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Electric properties of Carbon nanotubes –epoxy composite

KEYWORDS: Carbon nanotubes, Epoxy polymer, D.C conductivity.

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ABSTRACT *In this study, effects of carbon nanotubes on electrical properties of Epoxy polymer have been investigated. Firstly, 0.01, 0.05 and 0.1% CNT were infused into epoxy. Samples of epoxy with carbon nanotubes appeared by using casting technique. Results showed that the D.C electrical conductivity increases with increasing the weight percentages of carbon nanotubes.*

INTRODUCTION

Since the documented discovery of carbon nanotubes (CNT) in 1991 by Iijima[1] and the realization of their unique physical properties, including mechanical, thermal, and electrical, many investigators have endeavored to fabricate advanced CNT composite materials that exhibit one or more of these properties[2-5]. For example, as conductive filler in polymers, CNT are quite effective compared to traditional carbon black microparticles, primarily due to their high aspect ratios.

Epoxy resin is the polymer matrix used most often with reinforcing fibers for advanced composites applications. The resins of this class have good stiffness, specific strength, dimensional stability, and chemical resistance, and show considerable adhesion to the embedded fiber[6]. Over the years, many attempts have been made to modify epoxy by adding either rubber particles [7-8] or fillers [9-10] to improve the matrix-dominated composite properties.

The effect of adding CNT on the electrical properties of polymers has been studied by many groups. These studies fall into a number of distinct categories. In some cases, the nanotubes have been used to increase the conductivity of relatively low cost polymers, as an alternative to currently used fillers such as carbon black [11-13]. The purpose of this work is to shows the effect of carbon nanotubes on the electric properties of epoxy, by introducding the CNT-epoxy composite.

EXPERIMENTAL WORKS

Composite thin films of epoxy containing multiwall carbon nanotubes(MWCNTs) with diameter ranging between (30-60nm), were prepared. To prepare MWCNTs reinforced polymer thin films, MWCNTs was first dissolved in chloroform for 1h on the magnetic stirrer and sonciated for another hour to achieve a good dispersion. Epoxy resin used as a matrix (master top 1210plus) was subsequently added in to different concentration of CNTs (0.01, 0.05 and 0.1%) suspension. After mixed the solution for 30min, hardener (Iranian BASF) was added and mixed for 3min. The mixing ratio of epoxy and hardener was 1:2.

Sheets from carbon nanotube and epoxy resin as matrix were prepared with 1mm film thickness; composite sheets were obtained once the solution cured. The composite films were cut into rectangular bars with dimension (3cm × 3cm×1mm) to study the electrical properties. Data was collected at room temperature up to 160Co with interval rate of 10Co.

CELL MEASUREMENTS

D.C. CONDUCTIVITY

For the dc- conductivity measurements, samples with plane geometry have been used. Kethley (616) digital meter was used for resistance measurements as a function of temperature.

The rate of heating of the samples was controlled using an oven type (memert 854). The activation energy of the films is calculated, from the plot of σ versus (103/T) and by using Stuke's equation [14].

$$\sigma = \sigma_0 \exp(-E_a / k_B T)$$

This equation is basically derived to give the change of the electrical conductivity with temperature for most cases of intrinsic semiconductors. Ea denotes the thermal activation energy of electrical conduction (σ) which is a parameter that depends on the semiconductor nature, (σ0) is defined as the proportionality factor which represents the conductivity when temperature approaches infinity and kB is Boltizman's constant and the activation energies (Ea) can be deduced.

RESULT AND DISCUSSION

D.C CONDUCTIVITY MEASUREMENT

The D.C conductivity for samples has been studies as a function of temperature at room temperature(R.T) to 160Co as shown in Figure.1. This figure shows increasing on the conductivity of the epoxy resin as the concentration of CNTs increased from 0.01% to 0.1%. From the figure one can see that the concentration less than 0.01% had low effect on the D.C conductivity of the epoxy resin. The increase in the conductivity of Epoxy /CNTs may be due to the dopant effect or the charge transfer from the polymer to the carbon nanotubes. Carbon nanotube relatively good electron acceptors, while epoxy can be considered a good electron donor, also due to the large aspect ratio and surface area of CNTs. As well as it's found that there are one stage of conductivity for epoxy / CNTs samples. In this case the thermal activation energy Ea occure at higher temperature and this energy is due to conduction of carrier excited into the extended states beyond the mobility edge.

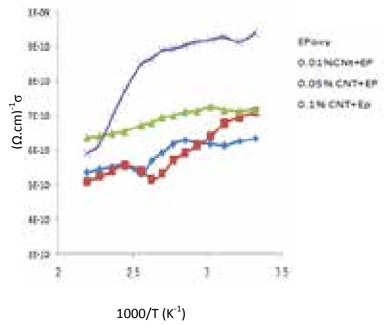

Fig. 1. The D.C conductivity as a function of 1000/T.

Table (1) shows that for increasing concentration of CNTs the thermal activation energy decrease.

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Table 1: Activation energy of the sample with different concentrations of CNTs

concentrations	Ea
Ep	0.592
0.01	0.588
0.05	0.257
0.1	0.26

From the above results for the D.C conductivity the relation between CNTs concentrations, DC conductivity and resisitivity at room temperature can be plotted as shown in Figures.2and 3.

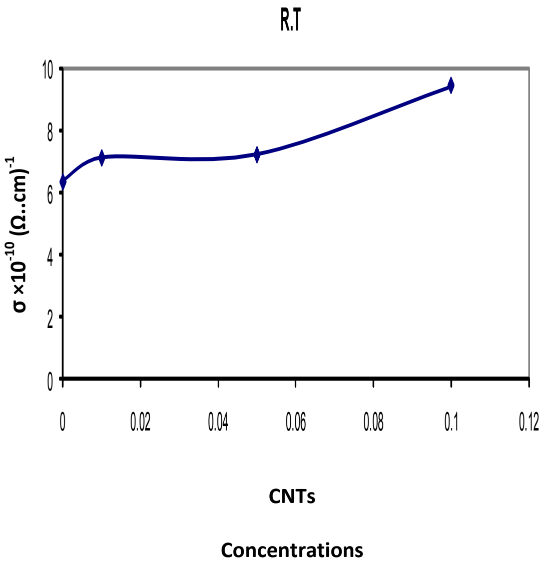

Fig.2. The conductivity of the films as a function of CNTs concentrations at room temperature.

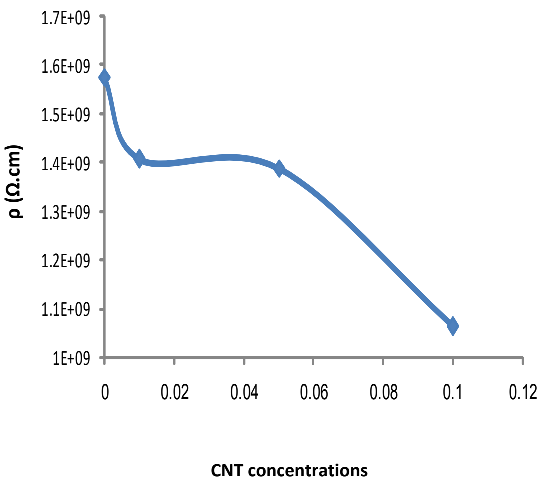

Fig.3. The resistivity as a function of CNTs concentrations at room temperature.

Epoxy resin is insulator and the D.C conductivity value of the film at room temperature is about 6.35×10-10 (Ω.cm)-1. Figure 2 shows that the DC conductivity of the MWCNTs / epoxy composite films with different concentration of MWCNTs (0.01, 0.05 and 0.1 %). Clearly, the electrical conductivity of the composite is highly enhanced by the introduction of the MWCNTs. Where the resistivity is decreases with increase MWCNTs concentrations.

CONCLUSION

In this work the D.C conductivity of pure and doped epoxy polymer with multi wall carbon nanotubes composite was studied, the measurements shows increasing in the conductivity of the MWCNTs-epoxy composite as the concentrations of CNTs increased from 0.01-0.1%, then those obtained for pure polymer.

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