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Revealing the Microstructural Information of the Quasi-Plastic Zone in a Boron Carbide Using the Advanced Precession Electron Diffraction Technique

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There has been a spike of scientific interest in studying the amorphous shear bands due to its ability to deteriorate ballistic performance in boron carbide. The extreme shear imposed during indentation experiments with a sharp indenter tip (Berkovich and cube corner) could activate amorphization even at very small loads [1]. Amorphous bands are characterized by the loss of crystallinity order in small zones, usually nanometers in width, containing within a crystalline volume with complex features [2]. Previous transmission electron microscopy (TEM) characterization of the quasi-plastic zones underneath the indents are very localized, mainly focusing on the amorphous shear bands [2, 3]. There lacked an overall microstructural understand of the quasi-plastic zones in general due to the large residual strain and complex diffraction contrast.

In this work, we employed an advanced precession electron diffraction (PED) technique integrated on a TEM (Tecnai 30F) [4-6] to offer the "bird's-eye view" of the microstructural information from the quasi-plastic zones. The model material is a Si-doped boron carbide. Nanoindentation was performed at room temperature using a Berkovich indenter tip.

Figure 1 displays an example of the overall microstructural information of an indented boron carbide using PED. Figure 1a shows a bright-field STEM image of the quasi-plastic zone. As expected, the area underneath the indent is highly strained. The diffraction contrast is complicated and difficult to interpret. Figures 1b and 1c illustrate the PED results of the quasi-plastic zone taken from the area of interest (the white boxed regions in Fig.1a, scanning step size of 5 nm). The orientation map is superimposed with the corresponding reliability map (Figure 1b). The color from the orientation map (indicating crystal orientation) of the quasi-plastic zones has only slightly changed due to permanent deformation to accommodate the plastic strain from indentation. The dark patches from the reliability map point to the locations of micro-cracks, amorphous bands, and overlapping crystals. Figure 1c shows the correlation coefficient map. The distinctive dark lines represent micro-cracks and amorphous shear bands; whereas the diffusive curved lines depict the elastic strain. We also noted some local shears bands and small degrees of misorientation close to the tip of the indent, which may reflect the strain gradient in the plastic zone. Taken together, PED is a powerful characterization technique that could provide nanometer-scale resolution microstructural information of highly strained regions, which was difficult to obtain using conventional S/TEM techniques.

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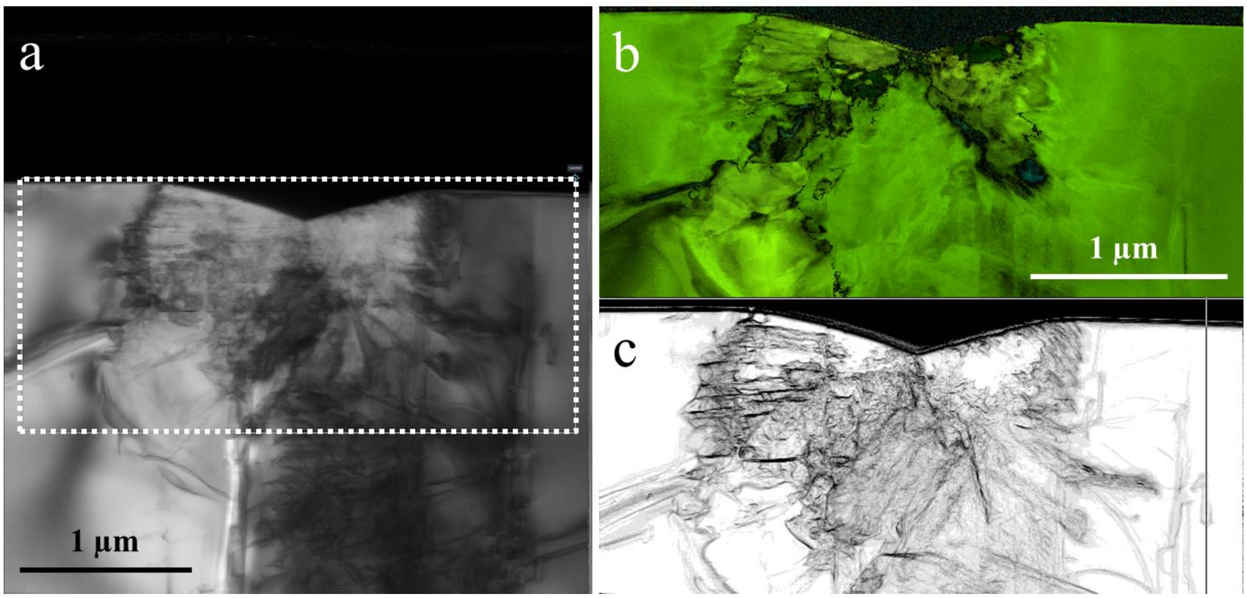

Figure 1. Bright-field STEM image of a Si-doped boron carbide underneath the indenter (a). Combined orientation and reliability map (b) and correlation coefficient map (c) for the Si-doped boron carbide.

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