Synthesis and study the electrical properties of carbon nanotubes-polyvinylchloride composites

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Abstract

The aim of this paper, study the effect of carbon nanotubes on the electrical properties of polyvinylchloride. Samples of polyvinylchloride carbon nanotubes composite prepared by using hot press technique. The weight percentages of carbon nanotubes are 0,5,10 and 20wt.%. Results showed that the D.C electrical conductivity increases with increasing of the weight percentages of carbon nanotubes. Also, the D.C electrical conductivity changed with increase temperature for different concentrations of carbon nanotubes. The activation energy of D.C electrical conductivity is decreased with increasing of carbon nanotubes concentration.

Key words

Carbon nanotubes , polyvinylchloride, electrical properties, conductivity

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تصنيع و دراسة الخواص الكهربائية للمتراكب بولي فانيل الكحول – انابيب الكاربون النانوية

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الخلاصة

الهدف من هذا البحث، دراسة تاثير انابيب الكربون النانوية على الخواص الكهربائية لبولي فاينيل كلورايد. نماذج من متراكب بولي فاينيل كلورايد وانابيب الكربون النانوية حضرت باستعمال تقنية الكبس الحراري. النسب الوزنية لانابيب الكربون النانوية هي .(0 ,5,10 and 20)wt.% . النتائج بينت ان التوصيلية الكهربائية المستمرة تزداد مع زيادة النسب الوزنية لانابيب الكربون النانوية. كذلك التوصيلية الكهربائية المستمرة تتغير مع زيادة درجة الحرارة لمختلف تراكيز انابيب الكربون النانوية. طاقة التنشيط للتوصيلية الكهربائية المستمرة تقل مع زيادة تركيز انابيب الكربون النانوية.

Introduction

The characteristic properties of metal nanoparticles and nanocomposites have been the subject of study for a long time because of their unique electrical, thermal, mechanical, electronic and optical properties[1]. Carbon nanotubes (CNTs) are ideal fillers for polymer composites due to their high Young's modulus combined with good electrical and thermal conductivity. The very high aspect ratio makes it likely that the addition of a small amount of CNTs strongly improves the electrical, thermal and mechanical properties of the polymer matrix. Thus, CNT/polymer composites combine the good processability of the polymers with the excellent mechanical and other functional properties of the CNTs[2]. However, the strong intermolecular van der Waals interactions among the nanotubes, in combination with their high surface area and high aspect ratio, commonly causes significant agglomeration, and prevents transfer of their superior properties to the matrix. Thus, dispersion of CNTs in polymer matrices plays a predominant role in the mechanical and other functional properties of polymer/ CNT composites [2]. The carbon nanocomposite can be used in many applications such as static dissipation, electromagnetic shielding, and radio frequency interference, where low to moderate conductivity is acceptable. The enhanced mechanical properties can be useful in applications such as aerospace and defense where weight and mechanical properties are critical [3]. Ibrahim in 2011[3] studied the effect of CNPs content on D.C and A.C electrical properties of polystyrene. The experimental results showed that the D.C and A.C electrical properties of such composites increase suddenly by several order of magnitude at a critical weight concentration. The present work deals with the effect of carbon nanotubes additive on the D.C electrical properties of polyvinylchloride.

Materials and Methods

The materials used in the paper are polyvinylchloride as matrix, it was obtained as powder from local markets, Tg is 85^0C, Tm is 180^0C and carbon nanotubes[supplied MER Corporation] as a filler. These mixed with weight percentages (Φ) of CNTs are 0, 5,10 and 20 wt.%. The Hot Press method used to press the powder mixture. The mixture of different CNTs percentages has been compacted at temperature 190^oC under a pressure 100 bar for 10 minutes. Its cooled to room temperature, the samples were disc shape of a diameter about 15mm and thickness ranged between (1.25-1.74)mm. The resistivity was measured over range of temperature from 30 to 80^oC using Keithly electrometer type (616ºC).

The volume electrical conductivity σ_v defined by:

$$\sigma_v = \frac{1}{\rho_v} = \frac{L}{RA} ------------(1)$$

where: A = guard electrode effective area.

R = volume resistance (Ohm).

L = average thickness of sample (cm).

In this model the electrodes have circular area $A= D^2\pi/4$ where radius (D) = 0.5 cm^2.

The activation energy was calculated using equation:

$$\sigma = \sigma_o \exp(-E_a/k_B T) \qquad (2)$$

σ = electrical conductivity at T temperature

σ_0 = electrical conductivity at absolute zero of temperature

K_B = Boltzmann constant

E_{act} = Activation Energy

Results and Discussion

Fig.1 shows electrical conductivity as function of the concentration of CNTs at a temperature of 30^oC .It seems that the curve profile is characterized by a rapid increase in conductivity. On the other hand, the critical filler fraction (Φ_c) corresponding to the insulator–conductor transition, i.e., the percolation threshold, lies at 20 wt.%. The general theory to explain the conduction mechanism of fibers or particle-filled polymer composites is the theory of conductive paths, which suggests that existence of conductive paths (conducting particles) those results in the conductivity of the composites. With increasing the content of the filler, conductive paths among the fillers will increase[3].

The variation of D.C electrical conductivity for (PVC- CNTs) composites of different concentration as function of temperature is shown in Fig.2. This figure shows that for low concentration ($\Phi< \Phi_c$), the conductivity increases with increasing of temperature characteristics of semiconductor materials.

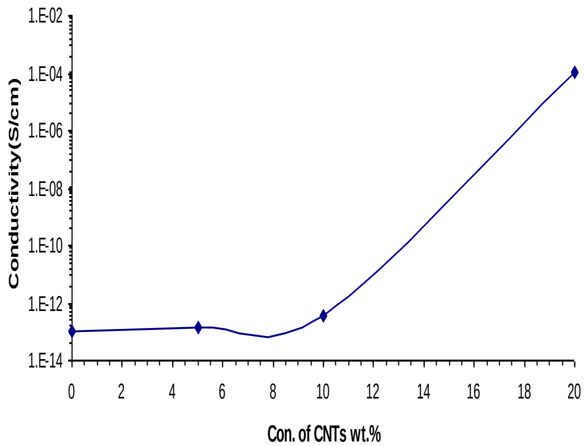

Fig.(1)
Variation of D.C electrical conductivity with CNTs wt.% concentration for (PVC-CNTs) composite.

This behavior can be related to the increasing of the charge carriers as well as increasing of polymer segmental motion as a result of temperature increasing [4]. For high

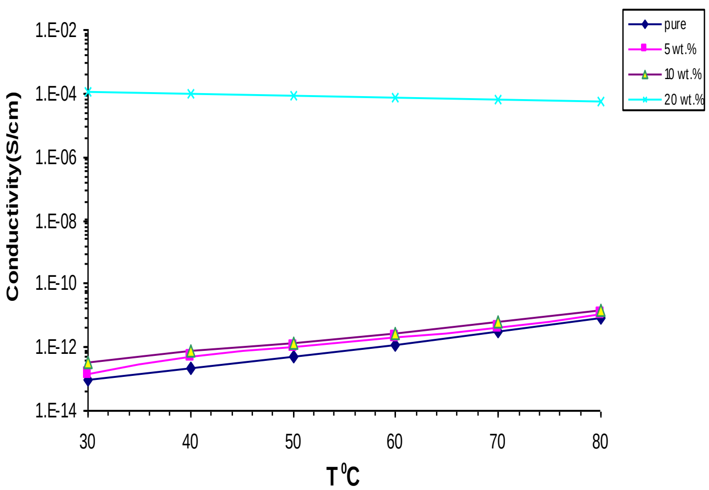

Fig.(2)

Variation of D.C electrical conductivity with temperature for(PVC-CNTs) composite

concentration of CNTs note that the electrical conductivity decreases with increasing of temperature because of the composite becomes a good conductive substance.

Fig.3 shows the relationship between the ln(conductivity) and inverted absolute temperature of composites. The activation

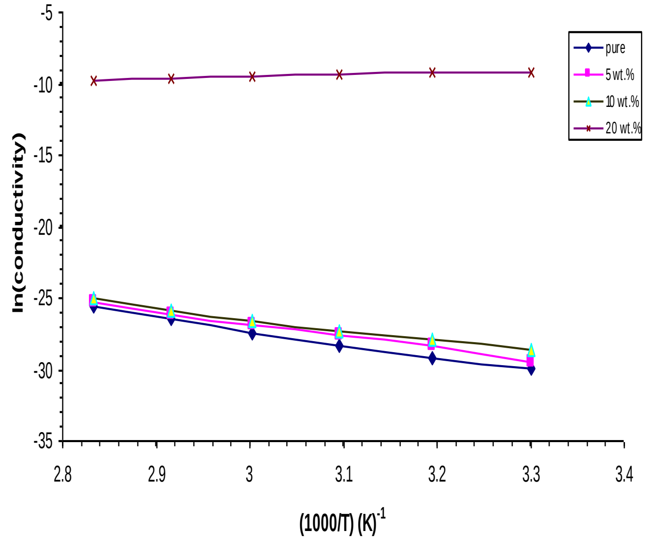

Fig.(3)
Variation of D.C electrical conductivity with resprocal absoute temperature for (PVC-CNTs) composite.

energy was calculated using eq.2. The high activation energy values for neat sample and low CNTs concentration sample and this is can be attributed to the thermal movement of the ions and molecules, whereas the low activation energy values for the samples of higher CNTs content can be attributed to the electronic conduction mechanism which is related to the decreasing of the distance between the CNTs particles [5].

The concentration increasing of CNTs less the result of the activation energy as shown in the Fig.4.

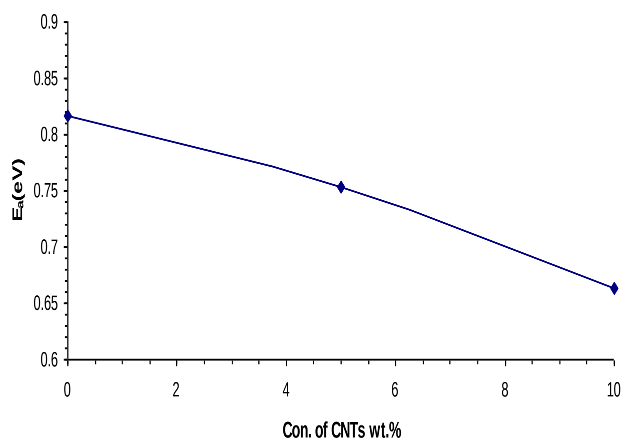

Fig.(4)
Variation activation energy for D.C electrical conductivity with CNTs wt.% concentration for (PVC-CNTs) composite

Conclusions

1. The D.C electrical conductivity of the polyvinylchloride increases with increase of CNTs concentrations and the temperature for ($\Phi<\Phi_c$) and it decreases by increasing of temperature for($\Phi>\Phi_c$).
2. The activation energy of D.C electrical conductivity decreases by increasing of CNTs concentrations.

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