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Effect of SiC Particles on Dielectrically Properties of Epoxy Reinforcement by (Bi-Directional) Glass Fiber

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Abstract

In this research was study the dielectric properties of the epoxy composites as a function of a frequency, “weight fraction- particle size” of fillers. Composite plates were prepared by incorporating fiber glass and SiC Particles of 0.1 μm, 3 μm, 40 μm diameter sizes at 10, 20, 30 and 40 weight percent in epoxy matrix. The experiments were performed to measure the dielectric constant and electrical conductivity in range (10-2000) KHz.

Keywords: Hybrid composites; Dielectric properties; Electrical conductivity; Epoxy composites

Introduction

Pure polymers are generally electrical insulators in their nature, so they are applied as electrically insulating materials. Polymers contain a very low Concentration of free charge carriers, and thus they are non-conductive and transparent to electromagnetic radiation [1]. Plastic polymers have chemical reaction properties similar to those of small molecules, though the polymers themselves are larger in size. This means that a range of different factors, including thermal conditions, stress cracking, or the diffusion of chemical additives, can alter the molecular structure, and thus the fundamental properties, of most plastic polymer materials [2]. Some changes, such as unintentional reduction in molecular weight, can lead to plastic degradation and product failure, while others can supplement or improve a polymer's characteristics [3].

Epoxy is one of the most important thermosetting polymers. Due to the high chemical and corrosion resistance, good mechanical properties and low thermal conductivity, epoxy has been extensively used in various fields including coating, high-performance adhesives, and composite matrix [4].

Hybrid epoxy composites are required used for a several industrial applications such as electrical, concept of optoelectronic and electronic devices protect electrical components from short circuiting, dust and moisture. In the electronics industry epoxy resins are the primary resin used in over molding integrated circuits, transistors and hybrid circuits, and making printed circuit board [5].

Development of a hybrid polymer composite retaining both types of characteristics is considered to be an active field of research. This research work aims to develop a hybrid polymer composite material using ceramic particle such as SiC and using glass fiber which will retain the advantages of both the fiber reinforced and particle-reinforced composites and emerges as a viable alternative to the existing polymer composites [6,7]. The preparation of composites is carried out using hand lay-up method and hence no expensive machinery/equipment is required. Many researchers have been development the study of effect of fillers such as (glass fiber, ferrite, silica, SiC, Al_2O_3) upon the dielectric properties of epoxy in a wide frequency range and temperature ranges [8]. There are many types of glass fiber, with the most common being E-glass fiber, C-glass fiber and S-glass fiber. E-glass fiber is the most common in use, because it draws well and has good tensile and compressive strength and stiffness, and good electrical and weathering properties [9].

Experimental

SiC particles with different particle sizes (0.1,3,40) μm were used with weight percent (10%, 20%, 30%, 40%) and then mixed with epoxy reinforcement by two layers of glass fiber (0°-90°). Euxit50 resin K (Epoxy) supplied by the Egyptian swiss chemical industrials Co., with formulated amine hardener in ratio 3:1 for curing. The epoxy resin is a liquid with low viscosity and transparent in. For preparing composite samples, a weighted quantity of SiC powder was first thoroughly mixed with a measured volume of epoxy resin. Then a half volume of hardener was added and the result mixture was well mixed so as to obtain a uniform composition. The samples the a.c measurement, each sample was in- shape like disc with diameter of 30 mm and thickness of 1 mm. A thin aluminum deposited on both sides of each sample by evaporation technique under pressure of 10-9 bar, using coating unite type Edward (E306A), to minimize the contact resistance and space charge effects.

Electrical Measurements

The broadband dielectric properties were measured by a precision LCR meter (HP-4275) at a constant temperature and various frequencies (10^{+3} Hz to 10^{+6} Hz). The dielectric constant ε' was calculated from the capacitance by using the following equation:

$$\varepsilon' = (C \bullet d)/(\varepsilon_0 \bullet A) \quad (1)$$

Where C is the capacitance (F), ε_0 is the free space dielectric constant value (8.85×10^{-12} F/m), A is the capacitor area (cm^2), and d is the thickness of the sample (m). a.c. conductivity (σ a.c.) was calculated from the relation

$$\sigma_{a.c} = wC\tan\delta(\frac{d}{A}) = \varepsilon'' w \varepsilon_0$$

Where, tan δ is the loss tangent was calculated from the relationship:

$$\tan\delta = \frac{\varepsilon'}{\varepsilon''}$$

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And ε” the dielectric loss, ω the angular frequency.

In this paper the dependence ε’, σ a.c of pure and hybrid composite on frequency, particle size and weight fraction will be study of (fiber glass, SiC) -epoxy composites.

Results and Discussions

Dielectric constant

Frequency dependence: It can be seen from Figures 1-3 that the dielectric constant of unfilled epoxy and epoxy composites decrease with an increasing frequency. Dielectric constant is a frequency dependence parameter in polymer systems. In atypical epoxy system based on an epoxy resin cured with a hardener as in the present case, the epoxy component of dielectric constant is governed by the number of oriental dipoles present in the system and their ability to orient under an applied electric field [10]. Usually, the molecular groups which are attached perpendicular to the longitudinal polymer chain contributed to the dielectric relaxation mechanism. At lower frequencies of applied voltage, all the free dipolar functional groups in the epoxy chain can orient themselves resulting in a higher dielectric constant value at these frequencies. As the electric field frequency increases, the bigger dipolar groups find it difficult to these dipolar groups to the dielectric constant goes on reducing resulting in a continuously decreasing dielectric constant of the epoxy system at higher frequencies [11].

Similarly, the inherent dielectric constant in SiC particle and glassfiber also decrease with increasing frequencies of the applied field. This combined decreasing effect of the dielectric constant for both epoxy and the filler result in a decrease in the dielectric constant of the epoxy composites also when the frequency of the applied field increases. This behavior is agreement with [10,12].

Wight fraction and particle size dependence: As shown in the same figures, we can see that the dielectric constant increase as the volume fraction of fillers in the polymer matrix is increased because of the system becomes more heterogeneous than the pure epoxy as more filler is added to it [13]. The increase in dielectric constant with increase in filler is attributed to the formation of clusters. A cluster may be considered as a region in the polymer matrix where particles are in physical contact or very close to each other. The average polarization associated with a cluster is larger than that of an individual particle because of an increase in the dimensions of the metallic inclusion and, hence, greater interfacial area. Similar result have been pointed by [10,13,14].

The effect of filler size on the epoxy composite for dielectric constant can be seen in the same figures. 40 Micron composites show a higher dielectric constant value than the small particle sized composites there can be two reasons for this observation (1) epoxy chain immobility in small particle sized composites and (2) influence of SiC permittivity. It has been reported the permittivity of bulk SiC small sized particle composites are almost the same or higher as compared to that of coarse- grain SiC [14]. So, the higher dielectric constant value in 40 micron composite is probably due to the fact that there is no restriction in the mobility of epoxy chains in them similar to the case of small sized particle composites [10].

Electrical conductivity

Frequency dependence: The variation in electrical conductivity of the composites as a function of frequency is shown in Figures 4-6. The electrical conductivity slowly increases as the frequency is increased in range (10-2000) KHz. The interpretation of this behaviour may be that the composite materials are basically attributed to high dislocation density near the interface. Electrical conductivity in turn depends on the number of charge carriers in the bulk of the material, the relaxation time of the charge carriers and the frequency of the applied electric field. Since the measurement temperatures are maintained constant, their influence on the relaxation times of the charge carriers is neglected. Over the current frequency range of measurement, charge transport will be mainly dominated by lighter electronic species [10]. In this situation the electrical properties of filler were almost dominated, since a network may start to connect filler particles to each other and a new kinetic path may be formed.

Weight fraction and particle size dependence: The general theory to explain the conduction mechanism of fillers (particle, fiber) filled polymer composites is the” theory of conductive paths”, which suggests that it is the existence of conductive paths (fibers and particle contacts) that results in the conductivity of the composites. With increasing of the content of the fillers, conductive paths among the fillers increase, and the average distance between the fillers becomes smaller; thus, the resistivity of the composites decrease and increase the electrical conductivity. The addition of a small amount of small sized particle colloid helps to build the conductive network and lowers

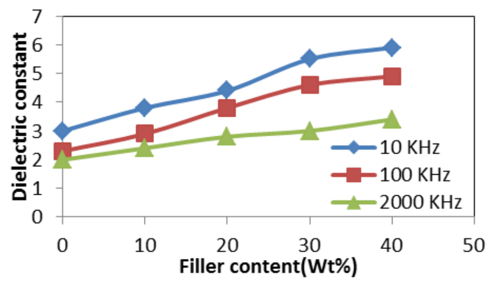

Figure 1: Variation of dielectric constant as a function of frequency for SiC – epoxy composites with different weight fraction of 0.1 μm SiC.

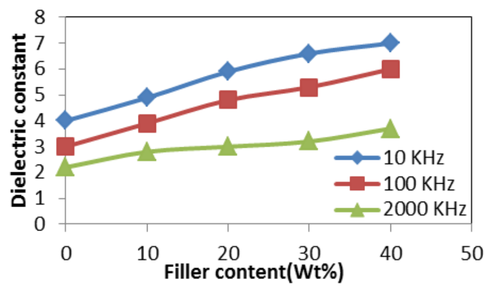

Figure 2: Variation of dielectric constant as a function of frequency for SiC – epoxy composites with different weight fraction of 3 μm SiC.

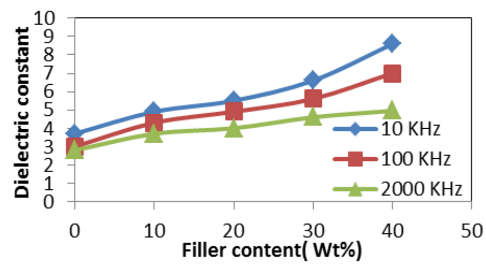

Figure 3: Variation of dielectric constant as a function of frequency for SiC – epoxy composites with different volume fraction of 40 μm SiC.

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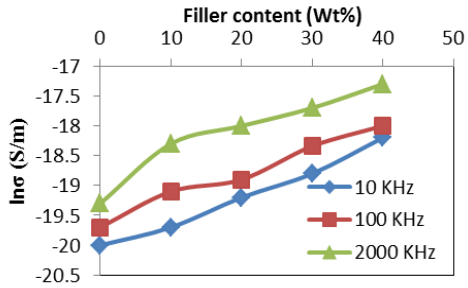

Figure 4: Variation of ln σ a.c as a function of frequency for SiC- epoxy composite with different weight fraction of 0.1 μm SiC.

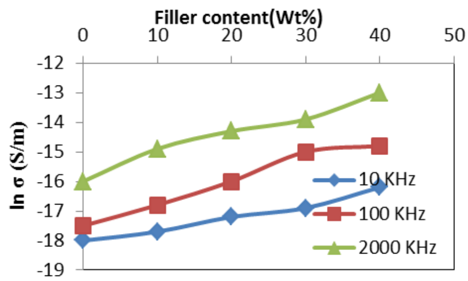

Figure 5: Variation of ln σa.c as a function of frequency for SiC- epoxy composite with different weight fraction of 3 μm SiC.

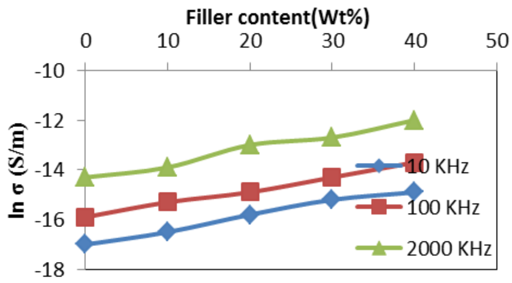

Figure 6: Variation of ln σ a.c as a function of frequency for SiC - epoxy composite with different weight fraction of 40 μm SiC.

the resistivity of the composite. Yet once connected, the addition of small particles seems only signify the relative contribution of contact resistance between the particles. Due to its small sized SiC contains the large numbers of particle when compared with 40 micron sized. This large number of particles should be beneficial to the inter connection between particles. However, it also inevitably increases the contact resistance. As a result, the overall effect is an increase in resistivity upon the addition of small sized SiC particles. That leads to decrease the electrical conductivity for small sized when compared with 40 micron sized [15,16].

Conclusions

The dielectric constant of epoxy composites with (SiC, glass fiber) decrease with an increase of frequency. The dielectric constant, electric conductivity increase with an increase of weight fraction of fillers, which has been attributed to interfacial polarization. The electrical conductivity is increased with an increasing in frequency, since a network may start to connect filler particle to each other and a new kinetic path may be formed. In this research, the epoxy with 40μm composites showed a higher electric property than the 3μm, 0.1μm composites.

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