Microstructure and Mechanical Properties of Acid-Treated Carbon Nanotube Reinforced Alumina Composites

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Abstract :

Recently, researchers have focused on carbon nanotubes (CNTs) which have outstanding mechanical properties, motivating their use in ceramic composites as a fibrous reinforcing agent. However, as reported in the previous studies, the improvement in the mechanical properties of ceramic composites has been limited due to the inhomogeneous dispersion of CNTs in the matrix [1]. It is a prerequisite for the fuller utilization of CNTs to achieve their homogeneous distribution in the CNT/ceramic composites. It is well known that acid treatments produce negatively charged functional groups on the surface of CNTs [2]. The functional groups make the CNTs easily dispersed in polar solvents, such as water and ethanol [3]. The objective of this work is to evaluate the effects of the duration of acid treatment by H_2SO_4/HNO_3 on the fracture process and the mechanical properties of the alumina composites.

The CNTs used in this study were multi-walled carbon nanotubes (MWCNTs). MWCNTs were refluxed in 3:1 (volume ratio) concentrated H_2SO_4/HNO_3 mixtures for 0, 0.5, 1, 2, 3 and 4 h at 70°C. MWCNT/alumina composites were prepared by spark plasma sintering, and bending strength and fracture toughness of the composites were measured [4]. Aluminum hydroxide powders were used as the starting material for the alumina matrix. Uniaxial tensile tests of individual MWCNTs [5] were carried out to characterize their mechanical strength. The dispersibility and pullout length of the MWCNTs and the matrix grain size were measured through the scanning electron microscope observations.

It was demonstrated that the dispersibility of the MWCNTs led to significant influence on both bending strength and fracture toughness of the composites. In contrast, the MWCNT content, matrix grain size, mechanical strength of the individual MWCNT and interfacial strength had little impact on the composite mechanical properties. The dispersibility of the MWCNTs decreased with the increasing MWCNT contents regardless of the acid treatment time, suggesting that the degradation of the dispersibility mainly caused the decrease of the mechanical properties of the composites even when the MWCNT content increased. The experimental results revealed that the composite made with MWCNTs treated for 2 h gave the highest mechanical properties. The measured bending strength and fracture toughness of the composite with 0.9 vol.% MWCNTs treated for 2 h were 689.6 ± 29.1 MPa and 5.90 ± 0.27 $MPa \cdot m^{1/2}$, respectively. These analyses suggest that the inhibition of the degradation of the MWCNT dispersibility associated with the high loading of the MWCNTs is needed for fundamental material design of MWCNT/ceramic composites, leading to improved mechanical properties.

References

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