PREPARATION OF SHORT CARBON FIBER/SiC MULTILAYER COMPOSITES BY TAPE CASTING

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Introduction

Silicon carbide (SiC) is one of the most promising materials for thermal protection system (TPS) of future reusable spacecraft. However, its low fracture toughness remains a major concern for its widely application in severe environment. SiC-based CMCs with long carbon fibers display improved toughness. However, owing to the matrix porosity, they easily undergo oxidation and then need tailored surface coatings for application as TPS of space vehicles.

As an alternative, also short C fiber reinforced SiC composites (C_{sf}/SiC), processed by hot-pressing [1] or spark plasma sintering [2]. Processing ceramics with a multilayer structure is another effective method to improve the toughness of ceramic materials [3, 4] and multilayer SiC, showing self-passivating behavior, has been proposed as an oxidation-resistant components of TPS [5].

The authors have been exploring the possibility to prepare, by tape casting, sheets of C_{sf}/SiC composites, to be stacked in a multilayer structure and finally submitted to pressureless sintering. Such a kind of processing path could provide an alternative method for C_{sf}/SiC composite preparation; different C_{sf}/SiC layers could also be integrated in a SiC-based multilayer TPS, in order to optimize its thermal conductivity behavior. Preliminary investigation about processing method, microstructure and properties of these multilayer C_{sf}/SiC composites is presented in this paper.

Experimental

SiC multilayer and C_{sf}/SiC multilayer composite specimens were fabricated by exploiting the tape casting technique. The processing method involved the following steps: SiC slurry preparation, fiber dispersion, mixing of the fibers with the SiC slurry, tape casting, debinding and pressureless sintering. The detailed method for the SiC slurry preparation was previously reported [5, 6].

The fiber dispersion was observed by optical microscope. The density of the sintered samples was measured according to Archimedes' Principle. The microstructure and fracture surface of SiC and C_{sf}/SiC specimens were observed by scanning electron microscope (Zeiss Supra 25 Field Emission Scanning Electron Microscope).

Results and Discussion

Fibers were dispersed in a solvent by using ultrasonic method. The dispersing effect of BYK-163, BYK-410, BYK-2150, BYK-9076, BYK-9077 (BYK Additives & Instruments) and Triton X100 (Sigma-Aldrich) on short C fiber (Toho Tenax HTC124) was compared, as shown in Fig.1a, b, c, d, e and f, respectively. Nonionic surfactant Triton X100 gave the best dispersion result (Fig.1f).

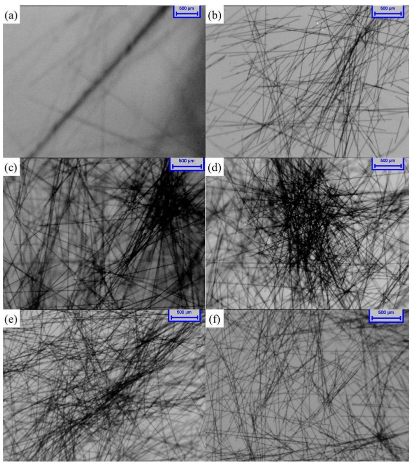

Fig.1 Effect of dispersants (1 wt.%) on fiber (0.075 vol%) in mixture of ethanol and butanol: (a) BYK-163, (b) BYK-410, (c) BYK-2150, (d) BYK-9077, (e) BYK-9076, (f) Triton X-100.

The fracture surface of C_{sf}/SiC multilayer composites (5vol%) after de-binding is shown in Fig.2. Fiber bundles were not observed, which means that the fiber are homogeneously distributed in the tape. Moreover, the fibers tend to align fairly well along the tape casting direction, since orientation of fibers in different directions was rarely observed.

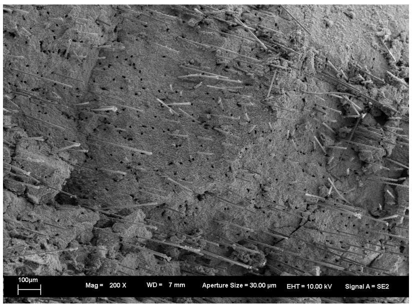

Fig.2 Fracture surface of 5vol% C_{sf}/SiC multilayer composites after debinding.

Density and shrinkage of SiC multilayer and C_{sf}/SiC multilayer composites are listed in Table 1. It is well evident that the addition of short C fiber inhabited the shrinkage in the plane containing fiber during sintering.

Table 1 Density and shrinkage of the SiC and C_{sf}/SiC multilayer composites.

Materials	Fibre content (vol%)	Relative density (%)	Shrinkage (%)		
			Length	Width	Thickness
SiC multilayer	—	69.456	13.76	16.77	18.83
C_{sf}/SiC multilayer composites	5	70.25	7.18	16.45	32.89
	10	72.75	5.60	11.92	35.38
	15	70.54	3.68	11.25	33.69

The resulting residual porosity would be detrimental to mechanical properties. Therefore, the sintering process should be improved for application requiring high mechanical strength. This last result could be achieved by applying pressure during sintering, optimizing other sintering parameters or using more effective sintering aids.

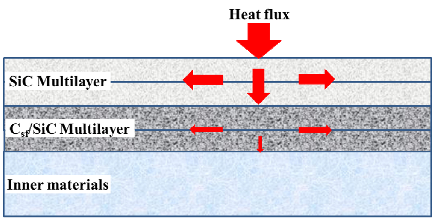

Fig.3 Prospective application of C_{sf}/SiC multilayer composites for thermal protection system.

On the other hand, for thermal protection systems, which do not require high mechanical strength, the residual porosity would be beneficial to decrease of thermal conductivity through the thickness. Therefore, this kind of composite layers could be integrated in a thermal protection system structure designed as shown in Fig.3. The outer dense SiC layers are expected to provide excellent oxidation resistance and good heat conductivity in the plane. The C_{sf}/SiC layers in the middle of the multilayer architecture could grant acceptable thermal conductivity in plane and low conductivity through the TPS thickness.

Conclusion

Nonionic surfactant Triton X100 proved to be the best dispersing agent for the C fibers under investigation. Short C fibers distributed uniformly in the green tape and aligned themselves along the tape casting direction. Addition of short C fibers hindered the shrinkage during sintering and resulted in enhanced residual porosity. This last feature could be exploited by integrating the porous C_{sf}/SiC multilayer composites in TPSs, with the aim of improving their insulation capability through the thickness without decreasing the thermal conductivity in the plane.

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References

[1] X.L. He, Y.K. Guo, Z.M. Yu, Y. Zhou, D.C. Jia. *Mater. Sci. Eng., A*. 527 (2009) 334–338.

[2] Y.S. Ding, S.M. Dong, Z.R. Huang, D.L. Jiang. *Ceram. Int*. 33 (2007) 101–105.

[3] W.J. Clegg, K. Kendall, N. McN. Alford, T.W. Button, J.D. Birchall. *Nature*. 347 (1990) 455–457.

[4] M. Pavese, P. Fino, A. Ortona, C. Badini. *Ceram. Int*. 34 (2008) 197–203.

[5] S. Biamino, V. Liedtke, C. Badini, G. Euchberger, I. Huertas Olivares, M. Pavese, P. Fino. *J. Eur. Ceram. Soc.* 28 (2008) 2791-2800.

[6] L. Fuso, D. Manfredi, S. Biamino, M. Pavese, P. Fino, C. Badini. *Compos. Sci. Technol*. 69 (2009) 1772–1776.