Application of carbon nanofibers in Field Emission Display

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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]. Nano phased carbon materials are an allotrope of carbons that exist abundantly as a natural and synthetic forms on earth. Their size are normally in the range from sub nano meters to several tens nano meters. Basically, 4 categories of nano phased carbon materials exist, such as carbon nanofiber (CNF), carbon nanotube (CNT), carbon nano cell (CNC, fullerene and related), and carbon nano particulate (CNP).

Due to their reliability, high efficiency and short switching time, CNT and CNF have been extensively studied using various methods in nano display as cold emitter [3-5, 9]. Direct growing fibrous nano-carbons on a substrate pre-patterned with a catalyst or producing nano carbon materials-containing slurry or paste and subsequent patterning on a substrate have been realized [3-5]. Such technologies are not effective to make a large size of cathode plate over large substrate area because of complicated fabrication processes. Screen-printing technologies, well known as a low-cost process, could be adopted to fabricate large area field emission display (FED) and field emission lamp (FE-lamp) devices [6]. To optimize and improve several key technologies are necessary for the commercial base; 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.

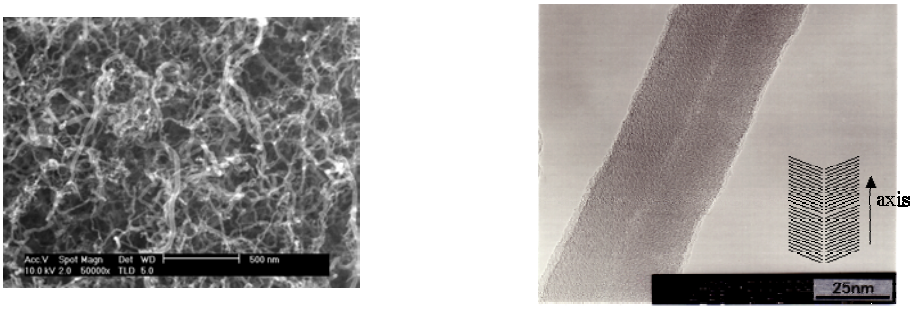
In this paper, we investigated the field emission characteristics of the various structured carbon nanofiber as a cathode material for the cold emitter using screen-printing technology. In this abstract, we summarized the short results of the emission properties of herringbone structured CNF. Also, we prepared a fully vacuum packaged in a diode structure.

Experimental

Herringbone CNF (HB-CNF) was prepared by a thermal CVD without any purification process [7-9]. SEM and TEM images of the raw material for HB-CNF are shown in Fig. 1. CNF is consisted of packing with nano-rod type primary structural unit and has diameters of ca. 15 ~ 20 nm.

The CNF pastes were mixed with organic vehicles, binder, surfactants and conductive materials. After forming the buffer metal layer, mixed CNF pastes were screen-printed on ITO coated glass through the screen metal mask. In order to burn out the organic binders, the firing treatment was done in the annealing furnace on air atmosphere. To activate the extraction electron from the edge of emitter, rubbing & peel-off method 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 with organic binders on the transparent ITO electrodes to form anode face-plate. The patterned green phosphor was used to show the screen image from the field emission.



(a) (b)

Fig. 1. SEM and TEM image of herring-bone types carbon nano fibers.

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/or in the form of vacuum-packaged panel.

Results and Discussion

Fig. 2 shows the surface morphology of HB-CNF cathode before and after the surface treatment. After the screen-printing with HB-CNF pastes on the cathode substrate, the plate was dried to evaporate the organic solvents.

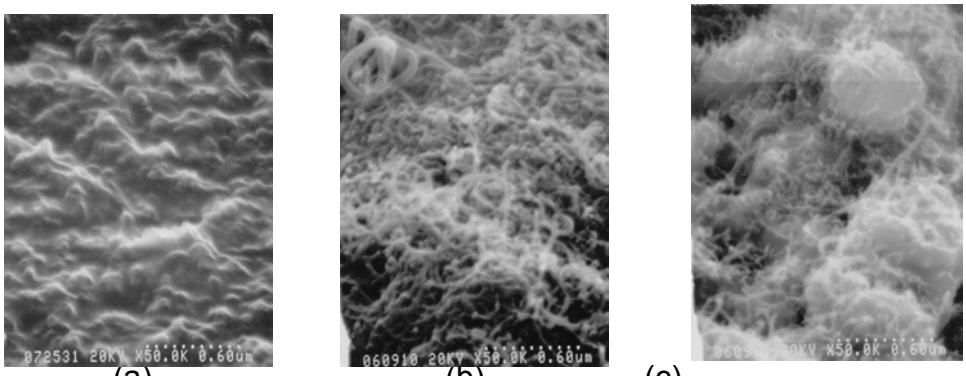


Fig. 2. SEM image of (a) as screen-printed (b) after annealing and (c) after surface-treatment of herring-bone types carbon nanofibers.

It is clearly shown that the polymer binders wrapped around the HB-CNF surfaces in Fig. 2 (a). Following adjustable annealing treatment, some parts of the bundle HB-CNF is activated partially from the adhesive surface of cathode plate in Fig. 2 (b). In order to activate the field emission sites, an air-jet-shooting and a ball-pushing as mechanical surface treatment was also tested. However, those of surface treatments had no effect to activate effective field emission. However, the rubbing and peeling off method gave rise to vertically align and to protrude HB-CNF emitters to the surface, as shown in Fig. 2 (c) [10].

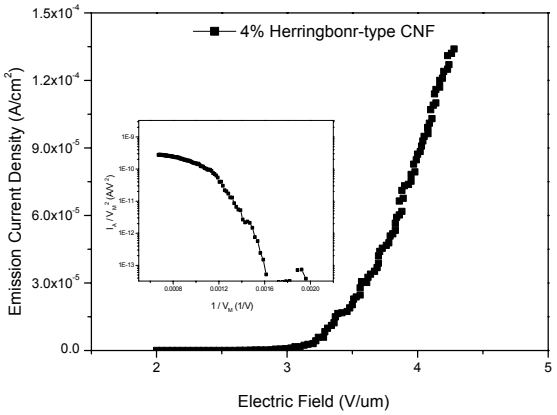


Fig. 3. *I-V* and Fowler-Nordheim plot of herringbone CNF.

An *I-V* characteristic of the electron emissions and Fowler-Nordheim plot in insert from diode type screen-printed HB-CNF emitters is shown in Fig. 3. The spacing of an anode-to-cathode was 250 μm and measured directly in the vacuum chamber. The pattered cell size is 300 x 250 μm and in a 3-inch diagonal panel with 96 x 64 pixels. In the case of as screen-printed sample, the emission current density from HB-CNF emitter was extremely low along with very poor uniformity. However, after the firing and

surface treatment, the initial turn-on field was about 2.5 V/μm. The emission current density was about 0.15 mA/cm^2 at 4.2 V/㎛ electric field with dc bias in vacuum chamber.

The electrical aging and degradation of HB-CNF emitters with screen-printed in vacuum are shown in Fig. 4. At this time, the spacing of anode to cathode was 300 ㎛ and applied voltage with a dc bias was 1300 V. In general, single wall carbon nano tube (SW-CNT) was thought to degrade with the oxidation of nano tube tip. On the other hand, as shown in Fig. 4, the current density of HB-CNF emitters decreased rapidly to 20 % of the initial value at about 5 hours. However, the current density did not decrease with increasing aging time. The main reason for this long life time is considered to the thick diameter closing to the multi wall carbon nano tube and many sites of electron extraction from the embedded nano rod.

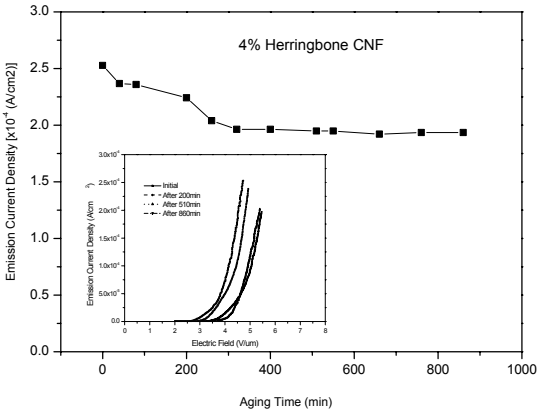


Fig. 4. The electrical aging and degradation of carbon nano fiber emitters.

Fig. 5. The field emission image of HB-CNF emitters with fully vacuum packaged panel.

After the vacuum packaged panel, the emission image in a dc bias operation is shown in Fig. 5. The panel size was 3-inch in diagonal with 96x64 pixels. The fully vacuum-packaged panel was made with the help of a glass bead of 500 μm. In especial, we

sealed the panel in an ultra high vacuum chamber, resulting in an ideal flat panel without an evacuation tube. After the sealing process, a laser or resistive heat activated the non-evaporable getter loaded inside the panel. The final vacuum of the packaged panel was approximately estimated in the range of 10^{-5} Torr. The measured brightness of showing text image was as high as 1000 cd/m^2 at an anode voltage of 1900 V. The stability and reliability of the panel was found to be strongly dependent on the vacuum level that was degraded by out-gassing from the cathode and/or anode during the panel operation. In order to suppress the out-gassing effect, a pre-processing was needed prior to the sealing.

Conclusions

We have measured the field emission characteristics of herringbone type carbon nano fibers. The screen-printing process was performed to fabricate a diode structure. As a result, it was shown that HB-CNF emitter showed the emission properties superior to the other emitters. In addition, we proposed that the HB-CNF emitters will be one of the promising field emission displays in the near future.

Acknowledgements

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