§ 10. Technical Evaluation of SiC Ceramic-Based Plasma Facing Components

Kohyama, A., Katoh, Y., Nozawa, T. (Kyoto Univ.)
Noda, N., Muroga, T.

Silicon carbide (SiC) -based ceramics and composites are potentially attractive materials for plasma-facing components in fusion devices due to their superior radiation-resistance, reduced activation and low after-heat properties and heat-flux capacity. The objective of this work is, through technical evaluation of SiC fiber-reinforced SiC matrix composites (SiC/SiC composites), to identify engineering issues for this material class for fusion plasma-facing applications.

For this purpose, a reference fusion-grade SiC/SiC composites, which are chemically vapor-infiltrated high-crystallinity near-stoichiometric SiC fiber composites, and an innovative SiC/SiC composites produced through NITE (nano-infiltration and transient eutectic-phase) process, developed by the present authors at Kyoto University, were evaluated in terms of elevated temperature properties after establishing respective processing techniques for tile-shaped components (NITE SiC/SiC tile is shown in Fig.1) with which an employment as first wall armors and/or divertor panels in the Large Helical Device (LHD) is assumed. Additionally, fundamental studies on issues for refractory metal-armored SiC/SiC composites had been initiated.

In the trial-fabricated NITE SiC/SiC tile, an apparent mass density of $2.7 g/cm^3$ was achieved. This densification to about 85% is not very encouraging and attributed to insufficient matrix slurry infiltration to fiber bundle interior during the prepreg processing. The room temperature flexural strength was measured to be about 500MPa, which corresponds to 70% of that for lab-grade materials. Nonetheless, the material exhibited pseudo-ductile fracture behavior with a second-linear extension in its stress-strain curve. The fractography presented in Fig.2 confirms rather sound pull-out of reinforcements but at the same time reveals another engineering issue in fiber packing density.

Figure 3 shows the comparison of elevated temperature tensile properties with room temperature properties for the reference CVI SiC/SiC and the pilot-NITE SiC/SiC. The result clearly indicates that the NITE SiC/SiC does not degrade its mechanical properties at 1573K in mildly-oxidative environment, owing to the superior corrosion resistance of individual composites' constituents.

For the refractor-armor development, a novel technique for thick tungsten coating on SiC/SiC composites at a reduced process cost was pursued. A co-sintering of 'NITE'-blend SiC raw materials and pure tungsten powder yielded in strongly-bonded coating that is free from macroscopic flaws. Detailed metallographic and chemical analysis suggested further need of understanding reaction-control kinetics and methodology for an improved combination of bonding strength, quality of sintered coating layer and interfacial thermal conductivity.

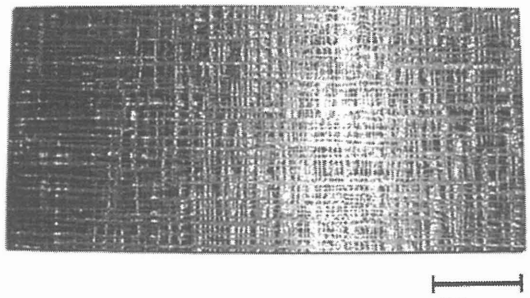

Fig.1 – Appearance of a SiC/SiC tile that has been trail-fabricated through NITE process.

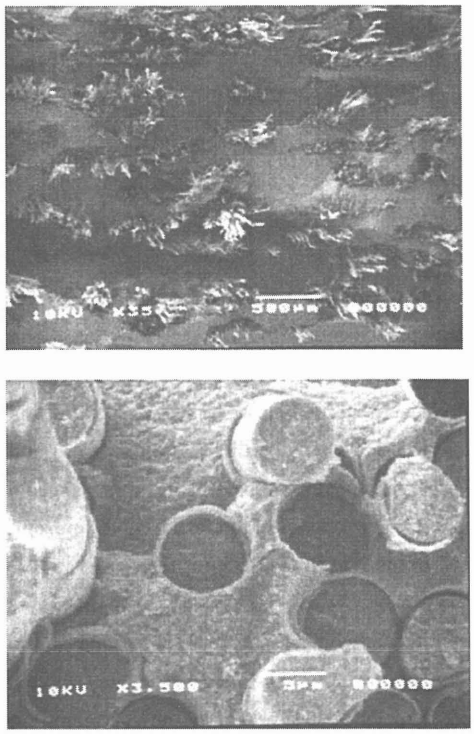

Fig. 2 – Scanning electron micrographs showing pseudo-ductile fracture surfaces of pilot commercial grade NITE-SiC/SiC tile.

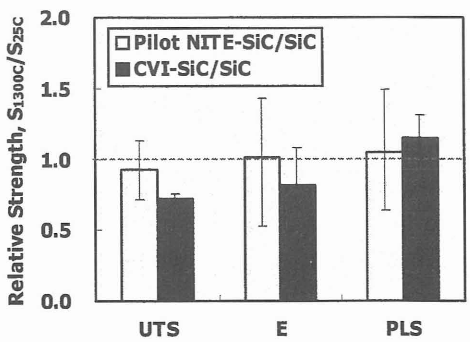

Fig. 3 – Relative retention of ultimate tensile strength (UTS), tensile modulus (E) and proportional limit stress (PLS) at 1573K in commercial argon environment.