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Characterization of amorphous carbon film-coated nanotubes as electron field emission material

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Abstract

Effects of amorphous carbon (a-C) thin film coating over carbon nanotubes (CNTs) on the field emission characteristics have been studied. Large-area surface-wave plasma (SWP) device was used both for growth of multi-wall CNTs on Ni-evaporated Si substrate and for deposition of a-C thin layer over CNTs. Field emission characteristics of the a-C film-coated CNTs prepared with different CVD durations were investigated. Experimental results show that the emission performance was significantly improved by coating a-C film typically with a thickness of 0.6–1 μm, that is, the ignition voltage for electron emission was reduced from 240 V for the sample of CNTs only to 110 V for that of CNTs deposited with a-C film during 60 min. The surface morphology has been also studied using the field emission type scanning electron microscopy (FE-SEM). It was deduced that the reduction of ignition voltage was due to the field enhancement originated from grain shape structures of the surface after a-C film deposition.

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Keywords: Field emission; Nanotube; Plasma CVD; Microwave plasma

1. Introduction

Recently, field emission (FE) performances of carbon nanotubes (CNTs) have been extensively studied aiming at developing the cold electron emitter materials for flat panel display. As compared with the diamond or diamond-like carbon films, CNTs have great advantages of lower emission electric fields and larger emission currents. Recently, it has been reported that an individual multi-wall CNT can carry the maximum current of 0.2–2 mA [1]. Furthermore, a significant reduction of applied voltage of CNT was accomplished as a result of field enhancement due to the tip-like structure of CNTs, where a field enhancement factor widely ranging from 10^2 to 10^6

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has been reported in various papers. However, the closely grown CNTs generally show a poor emission performance because of field screening effect [2,3]. Therefore, it is desirable to grow vertically aligned CNTs with a relevant interval or to select the emission sites of closely grown CNTs by some technique to realize field enhancement.

In our previous study, we reported that the amorphous carbon (a-C) film have a relatively good electron emission performance, that is, the threshold electric field of 3.5 V/μm at emission current density of 1 $\mu A/cm^2$ [4]. It was considered that the good electron emission performance might be attributed to the field enhancement due to localized conduction channels, which were formed by sp^2-carbon (graphite) components including inside the a-C film [5].

Thus, we propose here a novel technique to improve the field emission performance by a-C film coating over CNT deposition layer. Experimental setup and results will be given in the following sections.

2. Experimental setup

A schematic drawing of the experimental setup is shown in Fig. 1. The surface-wave plasma (SWP) was produced in a 400-mm diameter, cylindrical vacuum chamber by introducing a 2.45 GHz microwave through a quartz window via slot antennas [4,5]. Growth of CNTs was carried out on the <100> n-type silicon wafer substrates placed on the substrate stage installed inside the chamber. Heater stage was about 15 cm below the quartz window of the microwave launcher. Effective stage area was 200 mm in diameter, where the substrate temperature could be controlled up to 850 °C by external heater and water-cooling system. Silicon substrates were cleaned beforehand by acetone in an ultrasonic bath and then vacuum-evaporated with Ni powder [6].

The CNT growth was carried out with a mixture gas of H_2, CH_4 and Ar at gas flow rates of 100 sccm, 20 sccm and 50 sccm, respectively. During plasma discharge, substrate stage was kept at temperature of 750 °C. The SWP was sustained by the microwave power of 700 W at gas pressure of 10 Torr for discharge duration of 10 min. While a-C film deposition was performed using the SWP with a

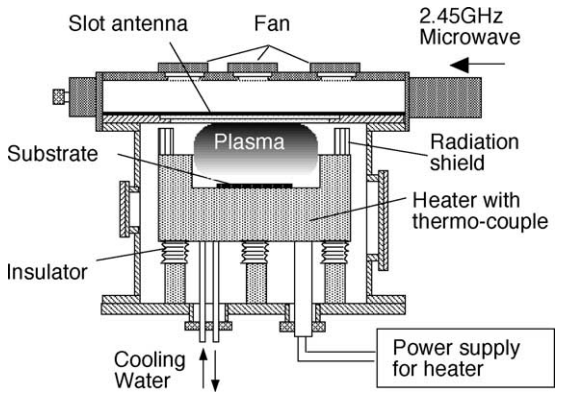

Fig. 1. Schematic drawing of the experimental setup for surface-wave plasma CVD.

He, CH_4 mixture gas at pressure of 200 mTorr at room temperature. The incident microwave power was typically 700 W, while the reflected power was tuned to almost zero with E–H tuner.

3. Results and discussion

The surface morphology of the samples was measured with a field emission type scanning electron microscope (FE-SEM). Fig. 2 shows FE-SEM images of the samples of CNT deposition only. It is seen that CNTs are grown randomly over the entire surface of Si substrate and the diameter was typically 30–60 nm. It has been also found that the CNTs grown on the substrates set at the center and edge of the substrate stage were almost the same in size and length.

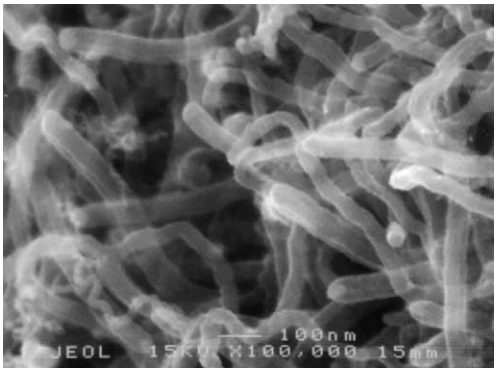

Fig. 2. FE-SEM image of CNTs deposited on Si substrate.