Environmental Barrier Coatings Development for SiCf/SiC Composite-Based Fuel Cladding Applications

Daejong Kim*, Jung Ho Shin, Hyun-Geun Lee, Ji Yeon Park, Weon-Ju Kim
Korea Atomic Energy Research Institute, Nuclear Materials Development Div., 989-111Daedeok-daero, Yuseong-gu, Daejeon 305-353
**Corresponding author: dkim@kaeri.re.kr*

1. Introduction

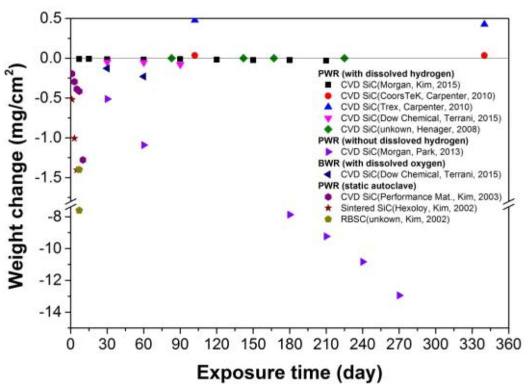
SiC-based composites are one of the candidate materials for accident-tolerant fuel (ATF) cladding because of its excellent hot steam corrosion resistance, high temperature strength, irradiation stability, and low neutron absorption cross-section [1]. However, SiC is likely to dissolve into the high temperature pressurized water [2]. There is a consensus that the SiC composites need the environmental barrier coating (EBC) for ATF applications.

Therefore, we tried to coat Ti-based EBC materials on SiC by an arc ion plating method and investigated hydrothermal corrosion resistance.

2. Methods and Results

2.1 Corrosion of SiC and Composites

Fig. 1 shows the corrosion rate of SiC ceramics and SiC composites. SiC ceramics tends to dissolve in high-temperature pressurized water. Among SiC ceramics, CVD SiC has best corrosion resistance. According to our previous corrosion tests [3], the recession rate of CVD SiC was very low and there was a mass reduction of about 0.011% after 210 days in the simulated PWR coolant environments with the dissolved hydrogen. However, its corrosion resistance can decrease under neutron irradiation environments [4]. SiC composite has less corrosion resistance than monolithic SiC because crystallinity of the composite is not excellent compared to the monolithic SiC phase.



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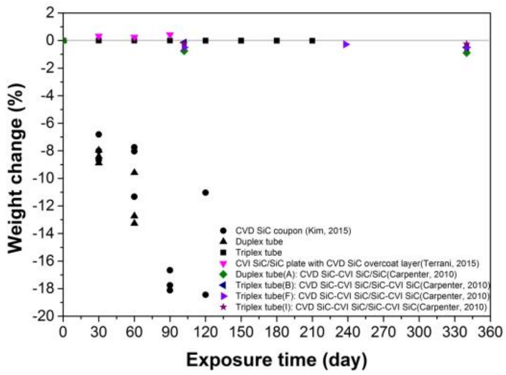

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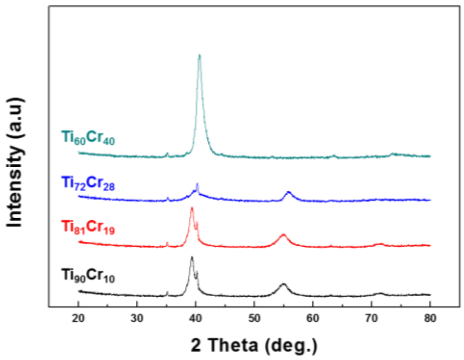
Fig. 1. Corrosion rate of SiC ceramics in the simulated PWR coolant environments [3].

2.2 Environmental Barrier Coating

EBC can effectively prevent corrosion of SiC composite cladding during normal operation. Unlike metal-based ATF cladding, the SiC composite itself has excellent accident resistance. Therefore, EBC materials for SiC fuel cladding should focus on improving corrosion resistance in normal operating environments rather than improving accident resistance. In this study, we selected Ti-Cr alloys and Ti-Cr-N ceramics for EBC materials which have relatively low thermal expansion coefficient, high corrosion resistance, and good mechanical properties. EBC materials was deposited using an arc ion plating method. Fig. 2 shows the X-ray diffraction peaks of Ti-Cr and Ti-Cr-N coatings.



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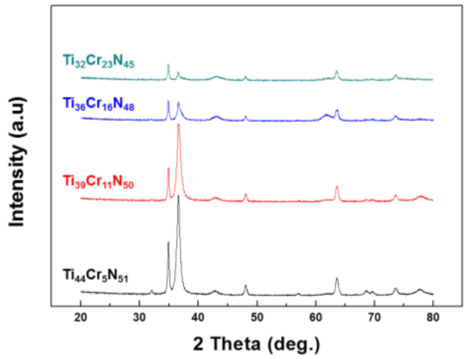

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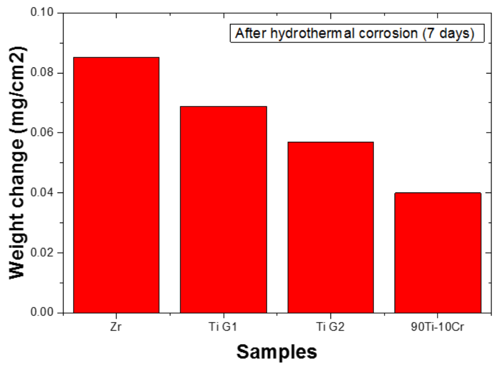
Fig. 2. X-ray diffraction results of (a) Ti-Cr and (b) Ti-Cr-N coatings.

Hydrothermal corrosion tests were carried out for 7 days in 310°C, 10 MPa water in static autoclave for the selection of coating materials. Fig. 3 shows the weight changes of Ti-Cr, Ti-Cr-N, Zr alloy, Ti Gr. 1, and Ti Gr. 2. Compared with a Zr alloy, weight gain of Ti and Ti-Cr alloys is small. Ti-Cr-N ceramics showed weight loss due to the dissolution. In particular weight loss of 44Ti-5Cr-51N was extremely small at -0.0085 mg/cm^2 after 7 days.



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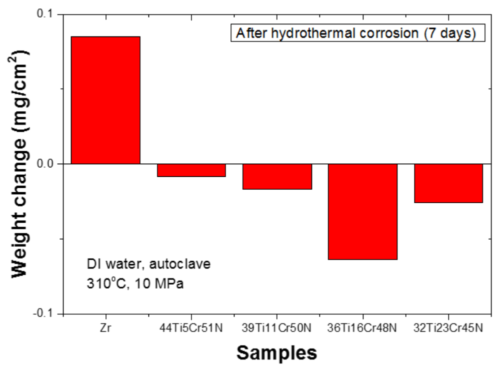

(b)

Fig. 3. Weight change of various materials after corrosion in pressurized water for 7 days at 310°C, 10 MPa: (a) Zr, Ti Gr.1, Ti Gr.2, Ti-Cr alloy and (b) Zr, Ti_xCr_yN

3. Conclusions

SiC-based fuel cladding is likely to dissolve into the high temperature pressurized water under neutron irradiation. Ti-based EBC can effectively prevent corrosion of SiC-based fuel cladding. Ti-Cr-N ceramic has excellent corrosion resistance.

Acknowledgement

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