

TEM Characterization of Microstructure of Polycrystalline Cubic Boron Nitrides

ChunLin Chen¹, Zhongchang Wang¹, Rong Huang², Naoya Shibata³, Takashi Taniguchi⁴, and Yuichi Ikuhara^{1, 2, 3}

¹World Premier International Research Center, Advanced Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

²Nanostructures Research Laboratory, Japan Fine Ceramics Center, 2-4-1 Mutsuno, Astuta, Nagoya 456-8587, Japan

³Institute of Engineering Innovation, The University of Tokyo, 2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan

⁴National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0044, Japan

Boron nitride has two representative crystal structures which are known as cubic boron nitride (cBN) and hexagonal boron nitride (hBN) [1]. hBN has a structure and properties similar to graphite. It is one of the most popular dry lubricants available today, due mostly to its lubricant properties and its inertness to molten metals and salts [2]. On the other hand, cBN has the same crystal structure as diamond. Therefore it has an extremely high hardness which is next only to the diamond [3, 4]. The extremely high hardness makes cBN be an excellent material of abrasives and cutting tools [5]. Since the property of material depends on its microstructure, here we will perform a detailed microstructural characterization of cBN to investigate the factors which influence its hardness.

In this study, we comparatively investigated the microstructures of two kinds of cBNs which were sintered under high pressure and high temperature at the National Institute of Materials Sciences (NIMS, Japan). The starting materials used were commercial cubic and hexagonal BN powders, respectively. The thin c-BN section for TEM observations were prepared by using the standard ion-milling technique. The ion-milling process will not change the microstructure of cBN. HRTEM observations were performed using a JEOL-3000F HRTEM. EELS analyses were carried out on a Cs-corrected JEM-2100F equipped with Gatan Image Filter (GIF).

The cBN sintered by cubic BN powder was fabricated at a pressure of 5 GPa at 1773 K (Namely, we call it cBN-5 GPa); and the polycrystalline cBN by hexagonal BN powder was sintered at 12 GPa at 1973 K (namely, cBN-12 GPa). The Vickers hardness of cBN-5 GPa was much lower than that of cBN-12 GPa. TEM characterizations revealed that the coarser grain size and twin width of cBN-5 GPa were two factors for its lower hardness, compared to those of cBN-12 GPa. HRTEM investigations suggested that the grain boundaries of cBN-5 GPa and cBN-12 GPa were both free from amorphous layer and any secondary phase. There was no obvious difference between the grain boundary microstructures of these two polycrystalline cBNs. EELS measurement revealed that there was oxygen segregation at the grain boundary of cBN-5 GPa. However, oxygen could not be detected at the grain boundary of cBN-12 GPa. The purity of cBN-12 GPa was higher than that of cBN-5 GPa. First principles calculations suggested that the oxygen segregation at the grain boundary of cBN-5 GPa may be another reason for its lower hardness.

References

- [1] T. Taniguchi et al., *J. Crystal Growth* 303 (2007) 525.
- [2] K. Watanabe et al., *Diamond Related Mater.* 20 (2011) 849.
- [3] O. Mishima et al., in *Electric Refractory Materials*, Y. Kumashiro, Ed. (Dekker, New York, 2000), chap. 21.
- [4] J. S. Zhang et al., *J. Appl. Phys.* 109 (2011) 063521.
- [5] K. Fujisaki et al., *J. Mater. Proc. Technol.* 209 (2009) 5646.

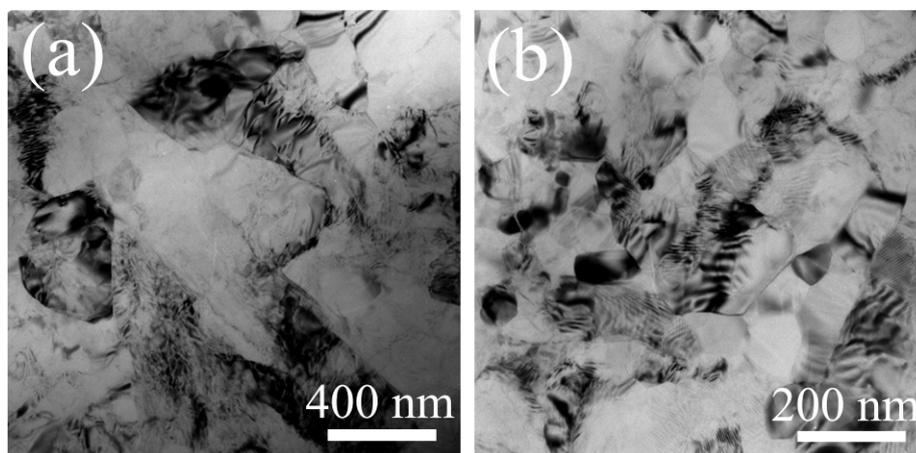


FIG. 1. Bright-field images of cBNs. (a) cBN-5 GPa, (b) cBN-12 GPa. It is obvious that the grain size of cBN-5GPa is larger than that of cBN-12 GPa.

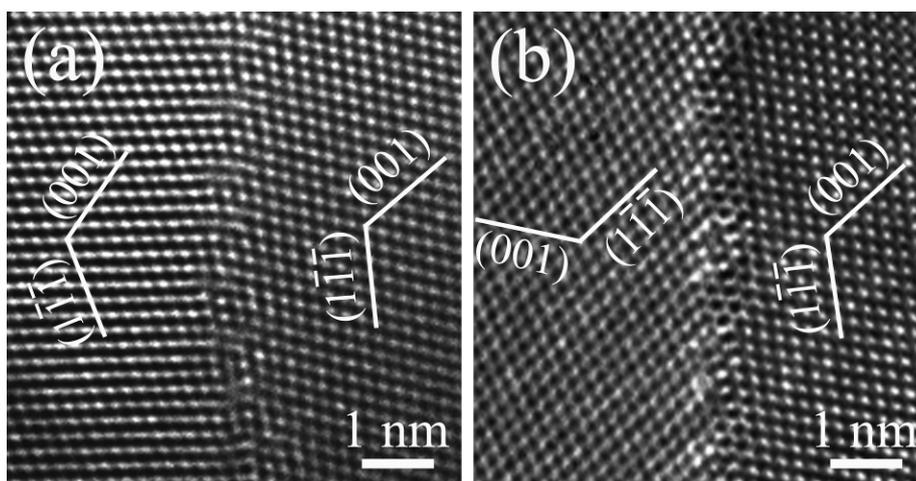


FIG. 2. HRTEM images of cBNs. (a) cBN-5 GPa, (b) cBN-12 GPa. The grain boundaries of cBN-5 GPa and cBN-12 GPa are both free from amorphous layer and any secondary phase. The images are taken from [110] zone axis.