Corrosion Behavior and Mechanical Property of CVD SiC

Hyun-Jin Cha*, Ju-Jin Won, Kyu-Tae Kim
Nuclear and Energy Engineering Department, Dongguk University
123, Dongdea-Ro, Gyeongju, Republic Of Korea, 780-714
**Corresponding author: chahyunjin@dongguk.ac.kr*

1. Introduction

SiC is broadly used as high temperature structure material because of its high temperature tolerance and superior mechanical properties. After the fukushima nuclear power plant accident, SiC proposed as one of the alternative materials for LWR fuel cladding to provide enhanced safety margin. In contrast with zirconium alloy which is currently used for cladding tubes, SiC generates little hydrogen caused by oxidation. In this study, corrosion tests for CVD SiC materials were performed under the PWR normal operation condition and three-point bending tests were performed for as-received and corroded specimen.

2. Experimental Methods

2.1 Specimen preparation

SiC specimens used in the experiment were supplied by Morgan Advanced Materials and prepared with CVD process. The dimensions of specimens were 10mm×10mm×3mm for corrosion tests and 20mm×5mm×3mm for three point bending tests. The specimens were polished to 0.25㎛ surface finish to examine the effect of corrosion on microstructure of CVD SiC exactly.

2.2 Corrosion test

To simulate the normal operation condition, the corrosion tests were performed with a pressure 15MPa at 360℃ and water of 3.5ppm LiOH using a static autoclave for 7, 15 and 30days. After the corrosion tests, the surfaces of the corroded specimens were examined using scanning electron microscope.

Table I. Corrosion test conditions

Specimen	Pressure (MPa)	Temperature (℃)	LiOH (ppm)	Test times (day)
CVD-SiC	15	360	3.5	7
				15
				30

2.3 Three point bending test

Three point bending tests were carried out to see the mechanical properties according to the corrosion of CVD SiC. The Instron model 3366 mechanical testing machine was used in this test and test speed was set to be 0.020mm/min. In addition, the fracture surfaces of the bending-tested specimens were examined using scanning electron microscope.

3. Results and discussion

Fig. 1 shows the effect of corrosion time on the changes in the weight of CVD SiC. The amount of weight loss increased linearly as time goes, indicating that specimens dissolved in water and the acceleration of corrosion was not observed. It is known that SiC forms SiO_2 which dissolves easily in water via the following reaction [1, 2]:

$$SiC + 2H_2O = SiO_2 + CH_4 \quad (1)$$

$$SiO_2 + H_2O = H_2SiO_3 = HSiO_3^- + H^+ = SiO_3^{2-} + 2H^+ \quad (2)$$

Fig.2 (a) shows the surface of as-received specimen observed with scanning electron microscope. It was found that there is no particular feature on microstructure of specimen before the corrosion test. However, as shown in Fig.2 (b), the grain boundaries were attacked and penetrated after the corrosion test for 7days. In addition, the grain boundary attack was increased over the time in Fig.2 (c) and (d). It can be seen that the increase in weight loss shown in Fig.1 is also correlated with the grain boundary attack shown in Fig.2.

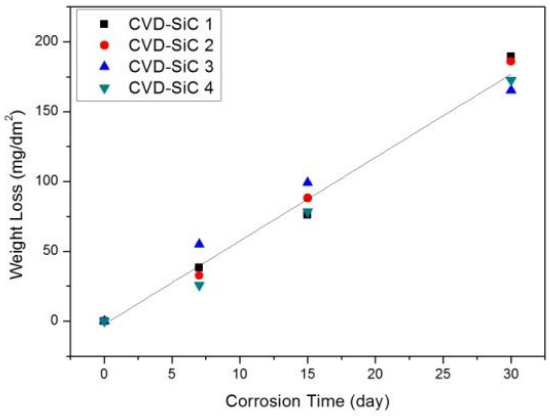

Fig. 1 The effect of corrosion time on CVD SiC weight loss at 360 ℃ under LiOH 3.5ppm water condition.

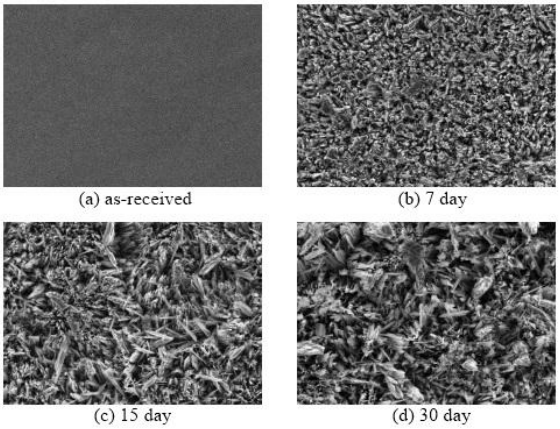

Fig. 2 Scanning electron micrographs of CVD SiC before and after the corrosion tests (x500)

Fig.3 shows bending test results of CVD SiC. Stress-strain curves show typical characteristics of ceramic with brittlement. Plastic strain did not exist, and relation between stress and strain was nearly linear. The ultimate bending strengths of CVD SiC were 358.86 and 303.95MPa for as-received and corroded specimen, respectively. This may be explained by grain boundary attack resulted from corrosion. The surface of as-received specimen was smooth while one of corroded specimen was rough because of grain boundary attack. Therefore, rough surface may play a role in cracks for starting point of failure.

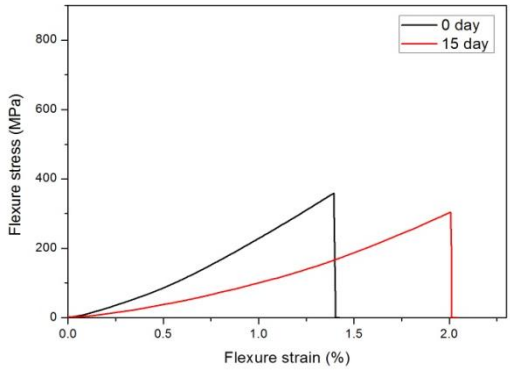

Fig.3 Three point bending test results of as-received and corroded CVD SiC

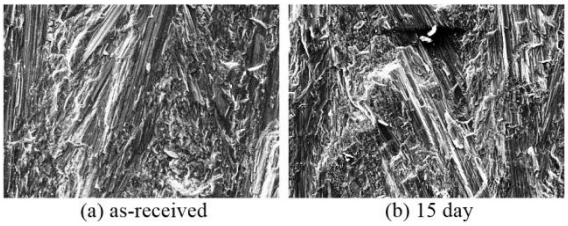

Fig. 4 Scanning electron micrographs of fracture surfaces on the bending-tested specimens before and after the corrosion tests for 15 days (x500)

Fig.4 shows scanning electron micrographs of the bending-tested specimen. Based on the fracture surfaces examination, both specimens show very brittle fraction and there is no difference between them. This indicates that there is no effect of microstructure on the amount of corrosion.

4. Conclusions

Corrosion test indicate that the amount of weight loss increased linearly with time. It may be caused by dissolution of specimen in water. The effect of microstructure on corrosion time of CVD SiC was analyzed by the scanning electron microscope. It can be seen that grain boundary attack increased with time. Three point bending tests of as-received and corroded specimens indicate that non-corroded specimen has larger bending strength than corroded one because rough surface caused by corrosion act as cracks for starting failure.

REFERENCES

[1] H. Hirayama, T. Kawakudo, A. Goto, "Corrosion behavior Silicon carbide in 290℃ water.", J. Am. Cerum. SOC., 72 111) 2049-53 (1989)
[2] C. H. Henager Jr., A. L. Schemer-Kohrn, S. G. Pitman, D. J. Senor, K. J. Geelhood, C. L. painter, "Pitting corrosion in CVD SiC at 300℃ in deoxygenated high-purity water", Journal of Nuclear Materials 378 9–.16 (2008)