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BCN films prepared by RF plasma enhanced chemical vapor deposition

Masamitsu NAGANO*[1], Md. Abdul MANNAN[1], Ryuji OSHIMA[1], Norie HIRAO[2], Yuji BABA[2]
[1] Department of Applied Chemistry, Faculty of Science and Engineering, Saga Univ.,
1 Honjo, Saga 840-8502, Japan
[2] Synchrotron Radiation Research Unit, Quantum Beam Science Directorate, JAEA,
Tokai-mura, Ibaraki 319-1195, Japan

Introduction

Boron carbonitride (BCN) films have attracted much attention due to their potential applications to hard coating and electronic devices[1]. The cubic phase is expected to be a hard material superior to diamond and the hexagonal phase (h-BCN) is attractive due to its semi-conducting properties with variable energy band-gap. Much effort has been devoted to synthesis of the BCN films with different compositions. However, the preparation of a single phase of the cubic or hexagonal BCN is still a great challenge.

This report relates to the h-BCN films synthesized from tris(dimethylamino)borane as a precursor by radiofrequency plasma enhanced chemical vapor deposition (RF-PECVD).

Experimental

The films were deposited on Si (100) surface at the RF power of 400~900 W at the working pressure of 0.2 ~ 0.4 Torr. The chemical bonds and composition of the films were investigated by FT-IR, XPS and NEXAFS. The XPS and NEXAFS measurements were performed at KEK-PF, using the linearly polarized synchrotron radiation.

Results and Discussion

FT-IR transmission spectrum of a typical sample showed two peaks; a strong and broad peak at 1380 cm^{-1} and a relatively weak peak at 800 cm^{-1}, suggesting the formation of the hexagonal BCN (h-BCN) although the phase could not be confirmed by XRD.

The film composition, estimated from XPS, was $B_{46}C_{18}N_{36}$.

The wide B1s XPS peak (FWHM~2.0 eV), compared with that of the pure h-BN (~1.0 eV), suggested that B atoms had various chemical environments. The B1s spectra could be well fitted by deconvoluting into two Gaussian peaks assigned to the sp^2 B-N bond and to the sp^2 B-C bond. The C1s and N1s XPS spectra also suggested the formation of various B-C-N hybrid bonds.

The NEXAFS spectra of the film at various incidence angles (θ) of the polarized X-ray are shown in Fig. 1. The π^* resonance peak B_2 almost similar to that of h-BN was observed at the normal incidence ($\theta = 0^\circ$). The dominating peak B_2, slightly broader than that of the h-BN, is assigned to the B-C-N bonds, suggesting the formation of BCN with a similar configuration to BN_3 in h-BN. The comparatively sharp NEXAFS spectrum of the sample implies the formation of the good homogeneity in configuration but in short range order because of the lack of XRD peaks.

As the grazing incidence increased ($\theta = 75^\circ$), the peak B_2 decreased and some other peaks such as B_1, B_3 and B_4 appeared clearer. It indicates the formation of various atomic configurations around B atoms besides BN_3. The peak B_1 could be ascribed to the B atoms in the B_4C-like configuration[2]. Peak B_3 is assigned to the B atom bonded to nitrogen atoms such as BN_2C or BNC_2. Peak B_4 is reported to be the B-O bond[3]. The notable decrease in π^* resonance peak and increase in the σ^* resonance peak (broad feature denoted by B_5) with the grazing incidence suggests that different sp^2 bonded BCN layers may be perpendicular to the substrate[4].

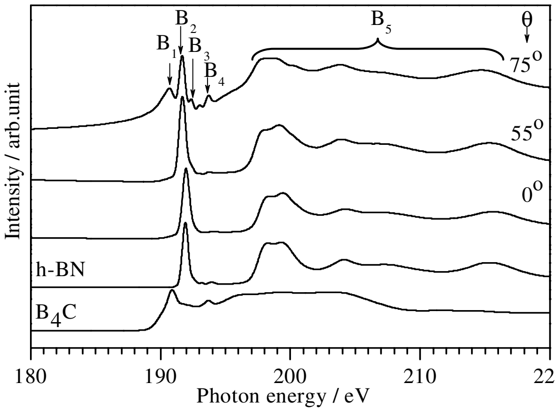

Figure 1. B K-edge NEXAFS spectra at various incidence angles (θ) of x-ray for a typical film. The spectra for h-BN and B_4C are also shown for comparison.

In conclusion, the formation of the hexagonal BCN by RF-PECVD was confirmed. XPS measurement revealed various B-N, B-C and C-N bonds to form graphite-like BCN configuration in a short range order. NEXAFS measurement suggested that different sp^2 bonded BCN layers may be perpendicular to the substrate.

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* naganom@cc.saga-u.ac.jp