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전계방출표시소자에서 나노 카본의 응용

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Application of Nano-carbons in Field Emission Display

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Abstract

The characteristic of single wall carbon nanotube (SW-CNT) and herringbone nano fiber (HB-CNF) emitters was described. SW-CNT synthesized by arc discharge and HB-CNF prepared by thermal CVD were mixed with binders and conductive materials, and then were formed by screen-printing process. In order to obtain efficient field emissions, the surface treatment of rubbing & peel-off was applied to the printed CNT and CNF emitters. The basic structure of FED was of a diode type through fully vacuum packaging. Also, we proposed a new triode type of field emitter using a mesh gate plate having tapered holes and could achieve the ideal triode properties with no gate leakage currents.

Key Words : Field Emission Display, Emitter, CNT, CNF

1. Introduction

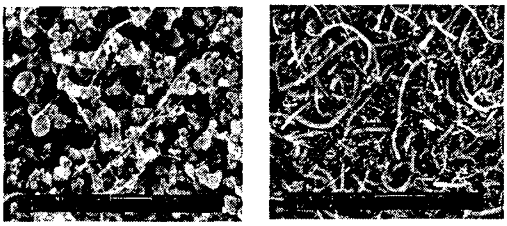
In order to overcome the drawback Spindt type such as Mo-tip [1-2], many researchers have been introduced the field emission source with nano-carbon materials [3-4]. Single and multi wall carbon nano-tubes (CNT) as well as carbon nano-fibers (CNF) are promising candidates for field emission display (FED) as cold emitter [3-5, 9]. Due to their reliability, high efficiency and short switching time, nano-carbon emitters have been extensively studied using various methods such as chemical vapor deposition, dispensing, photo-lithography [3-5]. These technologies are difficult to make a large size of cathode faceplate over large substrate area because of complicated fabrication process. However, screen-printing technologies are well known as a low-cost process, and could be adopted to fabricate large area field emission display (FED) devices [6]. It is also necessary to optimize and improve several key technologies; improving the surface morphology of nano-carbons, activating the surface to protrude and vertical alignment, and increasing the open ratio of the control gate electrode.

In this paper, we introduce the fabrication technologies and prototype mono FED device using screen-printing technology of CNT and CNF pastes. Also, we proposed a new triode type field emitter using a mesh gate plate having tapered holes.

2. Experiment

2.1 Process

Single wall nano-tube (SW-CNT) grown by arc discharge without any purification process [7-8]. Herringbone type of nano-fiber (HB-CNF) prepared by a thermal chemical vapor deposition (CVD) [9]. The raw materials of SW-CNT and HB-CNF is shown in Fig. 1.



(a) SW-CNT (b) HB-CNF

Fig. 1 Image of (a) SW-CNT and (b) HB-CNF

The CNT and CNF pastes were mixed with organic vehicles, binder, surfactants and conductive materials. Mixed CNT and CNF pastes were screen-printed on ITO or Ag/ITO coated glass through the metal mesh mask. In order to burn out the organic binders, the firing treatment was done in the annealing furnace. Rubbing & peel-off methode as a surface treatment was adopted to protrude efficient electron emissions from the emitter surface. An additional firing process at a high temperature might be made to get rid of the residual organic species.

The conventional CRT green phosphor, ZnS:Cu,Al was also screen-printed on the transparent ITO electrodes to form anode face-plate. The patterned green phosphor, was used to show the screen image. To make the triode construction, mesh gate plate using by sand blaster which tapered hole arrays were formed on the glass substrate. A metal layer was formed on the upper surface of the glass mesh plate as an extraction gate electrode. The anode and cathode plates were then sealed with spacers by using a frit glass under high vacuum chamber. After the sealing process, non-evaporable getters in the panel were activated. The simple diode structured samples were tested directly in a vacuum chamber and in the form of vacuum-packaged panel. The triode panel with the mesh gate plate was fabricated.

3. Results and Discussion

Fig. 2 shows the surface morphology of SW-CNT and HB-CNF samples after the surface treatment.

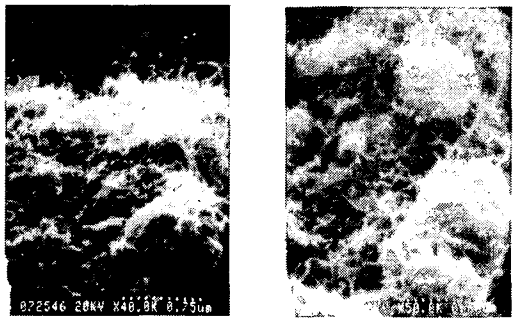
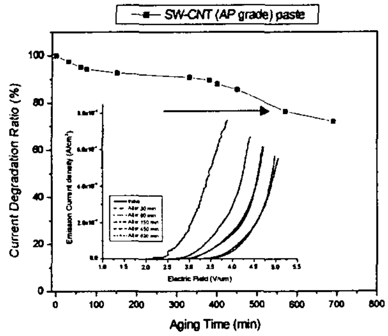


Fig. 2 Surface morphology of SW-CNT and HB-CNF with surface treatment.

After the screen-printing with CNT and CNF paste on the cathode substrate, the plate was dried to evaporate the organic solvents. In order to activate field emission sites, the proper surface treatment was adopted by the rubbing and peeling off methods. An air-jet-shooting and a ball-pushing as mechanical surface treatment was tested. However, had no effect to activate the field emission.

Fig. 3 shows *I-V* curves and electrical degradation of SW-CNT and HB-CNF into the graph. The spacing of an anode-to-cathode was 250 m and measured directly in the vacuum chamber. In general, the field emission of SW-CNT started from 2.0 ~ 2.5 V/μm and continually degraded to 3.5 ~ 4.0 V/μm in vacuum chamber of diode structure. In case of HB-CNF, initial turn-on field was small higher than SW-CNT at 2.5 ~ 3.0 V/μm. However, the current density decreased to 80% with increasing aging time, and then did not degrade any more. In the case of as screen-printed sample, the emission current density from HB-CNF emitters was extremely low along with



an very poor uniformity.

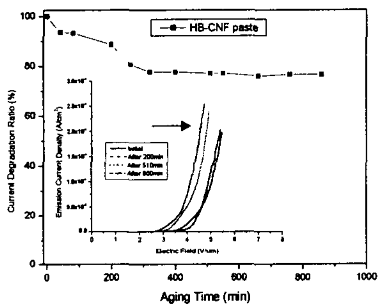


Fig. 3 I-V curves and degradation of SW-CNT and HB-CNF.

After electrical aging, the emission current density was about 0.5 mA/cm^2 and 0.2 mA/cm^2 at a field of 5.0 V/μm SW-CNT and HB-CNF, respectively.

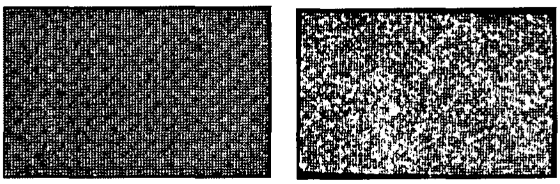
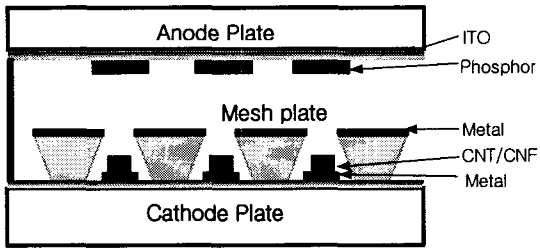


Fig. 4 The image of SW-CNT and HB-CNF emitters in vacuum chamber.

Fig. 4 shows the direct image of SW-CNT and HB-CNF emitters. In case of SW-CNT, we achieved relatively uniform field emissions in a 3-inch diagonal panel with 96x64 pixels. However, HB-CNF was different image poor uniform because nano fiber had different size distribution and thick diameter shoing in Fig. 3.



(a) triode structure with mesh-gated panel

(b) emission image

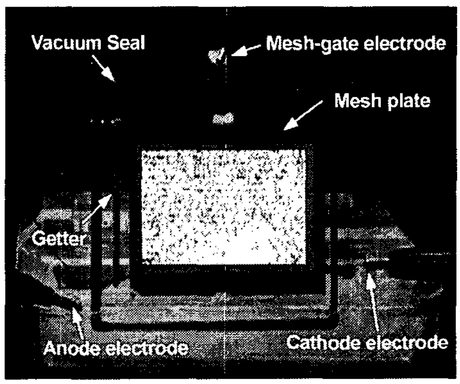


Fig. 5. Schematic diagram of mesh-gated panel (a) and emission image (b) from a vacuum packaged 3-inch panel with 96x64 pixels.

Fig. 5 shows new triode cathode structure with a mesh plate gate and an emission image from the fabricated panel. In the experiment, the mesh was made of glass with a thickness of 0.23 mm. The size of gate holes was designed to be comparable to the thickness of the mesh plate, ensuring to shield the CNT and/or CNF emitters from the electric field induced by the anode voltage. Therefore, we can increase the anode voltage without any high voltage damage in the CNT emitters and then achieve a highly bright FED panel. The upper and lower hole sizes were about 0.27 mm and 0.38 mm in diameter, respectively. The metal layer was formed on the upper surface of mesh plate as the extraction gate electrode for field emission. The anode plate was placed above 0.3 mm from the mesh plate. The gate hole is aligned to the CNT emitters in each pixel. We have successfully operated the panel by applying the extraction voltage to the mesh electrode with a fixed anode voltage.

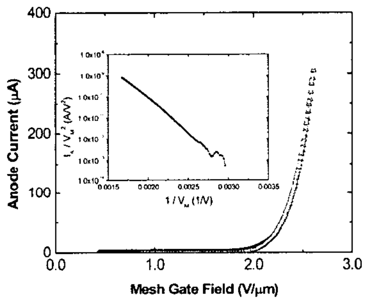


Fig. 6. *I-V* characteristics of mesh-gated CNTs from a vacuum packaged 3 inch panel at an anode bias of 1000V. The inset shows the corresponding Fowler-Nordheim plot.

The field emission results of the mesh gated CNT emitters and the corresponding F-N plot are shown in Fig. 6. The emission current was measured by increasing the mesh gate voltage at an anode voltage. The field emission currents were observed to be fairly reproducible for several mesh gate voltage scans ranging from 400 to 700 V. The turn-on field was about 1.5 V/m. It was specially noted that the mesh-gate leakage current was hardly detected and the anode voltage did not affect the emission current, showing the ideal triode behaviors like Spindt-type emitters [1-2].

4. Conclusions

The properties of FED device with SW-CNT and HB-CNF emitters were presented. The screen-printing process was performed to fabricate a diode and triode structure with the mesh plate. The triode structure with mesh gate showed the ideal Spindt-type emitters without leakage currents. The CNT and CNF emitters will be one of the promising field emission display in the near future.

Acknowledgements

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