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Impregnation of Si-C-O Preceramic Polymer into SiC Woven Fabric

Sun-Han Kim [a,b], Yang-Il Jung [a,*], Jeong-Yong Park [a], Sun-Ig Hong [b]
[a]*LWR Fuel Technology Division, Korea Atomic Energy Research Institute, 989-111 Daedeok-dearo, Yuseong, Daejeon, 305-353, Republic of Korea*
[b]*Energy Functional MaterialLaboratory, Chungnam National University, 79 Daehangno, Yuseong, Daejeon, 305-764, Republic of Korea*
[*]*Corresponding author: yijung@kaeri.re.kr*

1. Introduction

Commercial nuclear fuel cladding tubes are currently made from various zirconium alloys. These alloys have been used because they show sufficient strength at normal operating conditions and have fairly low neutron capture cross sections. Since the accident in Fukushima, however, high interest has been focused on the stability of nuclear plants during accidents. It is therefore necessary to develop cladding tubes that have enhanced stability in accidents

For existing zirconium alloys, oxidation occurs accompanied by a rapid corrosion when they reach 700–1200℃. Then, their strength abruptly degrades, generating large amounts of hydrogen. On the other hand, SiCs maintain their durability without a strength degradation at up to 1500℃. They do not generate hydrogen since there is no oxidation. Recently, cladding tubes with a metal-ceramic duplex structure are being studied [1,2]. The new tubes form 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, filament winding of SiC fibers on the zirconium alloy cladding tubes, and second, impregnating the polymers between the SiC fibers and the zirconium tube, and in the empty space in the filament wound SiC composite [3]. This study aims at finding the optimal process conditions for the impregnation of polymers using a sol-gel method.

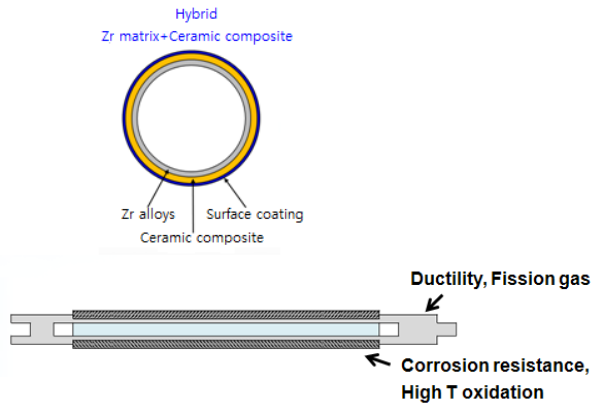

Fig. 1. Schematic illustration of metal-ceramic hybrid fuel cladding tubes.

2. Methods and Results

2.1 Methods

Preceramic polymer (PCP) with Si-C-O structures (Synthesized by a domestic company) was used to fill an open space within 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 (see Fig. 2). Fig. 3 shows the experimental procedure. SiC woven fabric was dipped in a PCP-dissolved *n*-hexane solution. Polymer impregnation was performed under a low vacuum of 20–40 kPa. The immersed fabric was dried in air or in a vacuum at 250℃, and then cured at 750℃.

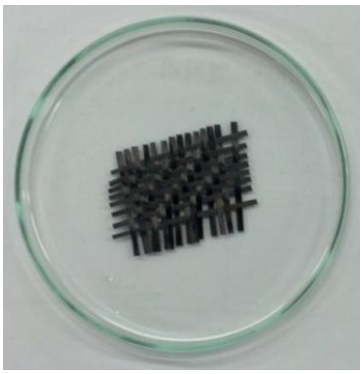

Fig. 2. SiC fabric used in the current study.

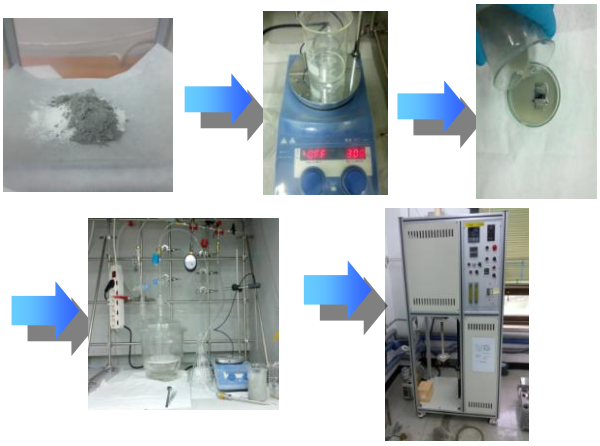

Fig. 3. Experimental procedure for the impregnation

To optimize the conditions for the impregnation of polymers, experiments were performed by varying the conditions, such as the kinds of PCS powder, the concentration of the solution, the curing time, atmosphere (a vacuum, or not) drying, and the curing temperature. Furthermore, SiC nano powder was added, or the filling times were increased. The specimens obtained in this study were investigated and analyzed using a scanning electron microscope.

2.2 Polymer Impregnation

The effect of a vacuum was evaluated using a thermo-gravitational test. Fig. 4 shows the mass changes depending on the temperature rise. The smallest increase in total weight was observed when a vacuum was utilized. The density was also increased in the samples impregnated in a vacuum, as shown in Fig. 5. The PCS solution crystallized during vacuum curing as shown in Fig. 6.

Fig. 7 shows microstructures of SiC fabrics used to compare the multiple runs of impregnation and curing (Fig. 7(b)), and the addition of SiC nano particles as a filler material (Fig. 7(c)). The rate of impregnation increased in proportion to the impregnation time. When SiC nano powder was added, it enhanced the rate of impregnation.

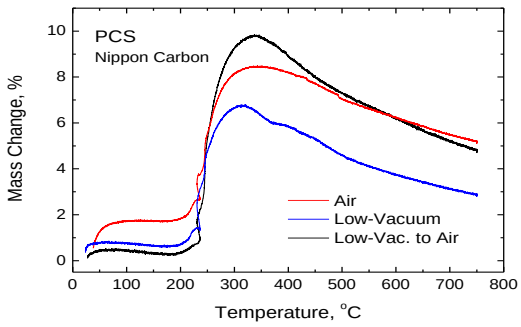

Fig. 4. Mass changes of the used precursor with temperature rising.

(a) (b)

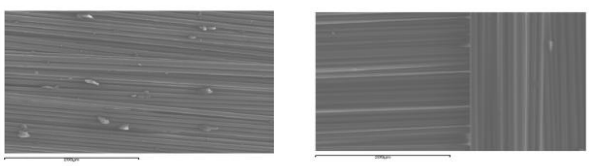

Fig 5. SEM images of SiC fabrics impregnated in (a) air and (b) a vacuum.

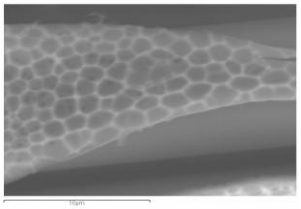

Fig. 6. SEM image of preceramic polymer coated on SiC fiber after curing at 750℃ in a vacuum.

(a) (b) (c)

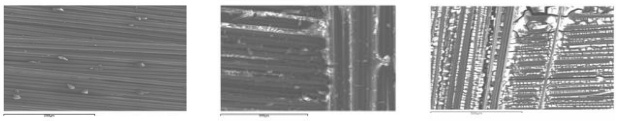

Fig. 7. SEM images of SiC fabrics (a) after one cycle of impregnation and curing, and (b) three repeated cycles, and (c) impregnated with the addition of SiC nano particles.

3. Conclusions

A preceramic Si-C-O polymer was impregnated into SiC-fiber fabrics. The density was increased when the impregnation was performed in a vacuum, as well as when the impregnation was repeated. In addition, nano-sized fillers in the preceramic polymer induced a high level of impregnation density.

Acknowledgment

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REFERENCES

[1] G. Griffith, "U.S. Department of Energy: Accidnet resistant SiC clad nuclear fuel development," INL/CON-11-23186, 2011.
[2] Y.-I. Jung, B.-K. Choi, H.-G. Kim, D.-J. Park, J.-Y. Park, "Metal-ceramic hybrid fuel cladding tubes aiming at suppressed hydrogen release properties," Trans. Korean Nucl. Soc., 2012, May 17-18, Jeju, Korea.
[3] Y.-I. Jung, S.-H. Kim, J.-Y. Park, "Manufacturing process for the metal-ceramic hybrid fuel cladding tube," ibid.