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Fabrication of simple diode structure FED device with connecting plate

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Abstract. By using the thick soda-lime glass plate and the flat thin glass, the connecting plates were formed easily. The carbon nanotube materials were prepared to form the field emitters. The simple small diode structure field emission display device with connecting plate was developed. The detailed fabrication technology for the whole device was also presented. The sealing of the vacuum room was performed by means of glass frit and the gas in the vacuum room could be evacuated out through the exhaust tube. The developed diode structure FED sample exhibited large field emission current, better field emission properties and image display performance.

Introduction

It was well known that the carbon nanotube (CNT) had very excellent field emission characteristics become of its high aspect ratios and small radii of curvature at their tips [1-2]. The CNT was usually used as cold cathode material for the field emission display (FED) device. In the vacuum environment, when the external work voltage was applied for the CNT cathode, the very strong electric-field would be formed on the cathode surface, and lots of electrons would also be emitted by the “field emission” form [3]. Many prototype of flat display device were realized by the CNT as cathode materials, which was called CNT-FED. In recent years the FED device with CNT field emitters had been remarkably investigated because of its advantages such as low power consumption, fast response time and wide-temperature-range [4-6]. Although until now the development of FED device, for the reason of some technological difficulties including the fabrication process and device structures, had not been as satisfactory as expected, the FED based on carbon nanotube cathode was also considered as the excellent next generation flat panel display device [7, 8]. The situations of complicated fabrication process and expensive manufacturing cost might be its critical demerit, so further research and discussion on industrial fabrication technology for practical display applications would be necessary. In this paper, the simple diode structure FED device with CNT as field emitters was reported. The design and detailed fabrication process of cathode back plane and anode back plane were presented. The connecting plates were formed by using thick soda-lime glass and the flat thin glass using for the liquid crystal display device. The cathode structure and the anode structure of whole flat display device were both fabricated using the simple screen-printing process.

Experiment

The schematic structure of developed simple diode type FED device based on carbon nanotube cathode was shown in Fig.1. The flat thick soda-lime glass that the thickness was 2mm was used as the outside glass plate, and the flat thin glass usually using for the liquid crystal display device, which the thickness was ca. 1mm, was used as the internal glass plate. Of course, the length and width of internal glass plate must be less than the outside glass plate. With the simple screen-printing process, the insulation slurry was printed on the internal glass plate. After the sintering process for the insulation slurry, the high quality insulating layer was formed over the glass surface for the internal glass plate, and the internal glass plate was also combined with the outside glass plate, which was named as connecting plate. The insulating layer pattern was formed by many small squares, which were distributed on the edge position of the internal glass surface. For the internal glass plate, the indium-tin oxide (ITO) thin film was evaporated over one of glass surface, and the insulation layer was formed over the other against glass surface. The spacing between the two glasses for the connecting plate was about 70μm, which was determined by the thickness of insulating layer.

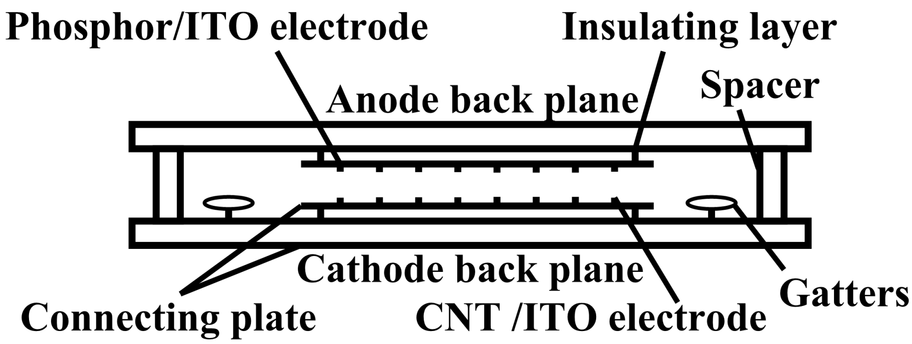

Fig.1 The schematic structure of fabricated diode type FED device.

The fabricated small FED device structure comprised of two connecting plates, which were used as the cathode back plane and the anode back plane, respectively. For the cathode back plane, the patterned bar cathode electrode was formed after the photolithography process of ITO thin film. The CNT-paste was composed of carbon nanotube materials, inorganic binder and other organic vehicles. Then the prepared CNT-paste was screen-printed onto the bar cathode electrode to form the field emitters. A post-treatment process was necessary for improving the field emission characteristics and the electrical contacts between CNT materials and the bar cathode electrode. For the anode back plane, the ITO thin film was also divided to form the bar ITO anode electrode with the precise photolithography process, and the green phosphor powder was screen-printed over the patterned bar ITO anode electrode. Finally, the cathode back plane, the anode back plane and the spacer combined to a vacuum room. Of course, the bar ITO cathode electrode and the bar ITO anode electrode were arranged in orthogonal directions. The getters were also located in the vacuum room. In an atmosphere of carbon dioxide gas, sealing of the vacuum room was performed by means of glass frit. The gas in the vacuum room could be evacuated out through the exhaust tube. After sealing the exhaust tube, the small whole display device was developed.

Results and discussions

The FED was a vacuum device, so the CNT could emit lots of electrons and the phosphor powder could be bombarded by the high-speed electrons which were accelerated by the anode work voltage. for the general FED device structure, the two flat glass plates and the spacer combined to make the device vacuum room, the flat glass plate which the phosphor powder was screen-printed over the glass surface was not only used to display image, but also utilized to sustain the atmosphere pressure difference between the inner and the exterior of whole FED device. It was no doubt that the FED image quality would be affected by the minute deformation of flat glass plate. For the developed simple diode structure FED device with connecting plate, the two outside thick soda-lime glass plates of connecting plates and the spacer combined to make the vacuum room, and the internal flat thin glass of the anode back plane was used to display image, which could ensure the better image quality because of the better glass smoothness. The internal flat thin glass of the cathode back plane was used to support the CNT cathode, which could ensure the emitting electron uniformity. So the whole FED device could sustain the minute deformation of soda-lime glass plates, the image quality of FED device would be improved.

For the developed diode structure FED device with connecting plates, the CNT cathode was grounded, and the anode voltage was applied to the anode bar ITO electrode. So the strong electric field was formed, and the electrons were emitted from the cathode surface. After the phosphor was bombarded by the high-speed electrons, the light emitted from the display device inner. Fig.2 showed the typical curve of emission current versus applied electric-field of fabricated diode structure FED sample. The pixel size of diode structure FED device with connecting plates was 400μm×400μm. The maximum field emission current was about 1556μA.

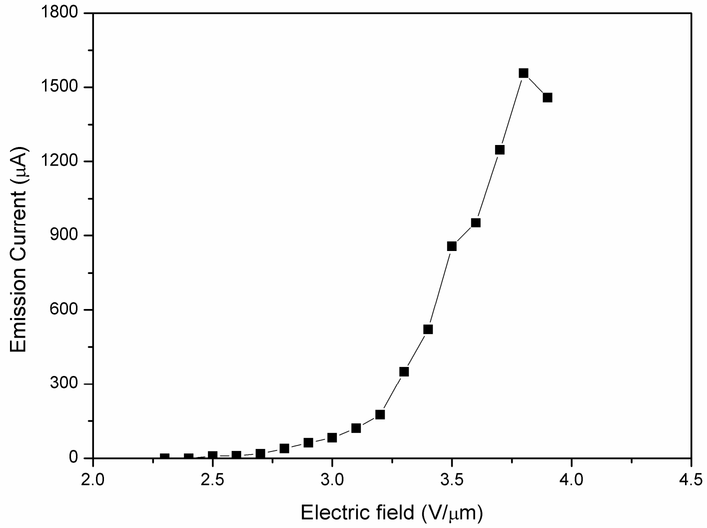

Fig.2. The typical curve of emission current vs. applied electric-field for the FED device.

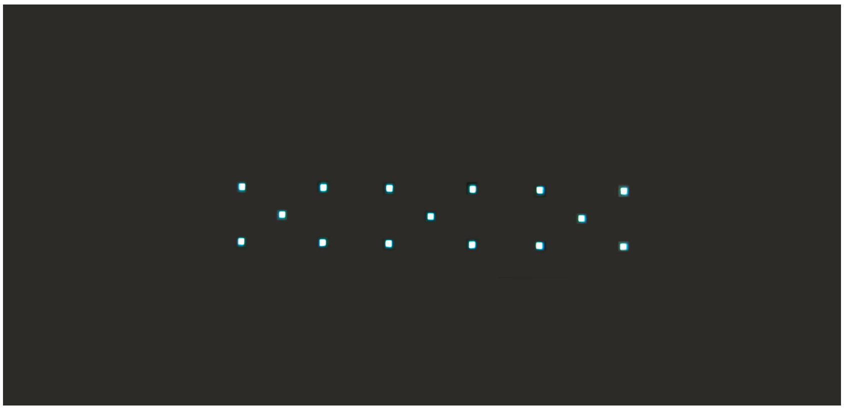

Fig.3 Emission matrix image of fully-sealed simple diode structure FED device。

Because the two flat thin glasses of connecting plates, which the each glass thickness was ca. 1mm, were all placed in the vacuum room, the distance of between two outside thick soda-lime glass plates of connecting plates was enough to accommodate the getters and the exhaust tube. The flash getter could maintain the vacuum level of whole display device, which could extend the device work life. It was obviously that the additional exhaust room was not required for the connecting-plate structure type display device. The gas could be evacuated out directly through the exhaust tube, so the whole device structure was very simple. These constructions would also simplify the fabrication process of whole FED device. Fig.3 showed the emission matrix images of FED device with connecting plates. The developed diode structure FED sample exhibited excellent field emission properties and image display performance. The large emission current was also obtained. The simple fabrication technology proved great potential industrial application in fabricating the large-area display screen.

Summary

The simple diode structure field emission display device was developed with screen-printing process. The carbon nanotube was printed to form the field emitters. By using the thick soda-lime glass plate and the flat thin glass using for the liquid crystal display device, the connecting plates were formed easily. The spacing between the two glasses for connecting plate was determined by the thickness of insulating layer. For the fabricated FED sample, the display image was not deformed although the minute deformation of device shell glass plate appeared, so the FED device possessed better image display performance.

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