FIELD EMISSION FROM MULTI-WALLED CARBON NANOTUBES

Martin Sveningsson, Martin Jönsson, Raluca- Elena Morjan, Oleg Nerushev[1], Eleanor E. B Campbell.

Department of Experimental Physics, School of Physics and Engineering Physics, Göteborg University and Chalmers University of Technology, SE-412 96 Göteborg, Sweden.

[1] Permanent address: Institute of Thermophysics, 1 Acad. Lavrentyev Ave., Novosibirsk 630090, Russia.

E-mail: f3amsv@fy.chalmers.se

Films of multi-walled carbon nanotubes are very efficient cathodes for field emission devices. Different films of vertically aligned MWNT are grown by thermal chemical vapour deposition (CVD) and investigated using electron microscope, SEM, TEM and Raman spectroscopy in order to determine the structure of the films. The results show that the films have excellent field emission properties with very high emission current densities and low turn-on and threshold fields. They also show that the presence of a surface coating on the MWNT with amorphous carbon has no impact on the field emission efficiency. Closer investigation shows that the current density as a function of applied electric field (on multiple cycles) is reproducible up to a value of 1 mA/cm^2. Exceeding this value leads to light emission from the MWNT film. Spectral measurements of this light shows a purely blackbody radiation effect with a temperature around 2000 K which is very different from what other groups have reported.

Introduction

Among all interesting properties of carbon nanotubes their very high efficiency for electron field emission is of high technological relevance [1]. Producing carbon nanotubes using a thermal CVD method gives the possibility to make larger areas of aligned and non-aligned films with different quality depending on the production parameters as the temperature, flow rate etc. [2]

Experimental

Films of aligned MWNT are grown on silicon substrates at a temperature of 750 °C with iron as catalyst particle and using acetylene as the carbon feedstock. The growth time for the clean film was 30 min and 3 hours for the coated film. The field emission measurements were carried out using a stainless steel anode with a hemispherical tip with a radius of R=2 mm and a distance of Z=100 μm between the anode and the nanotube film. The effective emission area is calculated using $A=2\pi RZ(2^{1/n}-1)$ where $n=(V/I)*(dI/dV)$. J is then given by $J=I/A$.

Results

Combining the information from the electron microscope pictures, Raman spectroscopy and the field emission properties we can see that the presence of a surface coating has no significant effect on the field emission current density (see fig. 1). A closer investigation of the same films shows that the current density as a function of the applied electric field is reproducible up to a value of 1 mA/cm^2 and can be cycled many times. If this value is exceeded we observe light emission from the nanotube film. The critical value of the current density of 1 mA/cm^2 also corresponds to the point in were there is a noticeable change in the slope of the Fowler-Nordheim plot [4] indicating that the local field conditions at the top of the nanotube film have changed (see fig. 2). The spectral measurements of this light, which is only observable at current densities above 1 mA/cm^2 show that it is purely blackbody radiation with a temperature around 2000 K (see fig. 3) with a strong correlation between the light intensity and the current density (fig. 2). This is in contrast to other groups that have reported strong emission in the visible at 400 nm [5], or around 700 nm for one single MWNT emitter at a emission currents of 20 µA [6].

References

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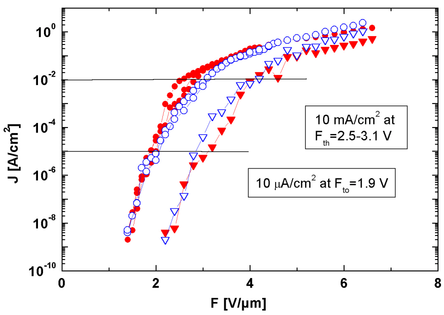

Fig. 1. Field emission current density as a function of the applied electric field for the clean (blue) and coated (red) films. Triangles: voltage scans after high current operations.

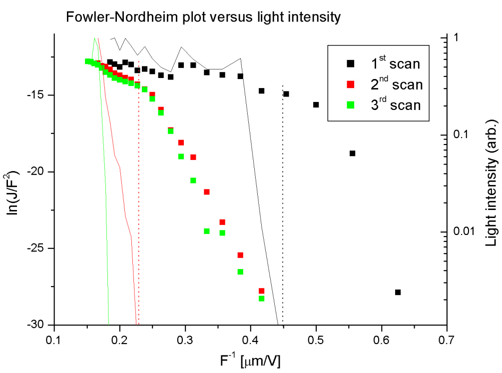

Fig. 2. Fowler-Nordheim plot from a spot on the coated film. Data from the light emission corresponds to the lines. The threshold for light emission correlates well with the change in the slope of the F-N plot.

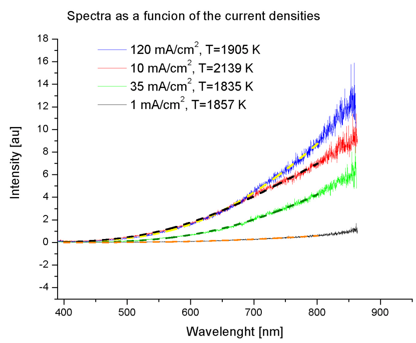

Fig. 3. Emission spectra for four different current densities. The data is fitted to a blackbody radiation curve in order to determine the temperature.