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Synergistic Effect of Carbon Nanotube as Sintering aid and Toughening agent in Spark Plasma Sintered Molybdenum Disilicide-Hafnium Carbide Composite

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Abstract

Hafnium carbide (HfC) along with sintering aids was consolidated at a relatively lower temperature i.e. 1600°C (i.e. $T = \sim 0.41 T_m$) under a uniaxial load of 50 MPa by spark plasma sintering. Two different sintering aids such as molybdenum disilicide (MoSi₂) and carbon nanotube (CNT) were added to enhance the densification and lower the extent of grain growth in the sintered pellets. Density of the sintered pellet increased from 96.0 ± 0.8 % in HfC + 5 wt. % MoSi₂ (HM) to 99.0 ± 0.5 % with the addition of 2 wt. % CNT in HfC + 5 wt. % MoSi₂ (HMC) at sintering temperature of 1600°C. Further, the extent of grain growth drastically reduced from 204% in HM to 50% in HMC. Analysis of linear shrinkage during densification revealed that CNT addition increased densification rate and decreased the time required to reach the density of 99.0 ± 0.5 % at 1600°C. Increased densification and lower degree of grain growth could be due to the synergistic effect offered by the CNT, which are as follows: (i) Lubrication effect of CNT, (ii) Lower activation energy for grain boundary diffusion (iii) Reduction in liquid phase sintering temperature and (iv) Grain boundary pinning. Fracture toughness of the sintered HM and HMC composite was obtained using indentation technique. By the addition of 2 wt. % CNT in HM, drastic increase of 91% in fracture toughness was seen. This significant improvement in fracture toughness was due to the enhanced densification and relatively lower grain size of HMC. Also crack bridging, crack deflection, crack arrest, CNT and graphene sheet pull-out and swording played major role in toughening of HMC pellet.

Keywords: Sintering, Ceramics, Composites, Grain refinement, Mechanical characterization

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