Current development of microtip FEDs and carbon nanotube FEDs

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Abstract

5.2" microtip field emission displays (FEDs) with high voltage applications are fabricated. Nano-structural analysis on microtips is performed for the reliable operation of FEDs. Chemical compositions on the apex of microtips are fully analyzed. A charging mechanism on spacers is simulated and experimentally confirmed with micro-images. A gas-aging mechanism is also studied with integration step of FEDs. The brightness of more than 300 cd/m^2 is achieved. In addition, as a new concept, 9" color carbon nanotube FEDs (CNT-FEDs) are introduced using well-aligned carbon nanotubes on glass substrates by paste squeeze and surface treatment techniques. A number of carbon nanotubes, 5-10/μm2, are uniformly distributed over a large area. The turn-on fields of 1 V/μm and field emission currents of 1.5 mA at 3 V/μm are acquired. Different mechanisms between microtip FEDs and CNT-FEDs are discussed.

Microtip FEDs

Since the low driving voltage is one of the most ideal features for widespread display applications, low voltage FED has attracted considerable attention. It has been under development for a long-term approach. Yet, low voltage FED with desirable brightness has not been achieved. On the other hand, high voltage FED demonstrated sufficient brightness since the CRT phosphor is readily available to high voltage FED[1,2]. However, there are other shortcomings that hinder reliable long-term operation of high voltage FED, and there has been no report that refers to reliable data that concern long term operation. The problems mainly originate from the use of high voltage. We consider these problems on the level of system integration, and nano structural analysis will be considered for degradation mechanisms.

Here, we present the system level integration of high voltage FED with a grid module composed of a metal mesh grid and spacers implemented for the electron beam focusing. We discuss the model for the voltage breakdown due to the surface charge built-up on the spacers. This model is confirmed by experiment. We analyze the morphology of the oxidized micro tip and its surface chemical modification. From the observed nano structural changes on the apex of the micro tips we infer the possible degradation mechanisms. Finally, we demonstrate a 5.2 inches high voltage FED fabricated by considering the issues mentioned above.

The emitted electrons from a tip reach the anode plate. Some of the electrons from the tips near a spacer strike the spacer surface. These primary electrons produce a few secondary electrons. Some secondary electrons hit again the spacer, and produce new secondary electrons or disappear on spacer. Then as is shown in Fig. 1, the equi-potential line near the spacer is vent down, and that indicates the positive charging of the spacer surface. In any case, the total amount of electrons reaching the anode is on an average the same as the amount of the emitted electrons from the tip, since the spacer become the surface charge build-up. Fig. 2 shows experimental data for dot images at the anode screen obtained with a CCD-camera. The separation between the cathode and anode is 1mm and the anode voltage is 1 kV. Fig. 2(a) is an image for a dot near the spacer while Fig. 2(b) is that for a dot away from spacer. The image for the dot away from spacer in Fig. 2(b) is brighter in luminescence and larger in size than that for the dot near the spacer in Fig. 2(a). This is agreed well with the predictions from our simulation results, though some conditions are not same. The designing concept of a spacer should be recommended to hide the image distortion due to the surface charge build-up on the wall of the spacer[3].

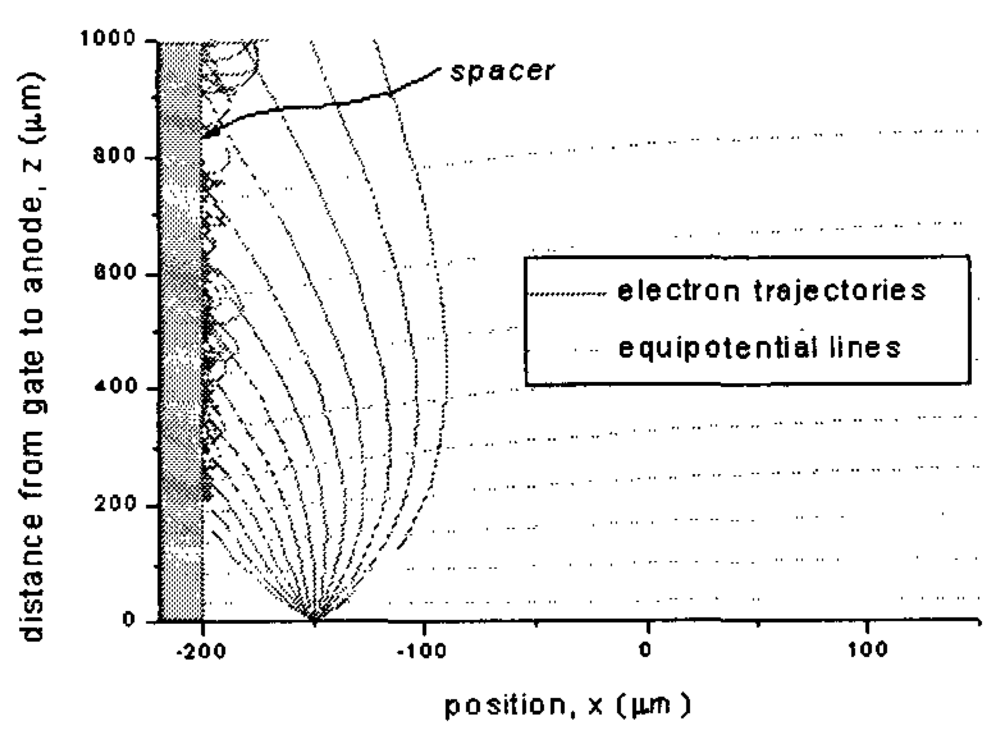

Fig. 1. A plot of electron trajectories (solid lines) and equipotential lines (dotted) near a positively charged spacer for a steady state.

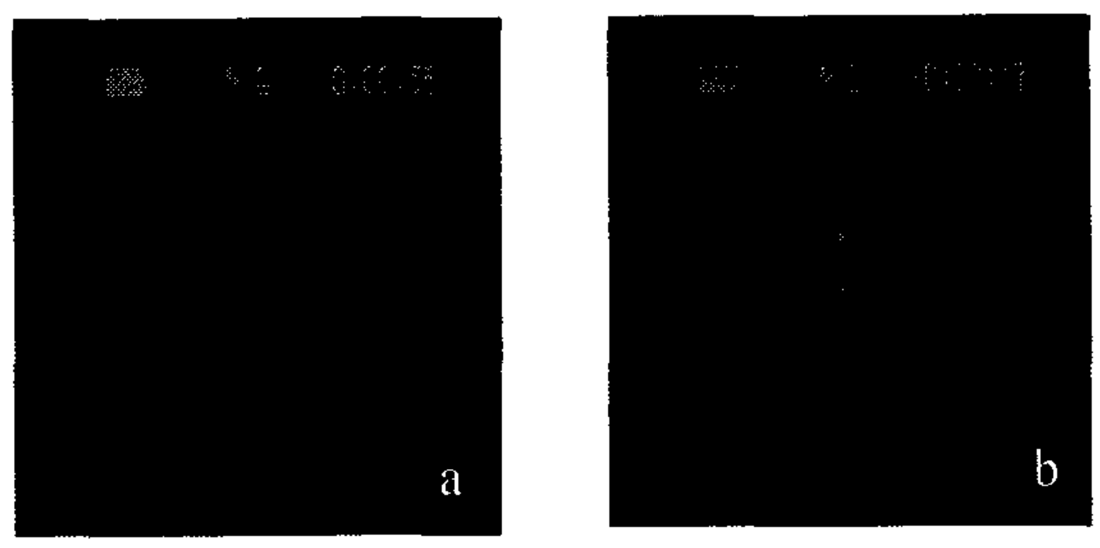

Fig. 2. Dot images at the anode screen obtained with the CCD-camera. The separation between the gate and anode is 500 μm and the anode voltage is 1000V. (a) is an image for a dot away from spacer. (b) is an image for a dot near a spacer.

We investigated nano-structural surface modifications that could have major effects on the reliability of FED. We fractured real panel of FEDs for the micro tips removed from a field emission array after the normal mode operation with running images. The analysis is performed using TEM and FE Auger electrton spectroscopy. TEM image of a micro tip is shown in Fig. 3. We observe the oxidation depth of 5 nm. We can not avoid this intrinsic oxide formation from the fabrication of FEDs. This intrinsic oxide layer could hinder the emission characteristics. To suppress the oxidation during thermal sealing, therefore, gas aging with argon /1.5% hydrogen is used. With our previous data[4][4], it was experimentally shown that this gas is very effective in preventing the oxidation of micro tips.

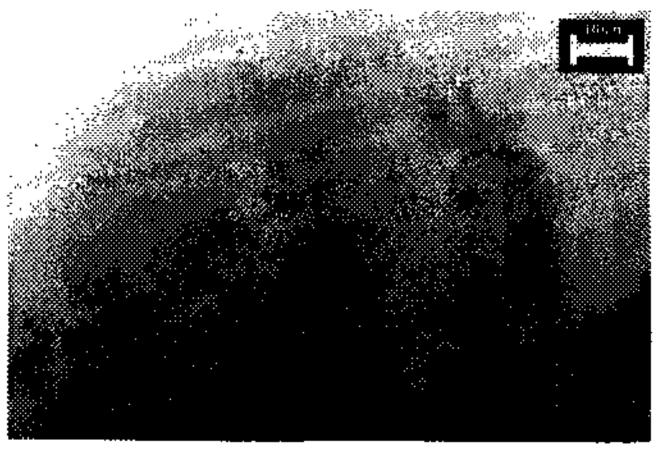

Fig. 3 TEM image of a microtip

Carbon nanotube FEDs

CNTs have a strong potential to be applied to field emitters for emissive devices including flat panel displays, cathode-ray tubes, backlights for liquid crystal displays, and outdoor displays. We have demonstrated fully sealed CNT-FEDs operating at low voltage with high brightness and high stability [5]. Here we present the first 9-inch CNT-FED with diode- and triode-type geometry. The first moving image demonstrates the high potential of large area and full color applications with very low cost fabrication and low power consumption.

The first 9" CNT-FEDs with a diode structure are integrated using paste squeeze technique. The panel is composed of 576 x 240 line with implementation of low voltage phosphors. CNT was aligned and laid out on the all area in the cathode electrode. For the anode plate, the Y_2O_2S:Eu, ZnS:Cu,Al, and ZnS:Ag,Cl low voltage-phosphors were screen-printed with a thickness of 7 μm on 576 lines of red, green, and blue colors respectively. The panel was evacuated down to the pressure level of $1x10^{-7}$ Torr. Non-evaporable getters of a Ti-Zr-V-Fe alloy were activated during the final heat-exhausting procedure, finally leading to the complete fabrication of a 9-inch CNT-FEDs

The magnified pixels of emitting images are shown in Fig. 4. Uniformly emitting pixels of red, green and blue colors were observed over the 9" panel, without cross talk between pixels. Figs. 5 and 6 show images of 9" CNT-FEDs with 576 x 240 lines matrix-addressable in a diode mode. The fully sealed CNT-FED was controlled by matrix-addressable mode with cathode-scanning and anode-data signal. Moving image was modulated at the peak amplitude of 200~ 400 V (1~2 V/μm). A uniform and stable moving image over the entire 9" panel was obtained at the operating field of 2 V/μm. Such high and uniform brightness over a large area implies that the CNTs are well aligned, uniformly distributed with a high number density, and highly efficient in emitting electrons. The whole fabrication processes were fully scalable and reproducible.

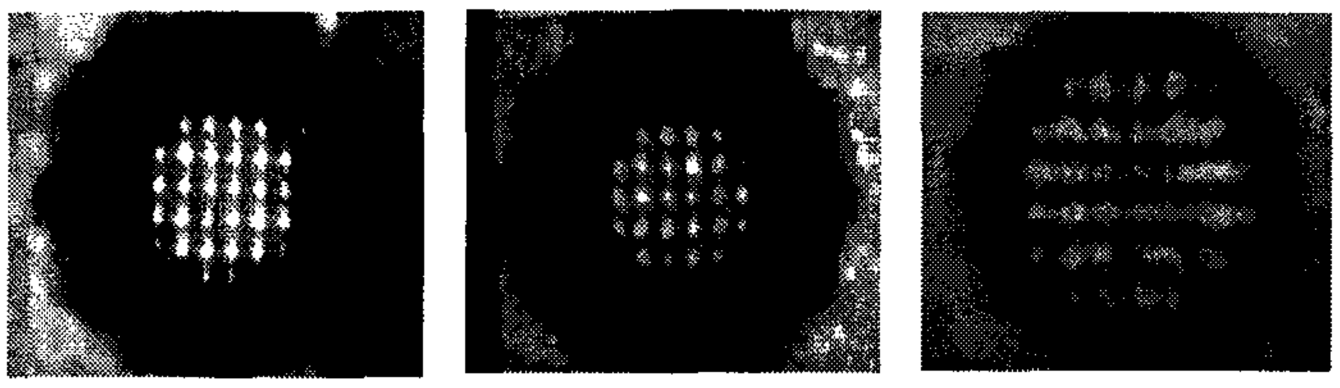

Fig. 4 Magnified images of emitting pixels

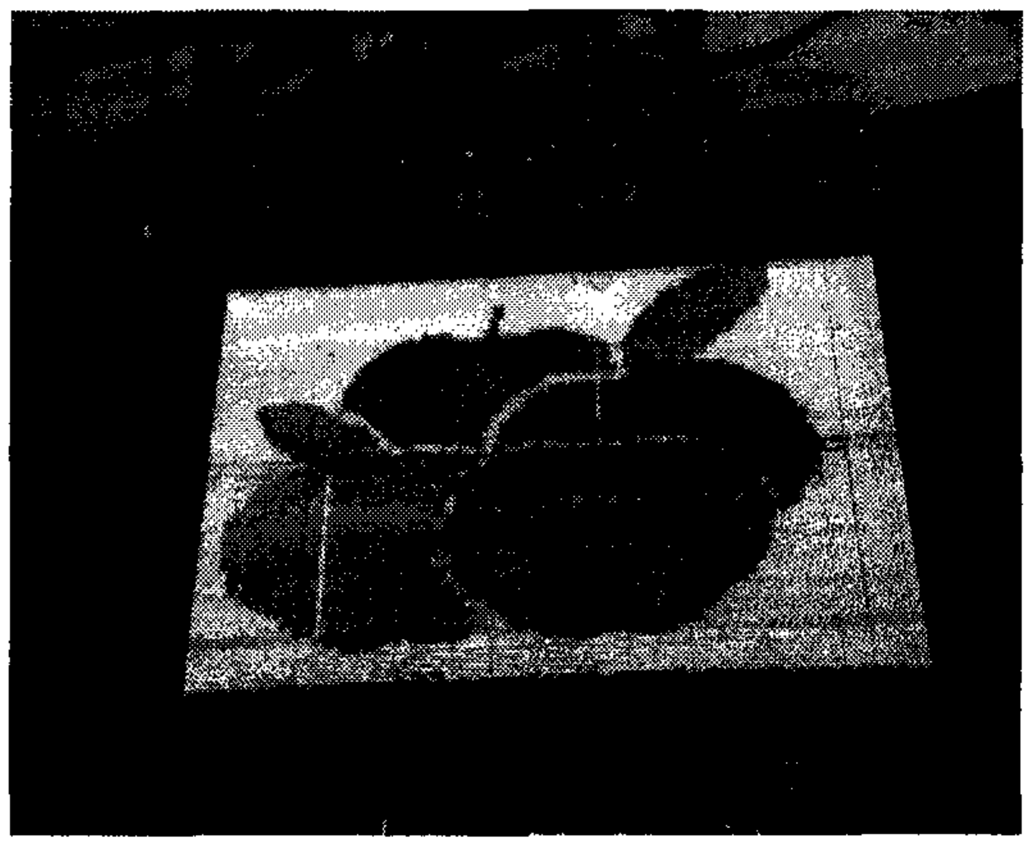

Fig. 5 Test image of diode-type 9" CNT-FED

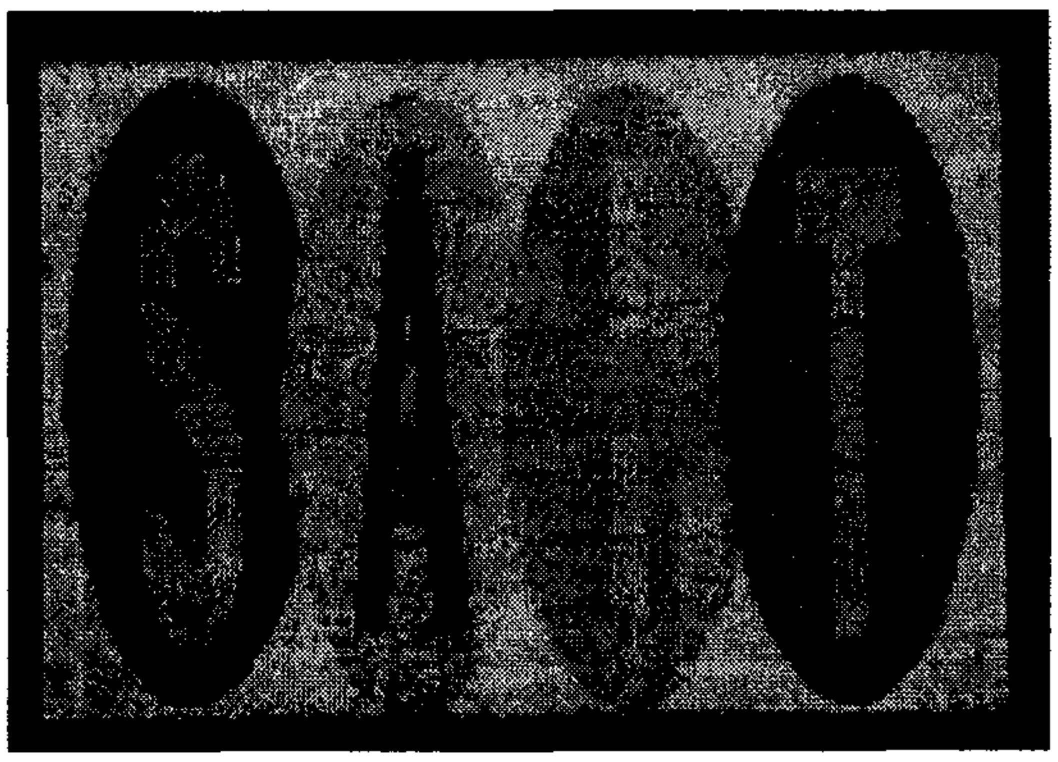

Fig. 6 A moving image of fully sealed 9" CNT-FED

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