Studying the Effect of Frequency on Dielectric Properties of Cu Powder reinforced Epoxy Composite Material

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Abstract

This paper discussed the effect of frequency on dielectric properties of different weight fraction of Cu powder reinforced epoxy composite materials. Dielectric properties of epoxy material was reinforced with (0, 5, 15, 30, 45) % weight fraction of Cu powder at frequencies ranges (($50Hz$ -10^6Hz) at room temperature. The results of this study show these dielectric constants and dielectric losses factor were increased with increasing in weight fraction due to interfacial polarization. The results also, exhibit that dielectric constant (έ) and dielectric loss factor ($\varepsilon^{''}$) decreased with increasing of frequency account of electric polarization changed with an electric field changed.

Keyword:_copper, epoxy and dielectric properties

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 lightweight 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].

Epoxy Resins are materials may be formulated for strength and rigidity. The addition of metals or other powders will increase thermal and electrical conductivity.

Epoxy resins can be formulated with a wide range of properties. These medium-to high-priced resins are noted for their adhesion, make excellent primers, and are used widely in the appliance and automotive industries. Their heat resistance permits them to be used for electrical insulation. They are used as electrical insulters because of their high electric strength at elevated temperatures [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. [3].

Nirvana studied the effect of both weight fraction of aluminium and frequency on dielectric properties of Al- powder reinforced polyester composite materials. In this paper 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 were studied. The results show the dielectric constant and dielectric losses factor were increased with increasing in weight fraction of aluminium [4]

Vishal studied the effect of temperatures and frequency on dielectric properties of aluminium –epoxy composite materials. It was found that this dielectric constant and dissipation factor were increased with increasing in temperatures whereas those were decreased in frequency increases [5].

Experimental Set up

1. The materials studied were Cu-powder reinforced polyester which consisted of its hardener in 3:1 ratio.
2. Cu-powder were mixed with polyester at different weight fraction (5, 15, 30& 45)wt %.
3. The mixture was moulding and the samples of polymer composite were cut with thickness 2mm and diameter 1 cm.
4. The sample surface was Polishing to improve smoothness.
5. The simplest capacitor structure disc form.
6. Dielectric constants έ and loss factors ε” were measured in the frequency range (50, 500, 1000, 1^5 &$1^{6)}$ Hz
7. The device precision LCR meter was accurately adjusted then used to measure the capacitivity (C_P) and resistivity (R_P) values on the electronic screen. From these values can be fined a dielectric constant (έ) and dielectric loss factor (ε˝), by equations 1 & 2 respectively. These measurements test for (50Hz -10^6Hz) at room temperature [6].

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

Where:

έ: dielectric constant, d : thickness of dielectric sample,2 cm, a : cross section area, cm^2, ε^{o} : vacuum permittivity ($8.854 *10^{-14}$ F/cm)

$\varepsilon^{''} = d / \omega \varepsilon^{o} R a$ -------------(2)

Where: $\varepsilon^{''}$: is the dielectric loss factor.

ω: angular frequency which (ω= 2πf)

R : is the resistance (Ω),

$\sigma_{a.c:}$ electrical conductivity, Ω^{-1} cm^{-1}

Results and Discussion

The results included the effect of frequency on electric properties of Cu - powder reinforced epoxy, the effect of weight fraction of Cu powder. After coating the samples with aluminium the conductor, the LCR-meter was used to measure the capacitance (C_p) and resistivity (R) values. From these values a dielectric constant (έ), dielectric loss factor ($\varepsilon^{''}$) and dissipation factor (tan δ) are obtained by equations 1 & 2 respectively. These measurement tests for (50, 500, 1000, 10^5 & 10^6) Hz

Effect of frequency

The variation of the dielectric constant (έ) and dielectric losses factor ($\varepsilon^{''}$) with different frequencies for all samples at room temperature as shown in figures (2-3), the results exhibit that the dielectric constant (έ) and dielectric losses factor ($\varepsilon^{''}$) are decreased with increasing the frequencies. 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.

Effect of weight fraction

The effect of different weight fraction of cupper was investigated in this work, there were (5 15, 30& 45) % weight fraction. The results showed that weight fraction of cupper were affected on dielectric properties of composite materials. The dielectric properties for the A, B, C, D &E samples as shown in figure (1-2)

Since the dielectric constant of epoxy is 5 and electrical conductivity of cupper is $1.67*10^4$ S\cm therefore, the dielectric constant increases with increasing weight fraction of cupper at constant frequency , the maximum value of dielectric constant and dielectric losses reached to (29.11)& (23.36)at (45%), respectively.The increase in values of dielectric constant and dissipation factor with increase in concentration of cupper was due to interfacial polarization, if materials are placed in an electric field, the charge particles interact with the field.

Conclusions

1. The dielectric constants and dielectric losses factor were increased with increasing in weight fraction.
2. The dielectric constant (έ) and dielectric loss factor (ε˝) decreased with increasing of frequency.

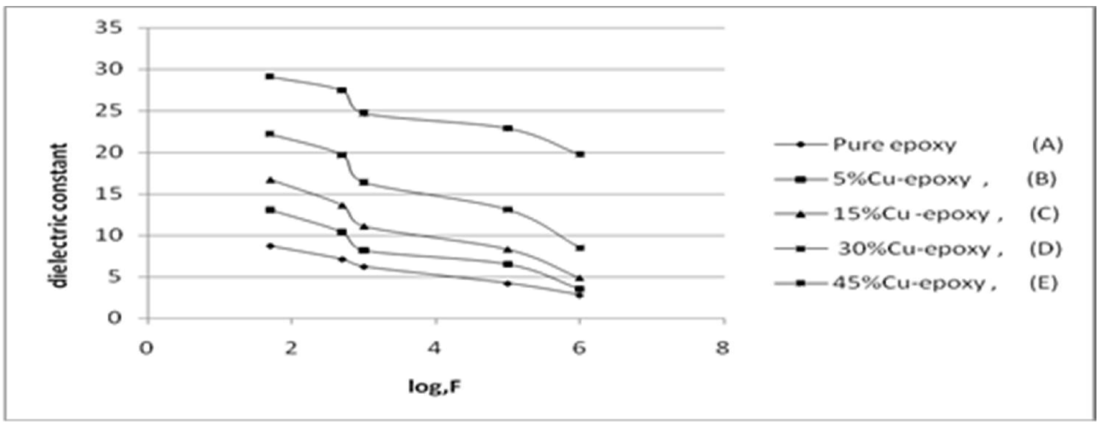

Figure 1: Variation of dielectric constant (έ) with frequency at room temperature

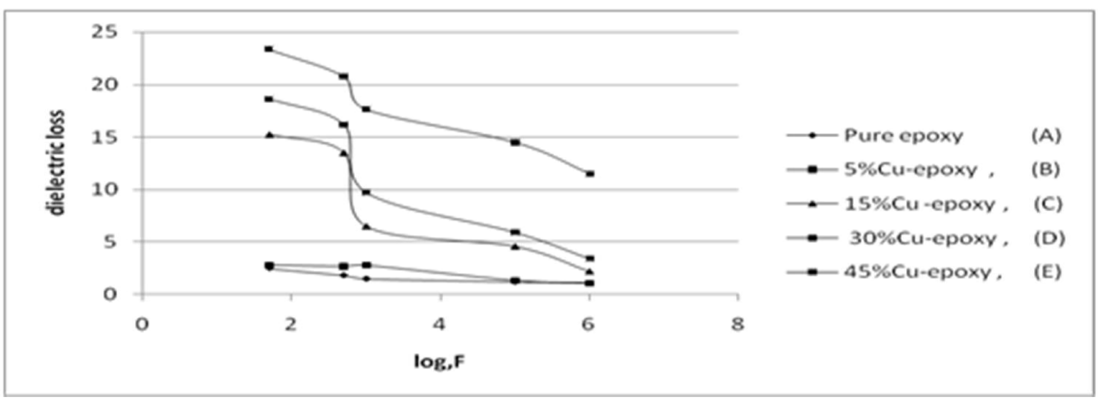

Figure 2: The variation of dielectric loss factor (ε˝) with frequency at room temperature

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دراسة تأثير التردد على خواص العزل الكهربائي للمواد المتراكبة من الايبوكسي المدعم بسحوق النحاس

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الخلاصة:

ناقش هذا البحث تأثير التردد على خواص العزل الكهربائي للايبوكسي المدعم بمسحوق النحاس. دعمت مادة الايبوكسي بكسور وزنية مختلفة من مسحوق النحاس (0, 5, 30,15, 45)% عند ترددات مختلفة ($50Hz - 10^6Hz$) بدرجة حرارة الغرفة. اظهرت النتائج ان قيم ثابت العزل وعامل الفقدان العزلي تقل عند الترددات العالية هذا يعود الى الجزيئات ثنائية الاقطاب بين السطحين لا تملك الوقت الكافي لترتب نفسها داخل الحقل الكهربائي بالإضافة الى ان قيم ثابت العزل وعامل الفقدان العزلي يزداد بزيادة الكسور الوزنية للنحاس بسبب توصيلية النحاس العالية.