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STUDY OF EFFECT Al_2O_3 NANOPARTICLES ON ELECTRICAL PROPERTIES OF EPOXY REINFORCEMENT BY CARBON FIBERS HYBRID COMPOSITES

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Abstract

In this paper was investigation the electrical properties of the epoxy "Hybrid Composites" as a function of a frequency. The composites constituents were epoxy using a matrix with reinforcement ratio (1:3) and volume fractions as (25% wt). The "Hybrid Composite" samples were prepared by addition alumina nanoparticles on the epoxy composites reinforced by carbon fibers with different volume fractions (0.1,0.3,0.5,0.7)w% by "Hand Lay-Up Molding". The experiments were performed to measure the electrical properties "Dielectric Constant, Dissipation Factor and Electrical Conductivity" in frequency range (10Hz-1MHz). The study showed that the reinforcement process resulted in an increase in the dielectric constant values of all manufactured models, and the addition of alumina nanoparticles leads to a decrease in the values of both the dielectric constant and the dielectric loss factor with increasing frequency and for all samples and for all values listed. Alternating electrical conductivity values increase significantly with increasing frequency and for all samples when alumina nanoparticles are added.

Keywords: Hybrid Composites; Dielectric Properties; Carbon Fibers; Al2O3 Nanoparticle; Epoxy Resin.

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1. Introduction

In recent years, carbon fibers as support materials has develop an lively region of investigation in emerging high behavior composite materials led to its unique properties mixture of greater mechanical properties counting high- particular "Strength, modulus, low density and thermal expansion, heat resistance, and chemical stability" [1]. Because of these features carbon fibers has been extensively used supported polymer composites in various fields of industrial and engineering [2]. Because of the excellent physical and chemical properties epoxy resins are considered the Essential component for the engineering and applications [3]. Today, the industries choose epoxy as a matrix material in composites materials due to their mechanical properties "low

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density, Thermal stability, Heat resistance, Adhesive strength, Chemical and Electrical resistance" [4,5]. The term hybrid is called composites materials has two or more types of reinforcement materials within the base material. The term hybrid is called advanced compositions consisting of a diverse mix of reinforcing materials such as the base material supported by fibers and particles together to obtain a new material with good qualities, such as resistance or balanced durability and balanced curvature [6]. The purpose of using two or more types of reinforcing materials in hybrid composites is to control the economic cost, which is an important factor in large industries. For example, cheap glass fibers can be used with expensive carbon fibers. The use of hybrid overlapping materials began with the manufacture of automobiles and sports equipment and then evolved to include the manufacture of parts of the aircraft in order to possess ideal [7].

Hybrid epoxy composites are utilized for some modern applications like "Electrical, Concept of Optoelectronic and Electronic devices, dust and moisture" [5].

Substantial the polymer matrix is the inexpensive and most used method to change the elementary properties of strengthened composites. The effects of fillers on the dielectrical properties of the created composites were studied. Epoxy based composites is favorite insulating materials for some electrical uses [8]. Epoxy based nanodielectric structures are being gradually examined for their electrical possessions, since the introduction of nanoparticles prove numerous advantages in their properties in comparison with the alike properties found for epox systems with nanoscale particles [9]. Epoxy resin is one of the most important widely used insulating resources in the electrical manufacturing is used as the base polymer material in the current study. The epoxy resin was selected because it was decent, had a low first viscosity, and its glass transition less 100 ºC [3,4]. Al_2O_3 has been the subject of several studies due to its extraordinary optical electronic possessions [5]. Epoxy resin was selected as a based due to its great Fusion with the fillers, having improved warm soundness protection from substance assault and protection from the debasement [6]. New fields of dielectric with high dielectric constants showed up as of late with the arrangement of clay nanoparticles, for example, nano TiO_2, Al_2O_3, MgO, and ZnO for polymer composites [7,8].

2. Experimental

Epoxy resin utilized that was (Nitofill, EPLV) from (Jordan Fosroc Company) with (Nitofill, EPLV) hardener as a network, and its thermoset polymer type as appeared in table (1), the blending proportion is [3:1] framing time (30 minutes) at room temperature. The molecule fillers are alumina nanoparticles (AL_2O_3-gamma), virtue (99.9%), (20-30) nm size, by assorted weight proportions (0.1%,0.3%,0.5%,0.7%) wt%. Plain-organized carbon filaments (200g/m^2), the miniaturized scale carbon strands utilized in this examination was brought from Fosroc Company, it has a little breadth (0.001 mm) and a length (50 cm) woven carbon fiber was utilized as major fortifying.

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Table 1: Typical properties of epoxy resin

Test Method	Typical Results
Compressive strength (BS 6319)	N/mm^2 70.0@ 20°C 93.0 @ 35°C N/mm^2
Tensile strength (BS 6319)	26.0 N/mm2 @ 35 °C
Flexural strength (BS 6319)	63.0 N/mm2 @ 35 °C
Young's modulus in compression	16GPa
Pot life	90 minutes @ 20 °C 40 minutes @ 35 °C
Specific gravity	1.04
Mixed viscosity	1.0 poise @ 35 °C

2.1. Samples Preparation

Nanoparticles by diverse weight ratios of nano-alumina (0.1%,0.3%,0.5%,0.7%) wt% with epoxy resin were mixed by "Magnetic Stirrer" at (600 rpm) for (half hours), used the homogenizer system for (5min) for separate and broken up the nanoparticles agglomeration to improve compatibility of the filler with material. The hardener was mixed with the mixture for (15minutes) by magnetic stirrer to get better homogeneity. The samples were prepared as (three carbon fibers layers) were wetted by the mixture (epoxy/nano alumina particlrs) layer by layer by using (Hand Lay-Up Molding). Wetted fabrics were placed on flat mold and subjected to curing process under temperature of (60˚C) with pressure of (120 KPa) for (1 hour) curing time. The samples were then cut in a circular shape with a diameter of 2cm as shown in figure (1).

Figure 1: Dialectical tests samples.

3. Electrical Measurements

Using the (LCR Metter) type (Agilent Impedance Analyz 4294A) of Taiwanese origin, electrical tests (isolation) of electrical insulation constant (Ɛ') and isolation loss factor (Ɛ'') were performed as a function of frequency and frequency range (10Hz-1MHz) and room temperature for manufactured samples. The dielectric constant (Ɛ') has been calculated from the capacitance by the relation (1):

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$\varepsilon' = \acute{C}\, d_{dis} / \varepsilon_o A$ ………..(1)

Where: - Ć: capacitance (F)

ε_o: free space dielectric constant value (8.85×10^{-12} F/m)

A: is the capacitor area (cm^2)

d: thickness of the sample (m).

And a.c. conductivity (σ a.c.) was calculated from the relation (2):-

$\sigma_{a.c} = \omega\, \varepsilon_o\, \varepsilon''$ ………..(2)

where: - ω: Angular frequency (Hz)

ε'': isolation loss factor

4. Results and Discussions

4.1. Dielectric constant

It's clear from Figure (2) that the dielectric constant decreases with increasing frequency and for all samples. The arrangement under the influence of the external electric field, the external electric field rotates the electrical dipoles in a direction parallel to the electric field, which leads to generate an electric field opposite to the original electric field, which works to weaken the original electric field and thus increase electrical insulation constant of the hybrid composite. When the frequency of the electric field is increased, the electrical insulation constant of the composite material decreases. This can be explained by the fact that in the low-frequency region, the time period is sufficient for the dipoles to arrange the molecules and align them Parallel the electric current that runs between the poles [10]. At high frequencies, the time period is short and less than the time needed by the molecules to arrange themselves with the direction of the external electric field. Also, the reason why the dielectric constant values are high at low frequencies is the different phases of the base material and the supporting materials (fibers and nanoparticles) that result in Interfacial Polarization. As well as, the polarization resulting from the electrodes is closely related to the formation of the sample charge between the poles. This depends on the composition and distances of the sample. The value of the dielectric constant depends on the contribution of four types of polarization (electronic, ionic, Interfacial and Orientational). At high frequencies, the value of the dielectric constant depends on ionic and electronic polarization only, which have the ability to follow the rotation of the external electric field, which leads to a decrease in polarization and thus a decrease in the dielectric constant [11]. We also note from the figure that the value of the dielectric constant at the same frequency increases when supported by carbon fiber and when adding and increasing the volumetric fraction of nanoparticles. In general, this increase in the value of the dielectric constant is due to the increase in Polarization.

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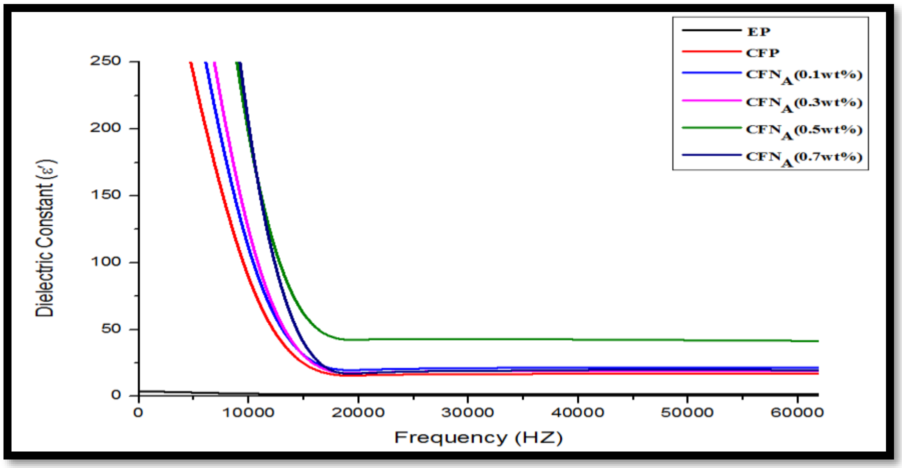

Figure 2: Electrical insulation constant as a function of frequency of carbon fiber epoxy composites and alumina nanoparticles with different weight ratios.

4.2. Dissipation Factor

Figure 3 shows the dielectric loss factor decreases with increasing the frequency of all samples. We also note that the dielectric loss factor is high at low frequencies and then decreases with increasing the frequency of the projected electric field. This is due to the enhancement of charge carriers that take place across the width of the electric charge area, and the decrease in the value of the dielectric loss factor at high frequencies so that the energy of the electron is equal to Fermi energy. Another reason that the dielectric loss factor changes with frequency is that the dipoles absorb energy from the electric field of the system to overcome the resistance of the viscous materials it encircles during rotation. Frequency and so the dipoles need more energy in the system to get relaxed and in this case decreases the isolation factor [12]. Note also that in figure (3), the value of the dielectric loss factor at the same frequency increases when reinforced by carbon fiber and glass fibers and when adding and increasing the volumetric fraction of both types of nanoparticles, and this is due to the increase in the number of polarized diodes resulting from the interface between the base material and the reinforcing material [13].

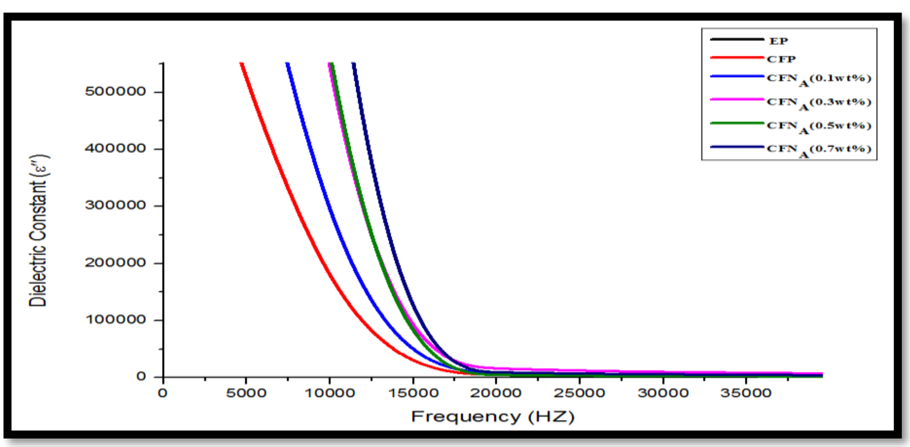

Figure 3: Isolation loss factor as a function of frequency of carbon fiber epoxy composites and alumina nanoparticles with different weight ratios.

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4.3. Electrical Conductivity (A.C)

Depending on the relationship (2), noting from figure (4) that alternating electrical conductivity increases significantly with increasing frequency and for all samples. This increase in alternating electrical conductivity due to the oscillation of the electric field with increasing frequency, which will lead to increased polarization in the sample and this shows in the increase of alternating electrical conductivity. Alternating electrical conductivity arises from the rapid transition between sites of different species, such as electrons or dipoles. It should be noted That alternating electrical conductivity in the dielectric is The amount of power lost when an alternating electric field is projected These appear as heat when the dipoles rotate in their positions and the vibration of the charge by the alternating electric field change is therefore dependent on the frequency [14]. The figure also shows that the value of alternating electrical conductivity at the same frequency is increasing Volumetric fraction ratio In general, this increase in the value of alternating electrical conductivity is attributable to the decrease in dielectric resistance due to the increase of the conductive molecules in the superposed material [15].

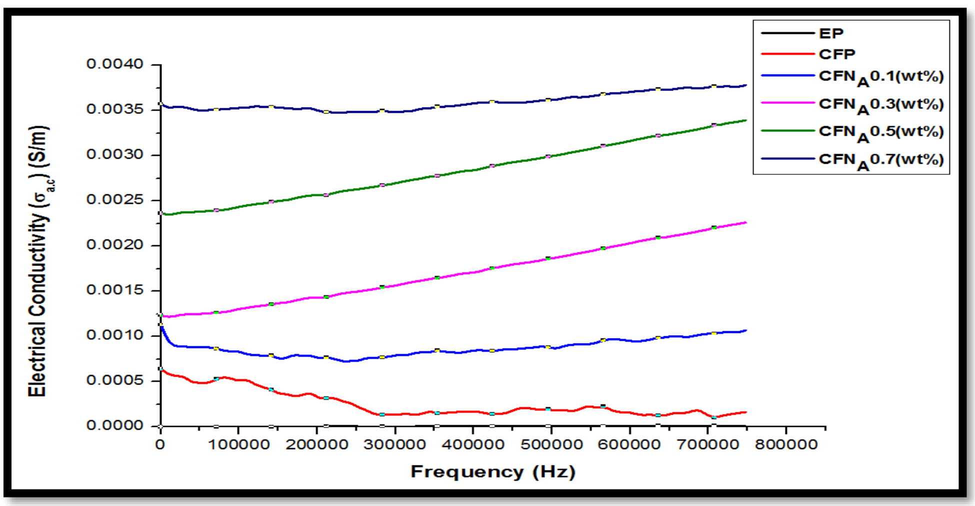

Figure 4: Electrical Conductivity (A.C) as a function of frequency of carbon fiber epoxy composites and alumina nanoparticles with different weight ratios.

5. Conclusions

The values of the electrical insulation constant and dissipation factor of the hybrid composite are increased by the volumetric fraction of the alumina nanoparticles at low frequencies, but suddenly it begins to decrease with increasing frequency. The values of electrical conductivity are increased by increasing the percentage of reinforced in alumina nanoparticles and also by increasing the frequency and for all manufactured samples.

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