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Preparation of boron carbon nitride thin films by radio frequency magnetron sputtering

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Abstract

Boron carbon nitride films were deposited by radio frequency magnetron sputtering using a composite target consisting of h-BN and graphite in an Ar–N_2 gas mixture. The samples were characterized by X-ray diffraction, Fourier transform infrared spectroscopy and X-ray photoelectron spectroscopy. The results suggest that the films are atomic-level hybrids composed of B, C and N atoms. The boron carbon nitride films prepared in the present experiment have a disordered structure. The sputtering power varied from 80 W to 130 W. This sputtering power was shown to have regular effect on the composition of boron carbon nitride films. The samples deposited at 80 W and 130 W are close to the stoichiometry of BC_3N. The sample deposited at 110 W is close to the stoichiometry of BCN. The samples deposited at 100 W and 120 W approach to BC_2N. It is very significant for us to synthesize boron carbon nitride compound with controllable composition by changing the sputtering power.

Keywords: Radio frequency magnetron sputtering; Boron carbon nitride thin films

1. Introduction

The structural similarity between hexagonal boron nitride and graphite inspires materials scientists to synthesize a ternary boron carbon nitride compound. The properties of the compound are expected to be between those of h-BN and graphite [1,2]. It is expected that boron carbon nitride compound may be used as hard coating [3] and semiconductor with adjustable band gap by controlling the atomic composition [4]. In addition, the boron carbon nitride can be applied to rechargeable lithium battery [5] and used as wear-resisted coating [6].

Several methods of preparing boron carbon nitride films have be reported, such as magnetron sputtering [7], ion beam deposition [8], hot filament assisted

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CVD [9] and plasma assisted CVD [10], etc. However, it is still difficult to synthesize boron carbon nitride compound with controllable composition by changing deposition parameter.

In this work, boron carbon nitride films were deposited by radio frequency magnetron sputtering using a composite target consisting of h-BN and graphite. The films were characterized by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS).

2. Experimental

Boron carbon nitride films were deposited by radio frequency magnetron sputtering on glass and Si (1 0 0) substrates using a 50 mm-diameter composite target consisting of h-BN and graphite. The composite target was composed of two semidisks: one of h-BN and the other one of graphite. The schematic diagram of the composite target is shown in Fig. 1. The distance between the target and the substrate was kept at 50 mm. The chamber base pressure was below 5×10^{-3} Pa. During the deposition, the mixture of Ar (80%) and N_2 (20%) was injected into the vacuum chamber and the total pressure was 1.3 Pa. The substrate temperature was 400 °C and the deposition time was 2 h. The sputtering power varied from 80 W to 130 W.

The chemical bonding state and composition of the films were determined by X-ray photoelectron spectroscopy (VG ESCLAB MKII). Fourier transform infrared spectroscopy (Nicolet AVATAR 370DTGS) was also used to characterize the bonding state. The microstructure of the samples was analyzed by X-ray diffraction (PW1710 BASED).

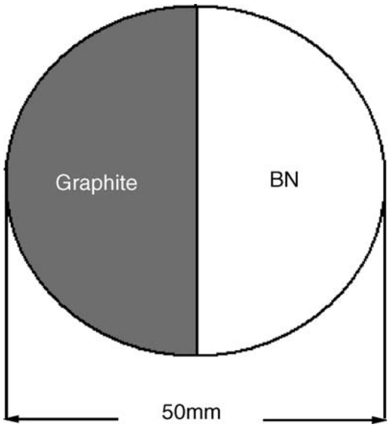

Fig. 1. Schematic diagram of the composite target.

3. Results and discussion

Fig. 2 shows the FTIR spectra of the samples deposited at different sputtering powers. All the samples have four similar peaks at about 1367 cm^{-1}, 1276 cm^{-1}, 1180 cm^{-1} and 844 cm^{-1}. Two IR peaks at 1367 cm^{-1} and 844 cm^{-1} can be attributed to the in-plane B–N stretching and the out-of-plane B–N–B bending modes, respectively [11]. Because the stretching mode of C–N is in the range of 1250–1360 cm^{-1}, the peak at 1276 cm^{-1} should be due to the C–N vibration mode [12]. Additionally, the peak at 1180 cm^{-1} comes from B–C stretching mode because the B–C stretching vibration is in the range of 1090–1200 cm^{-1} [12]. These results suggest that the films are atomic-level hybrids composed of B, C and N atoms, but not the mixture of graphite and h-BN.

In order to further determine the composition and the chemical bonding of the films, XPS measurements were carried out for the as-deposited films. Fig. 3 shows the XPS spectra of B1s, C1s and N1s for the sample deposited at 110 W sputtering power. It can be seen that the binding energies of B1s, C1s and N1s are 190.6 eV, 284.6 eV and 398.5 eV, respectively. The results agree with the reported data: 189.5 eV,

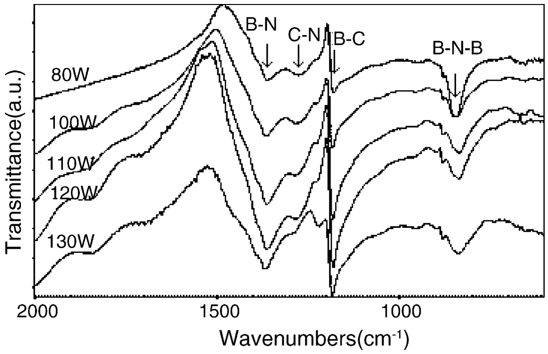

Fig. 2. FTIR spectra of the samples deposited at different sputtering powers.