Studying the Effect of Aluminum Powder Addition on Dielectric Behavior of Polyester Composite Materials

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ABSTRACT

The effect of both weight fraction of aluminium and frequency on dielectric properties of Al- powder reinforced polyester composite materials were investigated. We study the dielectric behaviour of composite materials reinforced with (0, 5, 15, 30 &45) weight fraction of Al and frequency ranges (50-10^6) Hz at room temperature. The results show the dielectric constant and dielectric losses factor were increased with increasing in weight fraction of aluminium due to high conductivity of aluminium. The decrease in the dielectric constant and dielectric losses with higher frequencies can be explained by the fact that as the frequency increases, the interfacial dipoles have less time to orient themselves in the direction of the alternating field.

Keyword: aluminium, polyester, dielectric and composite materials

دراسة تأثير اضافة مسحوق الالمنيوم على سلوك العزل الكهربائي للبولي استر

الخلاصة

تم في هذا البحث دراسة تاثير الكسر الوزني والتردد على خواص العزل الكهربائي للبولي استر المدعم بكسور وزنية مختلفة من مسحوق الالمنيوم. تم دراسة سلوك العزل للمواد المتراكبة المدعمة ب (٠, ٥, ١٥, ٣٠&٤٥)% من مسحوق الالمنيوم عند معدلات تردد (٥٠ -١٠٦) Hz عند درجة حرارة الغرفة. اظهرت النتائج ان قيم كلا من ثابت العزل وعامل الفقدان العزلي يزداد بزيادة الكسور الوزنية للالمنيوم ويعزى ذلك الى التوصيلية العالية للالمنيوم. في حين قلت قيمهم عند الترددات العالية وهذا يوضح الحقيقة وهي عندما يزداد التردد,الجزيئات ثنائية الاقطاب بين السطحين تملك وقت قليل لترتب نفسها داخل الحقل الكهربائي.

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INTRODUCTION

Composite materials, which are usually fabricated with emphasis on properties such as mechanical strength, have also been used in electronic applications. One such class of composite materials is particulate-filled conductive polymer matrix composites. These composites consist of a polymer matrix in which a second phase, which is usually either a metal or carbon based filler, is dispersed. Conductive polymer composites, which are light weight materials and combine the inherent process ability of polymers with the electrical conductivity of metals, have been used in a number of applications such as electromagnetic frequency interference (EMI) shields and antistatic devices [1].

All dielectric materials are insulators. The distinction between a dielectric material and an insulator lies in the application to which one is employed. The insulating materials are used to resist the flow of current through it when a difference of potential is applied across its ends. On the other hand, the dielectric materials are used to store electrical energy. A dielectric material is one which stores electrical energy with a minimum dissipation of power, since the electrons are bound to their parent molecules and hence, there is no free charges [2].

A material may be required to conduct electrical currents. This includes metals and some non-metallic elements such as adhesives, greases, and other compounds loaded with graphite or metal powder. If electrical conductivity is important, then the resistivity of the material must be considered because electrical resistance creates voltage drop and heat generation, either of which may be a desirable or an undesirable consequence. In screening for electrical conductors, a maximum electrical resistance requirement must be defined, thus materials with equal or lower electrical resistivity become candidates for selection.

Electrical resistivity is temperature sensitive; thus it is necessary to make sure that the material electrical resistivity is satisfactory over the temperature range of interest. Conversely, it may be necessary to electrically isolate a component or current carrying member to protect from undesired electrical shorts. Materials used as electrical insulators, such as mica or glass or ceramics and many plastic materials, have very high electrical resistivity, are poor conductors of electricity, and are employed to provide electrical isolation. Pure aluminium and some of its alloys have exceptionally high electric conductivity (very low electrical resistivity) [3].

Vishal studied the effect of temperatures and frequency on dielectric properties of aluminium –epoxy composite materials. It was found this dielectric constant and dissipation factor were increased with increasing in temperatures whereas those decrease in frequency increases [4].

Parkash studied the effect of lanthanum and nickel (La, Ni) concentration in compound (Ba La Ti Ni O3). He shows the dielectric constant and dissipation factor decreases with increasing of the frequency and the dissipation factor increases with increasing of lanthanum and nickel concentration [5].

EXPERIMENTAL WORK

Materials

- Polyester resin and its hardener, Germany
- Aluminium powder , U.S.A(50-60 µm, purity 99%)

Experimental set up

The composite material prepared by mixing the polyester resin with its hardener in 3:1 ratio and then the Al powder added to the mixture in different weight then pours the mixture in cylinder mould and left the mixture in room temperature for 45 minutes. The samples were cut with (2& 0.5) cm dimensions then polishing the sample surface to improve smoothing. Make the electrodes by silver electroplating on the two sample sides to improve the electrical properties by silver paste.

LCR test

The device precision LCR meter, B&K precision crop.889A was accurately adjusted then used to measure the capacitivity (C_P) and resistivity (R) values on the electronic screen. Dielectric constants $\acute{\varepsilon}$ and loss factors ε'' were measured in the frequency range (50, 500, 1000, 10^5 &10^6) Hz and at room temperature in all samples. From these value can be fined a dielectric constant ($\acute{\varepsilon}$), dielectric loss factor (ε''), and dissipation factor (tanδ) by equations 1, 2& 3 respectively. These measurements test for (50Hz -10^6Hz) at room temperature.

$$\acute{\varepsilon} = c_p\, d / \varepsilon^{\circ}\, a \qquad \text{----(1)}$$

Where:

$\acute{\varepsilon}$: dielectric constant
d :thickness of dielectric,0.5 cm
a : cross section area, 3.14 cm^2
ε° : vacuum permittivity (8.854 *10^{-14} F/cm)

$$\varepsilon'' = d / \omega\, \varepsilon^{\circ}\, R\, a \qquad \text{----(2)}$$

$$\tan\delta = \varepsilon'' / \acute{\varepsilon} \qquad \text{----(3)}$$

Where

ε'': is the dielectric loss factor, ω: angular frequency which (ω= 2πf)rad/sec
R : is the resistance (Ω), tan δ: dissipation factor.

Figure (1) photo the specimens.

RESULTS AND DISCUSSION

In this capacity they have to be able to cope with range of frequencies. Variation in electrical properties aluminium reinforced polyester composite materials as shown in Tables (1-3). This variation of the composite material was investigated as function of weight fraction (5, 15, 30 &45) %of aluminum and frequencies (50, 500, 1000, 10^5 &10^6) Hz.

Effect of Weight Fraction

The dielectric constant of polyester is ranged (2.8-4.1). Since aluminum has high conductivity (3.5 *10^7 S/cm), as shown in figures (2&3) the dielectric constant increases with increasing weight fraction of aluminum at constant frequency , the maximum value of dielectric constant and dielectric losses reached to (28.11)& (12.36)at (45%) .

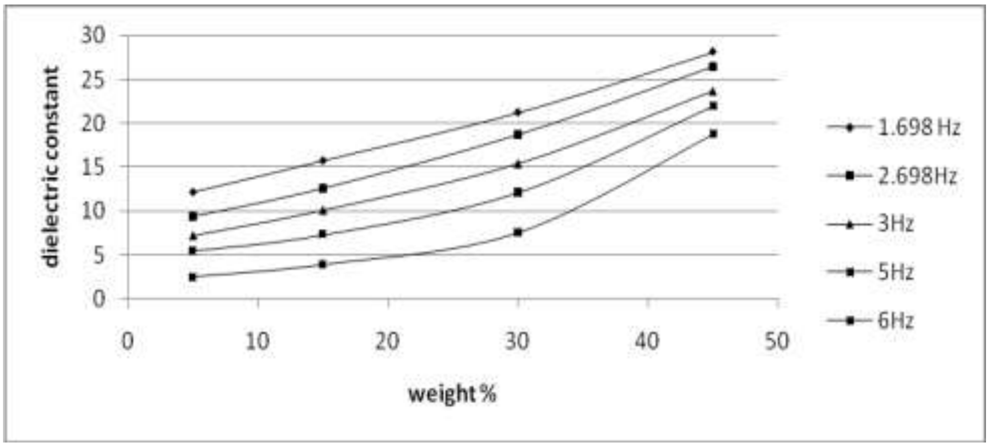
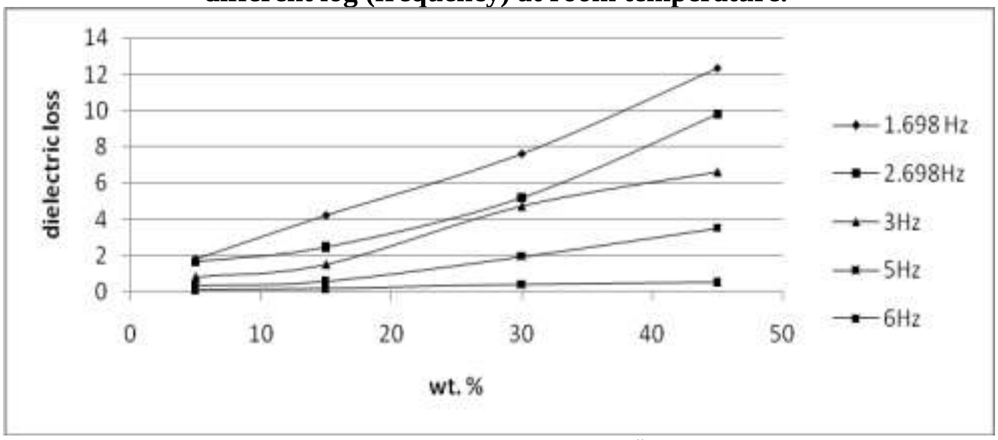
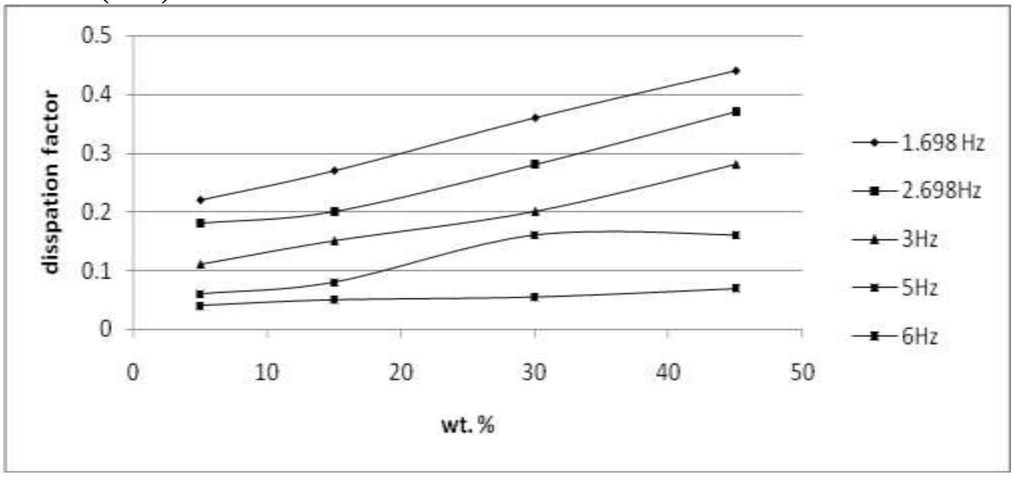


Figure (2) variation of dielectric constant (έ) with weight fraction and different log (frequency) at room temperature.



Figure(3) The variation of dielectric loss factor (ε") with weight fraction and log (frequency) at room temperature.

Dissipation factor (tan δ) was also investigated; Figure (4) shows that dissipation factor (tan δ) increases with increasing weight fraction of aluminium, it reaches (0.44).



Figure(4) The variation of dissipation factor (tan δ) with weight fraction and log (frequency) at room temperature.

The increase in values of dielectric constant and dissipation factor with increase in concentration of aluminium was due to interfacial polarization, if materials are placed in an electric field, the charge particles interact with the field.

If material is a conductor, the free electrons move to the nearest positive electrode. No field is, thus, left within the material. If a material is non- conducting or an insulator or dielectric the electrons are only locally displacement, because they are bound to individual atoms. The local displacement polarizes the material[6].

Effect of frequency

Dielectric properties as function also to frequency, Figures (5-7) show the variation of the dielectric constant (έ) and dielectric losses factor (ε˝) with different frequency at room temperature; the results exhibit that dielectric constant (έ) and dielectric loss factor (ε˝) decreased with increasing of frequency. It was attributed interfacial dipoles have less time to orient themselves in the direct of the alternating field. The permittivity depends on the dipoles and charges movement in the dielectric material, due to change in the field direction, because of an electric field alternation. The intensity of alternating electrical field was represented by the frequency of applying voltage, that effected by a dipoles of dielectric material into frequency range, this means the electrical polarization changed with an electric field changed.

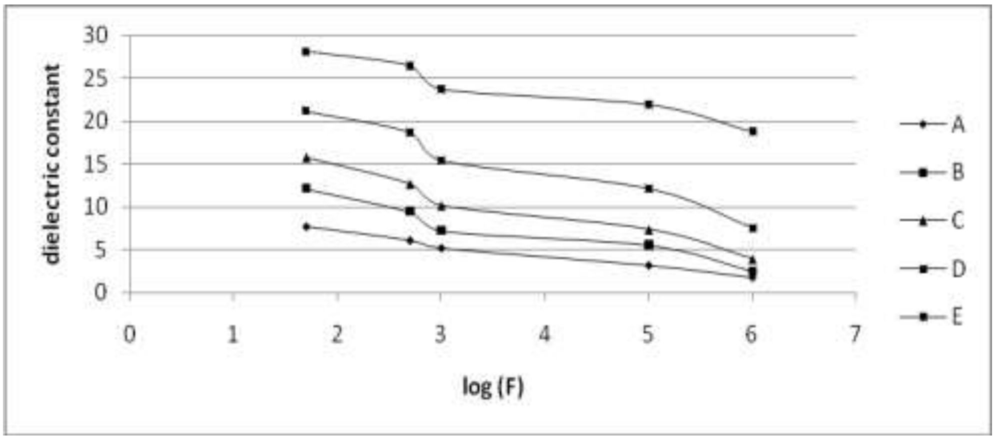
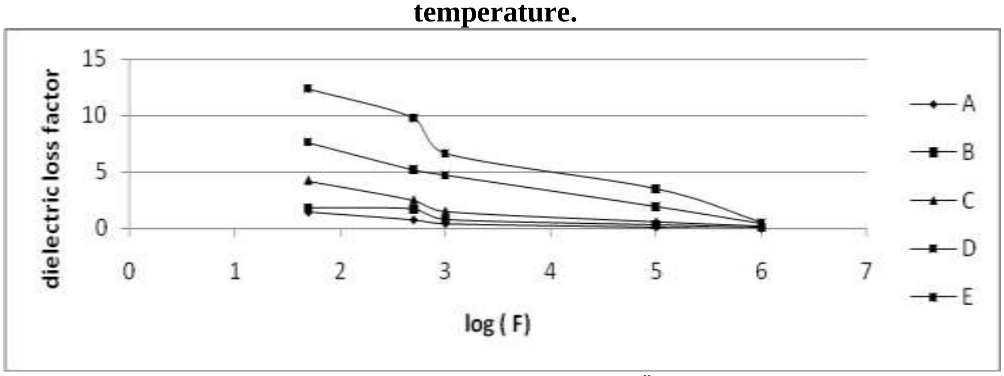
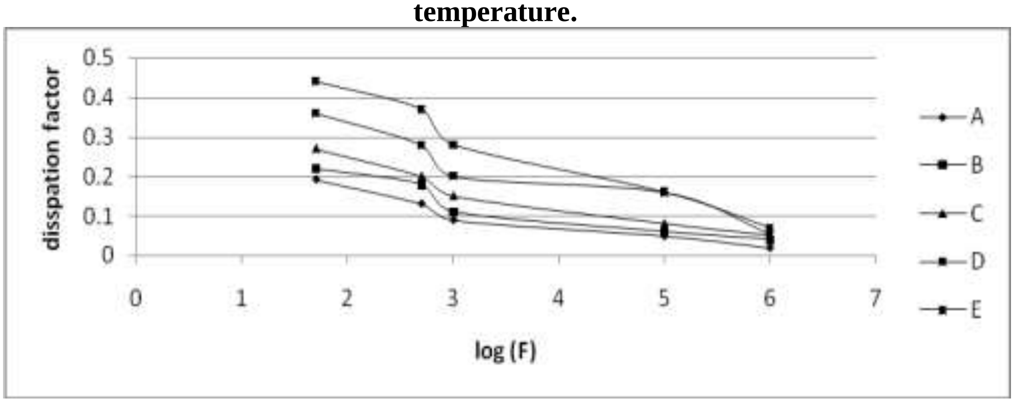


Figure (5) variation of dielectric constant (έ) with log frequency at room temperature.



Figure(6) The variation of dielectric loss factor (ε") with frequency at room temperature.



Figure(7) The variation of dissipation factor (tan δ) with different frequency at room temperature.

CONCLUSIONS

1- As frequency increases, both dielectric constant and dielectric loss factor were decreased.
2- Dielectric constant and dielectric loss factor were increased with increase the of weight fraction.

3- Dissipation factor has the same behaviour of each dielectric constant and dielectric loss factor in both frequency and weight fraction of aluminium.

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Table (1) The Variation of dielectric constant (έ) with different frequency at room temperature.

Samples	Dielectric constant (έ)				
F(Hz)	50	500	1000	10^5	10^6
Pure polyester (A)	7.7	6.1	5.21	3.2	1.8
5% Al-polyester , (B)	12.1	9.4	7.2	5.51	2.5
15%Al-polyester ,(C)	15.7	12.62	10.11	7.33	3.9
30%Al-polyester ,(D)	21.2	18.71	15.43	12.12	7.53
45%Al-polyester ,(E)	28.11	26.44	23.72	21.92	18.78

Table (2) The variation of dielectric loss factor (ε˝) with frequency at room temperature.

Samples	Dielectric loss factor (ε˝)				
F(Hz)	50	500	1000	10^5	10^6
Pure polyester, (A)	1.47	0.79	0.46	0.16	0.03
5%Al-polyester, (B)	1.81	1.69	0.79	0.33	0.1
15%,Al-polyester (C)	4.23	2.5	1.5	0.58	0.19
30%,Al-polyester (D)	7.63	5.2	4.74	1.93	0.41
45%,Al-polyester (E)	12.36	9.78	6.64	3.5	0.52

Table (3) The Variation of dissipation factor (tan δ) with different frequency at room temperature.

Samples	dissipation factor (tan δ)				
F(Hz)	50	500	1000	10^5	10^6
Pure epoxy, (A)	0.192	0.131	0.09	0.05	0.02
5%Al-polyester, (B)	0.22	0.18	0.11	0.06	0.04
15%,Al-polyester (C)	0.27	0.2	0.15	0.08	0.05
30%,Al-polyester (D)	0.36	0.28	0.2	0.16	0.055
45%,Al-polyester (E)	0.44	0.37	0.28	0.16	0.07