Fabrication of SiC_f/SiC Composite Incorporated with SiC Nanowires for VHTR Applications

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1. Introduction

Nuclear grade SiC fiber-reinforced SiC matrix composite (SiC_f/SiC) is excellent in neutron irradiation resistance, and there is no significant reduction in strength to approximately 1500ºC. Therefore, it is suitable for use as VHTR internal structures which are exposed to high temperature and high neutron irradiation [1,2]. The SiC_f/SiC composite has excellent performance in the reactor core when it has high purity and high density. Since the high purity composite is manufactured by the chemical vapor infiltration (CVI) method, however the density is low and the mechanical strength can be lowered.

Therefore, in this study, we tried to fabricate the high purity SiC_f/SiC composite using the CVI method, and simultaneously we tried to form the SiC nanowire inside the SiC matrix to increase the density.

2. Methods and Results

When the SiC matrix is infiltrated by the CVI method, the SiC is uniformly deposited on the SiC fiber. Therefore, SiC is not well infiltrated in a large space of the fiber preform woven by winding or weaving methods. In order to prevent this phenomenon, SiC nanowires were grown in a large space before the infiltration step, and then SiC was infiltrated into these portions to reduce the porosity.

SiC fabrics woven by Tyranno SA3 SiC fiber were stacked to form a fiber preform and CVD parameter study was performed for nanowire growth using the fiber woven-plate preform. A tubular shaped preform was prepared by a filament winding method, and PyC interfacial material was deposited on SiC fiber. Then the SiC nanowire was deposited on a fiber preform.

The SiC nanowire was deposited at 1000 - 1200ºC and 10 - 100 torr using methyltrichlorosilane (CH_3SiCl_3, MTS).

2.1 Growth Behavior of SiC Nanowire

Fig. 1 shows the distribution of a nanowire formed on the SiC fiber preform with a 2 inch diameter. When the temperature is too low, nanowire was not grown at all. At 10 torr, the diameter of the SiC wire becomes thick, which can result in the freeze chocking phenomenon at the early stage of a CVI process. The most uniform and thin nanowire was formed at 1100℃, 50 torr.

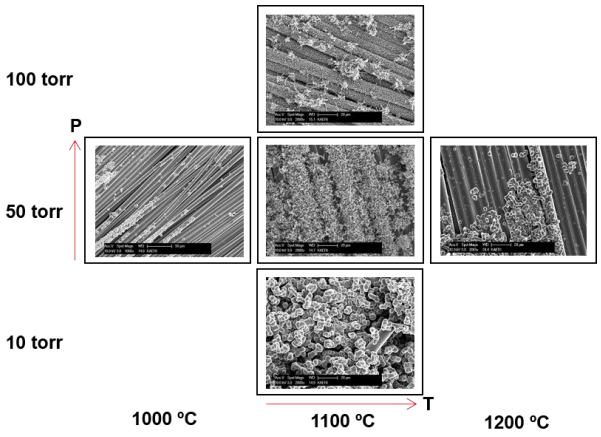

Fig. 1. Growth behavior of SiC nanowire on SiC fiber preform.

Fig. 2 shows the microstructure of nanowires formed under optimized CVD conditions. It can be seen that SiC nanowires of less than 100 nm are formed very uniformly on the fiber preform.

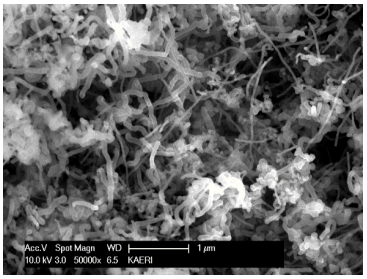

Fig. 2. Microstructure showing nanowires formed on SiC fiber preform deposited at 1100ºC, 50 torr.

2.2 Growth of SiC Nanowires on Tubular SiC Preform

Fig. 3 shows the tubular SiC preform after growing the nanowire using single and multi-nozzle. The nanowires are formed only at the top of the preform because a source gas predominantly passes through the top by the forced-flow CVI process when the single nozzle was applied. To prevent this problem, the total flow rate was increased from 2400 to 3600 sccm, and the source gas was supplied through the multi-nozzle to the side of the SiC preform. As a result, nanowires of the brown color was deposited very uniformly on a 300 mm long tubular preform.

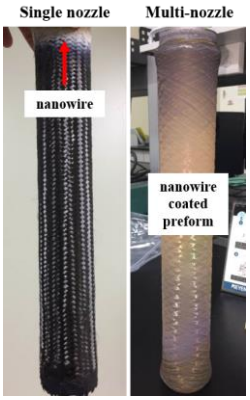

Fig. 3. Nanowire-coated SiC fiber preform prepared using single and multi- gas nozzles.

Fig. 4 shows the microstructure of the SiC nanowire at different positions of the 300 mm long composite preform. It can be seen that a fairly uniform nanowire is formed.

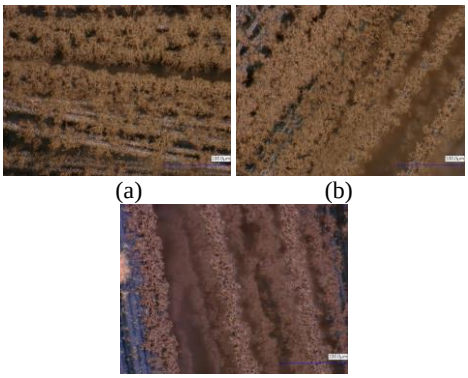

Fig. 4. Nanowire formed on SiC fibers at the (a) top-, (b) middle-, and (c) bottom-side of the SiC fiber preform tube.

2.3 Fabrication of SiC_f/SiC Composite Tube

Fig. 5 shows the microstructure of the SiC_f/SiC composite after infiltrating the SiC matrix on the nanowire-formed preform by the CVI method. The large pores between the SiC fiber bundles are heavily filled by the SiC matrix compared with conventional SiC_f/SiC, which significantly reduces the porosity of the composite.

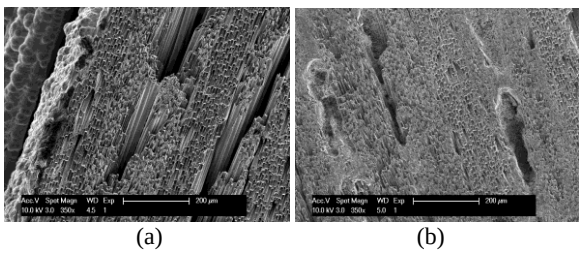

Fig. 5. Microstructures of the SiC_f/SiC composite tube; (a) without nanowire and (b) with nanowires.

3. Conclusions

High density SiC_f/SiC tube with nanowire was fabricated by CVI method. By using the multi-nozzle, it was possible to form homogeneous nanowires on the 300 mm long composite tube by supplying the source gas. The density of the SiC_f/SiC was improved by filling the large pores of the composite with nanowires.

REFERENCES

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[2] Y. Katoh, L. L. Snead, T. Nozawa, T. Hinoki, A. Kohyama, N. Igawa, and T. Taguchi, Mechanical Properties of Chemically Vapor-Infiltrated Silicon Carbide Structural Composites with Thin Carbon Interphases for Fusion and Advanced Fission Applications, Materials Transactions, Vol.46, P. 527, 2005.