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Study of Electrical Properties of (PS-Cu_2O) Composites

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Abstract

The electrical properties of PS-Cu_2O composites were studied. The effect of copper oxide concentration and temperature on the D.C electrical properties have been investigated. Also, the effect of copper oxide concentration and frequency on the A.C electrical properties have been studied. Results showed that the D.C electrical conductivity increased with increasing the copper oxide concentrations and temperature. Also, the activation energy change with increasing of additional copper oxide. The dielectric constant, dielectric loss and electrical conductivity are increasing with increase the concentration of the copper oxide. Also the dielectric properties (dielectric constant, dielectric loss and electrical conductivity) changed with increase the frequency.

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Introduction

The pace of research on dielectric properties of heterogeneous materials has accelerated in recent years. Industries such as the aerospace, electronics and others, have continuously provided the impetus pushing the development of new materials in a fascinating and rich variety of applications. Examples abound, ranging from shielding enclosures to capacitive video disk units to antistatic devices and electromagnetic absorbing materials. The trend towards a wider variety of applications is almost certain to continue (Brosseau C. et al., 1997).

The magnitudes of electrical conductivity of a polymer are determined by their chemical and physical structures as well as composition. From the measurements of other investigators it is already known that ceramic filler influences mechanical, thermal, electrical and dialectical properties of polymers (Yuji Hiraoka, et al., 2011 and Nevenka A., et al., 2002). Polystyrene is a preferred material in electronic technology due to its dielectric and mechanical properties and its low cost. PS can be subjected to high temperature and pressure variations, during the manufacture of electronic components (EL – Tawansi A. et al. ,1989). The present work deals with the effect of copper oxide on the D.C and A.C electrical properties of poly-vinyl alcohol composite.

Experimental work

The materials used in this study are polystyrene and copper oxide. The weight percentages of copper oxide are (0,3, 6 and 9)wt.%. The samples were prepared using casting technique thickness ranged between (457-784)μm. The resistivity was measured at room temperature using Keithly electrometer. The volume electrical conductivity σ_v defined by :

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

where:
A = guard electrode effective area.
R = volume resistance (Ohm) .
L = average thickness of sample (cm) .

The activation energy was calculated using equation :

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

σ = electrical conductivity at T temperature
σ_0 = electrical conductivity at absolute zero of temperature.
K_B = Boltzmann constant and E_{act} = Activation Energy

The dielectric properties of PS-Cu_2O composites were measured using (Agilent impedance analyzer 6500B).

In the frequency (f) range (1-10) MHz at room temperature. The measured capacitance, C(w) was used to calculate the dielectric constant ,$\acute{\varepsilon}(w)$ using the following expression:

$$\acute{\varepsilon}(w) = \frac{d}{\varepsilon_o A} C(w) \qquad (3)$$

Where d is sample thickness and A is surface area of the sample . whereas for dielectric loss $\varepsilon''(w)$:

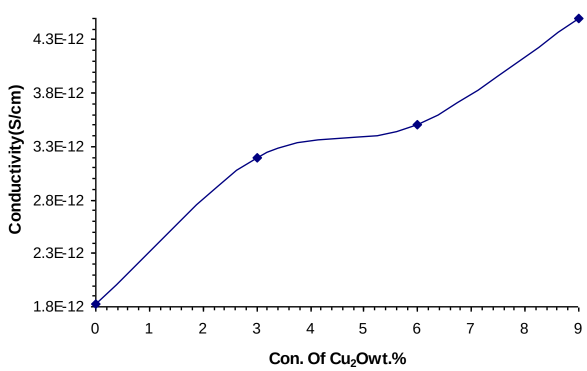
$$\varepsilon''(w) = \acute{\varepsilon}(w) \times \tan \delta(w) \qquad (4)$$

Where $\tan \delta(w)$ is dissipation factor . The AC conductivity σ_{ac} can be calculated by the following equation:

$$\sigma_{ac}(w) = \varepsilon_o w \varepsilon'' \qquad (5)$$

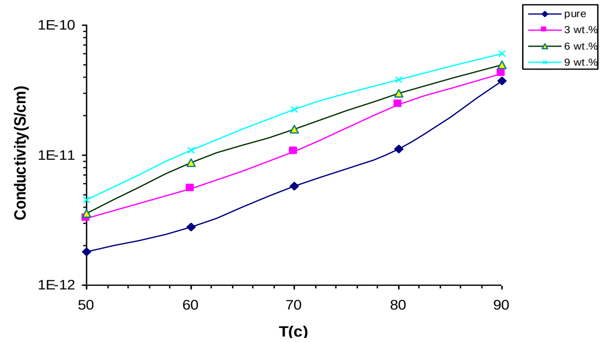
Results and Discussion

Figure (1) shows electrical volume conductivity as function of the concentration of copper oxide at a room temperature, the conductivity increases with increasing copper oxide additive concentration. The D.C electrical conductivity increases with concentration of copper oxide is increased. This result may be attributed to the increasing in the ionic charge that can be due to increase the electrical conductivity with increase the concentration of copper oxide (Srivastava N. K. et al., 2009).



Figure(1):The relationship between the electrical conductivity and concentration of copper oxide

The variation of D.C electrical conductivity of composites of different concentration of copper oxide as function of temperature is shown in figure (2). The figure shows that for all samples of composite, the conductivity is increasing with increasing temperature characteristics of semiconductor materials.. 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 (Sindhu S., et al, 2002).



Figure(2):The relationship between the electrical conductivity and temperature for (PS-Cu_2O) composites

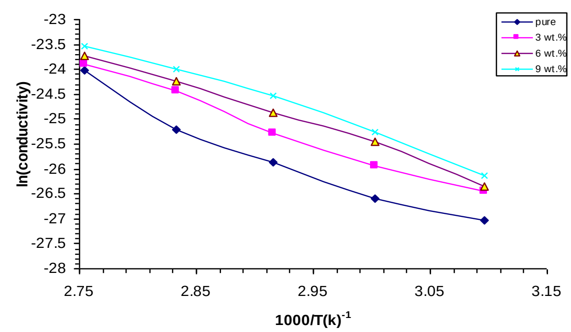


Figure (3): The relationship between the ln(conductivity) and inverted absolute temperature for (PS-Cu_2O) composite.

Figure (3) shows the relationship between the ln (conductivity) and inverted absolute temperature of composites, using equation (2) was calculate activation energy as shown in figure(4), the high activation energy values for neat sample and low concentration of copper oxide can be attributed to the thermal movement of the ions and molecules, whereas the low activation energy values for the samples of higher copper oxide content can be attributed to the electronic conduction mechanism which is related to the decreasing of the distance between the copper oxide particles(Hamzah M., et al.,2008)

The variation of dielectric constant of composites of different concentration copper oxide as function of frequency at room temperature is shown in figure (5). At low frequency region in addition to polarization due to polystyrene and copper oxide, the space charge polarization plays a major role in increasing dielectric constant of composite(Hamzah M, et al., 2009).

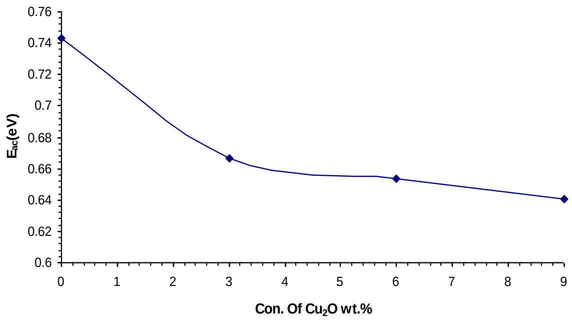


Figure (4):The relationship between the activation energy and concentration of copper oxide

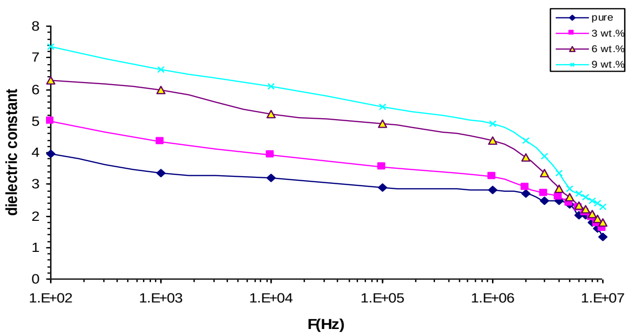


Figure (5):The variation of dielectric constant with the frequency of (PS-Cu_2O)

The dielectric constant increases with weight percentages of copper oxide as shown in figure (6). The increase in dielectric constant with weight percentages of copper oxide supports the fact of the space charge polarization contribution. The dielectric constant of composite increases with addition of copper oxide reflects the formation of capacitance network of copper oxide (Sindhu S., et al., 2002).

The variation of the dielectric loss composites as a function of frequency at room temperature is shown in figure (7) , the values of ε'' are oscillatory with frequency. The oscillatory behavior of ε'' may be due to some relaxation processes which usually occur in heterogeneous system (Revanasiddappa M., et al., 20077)

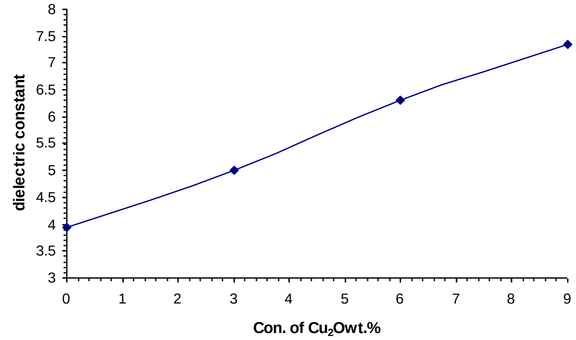


Figure (6): The relationship between the dielectric constant and concentration of copper oxide at 100 Hz.

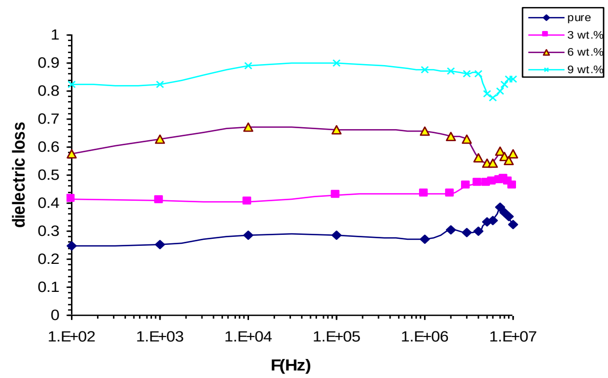


Figure (7) shows dielectric loss as a function of the concentration of copper oxide at a room

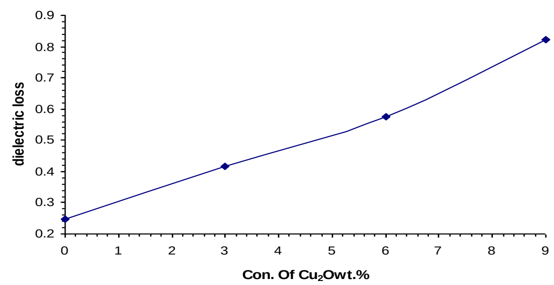


Figure (8):The relationship between the dielectric loss and concentration of copper oxide.

Figure (8) shows dielectric loss as a function of the concentration of copper oxide at a room temperature, the dielectric loss increases with increasing copper oxide additive concentration. This result attributed to the increasing in the ionic charge in composite (Revanasiddappa M., et al., 20077).

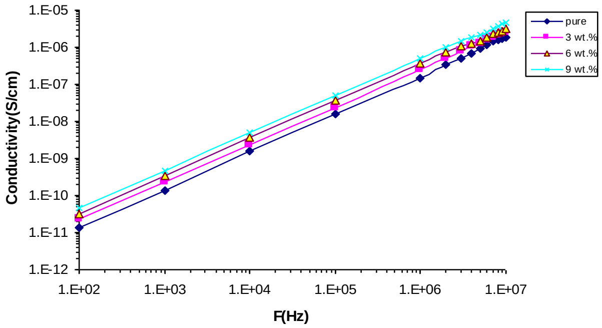


Figure (9): The variation of electrical conductivity with the frequency of composites.

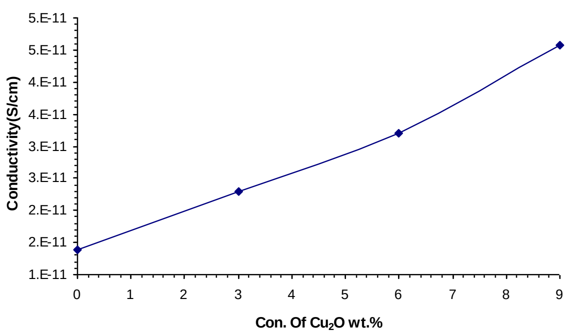


Figure (10):The relationship between the electrical conductivity and concentration of copper oxide at 100 Hz.

The behavior of A.C conductivity of composite for various concentration of the filler as a function of frequency is show in figure (9). The figure shows that the electrical conductivity of composites is increasing with frequency. The increasing of electrical conductivity with frequency attributed to the space charge polarization that occurs at low frequencies, and also to the motion of charge carriers by hopping process (Hamzah M., et al., 2009).

Figure (10) shows A.C electrical conductivity as a function of the concentration of copper oxide at 100Hz.
The conductivity is increasing with the increase of the concentration of copper oxide as a result of the increase of the ionic charge carriers and the formation of a continuous network of copper oxide ions inside the composite (Hamzah M., et al., 2009).

Conclusions

1. The D.C electrical conductivity of the polystyrene increases by increasing the copper oxide concentrations and the temperature
2. The activation energy of D.C electrical conductivity decreases by increasing copper oxide concentrations..
3. The dielectric constant decreases with increase the frequency and increases with copper oxide content.
4. The dielectric loss is oscillatory with increasing the frequency and increases with increasing the copper oxide content.

The A.C electrical conductivity of composites increases with increasing the frequency of applied electrical field and copper oxide content.

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