Fabrication Techniques for Carbon Nanotube Field Emitters by Screen Printing

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Abstract
The carbon nanotube emitters for field emission displays were fabricated by screen printing techniques. The pastes for screen printing are composed of organic binders, carbon nanotubes, and some additive materials. Then the pastes were printed on Cr-coated/Ag-printed soda-lime glass substrates. From the I-V characteristics, the turn-on field of SWNT was lower than that of MWNT. The decrease in the mesh size of screen masks resulted in decreasing the turn-on field and increasing the electron emission current. When the carbon nanotubes were mixed with glass frit, glass frit appeared to contribute to the vertically aligning of carbon nanotubes on glass.

1. Introduction
Since the discovery of carbon nanotubes by Dr. Iijima in 1991 [1], CNTs (carbon nanotubes) have fascinated many researchers concerned in many scientific and industrial fields.

Because of their high aspect ratio (length/diameter), CNTs are considered as proper materials for field emitters [2-4]. The efforts to fabricate CNT field emitters have been developed largely in two types; screen printing techniques and thin film process such as CVD.

In this study, carbon nanotube field emitters were fabricated by screen printing techniques, which is low-temperature process so that we can utilize soda-lime glass as a substrate. I-V characteristics were investigated for different carbon nanotubes with different fabrication conditions such as mask mesh size, additives, etc.

2. Experiments
The CNT pastes were formulated with organic binders (ethyl cellulose and Terpineol), CNT, and additives such as glass frit, etc. The CNT pastes were mixed by 3-roller mill for good dispersion. The CNT pastes were then printed on glass substrates through 3 different sizes of screen mask mesh (250, 400, and 500 mesh). Its opening sizes were 58 ㎛, 38 ㎛, and 30 ㎛ respectively. The printed patterns were kept at 400℃ for 1 hour to remove organic binders. To measure the effect of additives, a glass frit was mixed in CNT paste and printed on the same glass substrate. The electrodes used in our experiments were 2 types; which are a silver electrode formed by screen printing techniques and a Cr electrode deposited by sputtering. The printed CNT emitters as a function of mesh size were characterized with FESEM, Optical Microscopy, and I-V measurement.

3. Results and Discussion
Figure 1 shows the printed MWNTs (multiwalled nanotubes) on Cr film/glass substrate after firing at 400°C, 1 hr. Figure 2 shows the printed SWNTs (single-walled nanotubes). The lengths of MWNT and SWNT are around 2-3 ㎛micron and 20 ㎛, respectively. From the both Fig. 1 and Fig. 2, the CNT emitters printed on glass through 3 types of mask mesh were different in their shape. As shown in

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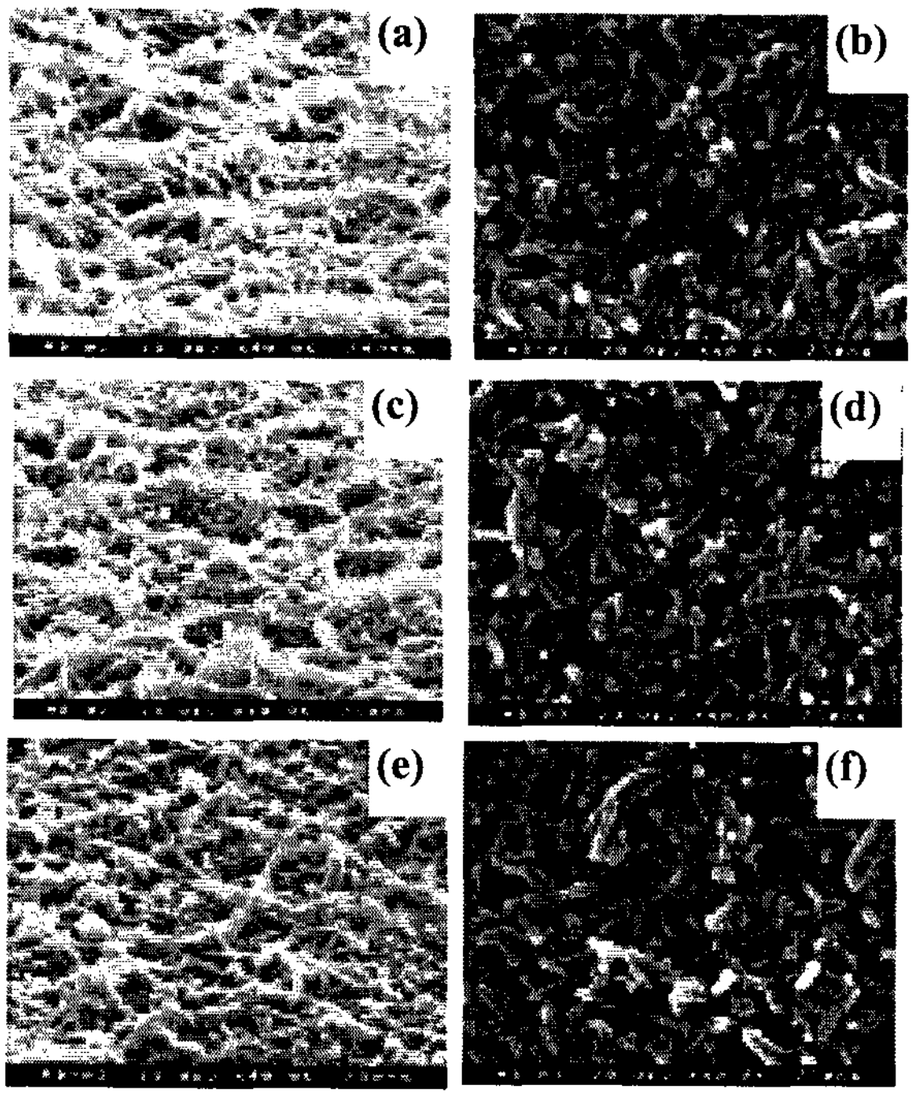


Figure 1 MWNTs screen-printed on Cr coated glass with screen mask of (a) 250 mesh, (c) 400 mesh, and (e) 500 mesh. (b), (d), and (f) are top views of (a), (c), and (e), respectively. (firing at 400°C, 1 hr)

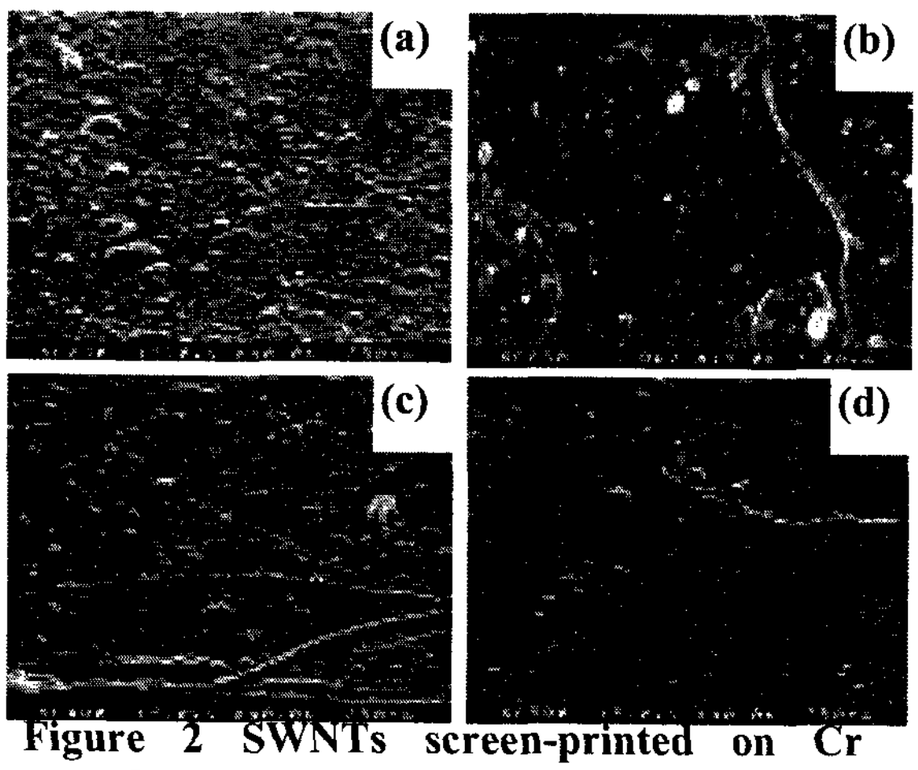


Figure 2 SWNTs screen-printed on Cr coated glass with screen mask of (a) 250 mesh and (c) 400 mesh, (d) 500 mesh. (b) is the top view of (a). (firing at 400°C, 1hr)

Fig. 1, with increase in the opening size of the mask mesh (i.e. more decrease in screen mesh size), more CNT were printed on substrate, giving more

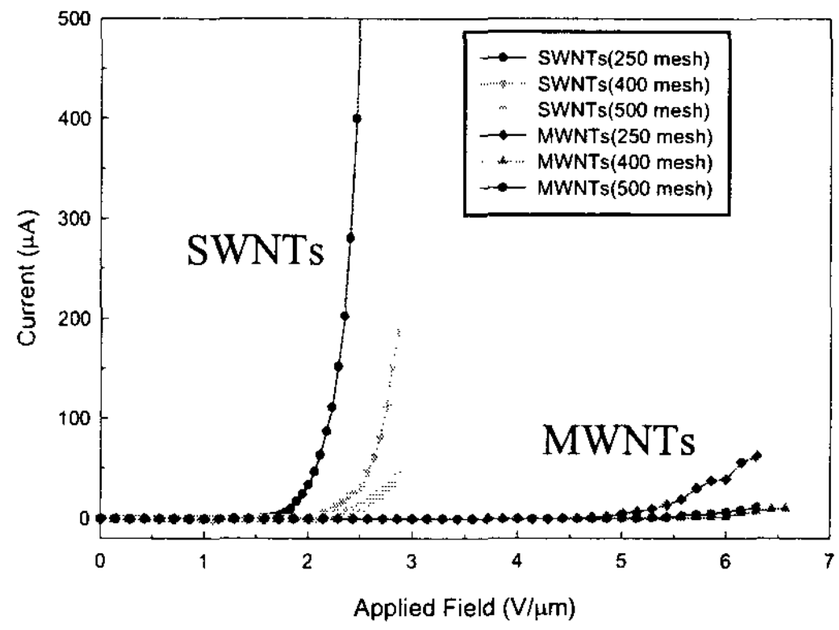


Figure 3 Field emission characteristics of CNTs screen-printed on Cr coated glass with variation of mask mesh.

possibility of holding together and increasing the fraction of vertical standing of CNT. This resulted in the higher current density and the lower turn-on field (Figure 3). Figure 2 showed that the printed SWNTs entangled with complexity and could not present any vertical standing due to its long length.

Figure 3 shows the field emission of the printed MWNTs and SWNTs. In the 250 mask mesh, the turn-on field of SWNT was 1.7 V/㎛ while that of MWNTs was 4.9 V/㎛. SWNT rather than MWNT showed better I-V characteristics under same conditions although SWNTs are not vertically standing.

In case of the mixing of glass frit with CNT pastes (Fig. 4) more CNT were erected on the substrate after removal of organic binders due to binding effect of frit. Figure 5 shows the I-V characteristics of MWNTs mixed with silver pastes as a function of CNT amounts. As expected, the more CNTs is added, the more emission current.

In case of CNT printing on different kinds of electrodes (Fig. 6), I-V characteristics of Cr electrode were uniform over measurement positions while those of sliver-printed electrode were not because of its irregular surface roughness.

4. Conclusion

We applied screen printing techniques, which is simple and low-temperature fabrication process for large area displays and mass production. We provided fundamental data for the fabrication of carbon nanotube field emitter devices by screen

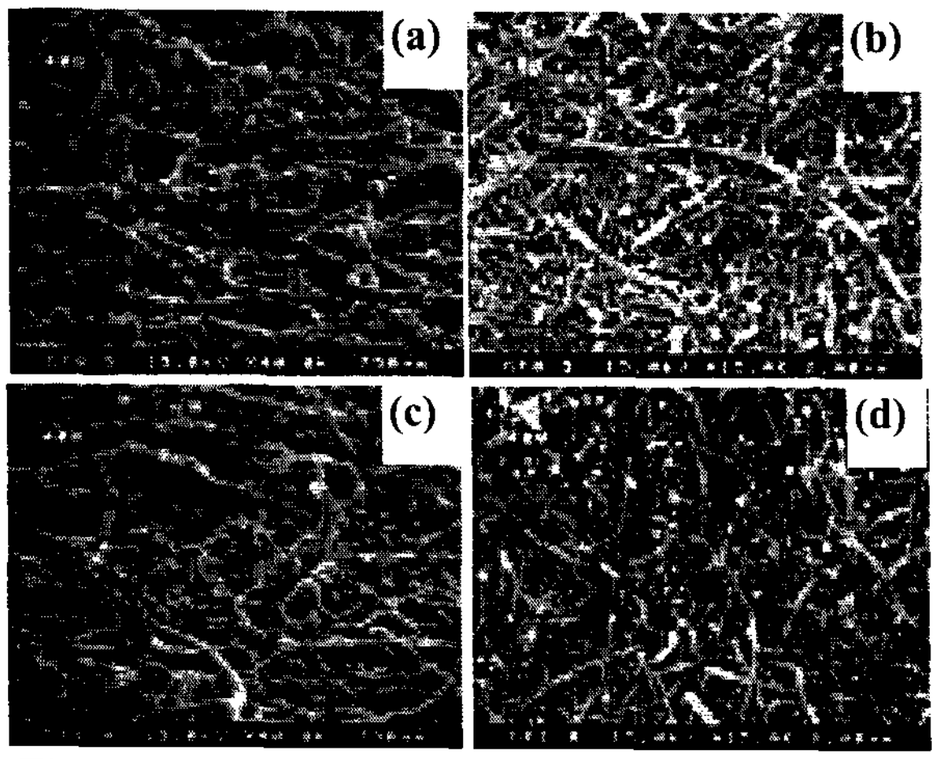


Figure 4 Screen-printed MWNTs with addition of glass frit of (a) 0.5 wt% and (c) 1 wt%. (b) and (d) are the top views of (a) and (d), respectively. (firing at 400°C, 1hr)

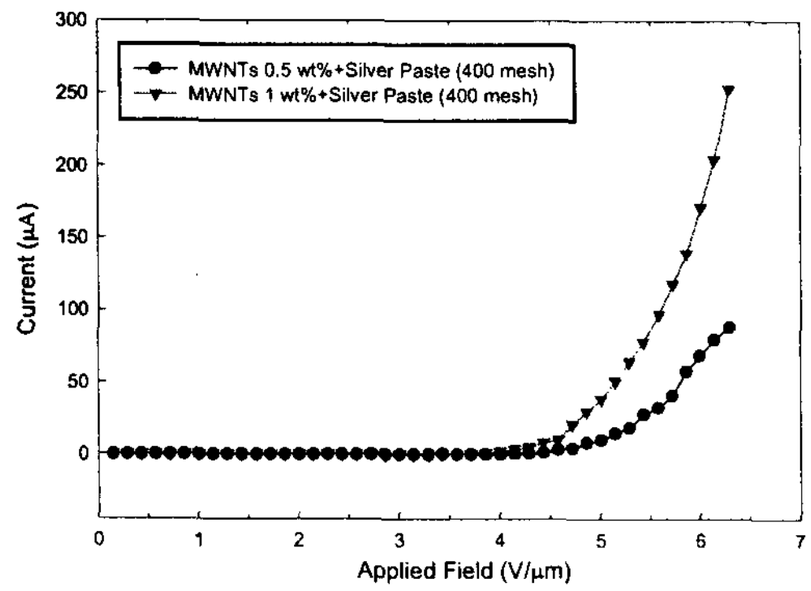
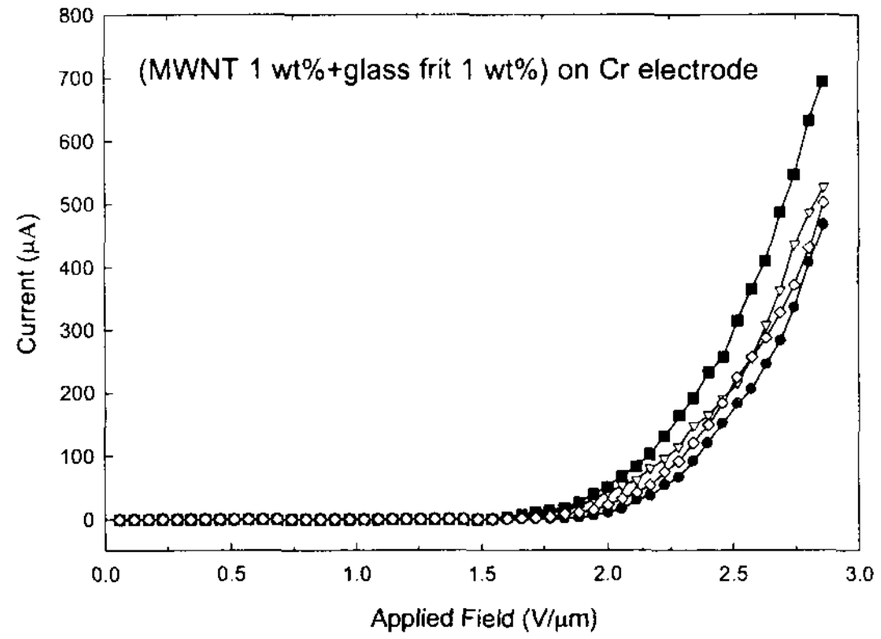


Figure 5 Field emission characteristics of screen printed MWNTs mixed with silver paste

printing.

The larger is the hole size of mask mesh, the more CNTs were printed on substrate, which resulted in the higher current density and the lower turn-on field. SWNTs had better I-V characteristics than MWNTs under same conditions. Glass frit appeared to contribute to vertical standing of CNTs.



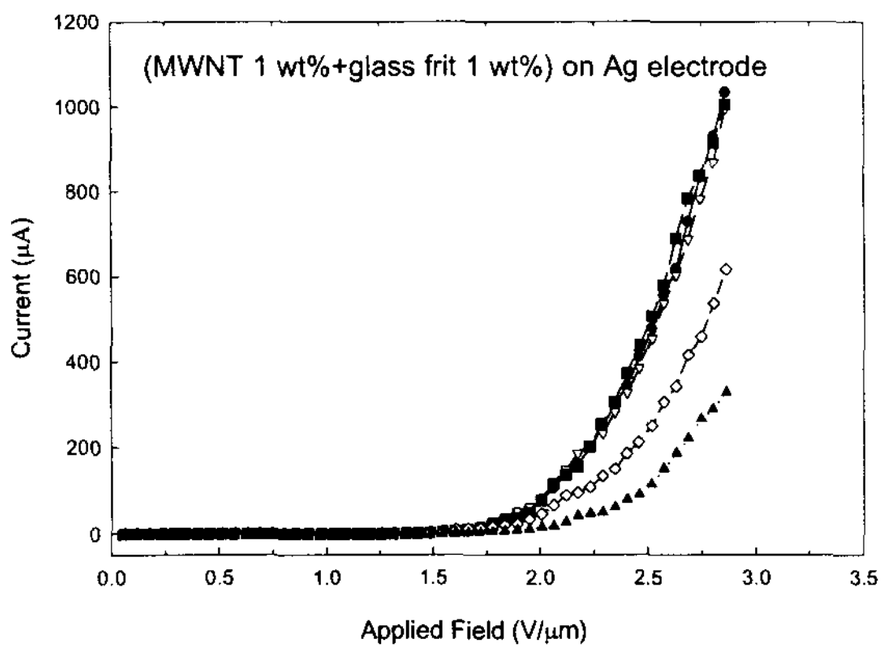


Figure 6 Field emission characteristics of MWNTs mixed with glass frit of 1 wt% which are printed on 2 different types of electrodes.

5. Acknowledgements

This study was supported by Display Device Research Center at Kumoh National Institute of Technology.

6. References

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