Abstract

A study has been carried out on processing and structure-property relations of silicon carbide (SiC) being consolidated from nanometric powders with the objective of identifying suitable processing steps and methodologies for achieving desirable combinations of microstructure and mechanical properties.

Nanocrystalline SiC based spherical granules have been produced using spray-freeze-drying (SFD) technique through the optimization of polyethyleneimine (dispersant) content, pH and solid loading of aqueous based slurry. Subsequently, a comparative evaluation has been carried out between microstructure and mechanical properties of SiC consolidated by pressureless sintering ($SSiC_A$), hot pressing (HP) and spark plasma sintering (SPS) of SFD-SiC granules. Further, an investigation has been perfomed to examine the influence of pressure and temperature on densification, microstructure and mechanical properties of the spark plasma sintered SiC using powder with 40 nm particle size as raw material.

It is observed that zeta potential and isoelectric point of SiC particles increases with the increase in PEI concentration upto 2 wt%. The pH range ≈ 7.6-9.3 has been optimized for obtaining minimum viscosity of the SiC slurry. The optimum slurry composition for obtaining desirable combination of flowability and viscosity for formation of the SFD granules has been found as :18 vol% SiC powder loaded slurry, 6wt% PEI (MW 25000), sucrose equivalent to 3 wt% C, and 1 wt% B_4C. Viscosity of SiC slurry and atomization gas pressure have a pivotal role in controlling the granule size.

On examining the microstructure of sintered SiC, it is noticed that $SSiC_A$ and HP-SiC exhibit elongated and interlocking α-SiC grains along with equiaxed β-SiC grains; whereas, the spark plasma sintered SiC shows only equiaxed β-SiC grains. TEM examination of the sintered SiC has revealed the presence of glassy phase at grain boundaries and triple junctions, which appears to have promoted the densification through liquid phase formation during consolidation at elevated temperatures. The glassy phase at the grain boundaries is found to be continuous and wider in the SPS-SiC, whereas it is found to be relatively less prominent in case of the HP-SiC, and can be hardly found in the $SSiC_A$.

On comparison of mechanical properties, it has been found that the HP-SiC possesses superior relative density and mechanical properties (elastic modulus, hardness, flexural strength and fracture toughness) compared to those of $SSiC_A$ or SPS-SiC. The presence of α-SiC in the microstructure contributes to significant toughness enhancement by promoting crack deflection and grain-bridging. The SPS-SiC has exhibited the worst mechanical properties, because of relatively lower density as well as presence of higher amount of interfacial brittle glassy phase at the SiC grain boundaries. Applied pressure and temperature used for SPS are found to have a significant influence on densification and microstructural evolution, with the best mechanical properties being observed in the SiC sintered at 1500°C.