HIGH THERMAL CONDUCTIVITY SiC/SiC COMPOSITES FOR FUSION APPLICATIONS -- J. C. Withers, W. Kowbel, and R. O. Loutfy (MER Corp., Tucson AZ); G. E. Youngblood (Pacific Northwest National Laboratory)* and C. Wong (General Atomics, San Diego CA)

OBJECTIVE

The objective of this work is to examine SiC composites fabricated by various processing methods designed to improve composite thermal conductivity. Specifically, it is desired to increase the thermal conductivity of these composites to meet requirements for advanced fusion energy systems.

EXTENDED ABSTRACT

SiC/SiC composites are considered for fusion applications due to their neutron irradiation stability, low activation, and good mechanical properties at high temperatures. The projected magnetic fusion power plant first wall and the divertor will operate with surface heat flux ranges of 0.5 to 1 and 4 to 6 MW/m^2, respectively. To maintain high thermal performance at operating temperatures the first wall and divertor coolant channels must have transverse thermal conductivity values of 5 to 10 and 20 to 30 W/mK, respectively [1]. For these components exposed to a high energy neutron flux and temperatures perhaps exceeding 1000°C, SiC/SiC composites potentially can meet these demanding requirements. The lack of high-purity SiC fiber and a low through-the-thickness (transverse) thermal conductivity are two key technical problems with currently available SiC/SiC. Such composites, for example produced from Nicalon™ fiber with a chemical vapor infiltrated (CVI) matrix, typically exhibit a transverse conductivity value of less than 8 W/mK (unirradiated) and less than 3 W/mK after neutron irradiation at 800°C [2].

A new SiC/SiC composite fabrication process has been developed at MER. First, a carbon/graphite precursor fabric is directly converted to a high-purity SiC fabric by using a chemical vapor reaction (CVR) process. A matrix of crystalline SiC is added by a hybrid CVI-polymer infiltration and pyrolysis (PIP) process. Crystalline matrix conversion is enhanced by B-doping the starting liquid polymer prior to infiltration and pyrolysis. Because of the high thermal stability of the CVR-reacted SiC fabric, high temperature anneals can be used to further enhance the composite thermal and mechanical properties. For instance, Figure 1 compares the stress-strain curves from 4-pt. bend tests for SiC/SiC made with CVR converted SiC fabric with either a standard CVI matrix or two different hybrid PIP/CVI matrices. The two PIP/CVI matrices were fabricated with either a 3- or 6-cycle PIP infiltration followed by a final heat treatment at 1400°C. The composite with a CVI matrix alone exhibited low strength and brittle fracture. In contrast, both composites with PIP/CVI hybrid matrices exhibited much higher bend strengths and non-brittle fracture. These latter curves are comparable to curves obtained for conventional 2D plain weave Nicalon/CVI composites [2].

In Figure 2, the effect of heat treatment temperature and doping on the measured room temperature thermal diffusivity for the 3-cycle PIP processed composite are illustrated. For reference, the thermal diffusivity values of Nicalon/CVI and Nicalon/PIP without doping or heat treatment also are given. Heat treatment more than doubles the thermal diffusivity values of either the doped or undoped CVR-fiber/PIP matrix composites, while doping alone appears to also double these values. Notably, the thermal diffusivity values of the doped and heat treated CVR-fiber/PIP composite are more than double that of the Nicalon/CVI reference material. Further optimization of the thermal transport properties is achieved when additional PIP infiltration cycles and a final CVI treatment are included. As an example, a RT thermal diffusivity value of 0.28 cm^2/s, equivalent to a thermal conductivity value of 45 W/mK, has been attained. This value indicates

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that by using a combination of doping and heat treatment methods, SiC/SiC thermal conductivity can be improved sufficiently to meet the thermal transport goals for potential use in a high flux radiation environment. Future work will be directed to testing the thermal performance of these materials after irradiation.

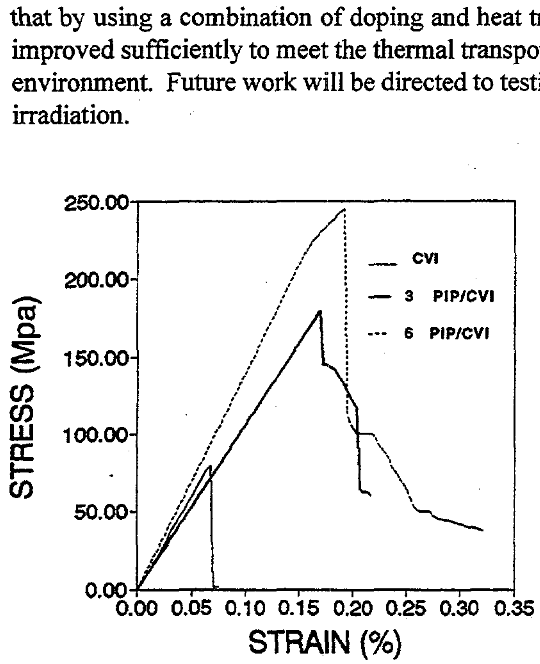

Figure 1. Comparison of stress-strain curves for SiC/SiC made by three different processes. The two PIP/CVI materials each had a final 1400°C heat treatment.

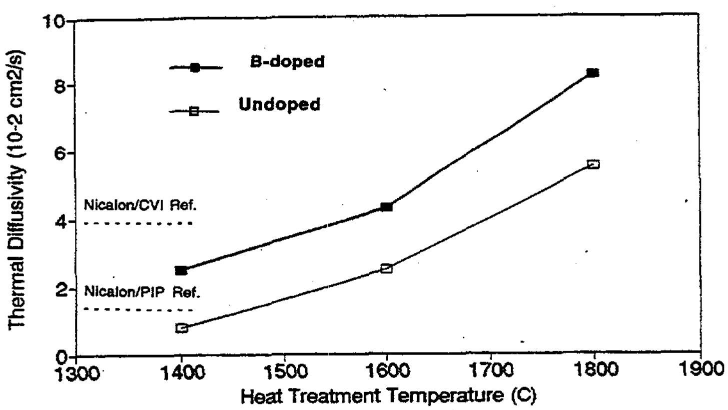

Figure 2. Effect of heat treatment on RT thermal diffusivity of undoped and boron-doped SiC/SiC composites made using 3 PIP cycles. For reference, the RT thermal diffusivity values of conventional Nicalon/CVI and Nicalon/PIP composite materials are shown.

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REFERENCES

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