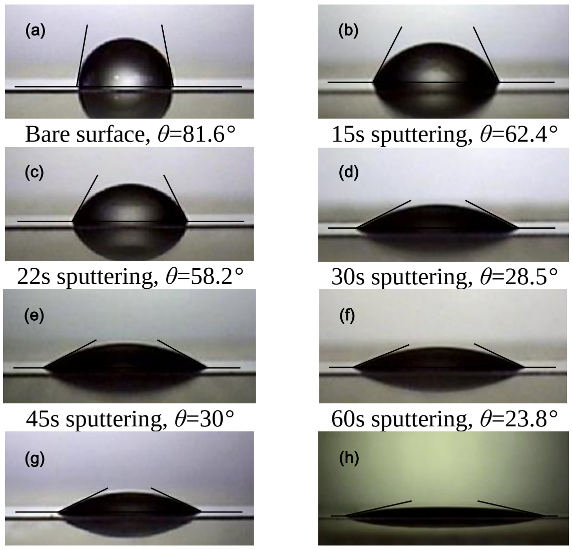
2.3 TiO_2 Sputtering Process

DC plasma sputtering was applied to create metal oxide layer on the heater surface. Before the sputtering process, the heater surface was cleansed by alcohol and dried. Target material was made of TiO_2. The sputtering process was initiated when the degree of vacuum inside the chamber reached 50mmTorr and it was kept between 50mmTorr to 80mmTorr during the whole process. The sputtering process was conducted under the room temperature and in the atmosphere of argon. The thickness of the deposited TiO_2 layer was controlled by changing sputtering time. It was assumed that the sputtering rate of the TiO_2 molecule was constant.

3. Result & Discussion

After the sputtering process, contact angle of the sputtered surfaces was measured. For each sputtered surface, pool boiling CHF experiment was conducted.

3.1 Contact Angle Measurement



Bare surface, θ=81.6° 15s sputtering, θ=62.4°
22s sputtering, θ=58.2° 30s sputtering, θ=28.5°
45s sputtering, θ=30° 60s sputtering, θ=23.8°
120s sputtering, θ=25.3° 600s sputtering, θ=11.35°

Fig. 3. Measurement of various contact angle

Williams and Goodman [1] experimentally showed that wettability of the silicon oxide coated surface was varied with the change of the coating thickness. Stoneham and Tasker [2] interpreted the phenomenon in terms of fixed charges present in the silicon substrate. The contact angle depended on the interfacial energy and the surface energies of the oxide and water. The interfacial energy and the surface energy of the oxide were influenced by the presence of charges in the silicon. The variation of contact angle reflected that those fixed charges were influenced by growing oxide film.

Likewise, the sputtered layer on the surface could influence the contact angle of the surface. The degree of contact angle could be varied by thickness of the sputtered layer. In this study, the thickness of sputtered layer was controlled by transition of sputtering time. As the sputtering time increases, the contact angle of TiO_2 sputtered surface was decreased. The variation of contact angle by sputtering time is shown in Fig. 4.

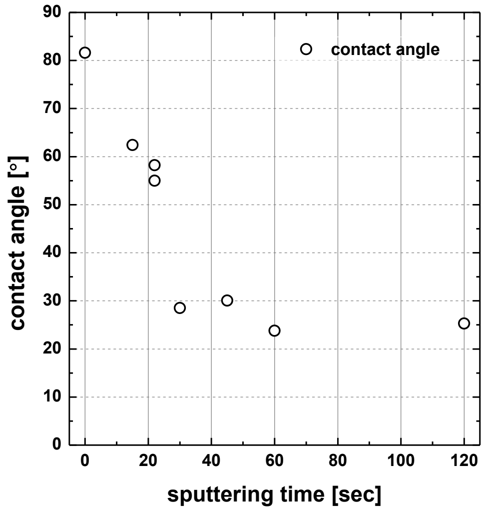


Fig. 4. Relationship between sputtering time and contact angle

3.2 Critical Heat Flux

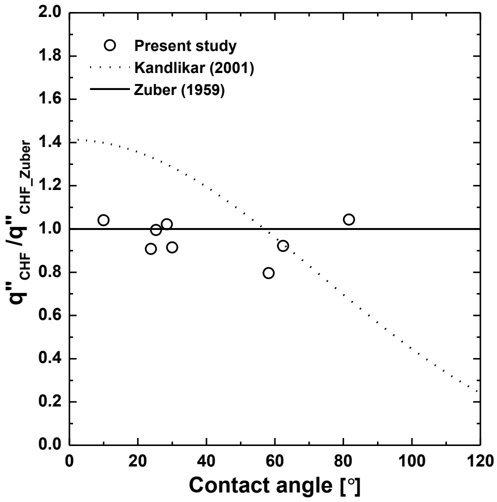


Fig. 5. Comparison of present data with Kandlikar's correlation [3]

The result of CHF experiment with TiO_2 sputtered surface was plotted and compared with the theoretical CHF model suggested by Kandlikar [3]. The prediction of Zuber [4] was plotted together, also.

According to the theoretical CHF model of Kandlikar [3], CHF is closely correlated to the contact angle, β. His equation is shown in equation (1):

$$q''_{CHF} = h_{fg}\rho_g^{1/2}\left(\frac{1+\cos\beta}{16}\right)\left[\frac{2}{\pi}+\frac{\pi}{4}(1+\cos\beta)\cos\phi\right]^{1/2}\left[\sigma g(\rho_l-\rho_g)\right]^{1/4} \quad (1)$$

Where the critical heat flux is q''_{CHF}, latent heat of vaporization is h_{fg}, density of gas phase is ρ_g, density of liquid phase is ρ_l, surface tension is σ, gravitational acceleration is g, inclination angle is ϕ and contact angle is β.

In this study, the inclination angle ϕ was 0. As shown by Fig. 5, wettability of the heater surface did not affect to CHF.

4. Conclusion

From the experimental data and comparison with the Kandlikar's theoretical model [3], the improvement of wettability did not affect to CHF significantly.

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