

Scanning anode field emission microscopy investigation of carbon nanotube thin films

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Abstract

Free electron sources are used today in a wide range of technical applications such as vacuum electron tubes, X-ray tubes, vacuum pressure gauges, electron microscopes etc. Most of these applications rely on thermionic electron emitter operating at temperatures in the range 950°-2200° C. The current development and beginning commercialization of field emission flat panel display's (FED) has triggered a strong worldwide interest in micrometer sized electron sources. Due to the problem of heat dissipation micron sized emitter can not rely on thermionic emitter, but make use of field electron emission.

At the heart of most field emission electron sources lies a field enhancing tip, needed to enhance the applied field, which is usually of the order of a few up to $100 \text{ V}\mu\text{m}^{-1}$, to the $2500-5000 \text{ V}\mu\text{m}^{-1}$ required to get measurable field emission currents. Today the Spindt-process to produce gated micro-tip field emitter arrays seems to be the most advanced, however due to need for lithographic patterning this process is rather expensive. In the search for low cost alternatives to produce planar field emitter, carbon nanotube thin films have attracted great attention due to low turn-on fields of the order of a few $\text{V}\mu\text{m}^{-1}$ and very low cost deposition techniques. A correct characterization and description of the field emission properties of such thin film emitters is a challenge.

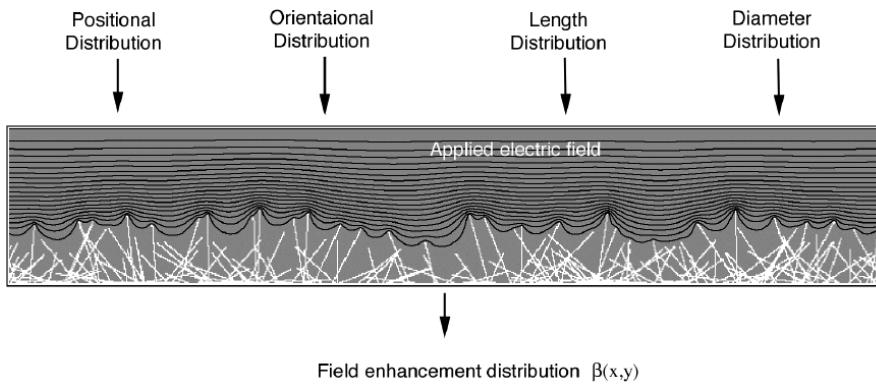


Figure 1

The figure above illustrates schematically how the distribution of field enhancing structures (e.g. nanotubes) influences the field emission properties and how these properties can be condensed into a "field enhancement distribution". Using combined data from field emission spectroscopy and constant current scanning anode field emission microscopy the field enhancement map can be determined. We will discuss the concept of field enhancement mapping and present and discuss data of carbon nanotube thin films exhibiting an emission site densities of up to $6 \times 10^6 \text{ cm}^{-2}$ at applied electric fields below $50 \text{ V}\mu\text{m}^{-1}$. Such kind of emission site densities however can not be achieved on macroscopic surface areas (e.g. mm^2). We will show how emitter degradation and disruption is the cause of limited emission site densities. We will discuss the possible origin of emitter degradation and show how the degradation can be studied at an individual emitter of the nanotube thin film. The role of the contact resistance on degradation and current limitation will be addressed. We will also point out the problems and dangers of investigating the emission properties of thin film emitter using large anodes or large anode-sample separations.

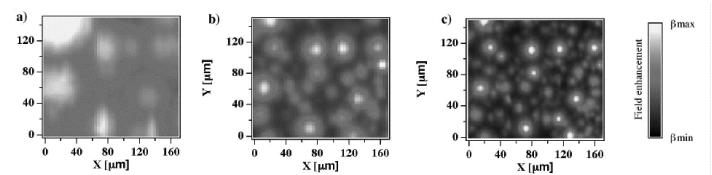


Figure 2
Field enhancement map of the same region on a carbon nanotube thin film at different anode-sample distances, where the distance decreases from a) to c).