Emission characteristics of boron nitride coated carbon nanotubes


a Center for Nanotubes and Nanostructured Composites, Sungkyunkwan University, 300 Chunchun-Dong, Jangan-Gu, Suwon 440-746, South Korea
b NCRI, SAIT, P.O. Box 111, Suwon 440-600, South Korea
c AE Center, SAIT, P.O. Box 111, Suwon 440-600, South Korea
d Thin Film Tech. Research Center, KIST, P.O. Box 131, Cheongryangri 130-650, South Korea

Abstract

Formation and the emission characteristics of boron nitride (BN)-coated carbon nanotubes (CNTs) was investigated. BN films of thickness 3–10 nm were deposited on the vertically aligned CNTs by reactive sputtering. The effect of various pre-treatment of CNTs prior to BN deposition on the emission characteristics was studied. Emission stability of BN-coated CNTs was evaluated in oxygen ambient and compared to that of as-grown CNTs. © 2002 Elsevier Science B.V. All rights reserved.

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Carbon nanotubes (CNTs) electron emitter has attracted a considerable attention because of its excellent field emission (FE) properties. However, further improvement in FE characteristics can be achieved by surface modification of emitter tips [1–4]. Besides the FE characteristics of CNTs, emission stability of CNTs should be fully addressed for the realization of CNTs emitters. A significant degradation of the FE characteristics of CNTs was reported [5, 6]. The emission stability can also be improved by coating CNTs with chemically stable materials. In this study, we coated the CNTs with boron nitride (BN) by reactive sputtering to enhance the emission properties and the stability of CNTs.

Vertically aligned CNTs were grown on glass substrate using DC plasma-enhanced chemical vapor deposition with C2H2 and NH3 gases [7]. BN films were deposited on CNTs using a radio-frequency unbalanced magnetron sputtering at room temperature. Prior to BN deposition, various pre-treatments of CNTs were performed. The morphology and microstructure of BN-coated CNTs were analyzed using high-resolution transmission electron microscopy. Emission properties of CNTs with and without BN layer were measured in a vacuum of 10−7 mbar using ITO-coated glass anode and the emission stability of CNTs was tested in the oxygen ambient of 5 × 10−5 mbar.
A thin continuous BN film with rough surface was coated mainly on tips of CNTs. The thickness of BN layer was changed from 3 to 20 nm depending on the deposition time. The deposited BN layer was partially crystallized. Prior to BN deposition, annealing of CNTs was carried out. The effect of annealing temperature on the emission characteristics of BN-coated CNTs was investigated and shown in Fig. 1. As-grown CNTs showed a turn-on field (defined as the electric field where the emission current density was 10 μA/cm²) of 4.0 V/μm. Turn-on field of the BN-coated CNTs was 4.6–6.1 V/μm depending on the annealing temperature. BN-coated CNTs annealed at 450°C for 20 min showed a lower turn-on field than BN-coated CNTs annealed at other temperatures. An increase in the turn-on field of BN-coated CNTs may be attributed to the insulating BN layer on the front surface of CNT tips.

An emission stability of CNTs with BN layer was evaluated and shown in Fig. 2. BN-coated CNTs showed the stable emission in a vacuum of 8 × 10⁻⁷ mbar. A degradation in an emission current was observed in the oxygen ambient of 5 × 10⁻⁵ mbar. Degradation in emission current is about two orders of the magnitude but, it is one order smaller than that observed in CNTs without BN layer. An enhancement in the emission current and emission stability of CNTs can be obtained through the optimization of BN layer deposition condition.

BN was deposited on the vertically aligned CNTs. The increase in the turn-on field and emission current was observed in the BN-coated CNTs. An annealing at 450°C before BN deposition was found to be effective to improve the emission current. The degradation of the emission from BN-coated CNTs in the oxygen ambient of 5 × 10⁻⁵ mbar was smaller than that of emission from as-grown CNTs by one order of magnitude.

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References