Field Emission from Multiwall Carbon Nanotubes Prepared by Electrodeposition without the Use of a Dispersant

S. M. Lyth, F. Oyeleye, R. J. Curry and S. R. P. Silva
Nanoelectronics Centre, Advanced Technology Institute, School of Electronic and Physical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH, United Kingdom
J. Davis
School of Biomedical and Natural Sciences, Nottingham Trent University, Clifton Lane, Nottingham, NG11 8NS, United Kingdom
*Electronic Mail: s.lyth@surrey.ac.uk, Tel. 01483 686083, Fax. 01483 689404

Carbon nanotubes (CNTs) are ideal candidates to be used as field emission sources. Electrodeposition could provide a viable method to deposit CNTs over large areas as part of an industrialized process. It has been shown that CNTs can be co-deposited with nickel onto various substrates, using a suitable CNT dispersant. In the present study, a multiwall carbon nanotube (MWNT): nickel (Ni) composite has been electrodeposited without the use of a dispersant. The field emission properties of the resulting electrodeposits were studied.

Unpurified MWNTs grown by CVD were added to a Ni plating bath comprising of 1M NiSO₄,6H₂O, 0.2M NiCl and 0.5M H₃BO₃. Due to their hydrophobic nature, MWNTs did not disperse naturally, so the plating solution was placed in a sonic bath for 15 minutes before electrodeposition. Electrochemical measurements were conducted using a µAutolab computer controlled potentiostat with a three-electrode configuration and typical cell volume of 10 cm³. A spiral wound platinum wire served as the counter electrode with a Ag:AgCl wire reference electrode. Cu plates were used as cathodes, with an exposed surface area of 2 cm².

After deposition, samples were thoroughly rinsed in deionised water to remove Ni salts. The resulting electrodeposits were imaged using a scanning electron microscope (FIG.1) Importantly, these deposits were observed after the samples were thoroughly rinsed in deionised water, suggesting that there is a strong adhesion between the nickel coated nanotubes and the substrate surface. FIG.1(a) shows MWNTs (0.013 mg/ml) electrodeposited directly after sonication. Note that a thick Ni coating is not observed (see inset), and that uniform MWNT deposition is observed over a relatively large area. FIG.1(b) shows MWNTs deposited with the same solution after five minutes. A much thicker Ni coating indicates that a relatively higher concentration of Ni to MWNT was present. This was probably due to a re-bundling of MWNTs over time, after the sonication process. FIG.1(c) and (d) show MWNTs deposited with a much lower concentration (0.005 mg/ml), and therefore relatively higher concentration of Ni, resulting in thicker Ni coating. Beads of Ni (visible in FIG.1(d)), approximately one micron in diameter completely encased the MWNTs, previously observed by Aria et al., using a poly(acrylic acid) dispersant.

Subsequently, the substrates were subjected to field emission characterisation using a 5 mm spherical stainless steel anode. The emission current was recorded as a function of macroscopic electric field at a vacuum of around 10⁻⁶ mbar. The threshold field was taken to be the field at which an emission current of 1 nA was detected and the macroscopic field was calculated by dividing the applied voltage by the electrode gap, which was typically 25 μm. Threshold fields of the order 20 V/μm were observed (FIG.2), after conditioning. It is expected that by altering the deposition conditions, the much lower threshold fields would be observed.

2 S. Arai, M. Endo, Electrochemistry Communications, 5, (2003), 797