Spark plasma sintering of WC-cBN composites using SiO_2 coated cBN

Cubic boron nitride is the hardest material only next to diamond and is expected to enhance the hardness and fracture toughness of other cutting materials such as tungsten carbide or alumina. However, the using of Co sintering aid for WC would like to induce the phase transformation of cBN to hBN and lead to a volume expansion resulting in cracking and low hardness of the products. In the present study, SiO_2 nanolayer was coated by a novel rotary CVD method on cBN to depress its phase transformation to hBN. The sinterability and the mechanical properties were also enhanced with SiO_2, indicating that the proposed coating method is promising for developing new cBN-containing cutting tools.

The novel rotary CVD apparatus developed in our group was used [1], with tetraethyl orthosilicate (TEOS) evaporated at 383 K as a precursor, to coat SiO_2 nanolayer on cBN powder (~4μm in diameter) at 973 K. Oxygen was also adopted to accelerate the decomposition of TEOS. Fig. 1 shows the typical TEM images of (a, b) cBN and (c, d) SiO_2-coated cBN powders, and SiO_2 nanolayer about 70 nm in thickness was observed to surround cBN uniformly.

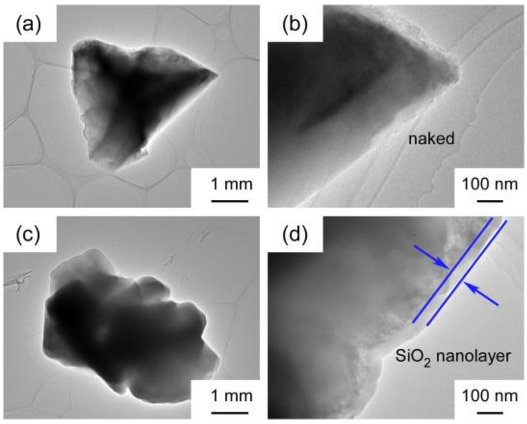

Fig. 1 TEM images of (a, b) cBN and (c, d) SiO_2-coated cBN

The as prepared SiO_2-coated cBN was mixed with WC (~60 nm in diameter) by ball milling for 6 h in ethanol using zirconia balls (3 mm in diameter). After drying at 333 K for 24 h, the milled powder was sieved through the 200 mesh, filled into the graphite die of 10 mm in inner diameter, and then consolidated by SPS (SPS-210LX, SPS Syntex Inc.) at 1773 to 2073 K, respectively. The more obvious shrinkage of WC-cBN/SiO_2 composites was found due to the incorporation of SiO_2 nanolayer. And the shrinkage ended after a holding time of about 60s at a sintering temperature of 1873 K, indicating that sintering completed.

Fig. 2 shows the X-ray diffraction patterns of WC-40vol% cBN/SiO_2 composites sintered at 1773 to 2073 K, respectively, as well as that of the raw powder. The phase transformation of cBN to hBN occurred only at a high sintering temperature of 2073 K, indicating that SiO_2 depressed the phase transformation of cBN effectively. The relative density of WC-cBN composites was also increased with increasing SiO_2 nanolayer content. After sintering at 1873 K, the relative density of WC-cBN was only 82%, but that of WC-cBN/SiO_2 was increased apparently up to 96%. Chen et al. coated amorphous SiO_2 layer on SiC whiskers (SiC_w) and Al_2O_3 powder, and found that the amorphous SiO_2 coating improved densification of SiC_w-reinforced Al_2O_3 composites due to the viscous flow of amorphous SiO_2 at a relatively low temperature (~1573 K) [2]. In the present study, the almost full densification of WC-40vol% cBN/SiO_2 may also be attributed to the viscous flow of the amorphous SiO_2 shell coated on cBN core.

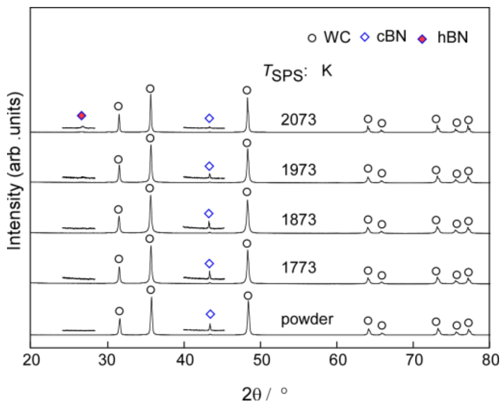

Fig. 2 XRD patterns of WC-40vol%cBN/SiO_2 raw powder and composites consolidated at 1773 to 2073 K

References

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