Characterization of Carbon Nanotube Cathodes with Surface Treatment by Polymer-Based Organic Materials

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Abstract

The effect of surface treatment on CNT cathodes used in field emission displays was investigated. A liquid method using a polymer-based organic solution and a mechanical method were applied. The liquid method, using PVA(polyvinyl alcohol) showed high potential compared to the mechanical adhesive taping and rolling method used in the fabrication of CNT cathodes for large-sized field emission displays with high emission uniformity and a low cost.

1. Introduction

Carbon nanotubes (CNTs) have attracted considerable attention among materials scientists because of their unique physical properties and their potential for applications in field emission displays (FEDs). The reason why CNTs can be used as materials for field emitters is the intense local electric fields caused by both the intrinsic needle-like shape of the CNTs and the fact that they protrude over the surface of the bonding materials. The use of a screen-printing process for preparing, fully-sealed FED prototypes with CNT emitters have recently been demonstrated. However, CNT-FEDs have some severe problems that must be solved in order to realize marketable products. One of the most important issues is the uniformity of field emission [1]. In this study, the effects of surface treatment of CNT-cathodes on field emission properties for use in high efficiency field emission displays was investigated. A polymer-based organic solution method was used for the surface treatment [2-5] and the results were compared to the conventional adhesive taping and rolling method, from the view point of emission uniformity and high process reproducibility.

2. Experimental

Figure 1 shows the experimental flow chart for this work. The CNTs were multi-walled carbon nanotubes. CNT powders were suspended in a solution of IPA(isopropyl alcohol). A CNT ink was prepared by strongly sonicating of CNT powders and an organic solution of IPA.

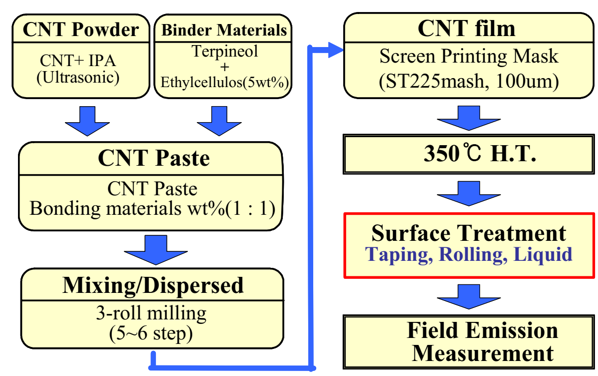

Figure 1. Schematic diagram of the experimental procedure used in this work.

A CNT paste for screen-printing was fabricated by adding an organic binder and inorganic bonding materials. The major components of the CNT paste were the CNT ink and the inorganic bonding materials. CNT patterns were produced by a screen-printing technique on ITO electrodes [6-7]. After firing the organic binder in the CNT paste at 350 °C in air, a special surface treatment was carried out. In this study, a polymer-based organic solution was used in the surface treatment. For comparison, a conventional adhesive taping [8] and rolling [9] method was also carried out. The field emission properties of the CNT films were characterized with a diode-mode in a high vacuum chamber at a pressure of $1x10^{-6}$ Torr. Optical microscopic (OM) observation was carried out to examine CNT protrusions and CNT films.

3. Results and discussion

Figure 2 shows a schematic diagram of the surface treatment using a polymer-based organic solution method. On the ITO (indium tin oxide) electrode, CNTs were buried with inorganic bonding materials and ash, a residue of the organic binder after the firing process. For the surface treatment, the PVA solution was poured on the surface of a screen printed CNT film. The PVA solution was converted to a PVA film during the drying process. When the PVA film was removed from the ITO glass, the ash attached to the CNTs could be removed successfully.

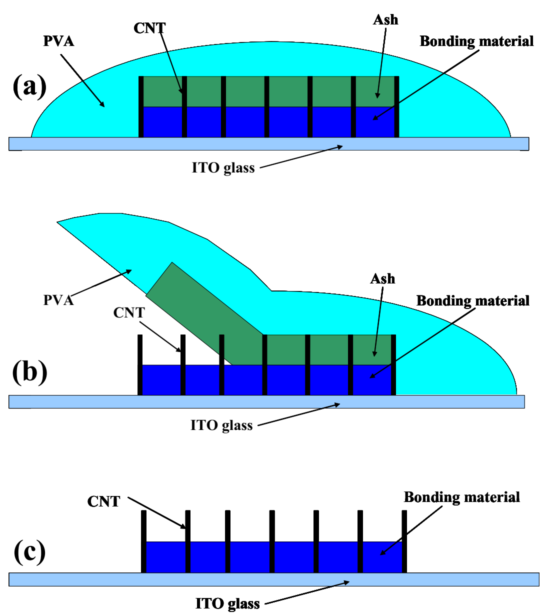

Figure 2. Schematic describing the surface treatment using the liquid method. (a) after applying the PVA solution, (b) detaching process of PVA film, (c) after surface treatment.

Figure 3 shows the OM (optical microscopic) photos for samples. Fig. 3(a) shows the sample before surface treatment, clealy showing a thick CNT film on the ITO electrode. Fig. 3(b) shows the sample with a PVA film on the CNT film. It can be seen that the CNT pattern is completely covered with PVA film. Fig. 3(c) and Fig. 3(d) show samples after removal of the PVA film for different concentration ratios of PVA powder to DI (deionized) water. Compared to Fig. 3(d), Fig. 3(c) showed thicker lines of CNT film on the ITO electrode. This is due to the stronger adhesive strength of the PVA film made from 5 wt. % PVA over a PVA film made using 3 wt.% PVA.

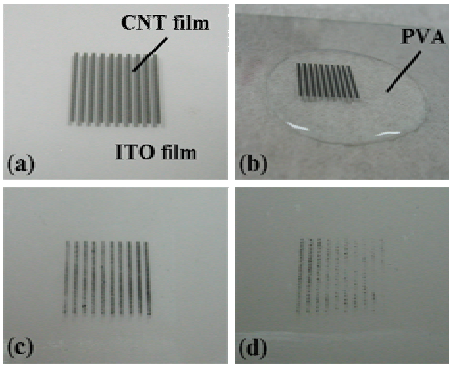

Figure 3. Optical microscopic photos of samples before and after surface treatment. (a) before surface treatment, (b) after applying the PVA solution, (c) after surface treatment using 3 wt. % PVA, (d) after surface treatment using 5 wt. % PVA.

Figure 4 shows OM(optical microscopic) images and field emission images for samples that were heat treated at 350 °C in an atmosphere of air using different surface treatments. As is known, the surface of the sample treated with a polymer-based organic solution using 5 wt.% PVA shows a poor emission image. However, the sample surface treated with a polymer-based organic solution containing 3 wt.% PVA showed an emission image comparable to the samples surface treated using conventional adhesive taping and rolling methods.

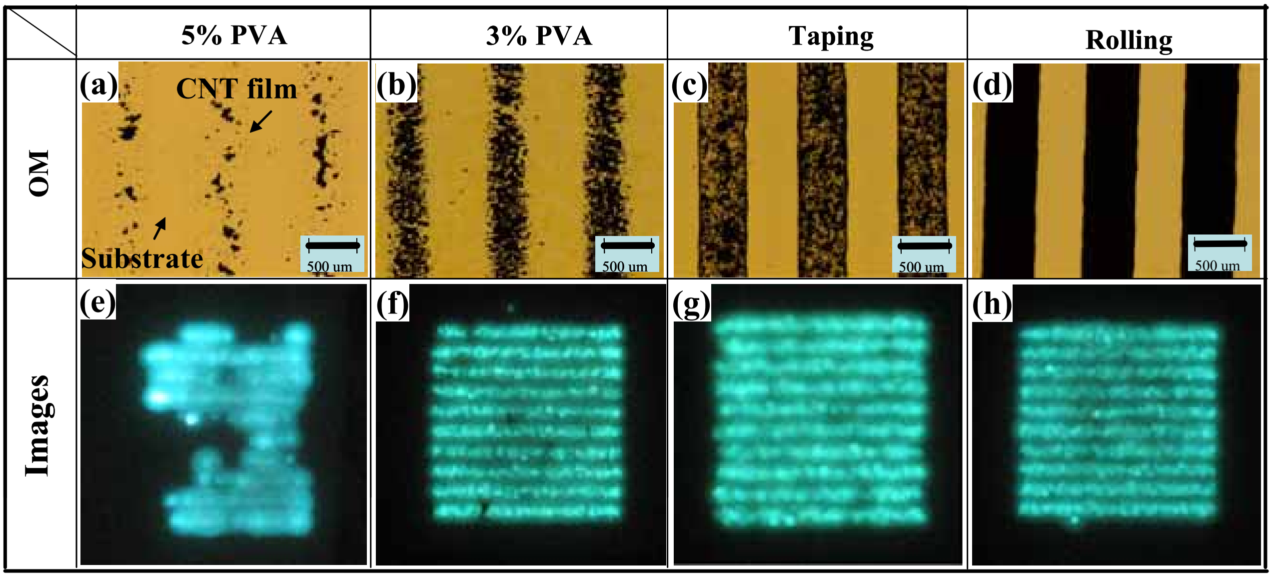

Figure 4. Optical microscopic photos and emission images for samples after different surface treatments. (a) 5 wt.% PVA, (b) 3 wt.% PVA, (c) Taping method, (d) Rolling method.

Figure 5 shows the field emission characteristics of CNT cathodes measured in the diode mode in a vacuum chamber, heat treated at 350 °C in a N_2 atmosphere, for the different surface treatments. The emission currents of the sample surface treated using the rolling method, the adhesive taping method and the liquid method at an electric field of 2.5 V/μm are 440 μA, 370 μA and 330 μA, respectively.

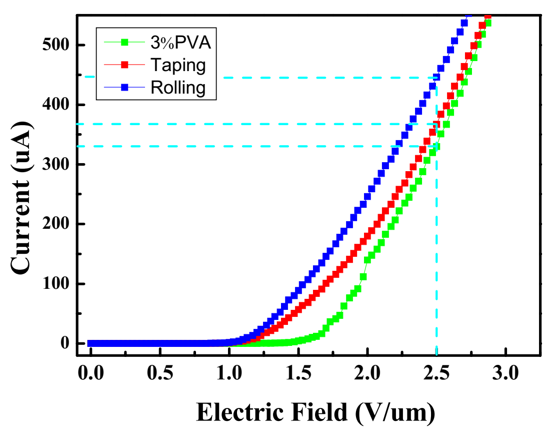

Figure 5. Effects of surface treatment on the field emission properties of screen printed CNT cathodes measured in the diode mode in a high vacuum chamber.

Compared to the rolling method, the liquid method resulted in a slightly smaller emission current. However, the liquid method is very simple and is also a low cost process. From this study, we conclude that the liquid method is more efficient than the mechanical method for achieving a uniform surface treatment for CNT cathode.

4. Conclusion

We found that the emission current in a screen-printed CNT cathode is dependent on the methods used in the surface treatment after the firing process. We also propose that the liquid method is one of the best surface treatments for CNT cathodes, resulting in a high uniformity. This result can be used as the criteria for choosing the surface treatment method for fabricating high-efficient and large-sized CNT-cathodes.

5. Acknowledgements

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6. References

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