Fabrication of CNT Electron Source for Field Emission Displays

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Abstract

We have develo**ped the technique of fabricating triode structure with simple stacking method using a polymer insulator that is suitable for large panel and the activation method after the fabrication. By the techniques, a **test panel was manufactured and proves good emission property and uniformity.

1. Introduction

Carbon nanotube (CNT) has a distinguishing structure such as a small radius and long length. By the high aspect ratio structure, the applied electric field is extremely multiplied on the tip of the CNT. Therefore the CNT has been said as an ideal field emission material. Moreover, by pasting the CNT and applying printing technique, a large size cathode can be easily manufactured with a very low cost. This is also suitable characteristic for a field emission display (CNT-FED) of large screen size and many companies have been developing the CNT-FED [1],[2],[3],[4],[5],[6],[7].

However, the CNT has a cohesive characteristic in its nature and it has been very difficult to remove the mass in the paste. Therefore the printed layer should be inevitably a rugged surface. The surface roughness impedes a simple triode fabrication method such as a stacking method, because the additional layer cannot be stacked well on the rugged surface. We had resolved the problem by developing a new dispersive material and drastically suppressed the cohesion of CNT in the paste. And the flat printed CNT surface with the roughness of less than 0.16 μm was achieved [8].

Another problem is the emission characteristics of the CNT after the printing process. Since most of the CNTs lie down in carbon complex, they only show poor emission property. We had also developed the additional activation treatment for the improvement of the emission characteristics and showed that the CNT could be practically applicable for electron source as FED [8].

In the previous paper, we described the results of test FED panel and showed the luminescent pattern. The results, especially the luminescent and efficiency, indicated that FED could be an excellent display device. But there were some problems on the uniformity between the elements. Our objective is to improve the emission uniformity between the elements.

2. Experimental Results

In this section, we will describe the method to form the triode structure, the activation method, and the emission property of the test manufactures FED.

Fig. 1 shows the process flow of the device. The patterned CNT cathode is formed with the screen-printing technique. The surface roughness of the printed CNT dots is less than 0.16 micrometers as mentioned above and this projection inhibits smooth insulator film on it.

We use a new material polyphenylsilsesquioxane (PPSQ) for the insulator film and the structure is shown

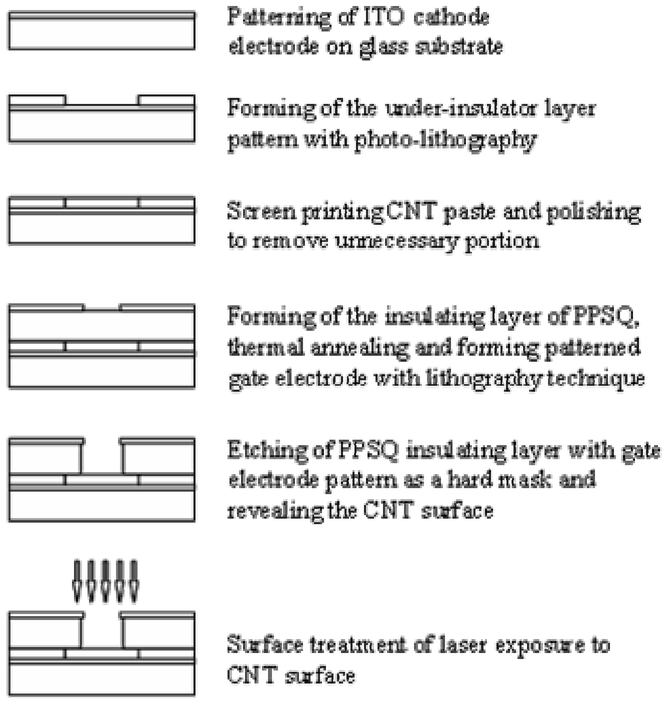


Fig.1 : Process flow of the CNT-FED using polymer insulator PPSQ.

in Fig.2. The PPSQ has excellent properties of simple deposition process for large screen size, thermo-stability, high breakdown voltage and low out gassing rate.

The CNT patterned substrate is coated by the PPSQ varnish, the substrate is annealed under N2 condition and the gate electrodes are deposited on it, followed by the patterning of the gate electrodes by photo-lithography method. Then the dry etching is applied to the insulator with patterned gate metal as a hard mask and CNT appears at the bottom of every gate hole.

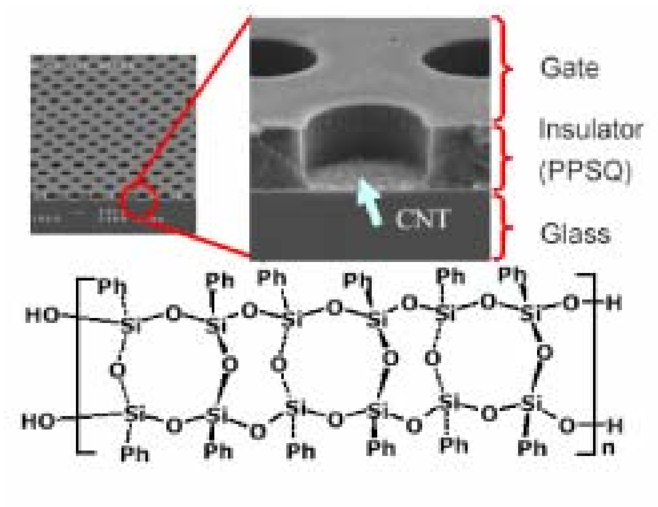


Figure2. Triode arrays of a micro-gate (top) fabricated in PPSQ(bottom).

The dry-etching method can well control the configuration, however the damage on the CNT surface has been serious because the etching gas can also corrode the CNT, the ion attacks the CNT or the deposit is formed on the CNT surface.

We have examined the relationship between the damages of the CNT surface and the dry-etching condition, especially the total pressure of the etching chamber, the partial pressure of each etching gas and the etching power. The appropriate condition that does not damage on the CNT has been obtained.

For the estimation of the damage on the CNT by the process, we measured the turn-on electric field of the CNT formed through the same process as mentioned above. We formed the CNT layer in the area of 2mm×2mm on the electrode by screen printing method. The substrate is processed the PPSQ deposition step, PPSQ dry-etching step and the activation step. The measured results are shown in Table 1. The turn-on electric field is defined here as the electric field when the emission is 1μA (i.e. 0.025mA/cm2).

The results are shown in table 1. In the table, (a) corresponds to the turn-on field of the CNTs without PPSQ forming and etching process, i.e. raw CNTs. (b) corresponds to the conventional etching process and the value is very poor because of the damage on the CNTs surface. (c) corresponds to the newly established condition and the value is same as that of (a) and by this results it is confirmed that the CNTs are not damaged under the newly developed condition.

Table 1 : Relationship of the turn-on field and etching condition. Each cathode was applied laser treatment.

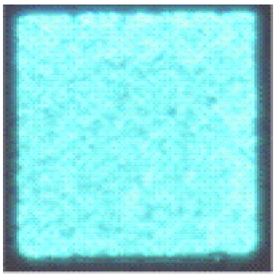
Etching condition	T/O field
(a) w/o etching (raw CNT)	2.1 V/μm
(b) Conventional etching	5.3 V/μm
(c) New condition	2.0 V/μm

In order to form a lot of tips on the surface and improve the emission characteristics, especially emission uniformity, the CNT surface should be activated.

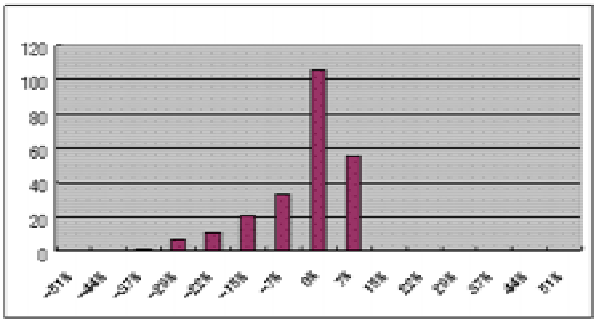
After the activation, the emission characteristics were measured by a diode system and the results are shown in Fig.3. In the experiment, the CNT layer had a size of 2mm squares and the thickness was about 4μm. The distance between the cathode and anode with phosphor was 100μm.

Figure 3 (a) shows the photographs of the luminescent pattern of the activated CNT layer. The photograph shows the excellent uniform emission pattern from CNTs after the activation. The Fig.2 (b) is the histogram of the brightness with the resolution of 20um squares. The figure shows that the deviation of the uniformity is nearly 10%. By considering the cathode size of the expected FED, a deviation between the pixels could be achieved less than 2%.

After these developments, we fabricated a FED with triode structure by the process and studied the emission property after the activation. The CNT-FED panel using PPSQ insulator was fabricated with the dry-etching method and vacuum sealed. The display has a area of 1.5 inches in diagonals. It consists of the total 2070 pixels, (6210 sub-pixels) 46 gates and 45x3 cathodes. A cathode pitch is 0.2 mm and a gate pitch is 0.6 mm. An anode



(a)



(b)

Figure 3. (a) the emission pattern from the CNT layer of 2mm squares and (b) is the histogram of the brightness of the photo with the resolution of 20um squares.

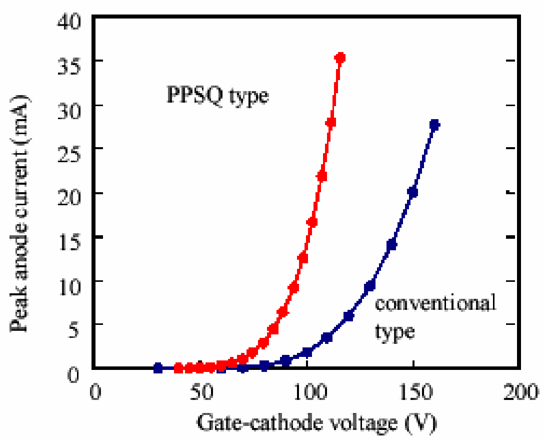


Fig.4 : The emission characteristics of the PPSQ type and conventional type using printable glass pastes.

screen consists of the high-voltage fluorescent substrate with 0.2 mm pitch to which RGB color stripes is applied with the aluminum film back. The distance between an anode substrate and a cathode substrate is 2 mm.

The emission characteristic of this panel was evaluated and the result is shown in Fig. 4. The turn-on voltage is 60V and the swing voltage is 60V. Figure 4 shows the result of comparison. PPSQ type has the high aspect gate-hole structure, the gate hole density can be high, the electric field on the CNT surface becomes uniform over the bottom of gate holes, the emission current was enhanced and the driving voltage was improved compared with printable glass type.

Figure 5 shows the emission pattern from the pixels of the test manufactured FED panel. The figure shows the uniform emission from the triode structure.

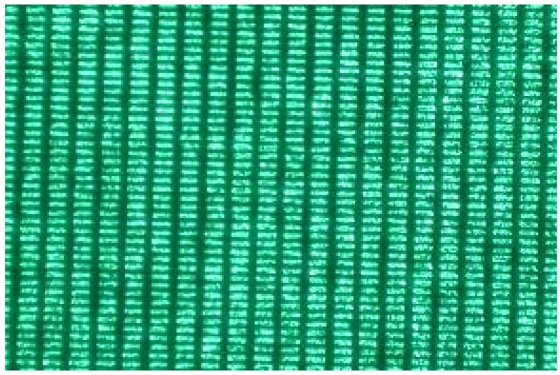


Figure 5 The pixel emission pattern of the test manufactured FED panel.

3. Conclusions

We have developed the triode structure using a novel insulator material (PPSQ) and the activation technique for the field emission uniformity improvement

A PPSQ was applied to the gate insulator of CNT field emitter array. We verified that the PPSQ was available for the fabrication of the fine gate hole structure without damage on the CNTs under the developed etching condition.

The CNT layer was activated and the emission uniformity was measured by the luminescent pattern of the phosphor on the anode. The brightness distribution was analyzed with the special resolution of less than 20 um. The result shows that the deviation is less than 10%. By considering the cathode area of the targeted FED, the deviation between the pixels would be less than 2%.

By using these techniques, we fabricated the small size FED and confirmed the emission characteristics and the uniformity.

These newly developed techniques will make it possible to commercialize the large screen CNT-FED with a very low cost.

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