Potentials of nano- and micro- reinforcements applied to ceramic matrix composites

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Abstract

Nano- and micro- reinforcements such as carbon nanotubes (CNT), silicon carbide nanowires (SiCnw), and silicon carbide whisker (SiCw) with high strength and large surface area have great potentials applied to ceramic matrix composites (CMCs) in the following ways. With superior performances, these reinforcements can be used to CMCs individually, meanwhile, they can also be used to improve the interfacial properties of fiber reinforced CMCs for better performance.

To overcome the challenge of poor dispersion quality of traditional CNT reinforced CMCs, in this work, various CNT assemblies were fabricated and applied to prepare their CMCs. SiCN ceramic matrix composites impregnated with multi-walled carbon nanotubes buckpapers (BP) were prepared by polymer impregnation pyrolysis (PIP). With 3 times PIP cycles, the composite showed complete and successful impregnation, and the obtained BP/SiCN composites showed excellent electrical conductivity of 185 S/cm, about 3 times higher than that of pure BP. CNT film (CNT_f) prepared by floating catalyst method was used to prepare CNT_f/SiC composite by chemical vapor infiltration (CVI) method. Test of mechanical properties indicates that CNT_f/SiC composite showed excellent tensile strength of 713 MPa with 2 CVI cycles, about 21 times higher than that of pure CNT_f. Electrical conductivity of CNT_f/SiC composite was 350 S/cm with 1 CVI cycle, about 10^7 times higher than that of pure SiC ceramic. CNT/SiC produced by direct infiltration of SiC matrix into a porous vertically aligned CNT arrays have been demonstrated to possess

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a unique microstructure and excellent micromechanical properties. The anisotropic compressive behavior of the composite was analyzed, and it was revealed that the longitudinal compressive strengths was 3 times higher than the transverse compressive strengths. An ice-segregation-induced self-assembly technique was employed to prepare CNT aerogel with well-defined macroporous architectures which was subsequently infiltrated with SiC matrix by 5 CVI cycles. The specimens exhibited lamellar structure with parallel lamellaes intersected at discrete angles. By observing, there are in fact five different representative anisotropic macrostructures of the composite. The compressive strengths of these five different loading modes with respect to lamella orientation were tested respectively, and the failure mechanisms were attributed to the anisotropic nature of the macrostructures. Porous SiCnw/SiC ceramic matrix composite with macroscopic unidirectionally aligned channels was also prepared by ice-segregation-induced self-assembly combined with CVI method. Flexural and compressive strengths of the composite with different CVI cycles were tested, and the results indicated an anisotropy of the composite. With 7 CVI cycles, transverse compression strengths of the composite was about 3.5 times higher than the longitudinal compression strengths.

Introducing nano- and micro- reinforcements into the interfaces of C/SiC composites will improve the performances of the composite efficiently. CNT-C/SiC composites were prepared via CVI combined with electrophoretic deposition (EPD) methodology which enables CNT-coating of reinforcing fibers at varying load fractions. It was found that as increase of CNT quantity during electrodeposition, tensile strength of CNT-C/SiC increased substantially by 10.7%, 39.3%, and 45.2% corresponding to the CNT deposition times of 5, 8, and 10 minutes, respectively. For the same EPD periods, work of fracture increased by 49.4%, 82.7%, 120.8%. The electromagnetic interference absorption shielding effectiveness of the CNT-C/SiC composites was also found to increase significantly with EPD duration, and it increased by 56.5% over C/SiC composites at an EPD duration of 10 min. The strength of C/SiC reinforced with 5 wt% and 15 wt% SiC_w brushed on the carbon fiber cloth increased by 98.5% and 64.3%, respectively.

Keywords: CMCs, CNT assemblies, Chemical vapor infiltration, Interfacial modification, Mechanical property