Fabrication of Field Emission Display with a novel emitter of CNX

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Abstract

Fabrication of field emission display (FED) has been carried out with a novel kind of emitter called Carbon Nanometer electron eXit (CNX). The emitter has been developed on nickel plate substrates with a special DC-plasma chemical vapor deposition (DCP-CVD) technique, the array density of which is about "$2X10^8$ /cm^2, and its V-I characteristics shows an emission current density of 109 mA/cm^2 at 2.5V/μm. By using this emitter as the cathode, two screen printed matrix layers of silver as the addressing and gate electrodes, SiO_2 material was used as the spacers, and ITO layer as the anode which was coated with matrix green phosphor, a FED has been successfully fabricated.

Introduction

The recent application of flat panel displays in our daily lives such as TVs, PC monitors, car navigation displays etc. has encouraged researchers to develop high performance and low cost devices technologies. Plasma display panel and liquid crystal displays are the main technology of FPD. However, as the future display device system, it is hoped that it has a higher performance such as high brightness, short response time, larger view angle, larger size, low power consumption, and so on. It is seems that PDP and LCD can not meet the requirements. Recently, field emission display has drawn a lot of attentions and are the most promising device to meet the above display request due to its high energy efficiency, low fabrication cost, fast response time, high brightness, good gamut, and large viewing angle.

For the past years, spindt-type emitters of Si, Mo, and other materials have been used to develop FED[1]. Recently, carbon nanotubes has attracted much attention since their unique electrical properties and their potential applications. Large aspect ratios of CNTs together with high chemical stability, thermal conductivity, and a higher mechanical strength are advantageous for their application in FED[2,3]. Further more, a new emitter called CNW has been reported [4], which present an excellent field emission efficiency compared with good emission carbon nano-tube , also, another advantage of CNW is that no catalyst is needed for its growth. All these emitters have been played an important role in the development.

In this study, a novel kind emitter called CNX has been developed on nickel plate substrate by using a special DC-plasma chemical deposition technique. Then, the crystal quality has been investigated by Raman spectrum. Also, characteristic properties of field emission of as grown samples have been carried out. Furthermore, screen printing technique was used to print phosphor, the spacers and addressing electriodes. Finally, a green FED has been fabricated.

Experimental procedure

Emitter growth and characteristic

The emitters film of CNX were grown on nickel substrates with a specially designed DCP-CVD. Methane and hydrogen were used as the reaction gases. The substrates were firstly treated in hydrogen ambient at a low operation current. Then, the operation current was increased to grow carbon film at a growth temperature of about 1000↔. The growth pressure was maintained at 75 torr, and the growth time was one hour. Scanning electron microscopy (SEM) was used to evaluate the surface morphology of our samples. Micro-Raman spectrum for the deposited carbon film was measured using a 100X objective lens and an Ar laser with a power of 150mW at a wavelength of 514.5nm. The field emission measurements of our samples were carried out by disc stainless anode with 5mm diameter in a vacuum of $1X10^{-6}$Pa, during which the distance between anode and cathode was set at 1mm.

Process of anode plate

The anode plate is schematically shown in Fig.1, which consists of front glass, ITO film, phosphor, three spacers and two electrodes (grid1 and grid2). Grid1 is a group of Ag stripes along the x direction. Grid2 is another group of Ag stripes along the y direction. These two electrodes are used as both the gate electrodes and addressing electrodes.

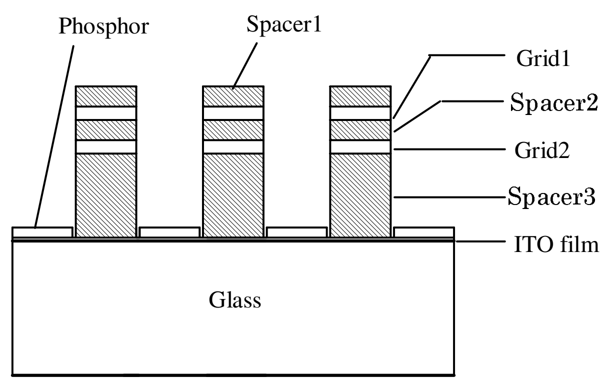

Fig. 1 Schematic diagram of anode plate

The green phosphor of P22 was firstly pattern-printed on the ITO glass by screen printing technique. Then, a 1.5mm thick spacer (spacer3) of SiO_2 was printed in the spare area of phosphor. Thirdly, a silver(Ag) layer was printed on the spacer as second addressing electrode(grid2). Forth, a SiO_2 layer with a thickness of 0.2mm was printed on the Ag layer as a spacer(spacer2). Then, another Ag layer was printed on the spacer2 layer as the first addressing electrode(grid1). Last layer is also a spacer(spacer1) of SiO_2 with a thickness of 0.2mm.

Fig.2 clearly shows SEM images of anode plate fabricated by the process steps described above. The pixels have a pitch of 1mm. Hole size is about 0.4X0.4mm.

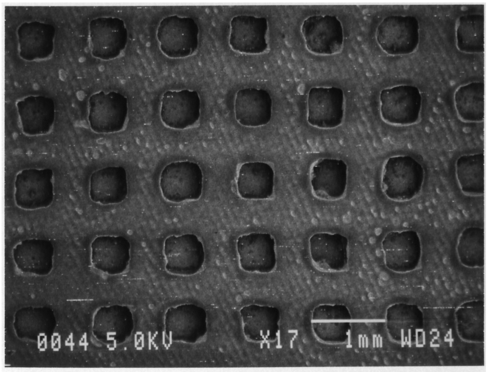

Fig.2 SEM image of anode plate taken from cathode side

Results and discussion

Fig.3 shows a SEM images taken from the carbon film

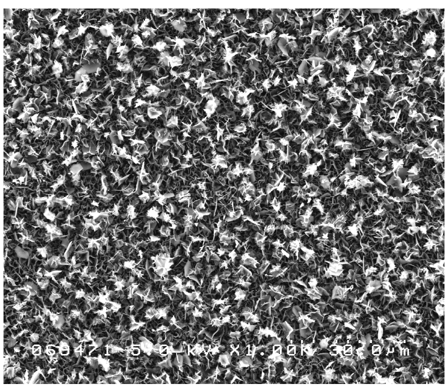

Fig.3(a) SEM image of CNX surface (×1000)

deposited on the Ni plate. Fig. 3(a) shows that there are many flower-like carbon structure in the carbon film, the density of which is about 2X10^{8}/cm$^{2.}$ This is very important for the emission uniformity of FED.

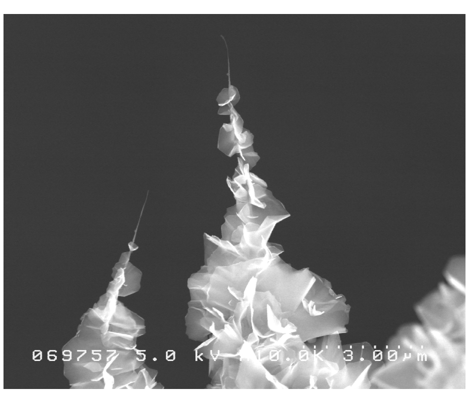

Fig.3(b) SEM image of CNX emitter (×10K)

Fig. 3(b) shows the carbon-flower image of sample shown in Fig. 3(a). A straight carbon needle stands upward, around which there are many pieces of nano-carbon walls. The carbon nano-walls at the bottom of needle are large, and those at the upside are small. The height of the needle is about 20μm.

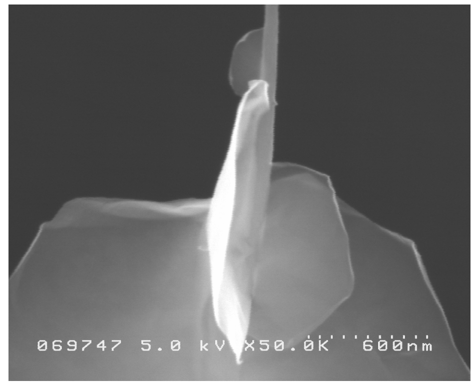

Fig. 3(C) SEM image of enlarged CNX emitter (×50K)

Fig. 3(C) indicates that the carbon needle with a diameter of about 70nm was firstly grown. Then, the nucleations of carbon nano-walls were formed along the needles from bottom to upside, and the carbon nano-walls were appeared and gradually become large with the growth time lasting.

Fig.3 addresses that the configuration of our carbon film is different from carbon nano-tube, carbon needle and carbon nano-wall. It seems a combination of carbon nano-needle and carbon nano-walls. Later we will show that our carbon film has an exvellent field emission. Therefore, this special carbon structure was denoted as Carbon Nanometer electron eXit, i.e. CNX.

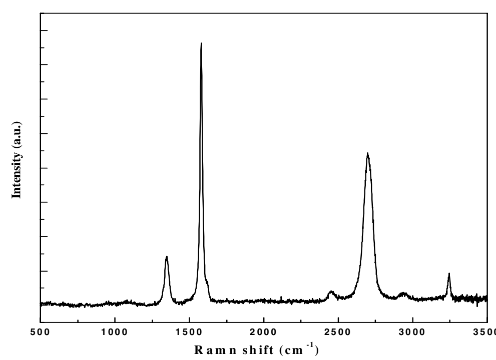

Fig. 4 Raman spectrum taken from CNX film

Fig. 4 shows a typical Raman spectrum taken from CNX. The line width of G peak (centered at 1580cm^{-1}) and the weak intensity of D peak(centered at 1350cm^{-1}) as well as the appearance of the two distinct phonon peaks(above2400cm^{-1}) suggest that CNX is high-degree graphitization and nice crystallinity.

Fig.5 indicates the field emission measurement result of CNX film. We define the threshold field as the field to obtain the emission current density of 1mA/cm^{2}. As revealed in Fig.7, the threshold field of CNX is about 1V/μm. Also, the emission current density of CNX could get to 109mA/cm^{2} at an electrical field of 2.5V/μm. These values are much better than those of diamond and Ta-C films and comparable to those of the high-grade CNT emitters. Compared with CNT, The CNX emitter, a carbon needle surrounded by many carbon nano-walls, not only has the high aspect ratio, but also has a good mechanical property. Besides, the special structure leads to a good electron conductivity, which could decrease the shake-head effect resulting in a good emission uniformity at the local area [5]. Also, since the special CNX structure, the field screen shield could be thought to be small. In additional, the CNX emitters are well-crystallized and high-degree graphitizated, which leads to the good electric conductivity for electron emission[6].

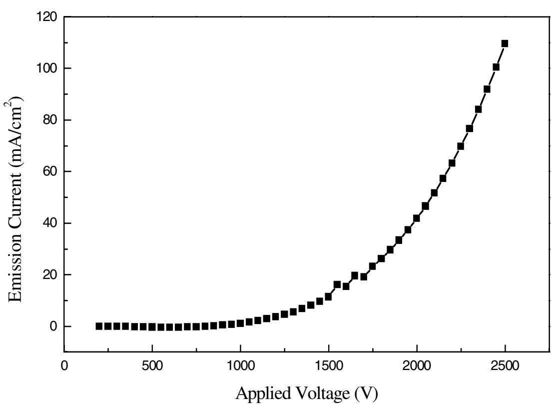

Fig. 5 Field emission property of CNX film

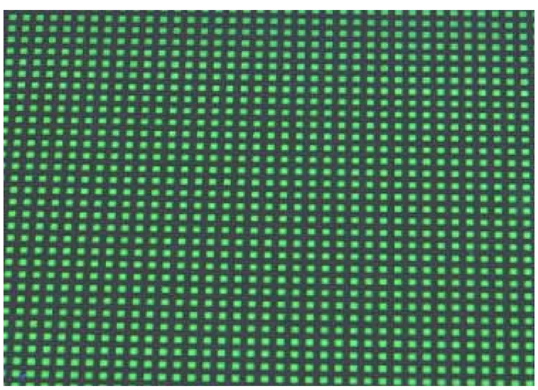

Fig. 6 Green field picture of FED

The anode plate with green phosphor and the CNX emitter Ni plate were assembled with a spacer to keep the space between the spacer1 and Ni plate about 0.1mm. The device was sealed in N2 ambient, and exhausted at a pressure of $1X1^{-6}$pa, then, was chipped off.

Part of the pure green field picture has been taken from the CNX-FED device with 1mm pixel pitch as shown in Fig.6, which shows an relative uniform color field. The display screen size was about 90X40mm. The image was observed at an anode voltage of 4KV, grid1 voltage of about 500V, grid2 voltage of about 800V, and a cathode voltage of 0V. The TV picture and full-color TV picture devices will be finished in our next step.

Conclusion

A novel kind of emitter called Carbon Nanometer electron eXit (CNX) has been developed on Ni substrate. The CNX film addresses high density of emitter arrays, which is important for the emission uniformity in FED. Also, the CNW film indicates a high-degree graphitization and nice crystallinity. Compared with CNT, the CNX shows a higher mechanical strength and good conductivity. In additional, the I-V characteristic properties of CNX shows an excellent emission efficiency. By using CNX Ni plate and screen-printing technique, a uniform green FED with a pixel pitch of 1mm has been fabricated.

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Author Biography

Hong-Xing Wang received his PhD in Engineering from the University of Tokushima, Japan in 2001. From 1983 to 1998, as an Engineer and Senior Engineer of the Technology Center, IRICO Group Corporation, China, he studied and developed CRT. From 1998 to 2003, as a researcher in the University of Tokushima, Tokushima, Japan, he studied and developed the growth of LED and LD. From 2003, as a director researcher in Dia-light Japan Co., Ltd., Osaka, Japan, where he is studying the carbon nano-material electronics. His research interests include CVD Engineering, optoelectronics, and light emitting devices.