Fabrication and field emission properties of the aligned carbon nanotubes synthesized by MPCVD

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Abstract

In this study, the optimal processing conditions for synthesizing the well-aligned CNTs on Si substrate (P type (100)) by microwave plasma chemical vapor deposition (MPCVD) were investigated. The carbon nanotubes and their properties are then characterized by using scanning electron microscopy (SEM), transmission electron microscopy (TEM), Raman spectroscopy, and I-V measurements. The main results are summarized as follows.

Firstly, the externally applied bias showed significant effects on CNTs growth and well-aligned CNTs were obtained when biased above 250 V. The Raman measurements also indicate that the greater applied bias the better the graphite crystallinity. The I_D/I_G ratio of the CNTs decreases with increasing negative applied bias which, in turn, improves their emission characteristics. We also studied the influences of N_2 and O_2 on the size distribution and morphology of Ni catalyst particles, and their effects on field emission characteristics. It is observed that clusters attacked on the top of carbon nanotubes can removed by adding N_2 and O_2 as assistant gases to get a appropriate flow rate of $H_2/CH_4/N_2$ or $H_2/CH_4/O_2$.The addition of N_2 results in better crystallinity quality but degraded field emission characteristics. On the other hand, the addition of O_2 results in poorer crystalline quality but better field emission properties. The underlying mechanisms for these intereling observations are not clear at present.

Furthermore, post-treatment by KrF excimer laser irradiation to the CNTs was carried out to improve the emission characteristics. The maximum emission current density after laser irradiation reached 2.46mA/cm^2 with applied electrical field of 3.55 V/μm. The turn–on field for CNTs emitters decreased from ~5 V/μm to 3 V/μm, corresponding to a decrease of turn-on voltage from~900V to ~550V with the laser irradiation treatment. The adding of oxygen during laser irradiation, however, degrades the performance of field emission properties, including current density, turn-on voltage, and field enhancement factor.

Finally, the correlation between I_D/I_G and field emission performance was roughly conformed. The ratio does not have a strong relation with field emission performance by modifying various growth parameters, including bias voltage, N_2 and O_2 assistant gases. By contrast, modifying I_D/I_G with low power laser post-treatment shows that there is a strong relationship between the ratio and field emission performance. We suggest that morphology (distribution and spacing) and graphite structure (crystallite quality) may both have influences on field emission properties. The SEM and TEM images provide a evidence for our previous suggestion.