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EELS Investigations of Carbon-rich Boron Carbide Nanomaterials

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Boron carbide has been widely utilized in industry and military because of its low mass-density, super-high hardness and good electric conductivity [1,2]. It is predicted that its excellent mechanical properties can be enhanced in nanomaterials [3]. The material is also one kind of thermoelectric compound working at high temperatures above 1000 ºC [4]. However, its thermoelectric properties, such as Seebeck coefficient and figure-of-merit, are low and need to be enhanced significantly for potential applications. Nanostructuring is an effective approach to improve thermoelectric properties [5] and boron carbide nanocomposites with high performances can be bottom-up-ed from nanomaterials by the approach. So boron carbide nanomaterials play a key role as starting materials of the carbide nanocomposites. Here, carbon-rich boron carbide nanomaterials are synthesized and characterized by electron energy-loss spectroscopy (EELS) on transmission electron microscope (TEM).

The boron carbide nanomaterials were synthesized by a microwave-assistant carbothermic reaction. The synthesized black materials were characterized by X-ray diffraction, as shown in Figure 1. The phase is not boron, carbon, nor B_4C. The UV-vis spectrum (inset in Figure 1) indicated that the band-gap of the nanomaterials is 2.30 - 2.50 eV, larger than that of boron-rich B_xC compounds (2.09 eV) [6]. In order to determine the chemical composition of the nanomaterials, EELS technique was utilized here to characterize the nanomaterials. EELS investigations were carried out on a JEOL 2100 FEG TEM equipped with an electron energy loss spectrometer.

EELS spectra and spectrum imaging were collected on one piece of the as-synthesized nanomaterials (Figure 2), which is consisted of nanocrystals. EELS spectra were collected from the marked region and a typical EELS spectrum is shown in Figure 3. Figure 3 indicated that the material is composited of boron and carbon. The ratio of boron to carbon is about 1:2. The high content of carbon maybe come from the un-reacted carbon in the composites or a pure carbon-rich single phase. Here no any diffraction rings of amorphous carbon were observed from selected area electron diffraction patterns (not show here). Therefore, it is reasonable to assume that the synthesized nanomaterials are one kind of carbon-rich BC_2 single phase. More work is being carried out to synthesize boron-rich B_xC phase. The zoomed spectrum (inset in Figure 3) indicted that the boron K-edge is consisted of a sharp edge and one broad edge, similar as reported [7,8].

In order to characterize the boron distribution in the materials, EELS spectrum imaging was carried out in the marked region shown in Figure 2. A spectrum image is shown in Figure 4a. Based on the spectrum image shown in Figure 4a, a boron EELS mapping was produced and shown in Figure 4b. It is clearly shown that boron uniformly distributed in the whole region. Carbon mapping (not shown here) indicted that carbon uniformly distributed in most regions of the material too. Therefore, the synthesized nanomaterials should be uniform BC_2 nanomaterials. The detailed crystalline structure of the materials is being carried out [9].

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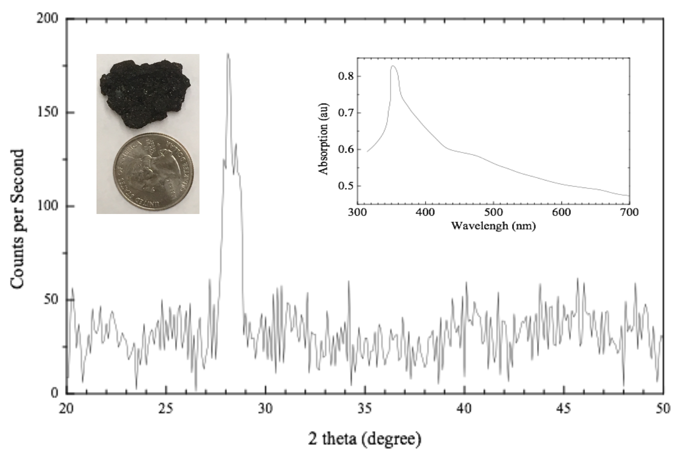

Figure 1: An X-ray diffraction pattern of BC_2 nanocomposites. Left inset: optical image of as-synthesized nanocomposites. Right inset: UV-vis spectrum

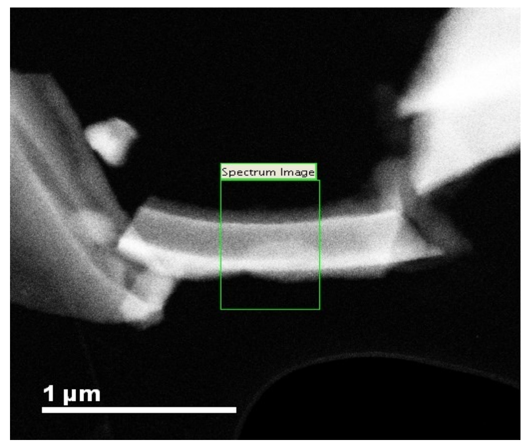

Figure 2: An STEM image of BC_2 nanocomposites. The spectrum image region is marked.

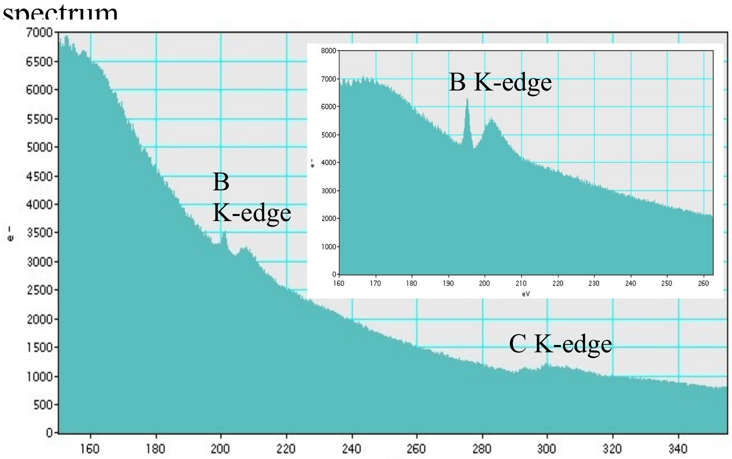

Figure 3: An EELS spectrum showing boron and carbon edges. Inset: zoomed boron K-edge.

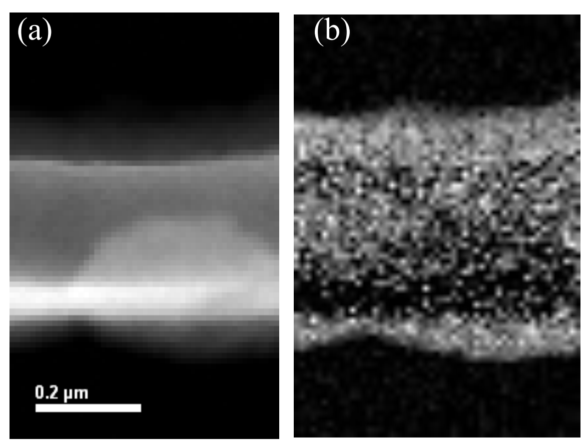

Figure 4: (a) EELS spectrum image. (b) Boron EELS mapping image.

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