CARBON NANOTUBE- BASED COMPOSITES FOR ELECTRONIC APPLICATIONS

CNT-conducting polymers, CNT-Cu

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Due to their singular mechanical and electrical properties, Carbon Nanotubes (CNT) could be very useful materials in composites, in order to improve a particular property for specific applications. We performed two different types of composites using carbon nanotubes: 1) CNT with conducting polymers, CNT-CP, as thin films that are either transparent (transmission coefficient T from 70% to 95%) and electrically conducting, to be used as transparent electrodes. 2) CNT with a metal, copper in our case, (CNT-Cu) to be used in electronic packaging.

1. Carbon nanotube-conducting polymers: CNT-CP

We prepared electrically conducting thin films, quite transparent (70% to 95%), that can be used as transparent electrodes. A thin network of Single Walled Carbon Nanotubes (CNT) was deposited on a transparent substrate [1]. As deposited, the network is conducting enough to be used as an electrode in order to electrochemically grow a conducting polymer on it. We essayed the deposition of doped polypyrrole (Ppy) and polyaniline (PA) conducting thin films. The composite films were observed by AFM and analysed by optical and Raman spectroscopy, and their transport properties were thoroughly characterized. The electrochemical conditions for the polymer thin film deposition were studied in order to improve their conductivity and transparency.

DC conductivity was measured in a four probe set-up at room temperature. Atomic force microscopy (AFM) show the samples are quite homogenous, with thickness from 150nm. By optical spectroscopy we obtained the transmission coefficient T, or transparency of the films. For small electrodeposition times, ($t < 35$ min) the transmission coefficient T is from 70% to 90%. The measured conductivity values on the thin networks of CNT, before the polymer deposition, are from 20 to 3 S/cm, depending on their amount. The conductivity increases by a factor from 2 to 5 after the Polyaniline [2] or Polypyrrole deposition.

Compared to the well known transparent conducting oxides like ITO, the best of our composite thin films are close to 10 times less conductive and highly transparent. As a great possibility, these conducting films could be prepared on a flexible substrate with a continuous deposition procedure.

Carbon nanotube-copper: CNT-Cu

A material designed for electronic packaging must support a big current, dissipating the heat and avoiding expansion, contacting silicon much easier than metallic copper. To fullfill these requirements a material with the following properties is needed: high electrical and thermal conductivity, and low coefficient of thermal expansion (CTE). Carbon Nanotubes have both these properties: Single Wall Carbon Nanotubes (SWNT) have an electron free path several orders of magnitude larger than metals like copper and, due to the ballistic conductivity mechanism, their intrinsic electrical conductivity is greater than the copper conductivity [3]. A system based on ballistic SWNT imbedded in a metal matrix might work as an ultra-low resistance material, that can have a room temperature resistance far below the resistance of conventional metal conductors like Cu.
Another interesting application of CNT-metal composites are based on their tribological properties. CNTs have favorable effects even at fillings as low as 12 vol%. They show significantly lower wear rate and friction coefficient compared with pure Cu [4].

We have prepared SWNT-Cu composites electrochemically, using a thick network of SWNT (Bucky paper) as working electrode, from a CuSO4 solution. The copper is visible on both sides of the sample. We inspected the samples by AFM and SEM. Looking at the cross-section by SEM it is possible to see that the Cu is significantly distributed in the bulk, rather inhomogeneously. The electrical conductivity and thermal expansion CTE of these composites are measured.

References:

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