Study on Field Emission Characteristics and Lateral Field Emission Devices of Carbon Nanotubes

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Abstract

In this dissertation, we study on field emission improvement of carbon nanotubes (CNTs) and the fabrication of lateral field emission devices. Due to CNTs' high aspect ratio, well chemical stability, high mechanical strength and small radii of curvature, carbon nanotube has become the hot material for field emission display. Microwave plasma-enhanced chemical vapor deposition (MPCVD) and thermal chemical vapor deposition (TCVD) are used to grow nanotubes.

The screening of the electric field by the dense arrangement of CNTs has been reported by several groups. The electric field is screened out for the closely spaced CNTs, which results in a reduced effective electric field near the CNT emitters. As a result, turn-on electric field increases and emission current density decreases. However, the

density of CNTs synthesized by MPCVD and TCVD is very high and is difficult to control.

To obtain better field emission characteristics, the density of CNTs should be optimized. We proposed some novel methods including partial oxidation of catalyst, oxide capping layer, morphology of CNTs with intermix of long and short nanotubes, pillar array of nanotubes and high density plasma post-treatment of nanotubes are used to improve the high density of CNTs and their field emission characteristics are also investigated.

It is observed that the density of nanotubes can be reduced by using an oxide capping layer on metal catalyst. The turn-on field can be reduced and the field emission density increases obviously.

Partial oxidation of metal catalyst to control the density of CNTs is proposed to improve the field emission characteristics. The results show that this method can produce two sets of CNTs with the structure of intermixture of long and short nanotubes and its field emission can also be enhanced. The turn-on filed can be reduced to 1.9V/μm and high field emission current density is achieved owing to effectively controlling of the density of CNTs.

A novel density control with the structure of intermixture of long and short carbon nanotubes are first synthesized by appropriately choosing the pre-treatment time and the contents of hydrogen during CNTs' growth. The results show that turn-on field can be reduced greatly and ultra high field emission current density can be achieved.

Pillar array of CNTs as field emitter by adjusting the growth condition is proposed to improve the field emission characteristics. The results show that when the ratio of

distance between pillars to height of pillar is 1/3, ultra low turn-on field, ultra low threshold and ultra high field emission current density can be achieved.

The effects of oxygen plasma post-treatment (PPT) on the morphology and field emission properties of carbon nanotube (CNT) arrays grown on silicon substrates are proposed. The experimental results reveal that improved emission properties can be achieved by optimizing the density of CNTs and the defects on nanotubes produced by plasma under proper plasma treatment conditions.

Finally, a vertical lateral field emission device (LFED) of CNTs is fabricated. The techniques employed are very simple and allow for good reproducibility in controlling the short distance from the polysilicon anode to the CNTs cathode inter-electrode distance. The experimental results show that low turn-on voltage (~0.2V) and high lateral field emission current (9.72 mA at 10 V) can be achieved when inter-electrode gap is 0.53 um.