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Fabrication of SiCf/SiC Composite by a Polymer Impregnation and Pyrolysis Process

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1. Introduction

Since 2012, the Korea Atomic Energy Research Institute (KAERI) has launched a national R&D project to develop suppressed hydrogen-release fuel cladding tubes. A metal-ceramic hybrid cladding tube is one of these concepts [1-5]. The tube forms composite ceramic layers on the zirconium alloy cladding tubes to enhance their stability during all accidents, as well as to prevent them from generating hydrogen gas under severe accidents (see Fig. 1). The new tubes can be made in the following two stages: first, producing zirconium alloy tubes, and second, forming ceramic composites on the tubes [2].

The fabrication of ceramic composites was focused in the current study. The composite layer is produced by a filament winding of SiC fibers on the zirconium tube, and then impregnating the polymers between the SiC fibers and zirconium tube, and in the empty space in the filament wound SiC composite. The rate of impregnation is dependent on the process conditions such as the precursors, atmosphere, and temperatures [3,5]. In this study, the effect of the kinds of solvent on the impregnation density was investigated through a microstructural and mechanical analysis.

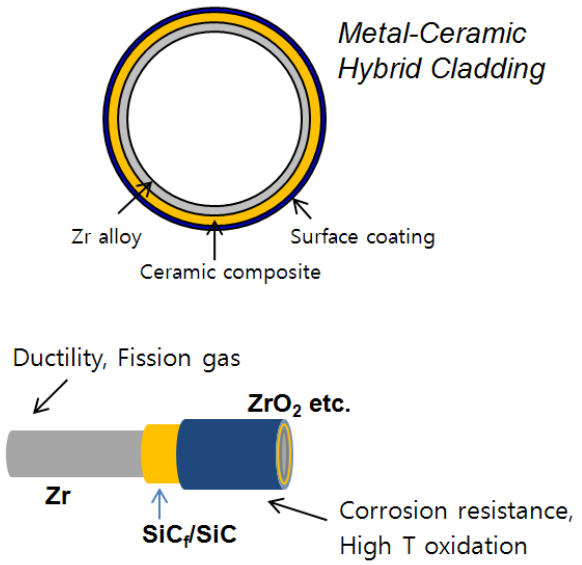

Fig. 1. Schematic illustration of metal-ceramic hybrid fuel cladding tubes.

2. Methods and Results

Preceramic polymer (PCP) with Si-C-O structures (ToBeMTech, Korea) was used to fill an open space within the fiber-wound layer. In the experiment, a two-dimensional fiber fabric of Tyranno-Lox M (Ube industry, twill weaved, Japan) was used for the process development. The fabrics were stacked to double layers, and then clamped at both ends, as shown in Fig. 2. The prepared sample was dipped in a PCP-dissolved *n*-hexane and/or divinylbenzene solution. Polymer impregnation was performed under a low vacuum of 60–70 kPa. The immersed fabric was dried and cured in air or in a vacuum at 600°C. The samples were prepared by repeating the impregnation and pyrolysis process three times. Finally, the microstructures were observed using a scanning electron microscope, and mechanical properties were evaluated through a bending test.

Fig. 2. Specimens of SiC-fiber fabric impregnated using a PCP-dissolved *n*-hexane and/or divinylbenzene solution.

The microstructures of impregnated SiC fabrics were observed with respect to different dipping solutions. Fig. 3(a) shows the SiC fabric impregnated using a PCP-dissolved *n*-hexane (HHH). In this case, the PCP was transformed into particle form. Fig. 3(b) shows a composite produced using a PCP-dissolved divinylbenzene (DDD). The precursor polymer was impregnated with a very high density, and does not form particles as shown in Fig. 3(a). Fig. 3(c) shows the composite impregnated using PCP in a mixed solution of *n*-hexane and divinylbenzene (HD). A high degree of packing was observed with both particulate and monolith filling materials.

Fig. 4 shows the corresponding mechanical properties for the samples shown in Fig. 3. The HHH sample showed the highest load bearing, although the density of impregnation was very low. On the other hand, the DDD sample with a very high density showed a sharp decrease in load, meaning a sudden fracture. However, the HD sample with mixed forms of filling materials in its microstructures exhibited a proper bending behavior, i.e. a high initial load and pseudo-ductility.

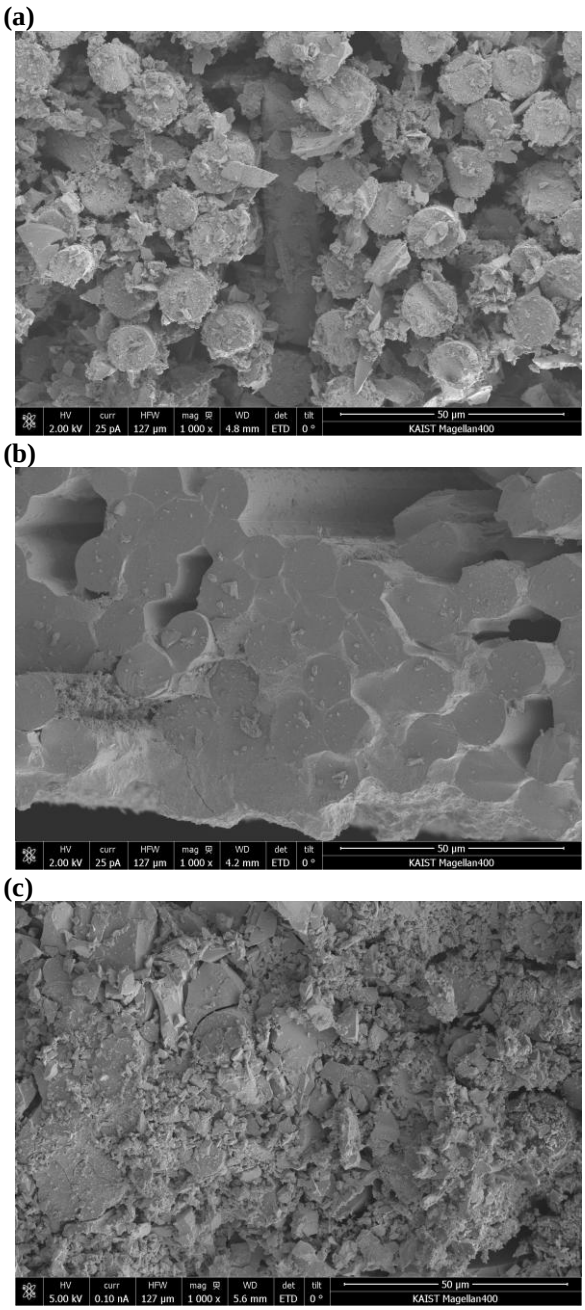

Fig 3. SEM images of SiC fabrics dipped in PCP-dissolved (a) *n*-hexane (HHH), (b) divinylbenzene (DDD), and (c) a mixed solution of *n*-hexane and divinylbenzene (HD), respectively.

3. Conclusions

A preceramic polymer was impregnated into SiC-fiber fabrics with different solvents of n-hexane, divinylbenzene, and mixed ones. According to the microstructural and mechanical properties, a fabric impregnated with a mixed PCP-dissolved solution (HD) showed intermediate characteristics with relative high density of filling as well as proper bending behavior.

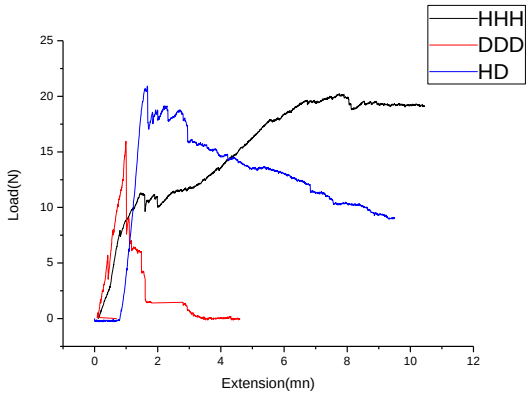

Fig. 4. Mechanical properties measured by a bending test.

Acknowledgment

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