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THE D.C AND A.C ELECTRICAL PROPERTIES OF POLYMER FILLED WITH METAL POWDER

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ABSTRACT

In this paper the effect of filler content on D.C and A.C electrical properties of polystyrene filled with copper powders has been investigated. The D.C conductivity of such composites increases suddenly by several order of magnitude at a critical weight concentration. The D.C electrical conductivity changed with increasing of temperature. Also the activation energy change with increasing filler concentration. The dielectric constant, dielectric loss, A.C electrical conductivity are increasing with increasing the concentration of the filler and frequency of applied electrical field.

Keywords: **Dielectric constant, percolation threshold ,polystyrene, electrical conductivity.**

الخلاصة

في هذا البحث تم دراسة تأثير إضافة النحاس على الخواص الكهربائية المستمرة والمتناوبة للبولي ستايرين. أظهرت النتائج إلى أن التوصيلية الكهربائية المستمرة تزداد فجأة عدة مراتب عند التركيز الحرج. كما ان التوصيلية الكهربائية المستمرة تتغير مع زيادة درجة الحرارة . كذلك أن قيم طاقة التنشيط تتغير مع زيادة تركيز النحاس المضاف.ثابت العزل،والفقدان العزلي، والتوصيلية الكهربائية المتناوبة تزداد مع زيادة تركيز النحاس المضاف وتردد المجال الكهربائي المسلط.

1. INTRODUCTION

Composites made of polymer with a conducting filler allowed the combination of mechanical properties , ease of processing and electrical properties for such applications requiring significant conductivity. Polymer-based electrically conducting materials have several advantages over their pure metal counterparts, which include cost, flexibility, reduced weight, ability to absorb mechanical shock, corrosion resistance, ability to form complex parts, and conductivity control. Filled conducting polymer composites are used for electromagnetic shielding of computers and electronic equipments. In addition, they are used as conducting adhesives in electronics packaging flip-chips, cold solders, switching devices, static charge dissipating materials, and devices for surge protection[Alvarez *et al*,2008, Younis Khalaf, 2008].Conductive polymer composite are used in a wide variety of industrial application such as battery and fuel cell electrodes. An indication of the fulfilling requirements of an in deal filler for a conductive composite many be obtained from the following properties; high electrical conductivity, improvement of the physical and mechanical properties, good dispersion characteristics, availability in controlled particle size, density, low moisture adsorption, non-inflammability, low cost and availability[A. Hashim *et. al*, 2011]. A surprising property of filled polymer composites is their conductivity profile as a function of filler concentration. It is found that their conductivity does not increase continuously with increasing filler content, but shows a sudden jump to higher conductivity. This conductivity behavior resulting in a sudden insulator-conductor transition is ascribed to a percolation process, and the critical filler concentration at which the conductivity jump occurs is called percolation threshold[Bhatlacharya *et al*, 2008]. Polystyrene is a preferred material in electronic technology due to its dielectric and mechanical properties and its low cost . Srivastava and Mehra 2009 studied the electrical properties of polystyrene-foliated graphite composite. They found at the percolation concentration of graphite content (0.02 vol. function), the conductivity is found to be ca. 10^{-5}S/cm.The present work deals with the effect of Copper additive on the D.C and A.C electrical properties of polystyrene composite.

1. EXPERIMENTAL WORK

The materials used in the paper is polystyrene as matrix and copper as a filler.

An electronic balanced of accuracy 10^{-4} have been used to obtain a weight amount of Cu powder and polymer powder. These mixed by Hand Lay up and the Microscopic Examination used to obtain homogenized mixture .The weight percentages of Cu are (20,40,50 and 60) wt.% . A Hot Press is used to press the powder mixture. The mixture of different Cu percentages has been compacted at temperature 175^{o}C under a pressure 100 bar for 10 minutes . Then cooled to room temperature . The samples were of disc shape of a diameter about 15mm and thickness ranged between (1.055-1.52)mm. The coating unit (Edward coating System E3C6A) has been used for deposition of thin film Aluminum electrode on both sides of each sample . The resistivity was measured over range of temperature from (30 to 80)^{o}C using Keithly electrometer type (616C) . The dielectric properties of PS-Cu composites were measured using (Agilent impedance analyzer 4294A).In the frequency(f) range (25×10^{2}-5×10^{6}) Hz at room temperature. The average size particles of filler about (60-70) micron.

2. RESULTS AND DISCUSSION

Figure(1) shows the electrical conductivity enhancement of the composite by increasing the concentration of the Cu filler at T=303^{o}k. At lower concentration of the filler [ϕ<45wt.%], the electrical conductivity of the composite increases slightly; while at higher concentration [$\phi \geq$45wt.%], the conductivity increases sharply where the composite becomes a good conductive substance. The source of the conductivity enhancement is the electrical contacts generated from the filler networks. At high filler content, the amount of the interconnecting networks is increased and the contact resistance between the filler is decreased, and hence a good electron conduction is achieved resulting in transformation of the polymer insulator to a good conductive polymer composite[Younis Khalaf, 2008].

Figure (2) shows the behavior of electrical volume conductivity of the samples with the temperature. Note that the electrical conductivity increase with increasing temperature($\phi<\phi c$ " percolation threshold ϕc, i.e. the lowest concentration of conduction particles at which continuous conducting chains are formed, is easily determined from the experimental dependence of conductivity on the filler concentration") that any of this material has a negative thermal coefficient of resistance .the interpretation of this is that the polymeric chains and Cu particles act as traps the charge carriers which transited by hopping process. On increasing the temperature, segments of the polymer being agitated, releasing the trapped charges. .

The released of trapped charges is intimately associated with molecular motion . The increase of current with temperature is attributed to two main parameters , charge carriers and mobility of these charges. The increase of temperature will increase the number of charge carriers exponentially. The mobility depends on the structure and the temperature [Al-Ramadhan,2008, Majdi and Fadhal,1997]. The electrical conductivity decreases with increasing temperature($\phi > \phi c$) that any of this material has a positive thermal coefficient of resistance(conductive material).

Figure (3) shows the relationship between the ln(conductivity) and inverted absolute temperature of the PS-Cu composites, utilizing equation $\sigma = \sigma_o \exp(-E_a/k_B T)$ to calculate activation energy; the high activation energy values for neat sample and low Cu concentration sample can be attributed to the thermal movement of the ions and molecules, whereas the low activation energy values for samples of higher Cu content can be attributed to the electronic conduction mechanism which is related to the decreasing of the distance between the Cu particles . [Hamzah *et.al* ,2008]

The decrease of activation energy with increasing Cu content as shown in the figure (4) of PS-Cu composite supports for the above discussion.

The variation of dielectric constant for PS-Cu composites of different Cu concentration as function of frequency at room temperature is shown in figure (5). At low frequency region , the space charge polarization plays a major role in increasing dielectric constant of composite[Hamzah *et al*, 2009]. The space charge polarization arises from the Cu/PS interfaces. The dielectric constant increases with weight fraction of Cu. The increase in dielectric constant with weight fraction of Cu supports the contribution of space charge polarization contribution . The dielectric constant of composite increases with addition of Cu reflects the formation of capacitance network of Cu. [Harun *et al*,2008, Raghavendra *et al*,2008] as shown in figure(6).

The variation of the dielectric loss of PS-Cu composites as a function of frequency at room temperature is shown in figure (7) , the values of ε'' are high for low frequencies, and decreasing with increasing the frequency. The oscillatory behavior of ε'' may due to relaxation processes which usually occur in heterogeneous systems. The relaxation peak at f=100kHz appears clearly in all low Cu concentrations. The increasing of Cu concentration increases the height of the peak and increasing its broadness for these specimens. This is due to the overlapping of relaxation process which are attributed to some structural changes that take place in the composite as result of filler addition . The increasing of the peak height of ε'' with increasing Cu concentration indicates the enhancement of conductivity in these specimens , i.e. enhancement of losses [Raghavendra *et al*,2007, Pillal,1980] as shown in figure(8).

The behaviour of A.C conductivity of PS-Cu composite for various concentration of the filler as a function of frequency at room temperature is shown in figure(9). The A.C conductivity response to the applied field frequency at low and intermediate range is flat, and at high frequency ranges there is a transition region where the response starts to bend downward. The bending region is shifted towards the higher frequency values as the concentration of filler increases. For specimens of high filler content the behavior of A.C conductivity can be explained via conductive pathways or network which formed as a result of infinite clusters formation. The flat response of A.C conductivity at these frequency ranges can be attributed to the fact that electrons will travel over large distances within these clusters without obstocles before it hops to other clusters .In fact most conductors give a flat response in the same frequency ranges[Vishnuvardhan *et al*,2006].

At lower concentrations of the filler the A.C electrical conductivity of the composite increases slightly; while at higher concentrations the conductivity increases sharply where the composite becomes a conductive substance. At high filler content, the amount of the interconnecting networks is increased and the contact resistance between the composite materials is decreased; hence an enhanced electron conduction is achieved resulting in transition of the insulating polymer to conductive polymer composite[Shui. *et al*,2004] .

3. CONCLUSIONS

1. The D.C electrical conductivity of the polystyrene increased with increasing the Copper concentrations and the temperature
2. The activation energy of D.C electrical conductivity decreases by increasing Cu concentrations..
3. The dielectric constant decreasing with the frequency and increase with Cu wt.% content .
4. The dielectric loss is oscillatory with increasing the frequency and increasing with increasing the Cu wt.% content .
5. The A.C electrical conductivity of PS- Cu composites is oscillatory with increasing the frequency of applied electrical field and increasing with increasing the Cu wt.% content .

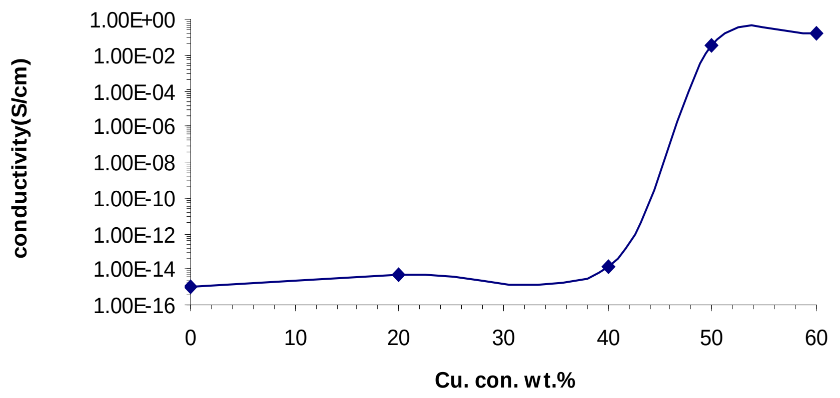


Figure (1) variation of D.C electrical conductivity with Cu wt% concentration for (PS-Cu) composite

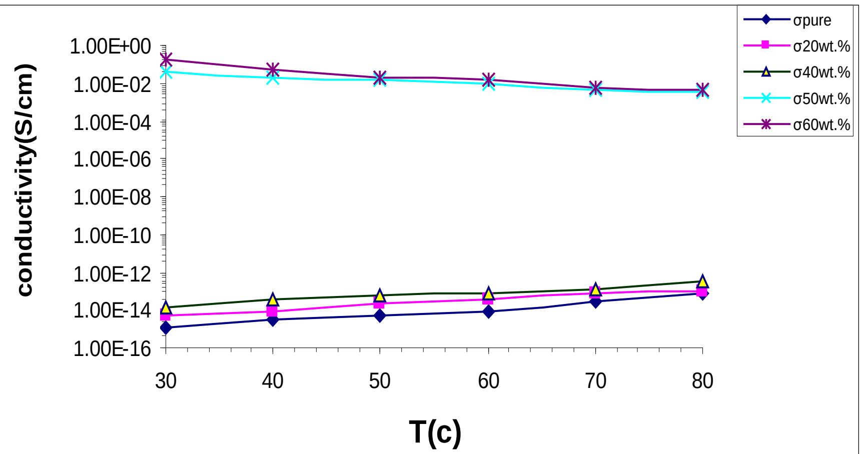


Fig.(2)Variation of D.C electrical conductivity with temperature for (PS-Cu) composite

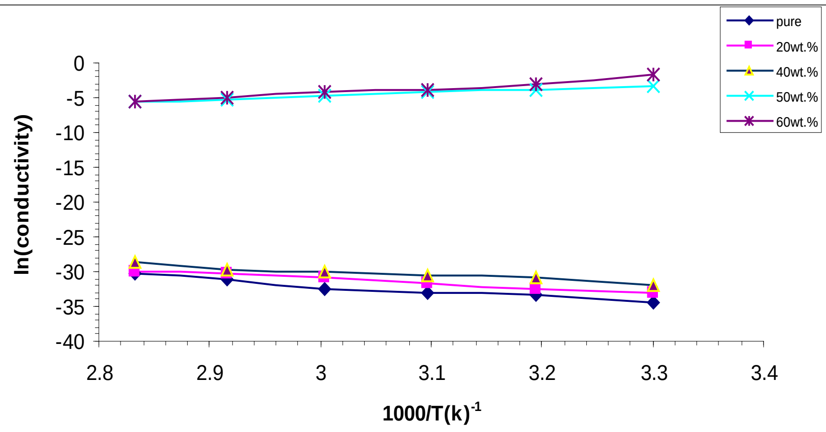


Fig.(3)Variation of D.C electrical conductivity with reciprocal absoute temperature for(PS-Cu) composite.

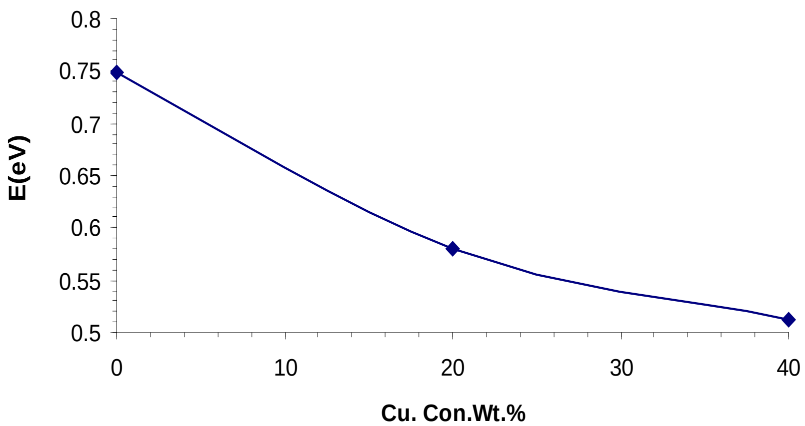
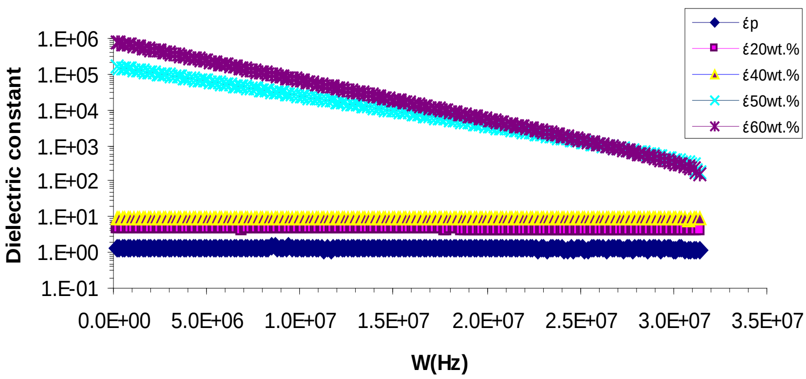
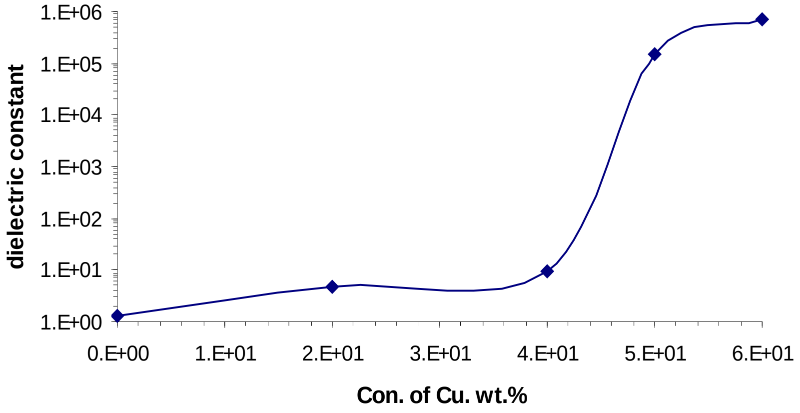


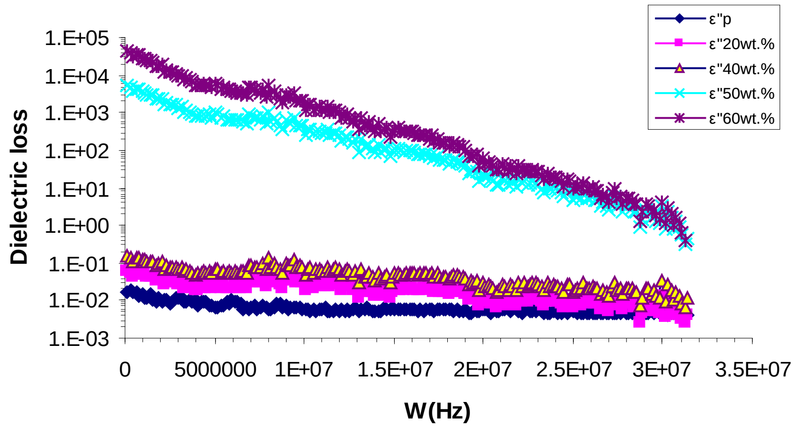
Figure (4)Variation activation energy for D.C electrical conductivity with Cu wt.% concentration for (PS-Cu) composite



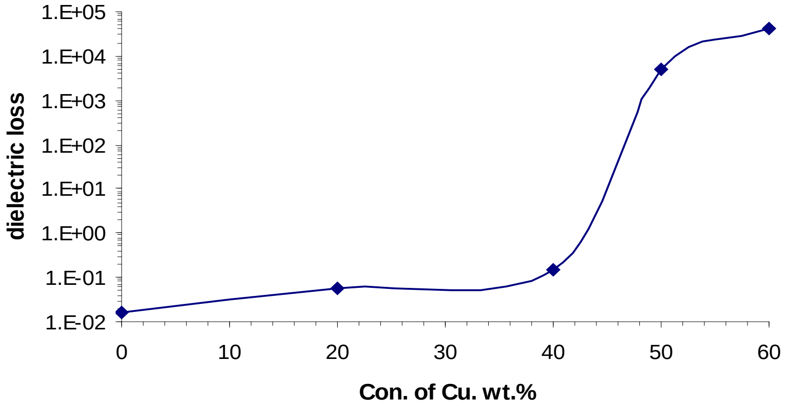
Figure(5) variation dielectric constant with angular frequency for (PS-Cu) composite.



Figure(6)Variation of dielectric constant with concentration of copper



Figure(7)Variation of dielectric loss with angular frequency for (PS-Cu) composite



Figure(8)Variation of dielectric loss with concentration of copper

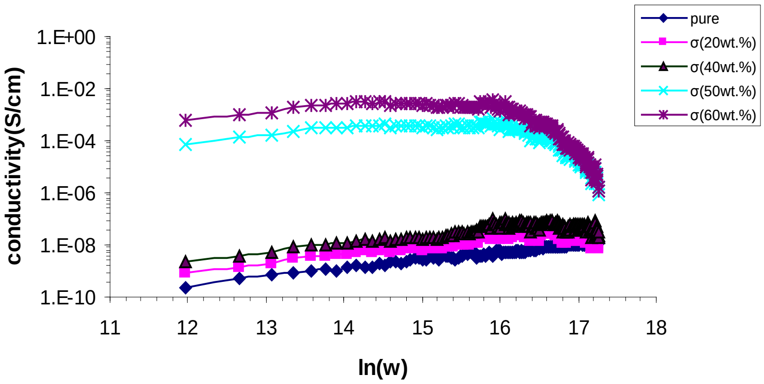


Figure (9) variation of A.C electrical conductivity Frequency for (PS-Cu) composite.

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