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

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SiC/SiC composites 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 composites using polymer, glass-ceramics and reaction bonding. One of the key for the development is the stability of the joining at application temperature. Using the 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 modifying 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) × 2.7 mm (wide) × 3 mm (thick) were machined from plate. The substrate SiC bars 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 formed. Mechanical properties of the joint were evaluated using the bars by tensile test according to ASTM C1275 and asymmetric four points bend 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 and fracture surfaces following mechanical test of the joint, coating and their interfaces 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 with forming thin NITE-SiC of approximately 10 μm-thick at interface. Figure 1 shows the backscattering image of the joint. No concentration of sintering additive was seen, while small white dots including the sintering additive were observed. In tensile test, specimens failed at the joint. The tensile strength was approximately 40 MPa on average, while relatively large scatter of data was seen. Apparent shear strength was approximately 50 MPa on average with relatively small scatter of data. Indeed the specimens did not fail at the joint. Actual shear strength was more than 50 MPa. The other test method or the notched specimen at the joint for the asymmetric four point flexural test is required to evaluate actual shear strength.

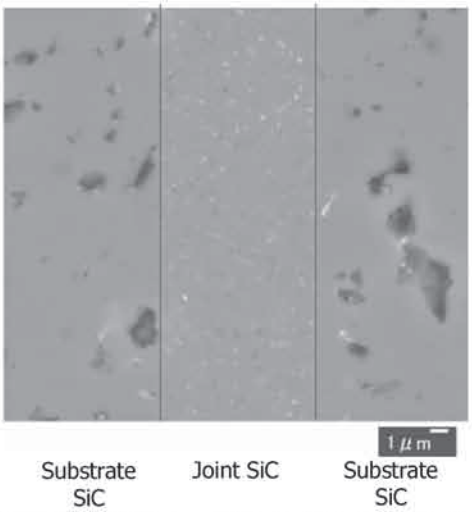


Figure 1: SEM Image of interface of joint of monolithic SiC

Fracture surfaces following the tensile test were observed. It was found the joint had approximately 40 % of porosity including the large pore, which might induced the stress concentration during the loading. The reason of the relatively small tensile strength of 40 MPa for SiC was due to the large non-bonded region, although even with the large porosity and the stress concentration the joint showed large strength compared with the other joint for SiC or SiC/SiC composites[3].

SiC/SiC composites were also joined using the same technique. The processing conditions were not optimized, and it showed similar tensile strength with the strength for monolithic including 40 % porosity at interface. Major difference of SiC/SiC composites from monolithic SiC for joint is the surface roughness. Pores were likely to appear compared with the joint for monolithic SiC.

References

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3) Katoh, Y. et al.: J. Nucl. Mater., 283-287 (2000) 1262-1266.