Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Experiment on Pool and Flow Boiling CHF for the SiC Surfaces under Atmospheric Condition

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1. Introduction

After the Fukushima accident in Japan, hydrogen explosion problem has been highlighted so far. There have been many studies regarding steam and water reaction to mitigate the hydrogen explosion. For materials of light water reactor (LWR) cladding, neutron absorption should be quite low for the neutron economy, and the reaction rate should be low for the integrity of the system. From many candidates, SiC has been used in this study. Many previous studies focused on the application of the SiC to the LWR cladding [1-4]. However, up to now, we thought that the most applicable and usable method for the application of SiC is SiC coating on the present Zircaloy cladding. In this aspect, we suggest PVD (Physical Vapor Deposition)-sputtering on the Zircaloy cladding.

Critical heat flux (CHF) is very important value for the thermal hydraulic phenomena. CHF is affected by many factors such as the material property, morphology, and liquid property. Previous studies have confirmed the factors affecting on the CHF [5-9].

The study has been performed with SiC surfaces under pool boiling condition and flow boiling condition. Under pool boiling condition, CHF of the SiC-coated stainless steel plate and the bare stainless steel plate have been compared. In flow boiling experiment, CHF of the α-SiC tube has been taken, and it was compared with the bare stainless steel tube.

2. Experimental Apparatus

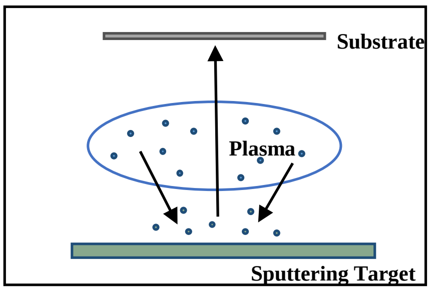

Fig. 1. PVD-sputtering process

2.1 Pool Boiling Experiment

The SiC coatings have been achieved through the PVD-sputtering on the stainless steel plate for 1 hour (400 nm) and 3 hours (1 μm) with 100 W power. Two kinds of thickness of the coating were prepared to measure the CHF and to assess the thickness effect.

The experiment has been carried out with DI water under atmospheric condition. The DI water was contained inside of the polycarbonate water tank. The test section was directly heated through the rectifier of capacity of 45 kW (15V, 3000A).

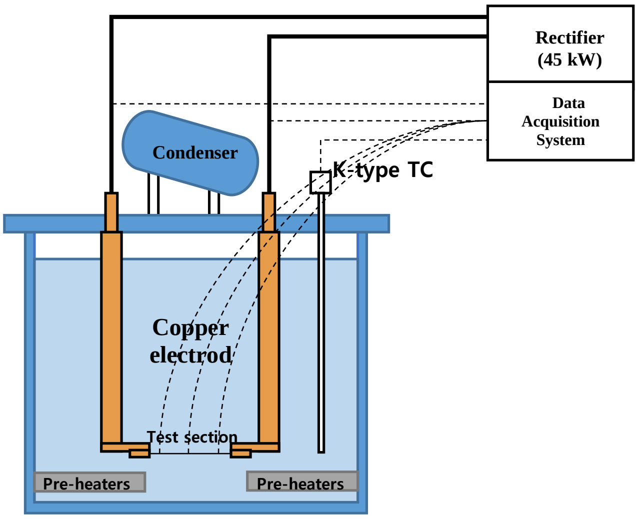

Fig. 2. Apparatus of pool boiling experiment

2.2 Flow Boiling Experiment

The α-SiC tube was made from the Lianyungang Zhong Ao Aluminium Co., Ltd., and the inner surface of the tube was rough. The tube was heated through the indirect heating method with nichrome wires. The inner and outer diameter was 8 mm and 15 mm, respectively. The heated length was 210 mm.

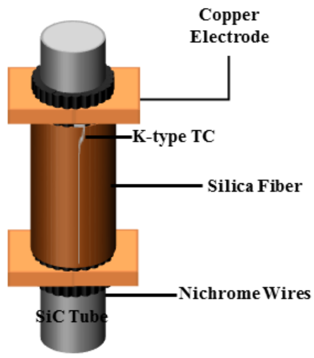

Fig. 3. Schematic design of the heater

The coolant in the test loop was pre-heated up to 360 K, and the mass flux of the system was 300 kg/m^{2}s. The test section was heated through the rectifier of capacity of 100 kW (25V, 4000A).

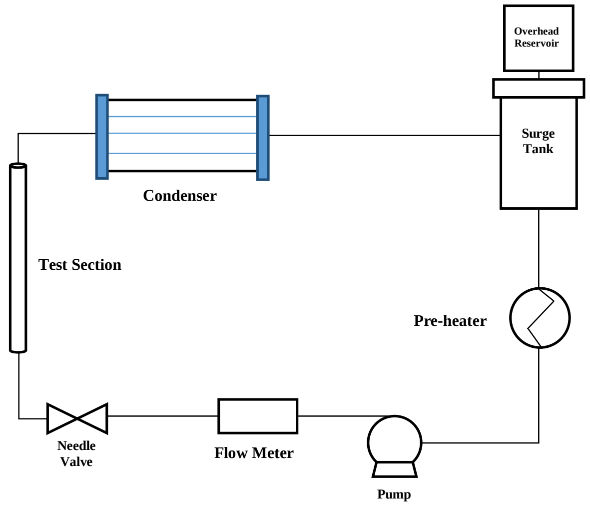

Fig. 4. Test loop of flow boiling experiment

3. Results

3.1 Pool Boiling Experiment

SiC-coated surface has shown the enhanced result compared with the bare stainless steel plate. The reason can be explained through the wettability on the surface as shown in Fig. 6. Furthermore, test section of the thicker coating has shown better margin that there also existed the thickness effect.

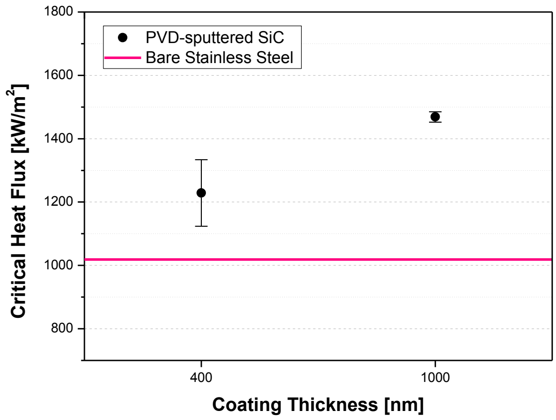

Fig. 5. CHF result of SiC-coated surface and the bare stainless steel surface.

(a) 19.6° (b) 17.3° (c) 57.7°

Fig. 6. Contact angle measurement. (a) 400 nm thickness, (b) 1 μm thickness, and (c) stainless steel with 5 μl of DI water.

3.2 Flow Boiling Experiment

α-SiC tube of the rough surface resulted in the increased CHF compared with the bare stainless steel tube. The enhancement is maybe due to the remained wetting on the surface [6] and the roughness on the surface [7-9].

Table I: Results of the flow boiling experiment

P : 1 bar **G : 300 kg/m^{2}s**	**SiC**	**Stainless Steel**
Quality (X_{exit})	**0.443**	**0.361**
CHF (kW/m^2)	**3010**	**2515**

4. Conclusion

Both experiments have shown that SiC surface shows better heat transfer performance than that of the stainless steel surface. Also, considering that the roughness of the coating was almost similar with that of the stainless steel plate, we concluded that at least SiC surface will show equal or even better heat transfer performance in the real situation.

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