Fabrication and Properties of Under Gate Field Emitter Array for Back Light Unit in LCD

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Abstract

We investigated under-gate type carbon nanotube field emitter arrays (FEAs) for back light unit (BLU) in liquid crystal display (LCD). Gate oxide was formed by wet etching of ITO coated glass substrate instead of depositing SiO_2 on the glass substrate. Wet etching is easer and simpler than depositing and etching of thick gate oxide to isolate the gate metal from cathode electrode in triode. Field emission characteristic s of triode structure were measured. The maximum current density of 92.5 μA/cm^2 was when the gate and anode voltage was 95 and 2500 V, respectively at the anode-cathode spacing of 1500 μm.

Introduction

Backlight units (BLUs) have been remarkably investigated for a recent few years because of development of large area liquid crystal display (LCDs)-TV. A large source for BLU is necessary in order to process viewable images on a LCD because LCD is not an emissive display compare with field emission display (FED). So for, cold cathode fluorescent lamp (CCFL)[1] has been widely used. But it has disadvantages such as using of inverter and Hg vapor and non-uniformity in large area. To overcome these disadvantages, CNT field emitter arrays (FEAs) were investigated. Also the gated CNT-FEAs have advantages in light efficiency, emission stability and uniformity in large area [2].

In this study, instead of the CVD method to form a gate oxide layer[3,4], we used wet-etching method to form an insulating layer and isolate cathode layer from gate electrode. The wet-etching process has many advantages such as simple manufacture process, mass production and low cost. We fabricated under gate triode structure because of its simplicity in fabrication process and beam broadening. We fabricate a new type of triode structure using wet-etching process and investigate their field emission characteristics, uniformity and efficiency for light source for BLU

Experiment

The schematic diagram of fabrication process for under-gate type triode with CNT emitter was shown in Fig. 1. Fig. 1 (a) shows that the substrate which was coated by photo resist using spin coating method, and then a opened-ITO line was formed by developer after UV exposure Fig. 1 (b). The substrate was patterned with width of 800 μm by wet etching process as shown in, Fig. 1 (c).

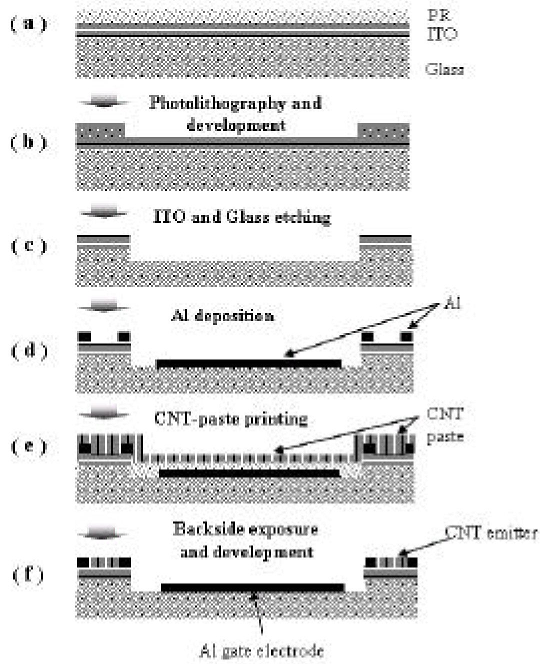

Figure 1. Schematic diagram of fabrication processes for under-gate type triode with CNT emitters.

Aluminum was deposited as a gate electrode on the substrate by thermal evaporator. The lift-off method Fig. 1 (d) was done to form a gate electrode. The substrate was printed with photosensitive CNT-paste [5] Fig. 1(e). The CNT-paste was fired at 450 °C. The schematic diagram of fabricated triode structure with CNT emitter is shown in Fig. 1(f). After the surface treatment using adhesive tape, the field emission characteristics of under-gate type CNT field emitters were measured.

Results and discussion

To optimize the triode structure with proper emission characteristics for BLU application, we simulated the electric field distribution and electron trajectory in triode structures by the SIMION simulator. The distance between anode and cathode is 1500 μm and the distance between gate and cathode is 80 μm. Cathode and gate electrode line width is 120 μm and 720 μm, respectively. The electric trajectory and field distribution of diode type was shown in Fig. 2(a). In simulation, the anode voltage is set constant of 2500V. And the gate voltage is set to be 0 [Fig. 2(b)] and 80V [Fig. 2(c)] under the constant anode voltage.

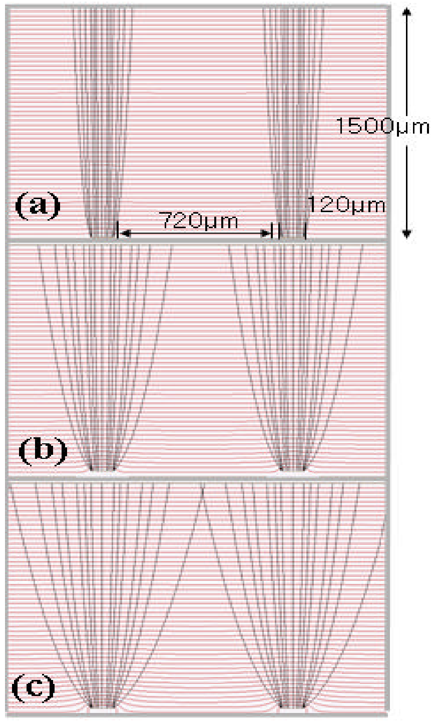

Figure 2. Simulation results of electric potential distribution and trajectories of emitted electrons near the cathode electrodes under various conditions. (a) Diode and Triode type for gate voltages of (b) 0 and (c) 80V. Anode voltage is 2500V.

The simulation results indicate that in case of the under-gate type triode structure, the electric field strength is concentrated at the edge of the cathode electrode. Electrons were emitted from the edges rather than the central areas of the cathode electrode due to the concentration of electric field. Beam broadening in triode mode completely covers the anode area even in the case other the cathode and gate wide line ratio was 1 to 7.3 when gate voltage is higher than 80V.

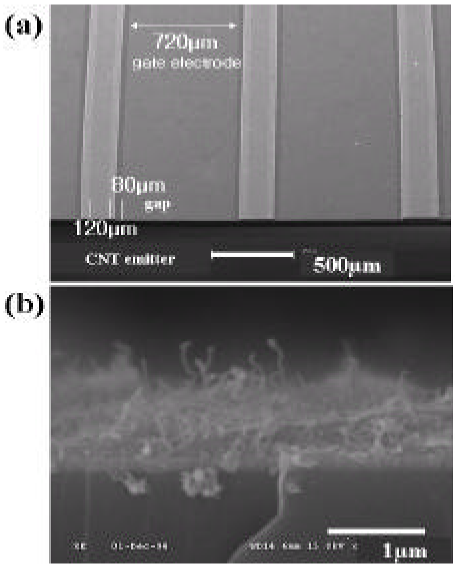

Figure 3. SEM image of (a) under gate structures and (b) morphologies of CNT-emitter on a cathode electrode after surface activation using adhesive tape.

We optimize and fabricate the triode structure base on the simulation results. The fabricated under gate type structures were shown by scanning electron microscopy (SEM) images in Fig. 3(a). The width of gate and cathode were formed with 720 and 120 µm, respectively. The distance between the gate and cathode electrodes is approximately 80 µm. The thickness of CNT emitter and gate oxide formed by wet etching was 0.9 µm 5 µm. After surface activation using adhesive tape thickness and morphologies of CNT-paste on a cathode electrode was shown by SEM images in Fig. 3(b). The cathode electrodes with CNTs of thickness of 0.9 µm were formed by screen printing, back exposure techniques and firing process.

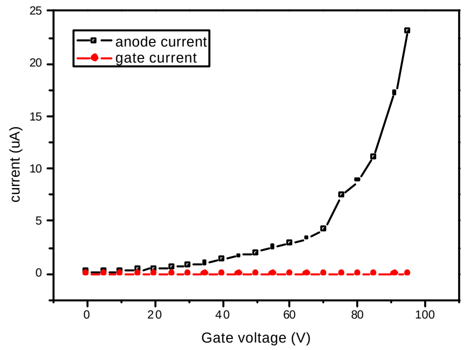

Figure 4. I-V characteristics of a under gate type triode with CNT emitters. Anode voltage is 2500V.

I-V curve in Fig. 4 was measured for the triode emission characteristics. The cathode size of under gate triode was 0.5 × 0.5 cm^2. The distance cathode and anode was about 1500 µm. The distance cathode and anode was about 1500 µm.The anode voltage was fixed to be 2500 V and the gate voltage was increased from 0 to 95 V with step of 5 V. Turn-on gate voltage of triode emitter was 75 V. The maximum current density 92.48 µA/cm^2 was obtainedat the gate voltage of 95V. The fabricated under-gate type triode showed low operating voltage. The negligible leakage current to gate electrode was measured. The leakage current was completely suppressed in the fabricated under gate structure. These results provide the way to fabricate the triode structure with some advantages such as reduction of discharging and turn-on voltage. Electrons emitted from the cathode in this structure are expected to be more widely spread than in the conventional triode structure where gate electrodes are above the cathode. Under gate type triode structure also have merit in its simple structure and simple fabrication process. Based on these results, it may be concluded that the under gate-type triode with CNT emitters using pattered substrate will be used for the fabrication of light source for the BLU of LCD.

Conclusion

We fabricated under-gate type carbon nanotube field emitter arrays (FEAs). Gate oxide was formed by wet etching of ITO coated glass substrate instead of depositing SiO_2 on the glass substrate. Photolithography and wet etching process were used to obtain the fine pattern of CNT emitter. From simulation results, we confirmed that the under-gate type triode had the advantage of beam broadening. The under gate type triode structure with line patterned was simply fabricated by wet etching process. Turn-on gate voltage of triode emitter was 75 V. The maximum current density was obtained approximately 92.48 $\mu A/cm^2$ at 1.17 V/μm in structure of under gated type triode. This simple process will be able to lead to advances in developments of CNT-FEA based on flat lamp for the BLU in LCD.

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