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

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Silicon carbide (SiC) fiber-reinforced SiC-matrix ceramic composites (SiC/SiC composites) produced through Nano-Infiltration and Transient Eutectic-phase (NITE) process were evaluated in terms of thermo-mechanical properties for potential application to fusion blanket / first wall structures. The composites produced by a technique incorporating a nano-infiltration and the optimized transient eutectic phase process demonstrated strength, fracture behavior, thermal conductivity and microstructure which are promising for applications in fusion blankets.

The composites were fabricated using Tyranno™-SA grade-3 polycrystalline SiC fibers (Ube Industries Ltd., Ube, Japan) in a uni-directional (U/D) architecture. Pyrolytic carbon (PyC) interphase was deposited on the fiber surface through chemical vapor deposition. The matrix was formed through a transient liquid-phase sintering of mixed powder of nano-phase beta-SiC and small amount of sintering additives. Uni-axial pressure of <20MPa was applied during sintering at 1720~1800°C. Mechanical properties were evaluated by tensile tests. The thermal diffusivity was measured in a through-thickness direction for selected samples in a temperature range of 19~1200°C in vacuum.

As for the mechanical (tensile) property, very significant stress increases beyond the proportional limit stresses were observed for all the nano-infiltrated composites, as shown in Fig.1. Both the ultimate tensile stress and the proportional limit stress increased with the increasing process temperature. This shows that the enhanced matrix densification through a sufficient matrix sintering is beneficial at least in terms of fast fracture properties and significant damage is not occurring to the fibers even at the harshest process condition employed. The pseudo-ductility of sub-micron particulate-loaded composites was not as encouraging as of the nano-infiltrated composites probably due to the fiber damages during processing. The fractography supported this interpretation, where a brittle fracture mode was dominating for the cases of sub-micron powder-loaded composites after sintering at 1780C.

The thermal stress figure of merit (M) of the NITE composite is plotted against temperature in Fig.2 along with those for other candidate fusion blanket materials. The M values are derived by the inset equation in the figure. The NITE-SiC/SiC composite exhibited the M value superior to any other material in all the temperature ranges. However, the composite's thermal conductivity appeared far below that of the typical liquid phase-sintered monolithic SiC sintered at the same temperature, in spite of the inclusion of high thermal conductivity fibers, indicates that the presence of intra-bundle pores and grain boundaries are hampering

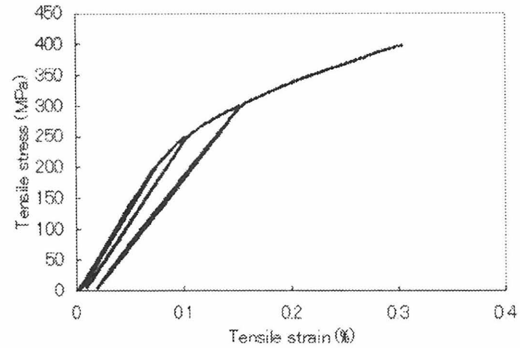

Fig.1 – Tensile stress-strain property of NITE-SiC/SiC composite. Proportional limit stress and ultimate tensile strength of 200MPa+ and 400MPa, respectively, are attained.

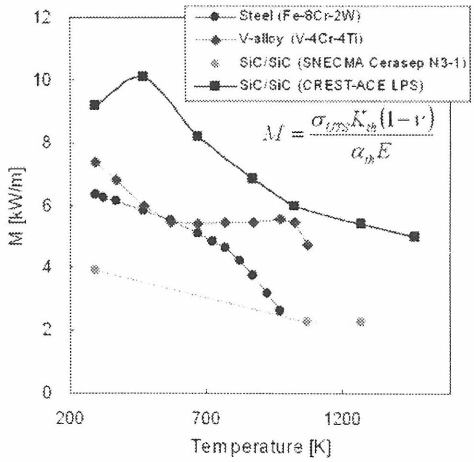

Fig.2 – Comparison of thermal stress figure of merit of NITE(indicated as LPS) –SiC/SiC with those of other candidate fusion blanket materials.

the composite's thermal conductivity. Further thermal conductivity improvement will be attained through improved processing technique development.

In conclusion, SiC/SiC composites produced through NITE process appeared very promising in terms of thermo-mechanical properties. The thermo-mechanical properties will be tailorable by controlling the matrix structure through varying the sintering temperature and time. Microstructural control in the matrix and interfaces for improved or tailored composite properties remains for future work. Creep resistance at elevated temperatures needs to be evaluated to be considered for structural applications.

References

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