# §9. Development of Joint Technique of SiC/SiC Composites

Hinoki, T., Park, J., Jung, H. (Institute of Advanced Energy, Kyoto Univ.),
Tanaka, T., Muroga, T.

Silicon carbide composites (SiC/SiC) are considered for use in extremely harsh environments at high temperature primarily due to their excellent thermal, mechanical and chemical stability, and the exceptionally low radioactivity following neutron irradiation. In particular, recent improvement in the crystallinity and purity of SiC fibers and improved composite processing have 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. The NITE processing can achieve both the excellent material quality and the low processing cost. The important issues to use the NITE SiC/SiC for industry are development of joining technique. Several kinds of joining techniques have been developed for SiC and SiC/SiC using polymer, glass-ceramics and reaction bonding. One of the keys for the development is the stability of the joining at application temperature. Using a SiC for joint of SiC or SiC/SiC has the advantage at the high temperature due to the no coefficient of thermal expansion (CTE) mismatch. The objective of this work is to develop joint technique for SiC and SiC/SiC composites using the SiC formed by modification of NITE processing. Sufficiently strong joining had been achieved by the joining condition of over 20 MPa and 1800 °C until last year. Considering real application, flexibility of joining conditions was studied in this year. Effect of joining on physical properties was also evaluated.

The substrate material for joining was Hexoloy® SA SiC (sintered α-SiC) and SiC/SiC composites fabricated by NITE processing. The substrates with dimension 23 mm (long) ×were machined from plate. The faces with 38 mm (wide) × 3 mm (thick) of the substrate SiC were joined with the slurry including SiC nano-powder (<20nm) and the sintering additive of $Al_2O_3$, $Y_2O_3$, $SiO_2$. They were hot-pressed at 1400-1800 ºC with the pressure of 5-20 MPa in Ar environment. Butt joint was applied to the plate and joining bars of 46 mm (long) × 2.7 mm (wide) × 3 mm (thick) were machined from the plate for mechanical tests. Mechanical properties of the joint were evaluated using the bars by tensile test according to ASTM C1275 and asymmetric four points bend test according to ASTM C1469. The specimens were gripped using a pair of wedge-type grips. The grips were connected to the load train using universal joints to promote self-alignment of the load train during the movement of crosshead and to reduce unwanted bending strains in the specimen. All tests were conducted at a cross-head speed of 0.3 mm/min at ambient temperature. Asymmetric four point flexural test was conducted using the same specimen for the tensile test. Inner span and outer span of the asymmetric four points test were 8 mm and 44 mm, respectively. The microstructure of joining interface and fracture surfaces following mechanical test were observed by optical microscopy (OM) and field emission scanning electro microscopy (FE-SEM), and analyzed by energy dispersive X-ray spectroscopy (EDS). Thermal conductivity and electrical conductivity were measured for joined materials, substrate and the bulk material fabricated at the same condition for joining at ambient temperature.

Densification wasn't sufficient at processing condition of less than 1600 °C due to insufficient grain growth. Silicon carbide substrates were successfully joined. Joining strength increased with increasing of processing temperature. Although the real strength of the joint was not obtained, the tensile strength and the shear strength at processing condition of 1800 °C were over 250 MPa and over 115 MPa, respectively. Joining strength was insensitive to processing pressure compared with processing temperature. The tensile strength and the shear strength were 190 MPa and 110 MPa, respectively even at processing condition of 5MPa. Specimens fabricated without processing pressure failed very easily. Figure 1 shows thermal conductivity of the reference material for joint region, the substrate material and the joint material. The thickness of the joint material is 1 mm with joint region of 0.1 mm. Thermal conductivity of the joint material was reduced to half approximately due to low thermal conductivity of the joint region. Electrical conductivity of the joint material was much higher than that of the substrate. Electrical resistivity of the joint material was close to that of the substrate due to too much difference of electrical conductivity of the joint region and the substrate. Both thermal conductivity and electrical conductivity of the joint materials were consistent with the results for constituents. This result also suggests that thermal conductivity and electrical conductivity can be controlled using the joining technique without significant change of mechanical properties.

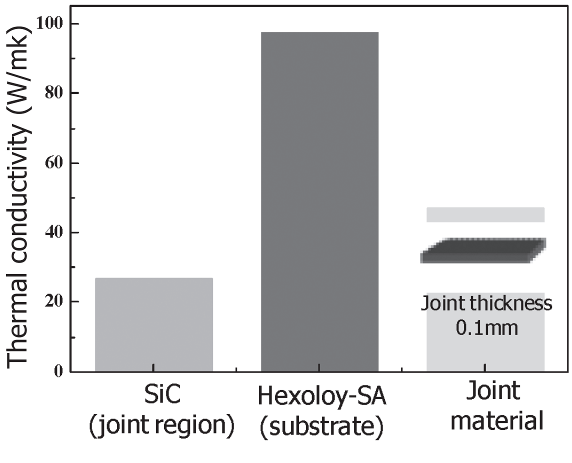

Figure 1: Thermal conductivity of the reference material for joint region, the substrate material and the joint material