Properties of Single-Walled Carbon Nanotubes integrated into Polyimide (SWNTs-Pi) Nanocomposites

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Due to their interesting properties, Carbon Nanotubes (CNTs) are the subject of intense research as well as industrial applications. In particular, the use of SWNTs as fillers for the reinforcement of polymer composite has attracted great interest recently. The high mechanical, electrical and thermal properties of CNTs make them a perfect candidate as filler in polymer composite[1-3]. So far, experimental research on CNT reinforced nanocomposites has yielded promising results, however, the extensive use and commercial success are yet to be demonstrated. Polyimides have been used largely in applications such as packaging, microelectronics and aerospace. However, one drawback associated with the use of insulating polymer matrix is the accumulation of electrostatic charge at the polymer surface. The accumulated charge can cause heating of the material which in turn can damage the material. By integrating SWNTs into the polyimide, one can reach a level of electrical conductivity high enough for electrostatic discharge, as well as improve the mechanical and thermal properties compared to the polymer without SWNTs. Another main challenge in the fabrication of CNT based nanocomposites is the manipulation and orientation of SWNTs into the polymer matrix to achieve optimal performance. Different techniques such as electrospinning, the use of magnetic fields or electric filed induced dielectrophoresis have been investigated in the last few years[3]. Although dielectrophoresis (DEP) has been used widely for the manipulation of SWNTs in a solvent, the DEP technique has been employed rarely for polymer matrix[4,5].

This work describes the integration of SWNTs into polyimide (Pi). The fabrication process of the nanocomposites, the alignment of SWNTs in the bulk polyimide and between micro-electrodes will be presented. The electrical conductivities of the SWNT-Pi nanocomposites with and without DEP are illustrated in *Fig1.a*. For both SWNT-Pi composites with and without DEP, the conductivity values increase by about 12 orders of magnitude as the SWNTs concentration is increased from 0 to 5wt.%. The percolation threshold has been defined to be when the electrical conductivity is around 10^{-6} S/m and is at 0.2wt.% SWNTs in our experiments. *Fig1.b* shows the electrical conductivity of the polymer matrix for SWNT concentration below 0.2wt.%. Below the percolation threshold, it can be seen that the presence of DEP for SWNT alignment appears to cause higher increase in the electrical conductivity of the polymer compared to samples without DEP for the same SWNT concentration. These results highlight the importance of the presence of DEP on the alignment of SWNTs below the percolation threshold. Simulation of the electric field distribution between the electrodes has been performed and is displayed in *Fig2*. Mechanical properties of the nancomposites have been determined by Dynamic Mechanical Analysis (DMA) as a function of SWNT concentration and temperature. Young's modulus values of the nanocomposites as a function of SWNT concentration are shown in *Fig3*. It can be seen that Young's modulus values of the nanocomposites increase by two orders of magnitude with SWNTs integration. Finally, the influence of temperature on the mechanical properties of the nanocomposite will be presented.

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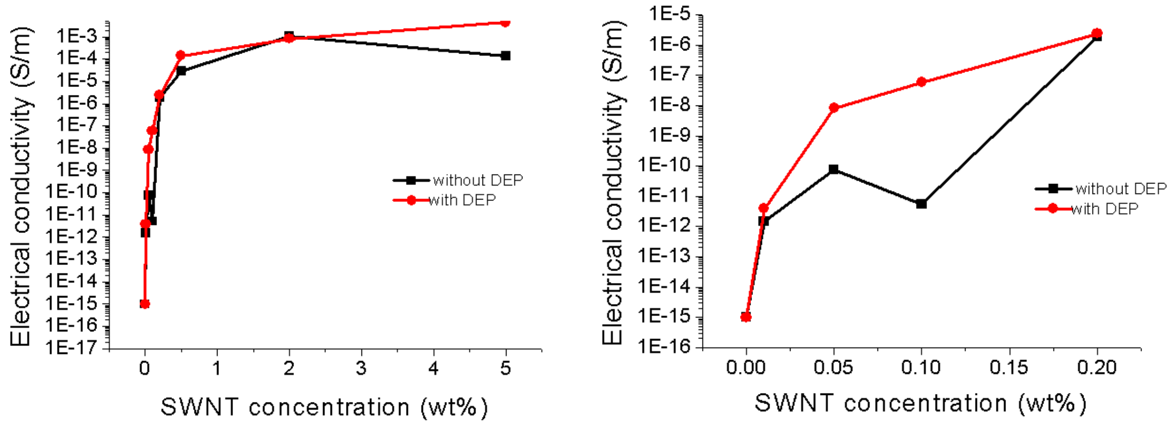

Fig1. Electrical conductivity of SWNT-Pi nanocomposite (a); influence of DEP on electrical conductivity of SWNT-Pi below percolation threshold (b)

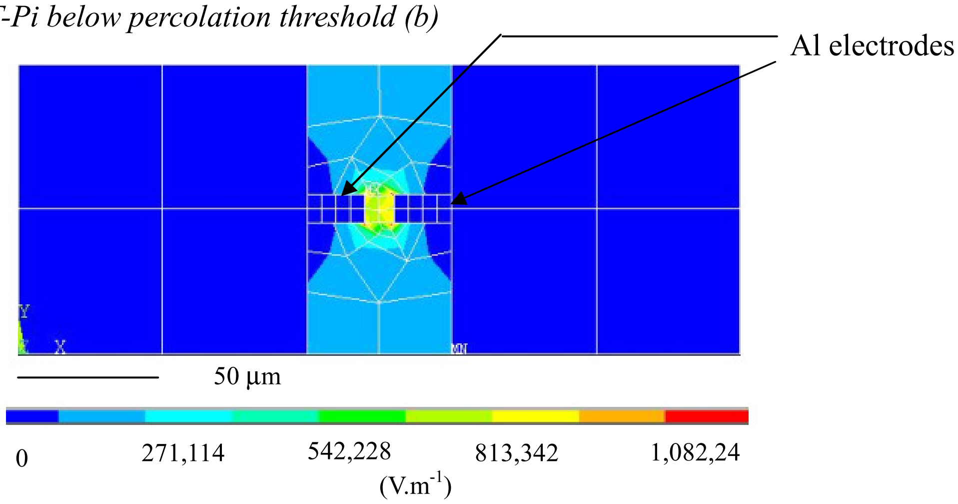

Fig2. Electric field simulations using ANSYS software with 8V_{p-p} applied between Al electrodes

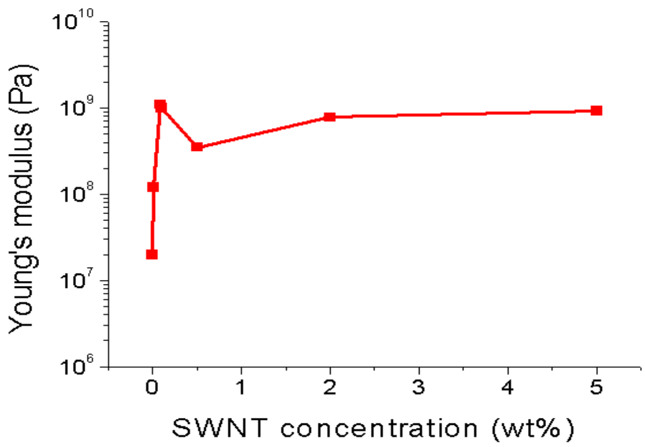

Fig3. Young's modulus of SWNTs-Pi nanocomposite with different SWNT concentrations