§32. Development of SiC Material for Flow Channel Insert in Liquid Blanket System

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Silicon carbide fiber reinforced silicon carbide matrix (SiC/SiC) composites are considered as functional-structural materials for advanced energy systems, because of their excellent thermal, mechanical and chemical stability, and the exceptionally low radioactivity following neutron irradiation. In particular, flow channel inserts (FCIs) made of SiC/SiC composites were proposed as a means for thermal-electrical insulation between the flowing liquid metal and the load-carrying channel walls to reduce the MHD pressure drop in the dual-coolant lead lithium blanket channels of fusion reactors.

In this collaborative study, electrical and thermal conductivities of NITE-SiC/SiC composites (NITE: Nano-Infiltration and Transient Eutectic-phase) have been examined. The materials were fabricated at Kyoto University. SiC/SiC composites consist of three constituents: SiC fiber, SiC matrix and Carbon interface layer. In the present study, electrical and thermal conductivities of the SiC/SiC composites have been examined focusing on their dependencies of SiC fiber orientations. Two-dimensional oriented SiC fibers (2D) were used for fiber reinforcement. The SiC fibers volume fraction was approximately 40 %. Electrical measurements were performed for the parallel and perpendicular directions to the SiC fibers. Gold electrodes were put and connected to a current source and voltmeter. In this work, four-terminal method was applied to measure electrical conductivity parallel to fiber direction as shown in Figure 1. The electrical conductivity was measured at ambient temperature and at 450 ºC through around 700 ºC. Thermal conductivities were measured by the laser flash method for the parallel and perpendicular directions. The laser flash method relies on the generation of a thermal pulse on one face of a thin sample and the recording of the temperature history on its opposite face. The thermal diffusivity can be determined from the time required to reach one-half of the peak temperature in the temperature rise curve on the rear surface. The thermal conductivity was measured at ambient temperature through 1200 ºC.

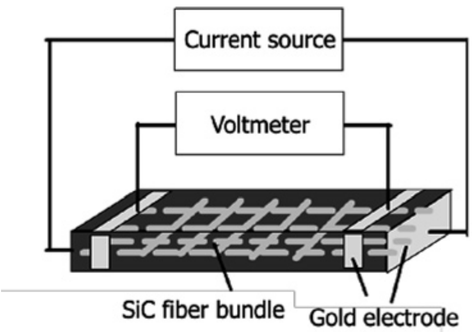

Figure 1: Schematic of electrical conductivity measurement for SiC/SiC composites by four-terminal method

Figure 2 shows the relationship between electrical conductivity of the NITE-SiC/SiC composites and measured temperature. The figure also includes results for various monolithic SiC and joined SiC reported in previous works. The electrical conductivities at ambient temperature were 3.1 × 10^3 S/m for the direction parallel to fiber reinforcement and 5.1 × 10^2 S/m for the direction normal to fiber reinforcement, although the electrical conductivity normal to fiber reinforcement direction was measured by two-terminal method. The electrical conductivity parallel to fiber reinforcement direction increased with increment of measured temperature and was 4.0 × 10^3 S/m at 708 ºC. The activation energy was determined as 0.017eV. The thermal conductivities at ambient temperature were 65 W/mK for the direction normal to fiber reinforcement and 61 W/mK for the direction parallel to fiber reinforcement. The thermal conductivity normal to fiber reinforcement direction decreased with increment of measured temperature primary due to phonon scattering and was approximately 10 W/mK at 1200 ºC.

It is considered that the SiC matrix dominates the thermal conductivity in the SiC/SiC composites. On the other hand, the anisotropic results in the electrical measurements imply that the electrical conductivities were affected by the carbon interfacial layers. Temperature dependence of NITE-SiC/SiC composites for electrical conductivity was limited, although NITE-SiC/SiC composites showed much larger electrical conductivity compared with the other monolithic SiC. The electrical conductivity was above the value required for the design. However electrical conductivity of SiC can be controlled in very wide range and joining with the other SiC with smaller electrical conductivity is also a realistic option. It isn't difficult issue to achieve design required electrical conductivity.

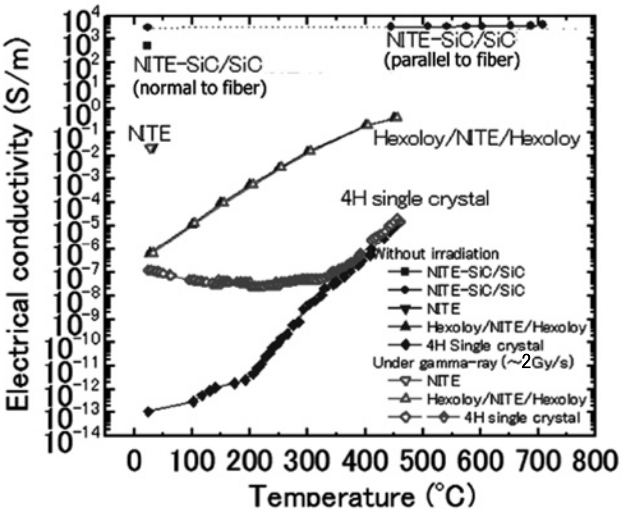

Figure 2: Temperature dependence of electrical conductivity of various SiC materials