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Fabrication and Characterization of Lateral Field Emission Device Based On Carbon Nanotubes

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Introduction

Lateral type field emission devices with Si or metal tips have been demonstrated, they have many advantages such as low turn on voltage, high current densities, and high transconductance. However lateral field emission devices have poor emission site densities, it needs complicated process to produce high emission current site densities.[1-2] As field emitters, CNTs exhibit excellent field emission characteristics due to their high aspect ratios, small tip radii of curvature, high chemical stability, and high mechanical strength. A low turn-on electric field of 0.8 V/μm [3] and high emission current density of 80 mA/cm^2 have been reported [4]. In addition, the lateral field emission device structure has little overlap between two electrodes and thus it has lower parasitic capacitance, therefore coplanar field emission vacuum diode is suitable for high speed operation.

Experiments

The fabrication procedure of the carbon nanotubes lateral field emission device is shown schematically in Figs. 1.

Results and Discussion

1.Effect of anode-to-emitter gap

The SEM micrograph of the fabricated CNTs lateral field emission device for the SiO_2 lateral etching time of 16 min is shown in Fig. 2. The average height of the CNTs is about 2.6 μm and the gap between the anode and CNTs is 1.84μm . The gap between the anode and CNTs can be controlled by varying the poly-Si lateral etching time. Figures3 show SEM micrographs of lateral-type CNT diode for the SiO_2 lateral etching time of 7 min. The growth time of the CNTs was also 20 min. The gap between the gate and CNTs can be further reduced to 0.55 μm .Fig. 3 indicates emission current-voltage characteristics of lateral-type CNT diode with different anode-to-emitter gaps. The voltage-current plot shows a good rectifying property, The turn-on voltages (V_{on}) defined at which the F-N plot become linear were 0.5 V and 0.2 V for the anode-to-emitter gaps of 0.55 μm and 1.84 μm , respectively. Low turn-on voltages were achieved for these CNT diodes. An emission current density of 10 mA/cm (definition: Emission current / the width of poly Si anode) was obtained at the anode voltages of 6.1 V and 9.2 V for the anode-to-emitter gaps of 0.55 μm and 1.84 μm , respectively. The corresponding F-N plots of the CNT diodes in Fig. 3 can be seen nearly straight lines, indicating the field emission phenomenon of the fabricated lateral CNT device.

2 Effect of carbon nanotubes length

The length of CNTs can be tuned by changing the growth time. The lengths of the CNTs are 0.2 μm, 0.6 μm, and 2.6 μm for the growth times of 3min,10 min, and 20 min, respectively. The field emission current-voltage I_a versus V_a characteristics of lateral-type CNT diodes for different lengths of CNTs are shown in Fig. 4. The turn-on voltages were 1 V, 0.4 V, and 0.5 V for the lengths of 0.2 μm, 0.6 μm, and 2.6 μm, respectively. Moreover, at the anode voltage of 10 V ,an emission current of 1.2 mA /㎝ , 5 mA /㎝ ,11 mA /㎝ can be achieved for the lengths of 0.2 μm, 0.6 μm, and 2.6 μm, respectively.

Summary and conclusions

Based on the selective growth of CNTs via the MPCVD, the CNT-LFED was fabricated for the first time. The distance between polysilicon collector and the CNTs emitter was determined by the wet etching process. Thus, the interelectrode gap is easily formed in good uniformity and repoducibility with dimensions below 1 um. The turn–on voltage of the fabricated device with interelectrode gap of 1.84um is as low as 0.4 volt, and the emission current density is as high as 5 mA/cm at 10 volt.

Acknowledgements

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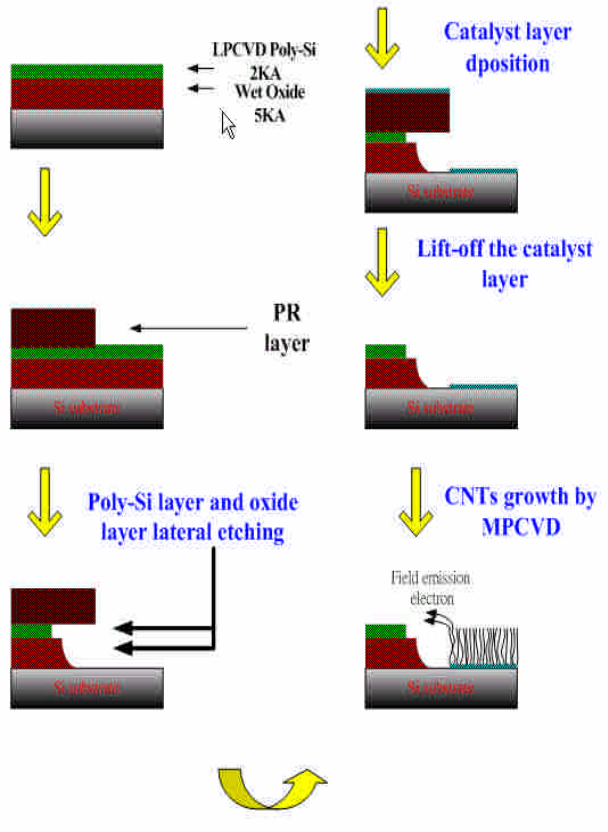

Fig.1 Fabrication procedure of lateral field emission diode

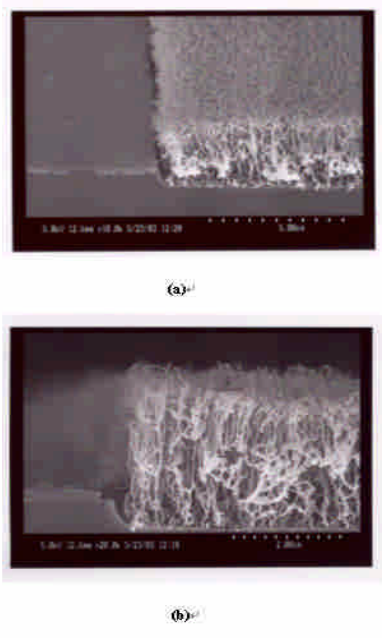

Fig.2 (a) SEM micrograph of lateral-type CNT diode for the SiO_2 lateral etching time of 7 min. (b) Cross-sectional SEM micrograph of the CNT diode shows the anode-to-emitter gap of 0.55 μm.

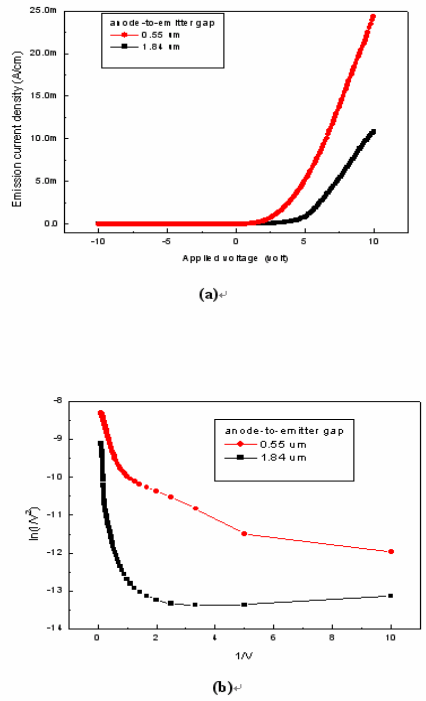

Fig. 3 (a) Emission current (I_a) and anode voltage (V_a) characteristics of the lateral-type CNT diode for different anode-to-emitter gaps, and (b) the corresponding F-N plots.

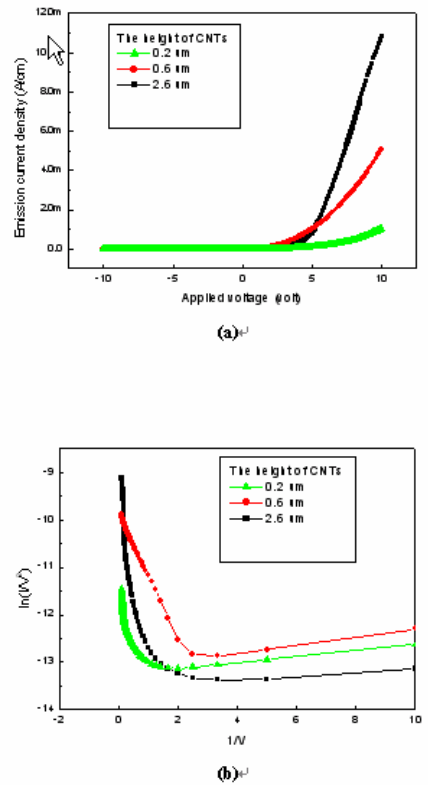

Fig. 4 (a) Emission current (I_a) and anode voltage (V_a) characteristics of the lateral-type CNT diode with different height of CNTs, and (b) the corresponding F-N plots.