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Electronic Conductance of Nano Composite Polymer Single Walled Nanotube with Spin Spray Variant

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ABSTRACT We have studied electronic conductance of nano composite polymer single walled nanotube with spin spray variant by using layer by layer technique. The study showed that there existed a critical number of polyelectrolyte bilayer below which the electronic conductance of the material was negligible. The sheet conductance increased above the critical value. This indicated that the material conductivity was controlled by the formation of a percolating network of highly conducting nanotubes in an insulating polymetric matrix. We have presented the dependence of junction resistance on the layer separation leaded to the logarithmic behavior. The quasi two dimensional model treated the nanotube as infinitely conducting rods with resistive junctions. A junction was formed when projections of two nanotubes on the plane of the material intersect. The junction resistance increased with inter layer separation. The results found were compared with previous results and were found in good agreement

KEYWORDS Electronic conductance, Nano Composite, Polymer, Spin Spray, Poly Electrolyte, Polymetric Matrix, Conductivity, Quasi Two Dimensional.

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INTRODUCTION

The conductance of carbon nanotube containing nano composites was studied [1] with the help of nano scale material structure, e.g., the nanotube density distribution, aspect ratio and poly dispersity [2-7] and the properties of nanotube contacts. It was previously studied [8-11] that films fabricated using traditional methods such as spin coating, a quantitative understanding of the micro structure of layer by layer nano composite films affected their conductance was lacking. The development of a model that demonstrated the dependence of the sheet conductance of an spin spray layer by layer assembled film on the number of poly electrolyte bilayers, the nanotube density in each bilayer and the nanotube junction resistance.

Then conductive nano composite films with tunable properties are of great importance for the development of electro mechanical, vapor and chemical sensors [12] and functional electrodes for batteries, solar cells and fuel cells [13-17]. Colloids integrated in polymeric composite film improved mechanical strength [18-21] enhanced electronic conduction [22] and tuned other film properties.

METHOD

The conductivity percolation threshold in our system involved multiple bilayers, contacts with finite electronic conductivity from nanotubes deposited in the same bilayer and also between nanotubes in different bilayers. These contacts occurred despite the fact that the nanotubes were co-deposited with a highly resistive polymetric matrix that separated them. Modeling of the film as a quasi two dimensional network of infinitely conductive rods representing nanotubes embedded in a highly resistive polymeric matrix. The assumption of infinite rod conductivity was supported by earlier studies that established that resistance in networks of single walled nanotube was dominated by that of contacts. We have considered rods of equal length *l* and negligible diameter. It was assumed that there existed a junction with finite resistance between rods if their projections on to the film plane intersected. This quasi two dimensional picture of the network structure was justified because the film thickness was less than 1nm per bilayer and nanotube diameter was 1-2 nm were much smaller than the nanotube length of 5-30 μm. In the standard conducting rod model all junctions between rods were equivalent. The conductance of the film vanished below the percolation threshold.

$\sigma = 0$ for $n_{tot} < n_{tot}^{perc}$

Where $n_{tot}^{perc} \approx 5.6$ is the percolation density? For $n_{tot} > n_{tot}^{perc}$, near the peculation threshold the conductance σ exhibited the critical scaling behavior $\sigma \sim \left(n_{tot} - n_{tot}^{perc}\right)^{\delta}$,

where $\delta \approx 1.33$ is the percolation exponent. In terms of conductance per bilayer this behavior corresponded to

$\sigma_1 \sim \left(k_1 - k_1^{perc}\right)^{\delta-1}$

For a rod density above the percolation threshold i.e., where the rods form a density connected network, the conductance is proportional to the number of junctions per unit area

$\sigma \sim mj$

For linear behavior

$\sigma_1 \sim k_1$

of the conductance per bilayer was obtained.

RESULTS AND DISCUSSION

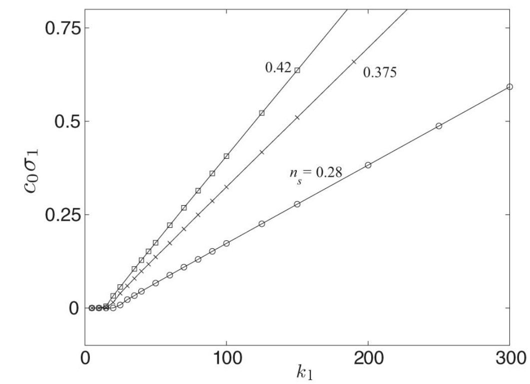
Graph (1) shows the conductance per bilayer of obtained results. The results of the classical conducting rod model, the obtained results revealed a percolation threshold and a subsequent growth of the conductance per bilayer with the number of bilayers k_1. The linear behavior predicted by the classical model is incomplete with experimental values. So standard conducting rod model is inadequate for the conductance of nano composite layer by layer films. We have used modified model that properly captured the experimental results. For the determination of conductance of sheet the stratified model film, we have made numerical calculations. A conducting rod network was constructed in a square periodic unit cell of size $L \times L$ by sequentially depositing k_1 layers of randomly distributed rods. The number of rods in each layer was $N_1 = n_s\left(\frac{L}{l}\right)^2$. A search for all clusters formed by connected rods i.e. rods with intersecting projections was performed and the sets of percolating and non percolating clusters were identified. The clusters that did not percolate in the y-direction were discarded and the voltage difference Δ between the boundaries $y = 0$ and $y = L$ was applied to the remaining percolation network. The electric current flux flowing through a unit cell was determined by solving system linear equations for a network of resistors. The sheet conductance was calculated from current j by using the relation

$$\sigma = \frac{J}{\Delta}$$

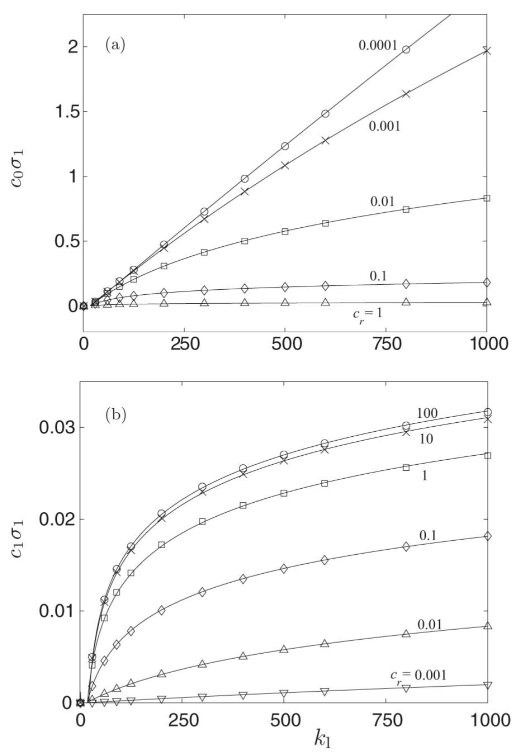
Graph (2) shows the dependency of the sheet conductance per bilayer σ_1 on the number of bilayers k_1 for a fixed density n_s and different values of the junction resistance parameter ratio

$$C_r = \frac{C_1}{C_0}$$

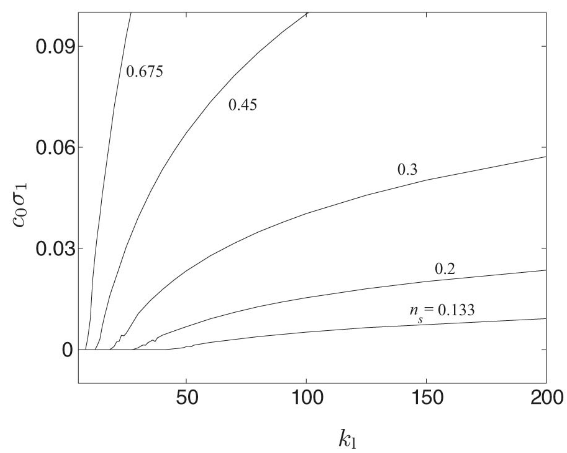
The Graph (2) (a) the results in the range of small and moderate values of the parameter ratio. Graph (2) (b) shows the range of moderate and large values of C_r. Graph (3) shows the behavior of the conductance σ_1 for different rod densities n_s. The results demonstrated that percolation occurred at $k_1^{perc} = n_{tot}^{perc} / n_s$. The obtained results were compared with previously obtained results of theoretical and experimental works and were found in good agreement.



Graph 1: Conductivity per bilayer σ_1 normalized by the junction resistance c_0 vs number of bilayers k_1 according to the standard rod-network model.



Graph 2: Conductance per bilayer σ_1 us number of bilayer k_1 for different values of the junction resistance parameter ratio C_r.



Graph 3: Normalized conductance per bilayer $c_0\sigma_1$ vs number of bilayer.

CONCLUSION

The electronic conductance of nanopolymer single walled nanotube with spin spray was studied. It was found that conductance of material of polymers carbon per bilayer vanished for film thickness below a critical value and above the threshold increased logarithmically with the number of polyelectrolyte bilayer. The quasi two dimensional models treated the nanotubes as infinitely conducting rods with resistive junctions using scaling arguments and numerical simulations. It was shown that linear dependence of the junction resistance on the layer separation leaded to the logarithmic behavior. Above the critical value the sheet conductance increased and that showed the conductivity was controlled by the formation of a percolation network of highly conducting nanotubes in an insulating polymeric matrix. The nanotube junctions with finite resistance formed not only between nanotubes deposited in the same bilayer but also between nanotubes deposited in different bilayers. The obtained results were found in good agreement when compared with previous results.

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