§4. Effect of Constituents on Thermal and Electrical Conductivity of SiC/SiC Composites

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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 (FCI) made of a SiC/SiC was 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.[1)] Additionally, recent improvement in the crystallinity and purity of SiC fibers and improved composite processing has improved physical and mechanical performance under harsh environments. The novel processing called Nano-powder Infiltration and Transient Eutectic-phase (NITE) Processing has been developed based on the liquid phase sintering process modification.[2)] The NITE processing can achieve both the excellent material quality and the low processing cost. Recently, application of SiC/SiC is expanding. Various ranges of properties are required in particular for thermal and electrical conductivity.[3)] One of important advantages for SiC/SiC is tailorability. Properties of SiC/SiC can be controlled by constituents and their volume fraction. It is known that electrical conductivity of SiC was affected by fabrication conditions and impurities significantly. The objective of this work is to obtain fundamental knowledge regarding effect of the constituents on thermal and electrical conductivity of SiC/SiC composites and tailorability of the thermal and electrical conductivity.

The material used was high purity single-crystal SiC (Cree Inc., $10\times10\times0.39$ mm^3), monolithic SiC ($10\times10\times1$ mm^3), and sandwich material of monolithic NITE SiC/Hexoloy SA SiC ($10\times10\times1$ mm^3). Electrical conductivities of these materials were measured in the ^{60}Co γ-ray irradiation facility at the Institute of Scientific and Industrial Research, Osaka University, from room temperature to 450 °C. Dose rate calculated by the Monte Carlo N-Particle Transport Code (MCNP) was 2.3 Gy/s. To evaluate electrical conductivity, a center electrode and a guard electrode were made on the surface by Pt sputtering for current measurement and prevention of the leakage current through the side surface, respectively. On the other surface, an electrode was made for voltage supply. The conductivities were examined by measuring the induced current through the bulk of the specimens. Thermal conductivities of each material were measured by laser flash method at the Institute of Advanced Energy, Kyoto University.

Fig.1 shows the temperature-dependent properties of the electrical conductivity. In the case of high purity single-crystal SiC, conductivity increase by the irradiation (Radiation Induced Conductivity; RIC) was relatively large. However the RIC decreased with temperature increase and electrical conductivity was determined by the thermal excitation at high temperature.

Although NITE and NITE/Hexoloy has high electrical conductivity at non-irradiation, RIC was not seen. Electrical conductivity of the SiC FCI in Dual-Coolant Lead Lithium (DCLL) blanket module requires below 100 S/m. The current result shows that RIC is not impediment to electrical insulation properties of the SiC FCI. Controlling of the electrical conductivity at high temperature becomes of particular importance.

Thermal conductivity of the NITE, Hexoloy, and NITE/Hexoloy at room temperature was 27 Wm/K, 98 Wm/K, and 47 Wm/K, respectively. Thermal conductivity of the joining material was dominated by the lowest thermal conductivity layer. It is reported that the thermal conductivity under neutron irradiation environment decreases, although it depends on irradiation temperature. However, the thermal conductivity of current SiC/SiC composites is higher than the expected value. Therefore, modification of constituents or combination with low thermal conductivity material is required.

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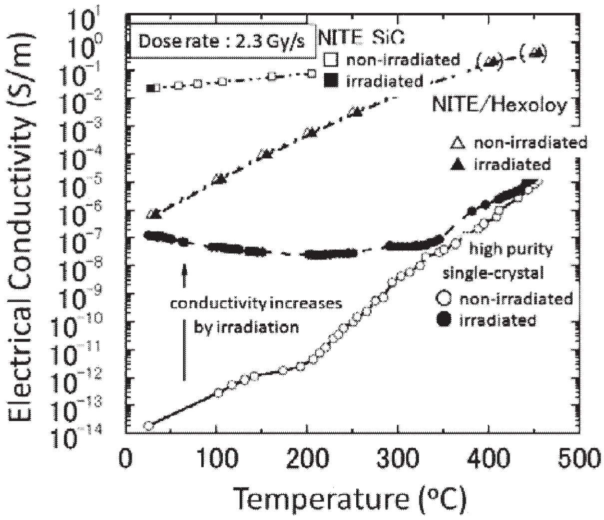

Fig. 1. Temperature dependence of electrical conductivity on SiC ceramics

1) Tillack, M. et al.: Proceedings of the 17th IEEE/NPSS Symposium Fusion Engineering (1997) 1000.
2) Hinoki, T. et al.: Annales de chimie science des matériaux, **30[6]** (2005) 659-671.
3) Abdou, M. et al.: Fusion Science and Technology, **47[3]** (2005) 475-487.