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

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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[1]. The novel processing called Nano-powder Infiltration and Transient Eutectic-phase (NITE) Processing has been developed based on the liquid phase sintering (LPS) process modification[2]. The NITE processing can achieve both the excellent material quality and the low processing cost. The important issues to use the NITE SiC/SiC composites 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 key for the development is the stability of the joining at application temperature. Using a SiC for joint of SiC or SiC/SiC composites 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.

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 1800 ℃ with the pressure of 15-30 MPa in Ar environment. Butt joint was applied to the SiC bars and 46 mm (long) × 2.7 mm (wide) × 3 mm (thick) bars were obtained 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. For the tensile test, the gauge section was 20 mm-long in the middle of the specimen. 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).

Silicon carbide substrates were successfully joined. No concentration of sintering additive and no pores were observed. Both in tensile test and asymmetric four point bend test, the joint processed at optimized condition didn't fail at the joint but at substrates. Although the real strength of the joint was not obtained, the tensile strength and the shear strength were over 250 MPa and over 115 MPa, respectively. The other test method or the notched specimen at the joint is required to evaluate real strength. The joint obtained in this method is sufficiently strong compared with the other joint for SiC or SiC/SiC composites[3] and further improvement to increase joint strength is not required. The issue for this joint is to evaluate flexibility of process for realization.

SiC/SiC were also joined using the same technique. Figure 1 shows a SEM image of the joined interfaces for NITE-SiC/SiC. No pores were observed like the joint for monolithic SiC. The tensile strength and the shear strength were 166 MPa and 103 MPa, respectively, and sufficiently strong compared with the other joint for SiC or SiC/SiC composites[3]. However concentration of sintering additive was observed at interface between joint and substrates. The effect of the concentration on the mechanical strength was not obtained. Further improvement to reduce the concentration might be required.

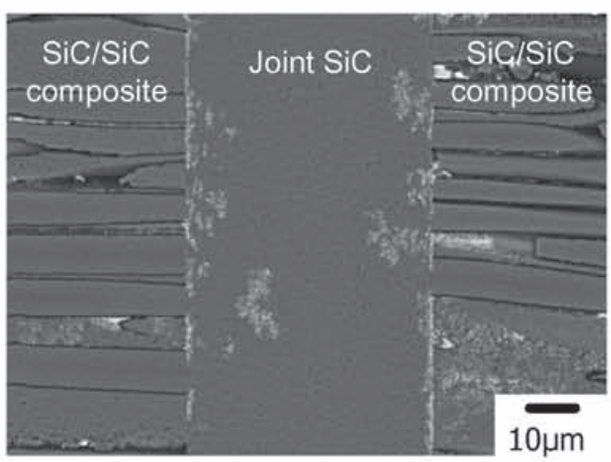

Figure 1: SEM Image of interface of joint for SiC/SiC composites

References
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2) Kohyama, A. et al.: Ceramic Transactions, 144 (2002) 3-18.
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