Field Emission Characteristics of Carbon Nanotube-Copper Composite Structures

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Abstract

Carbon nanotube-copper composite structures were fabricated using composite plating method and their field emission characteristics were investigated. Multi-walled carbon nanotubes synthesized by chemical vapor deposition were used in the present study. It was revealed that turn-on field of the structures was about 3.0 V/μm at the current density of 0.1 μA/cm^2. We observed relatively uniform emission characteristics as well as stable emission currents. CNT-Cu composite plating method is efficient and it has no intrinsic limit on the plating area. Moreover, it gives strong adhesion between emitters and an electrode. Therefore, we expect that CNT-Cu composite plating method can be applied to fabricate electron field emitters for large area FEDs and large area vacuum lighting sources.

Introduction

Carbon nanotubes (CNTs) [1] are promising new materials for the industrial applications due to their outstanding physical and electrical properties such as high tensile strength, high elastic modulus, high thermal conductivity and electric conductivity [2, 3]. Since CNTs also have high aspect ratio with very small diameter, chemical stability at high temperatures, researchers have tried to use CNT emitters for the development of field emission displays [4]. Some methods of adhering CNTs to an electrode have been reported. However, attaching CNTs using conductive pastes [5] suffers from low adhesion and remaining out-gassing and direct growth of CNTs on the electrode [6-8] requires high processing temperature and has problems of low uniformity. Significant interests have been recently focused on CNT composites due to their enhanced mechanical and electrical characteristics higher than those of the host materials [9, 10]. Particularly, metal composites incorporating multi-walled carbon nanotubes (MWNTs) are regarded as one of promising CNT-composite materials exhibiting improved functionality [11]. In this paper, we formed CNT-Cu composite structures using composite plating on glass substrate and investigated their field emission characteristics.

Experimental

The present experiment utilized CNTs, which are commercially available MWNTs (Iljin Nanotech Co. Ltd, Korea), produced by catalyst assisted CVD. The MWNTs are typically 10 ~ 20 ㎚ in diameter and 10 ~ 50 ㎛ in length. A composite plating solution (sulfuric acid-copper sulfate chemical solution) used in the present study contains 75 g/l of $CuSO_4 \cdot 5H_2O$, 180 g/l of H_2SO_4, 70 mg/l of HCl, 1g/l of MWNTs, which were dispersed by ultrasonic agitation for 1 hour. Pulse plating with peak current of 780 mA, duty ratio of 60% and frequency of 1000 Hz was employed. Field emission characteristics of CNT-Cu composite structures were investigated by using a diode type configuration, a cathode and a parallel anode plate, in a vacuum chamber maintained at a pressure of 4×10^{-7} torr with an oil-free turbo-molecular pump. To prevent abrupt breakdown, the cathode was grounded over 2 ㏁ ballast resister. The specimen with CNT-Cu composite structures and an indium tin oxide (ITO) glass were used as the cathode and the anode, respectively, and 320 ㎛ thick polyimide foil was located between the anode and the cathode as a spacer. The emission current was evaluated by averaging the measured current over the area of a hole with 6 mm diameter in the spacer, through which the current was collected. Keithley 248 high voltage supply was used for power source and Keithley 2000 multi-meter was used for current measurement.

Results and Discussion

Figure 1 shows SEM images of the CNT-Cu composite structures formed by composite plating. The CNT-Cu composite structures have shape of sharp needles with uniform length and are typically 30 ㎚ ~ 1 ㎛ in diameter and about 10 ㎛ in length. Figure 2 shows current-voltage (I-V) curves with Fowler-Nordheim plots and Fig. 3 shows emission images in a vacuum chamber using CNT-Cu composite structures as electron field emitters. Turn-on field was about 3.0 V/㎛ at the current density of 0.1 ㎂/cm^2. We observed relatively uniform emission sites as well as stable emission currents. The cathode formed by the present method is expected to be outgassing-free and could be applied for a large area vacuum displays.

Conclusion

We fabricated CNT-Cu composite emitters using composite plating method, which is a low temperature wet process. Therefore, we expect that CNT-Cu composite structures could be applied to the electron field emitters for large area FEDs as well as large area vacuum lighting sources because of their uniformity, low formation temperature and low turn-on field.

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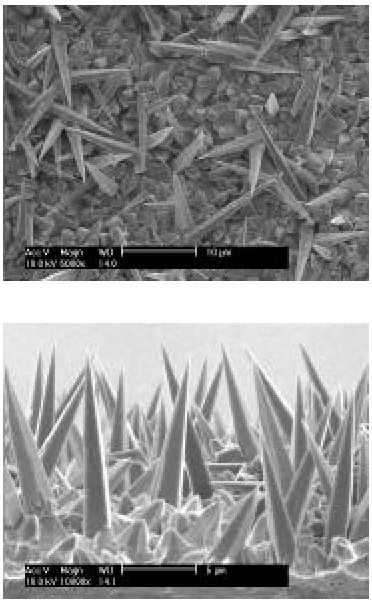

Fig. 1. SEM images of CNT-Cu composite structures.

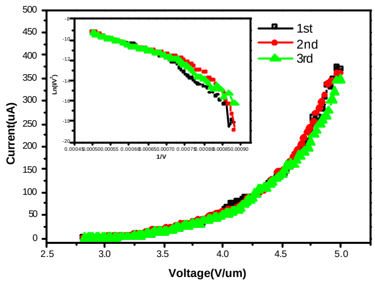

Fig. 2. I-V curves and F-N plots.

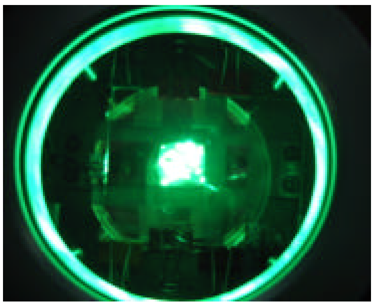

Fig. 3. Emission image in a vacuum chamber using CNT-Cu composite structures as electron field emitters.

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