DIELECTRIC PROPERTIES OF INDUSTRIAL POLYMER COMPOSITE MATERIALS

Nadia A. Ali, Farah T. Mohammed Noori* and Sinaa I.Hussin
***Physics Department, Collage of Science, University of Baghdad, Iraq.**

Abstract

Frequency and temperature dependence of dielectric constant (ε) and dielectric loss (έ) in pure epoxy resin and polymer composites with glass fiber are studied in the frequency range 40Hz-110 MHz and in the temperature range $(25\text{-}150)^0$C.The experimental results show that ε and έ increased with the addition of glass fiber in epoxy resin. The value of (ε) decreased with increasing frequency which indicates that the major contribution to the polarization comes from orientation polarization .Dielectric loss peaks were also observed in the composite materials at high temperature due to Tg of epoxy .The value of (έ) increased with increasing temperature, and is due to greater freedom of movement of the dipole molecular chains within the epoxy at high temperature.

Keywords: epoxy, E-glass, dielectric constant, dielectric loss.

Introduction

It is well known that composites can be produced exhibiting enhanced properties that the constituent materials may not exhibit [1-4]. For instance, from the combination of different fibers or fillers with polymer matrices one can produce polymer-matrix composites, a material important to the electronic industry for its dielectric properties in the use of capacitors[5-7]. The effective utilization of filled polymers depends strongly on the ability to disperse the fillers homogeneously throughout the matrix [8]. One of the most attractive features of these filled composites is that their dielectric properties can be widely changed by choice of shape ,size, and the conductivity of filled constituents in the polymeric matrix. Most of the interesting properties of polymers are attributable to the complex motion within their molecular matrix. In the polymeric system ,molecular relaxations exhibit various transitions [9]. As very little work has been reported on double-layer systems, the intention in the present work is to study dielectric properties of such a system. The polymeric interfaces act as charge-carrier trapping sites [10]. Therefore, it has become essential interfaces on the charge-carrier generation, transport and storage in polymeric systems. The study of dielectric constant and dielectric loss, as a function of temperature and frequency is one of the most convenient and sensitive methods of dielectric behavior [11]. The dielectric properties of polymer composite materials have been studied with a view to modifying the properties of polymer systems for practical applications. The conventional inorganic of their unique ability to be tailor made for specific needs. Epoxies and polyesters have been used in electronics as insulators, dielectrics, substrates, potting compounds, embedding materials and conformal coatings [12]. 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. In the electrical/ electronics industry, these composite materials are used for making panels, switches, insulators and for many insulation purposes. So by way of industrial expectation, all materials will need to be characterized for and prior to such applications [13].

Experimental Produce

Measurement of Dielectric Constant

Frequency and temperature dependence of dielectric constant and dielectric loss in pure epoxy resin and polymer composites with type of E-glass fiber has been studied in the frequency range 40 Hz-110MHz and in the temperature range $(25\text{-}150)^0$C Capacitance and dielectric loss έ in the frequency range from 40 Hz-110MHz at different temperature measured by using LCR meter type Agilent 42942A terminal Adapter to study the effect of studying polymeric structure. For polymer composites in the solid or viscoelastic state, the physical structure is of great importance in determining the dielectric constant and dielectric loss.

Result and Discussion

Fig.(1) give the variation of the dielectric constant ε with frequency at room temperature for pure epoxy sample A) and epoxy reinforced E-glass sample B) at room temperature, marked differences were found in dielectric constant ε between epoxy resin and composite materials with E- glass fiber. An important observation is that ε increases considerably with the addition of glass fiber in epoxy resin. Which is most likely explained by the glass having a higher dielectric ε than the base epoxy resin , thus resulting in the higher dielectric constant contribute to the rise in dielectric constant ;the absorption of moisture at the fiber resin interface ,as the dielectric of water is very high Fig.(2 a-b) shows the variation of with frequency at different temperatures for samples A and B. It is evident from these figures that decreases with increasing frequency at fixed temperature .It is also evident from these figures that decrease in is very prominent at both low frequencies and at high temperature. The decrease of ε with increasing frequency is the expected behavior in most dielectric materials .This is due to dielectric relaxation which is the cause of anomalous dispersion .From a structural point of view , the dielectric relaxation involves the orientation polarization which in turn depends upon the molecular arrangement of dielectric to be material .So ,at higher frequencies , the rotational motion of the polar molecules of dielectric is not sufficiently rapid for the attainment of equilibrium with the field , hence dielectric constant seems to be decreasing with increasing frequency [14,15].

Fig.(3 a-b) shows the variation of with temperature at different frequencies for samples A, and B. The value of increases with temperature at fixed frequency. This is true for all the samples at all frequencies. At lower frequencies this effect is more prominent. The increase in with temperature is due to greater freedom of movement of dipole molecular chain of epoxy at high temperature. At lower temperature, as the dipoles are rigidly fixed in the dielectric, the field can not change the condition of dipoles. As the temperature increases, the dipoles comparatively become free and they respond to the applied electric field. Thus polarization increased and hence dielectric constant is also increased with the increase of temperature [16, 17].

Fig.(4a-b) shows the variation of dielectric loss factor with frequency at different temperature for two samples. The value of decrease with the increase of frequency at fixed temperature in two samples. But loss peaks are observed at about 1KHz at high temperature (150 C) in composite materials, which may be attributed to Tg, the temperature glass transition in epoxy [18]. This effect can be seen in Figs.(4a-b). The loss peak is not observed in pure epoxy, as shown in Fig. (4a): it may be at lower frequency than the lowest observable frequency of our measuring set. In composite materials the absorbed moisture at the fiber–resin interface acts as polymer, which increases the mobility of the polymer chain and hence brings the loss peak due to Tg got epoxy at high frequency value to be detected by our measuring [19]. The dielectric loss factor increase with temperature, particularly at lower frequency at which dielectric loss due to chain motion of epoxy is more effective due to the glass transition temperature of the polymer. At high frequencies, however, the dielectric loss factor is low and remains more or less constant with increasing temperature because the orientation polarization due to chain motion of polymer can not keep phase with the rapidly oscillating electric field.

Conclusion

The experimental results indicate that and increased with the addition of glass fiber in epoxy resin. The decrease in with increase of frequency is due to the orientation polarization and increase in with increase of temperature is due to greater freedom of movement of dipole molecular chain of epoxy at high temperature. Dielectric loss peaks in the composite materials at high temperature is due the glass transition temperature of epoxy resin.

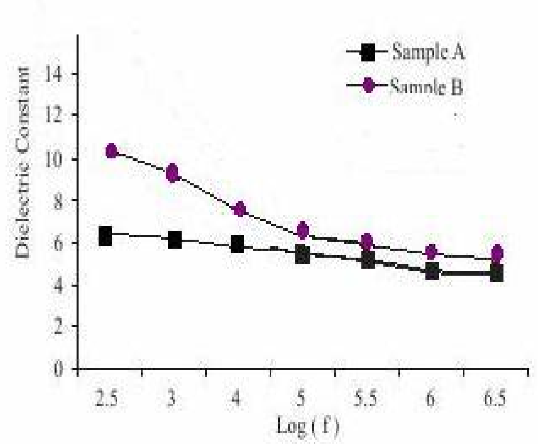

Fig.(1) : Frequency dependence of dielectric constant at room temperature for sample A, and sample B.

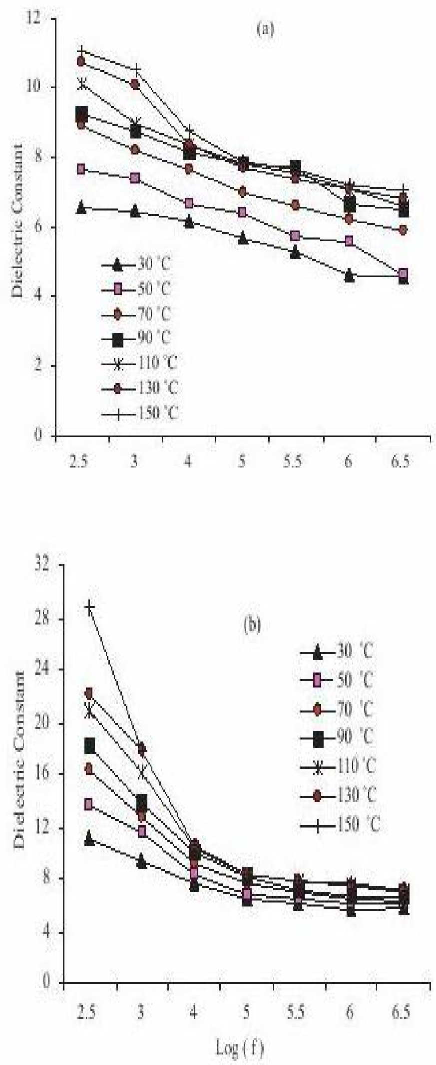

Fig. (2):Frequency dependence of dielectric constant at different temperatures for (a) sample A, (b) sample B.

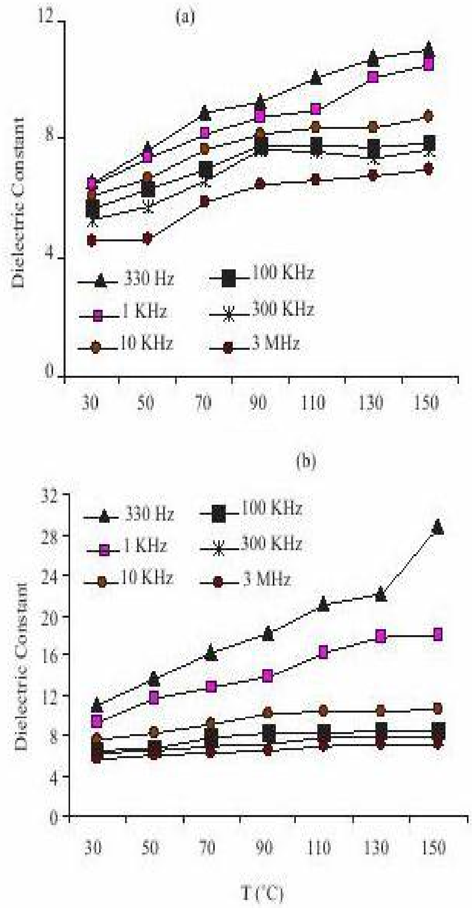

Fig.(3):Temperature dependence of dielectric constant at different frequencies for (a) sample A, (b) sample B.

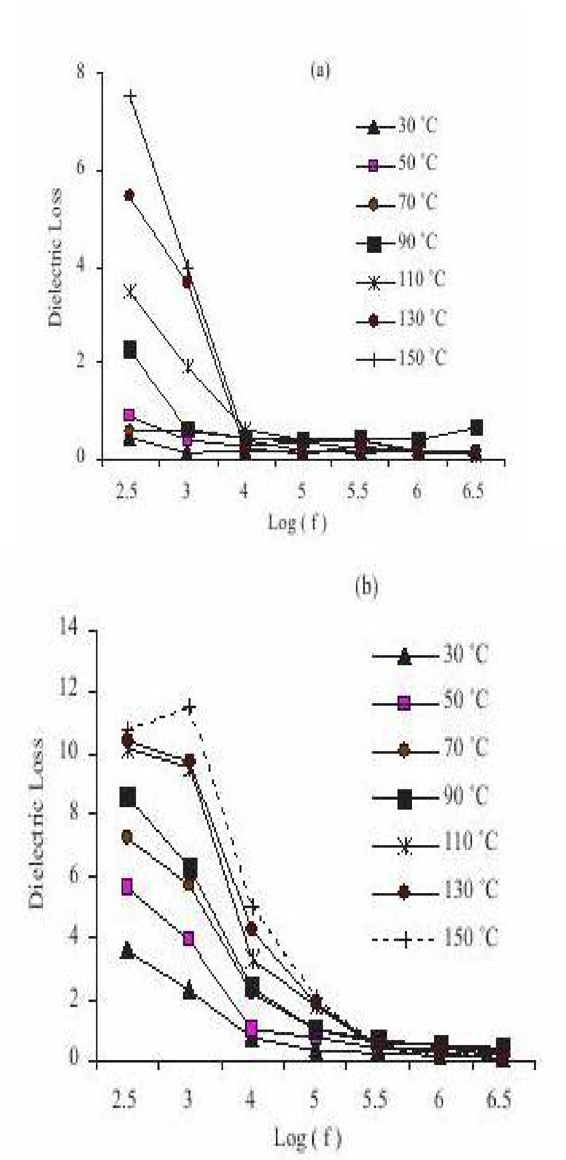

Fig. (4):Frequency dependence of dielectric loss at different temperatures for (a)sample A,(b)sample B.

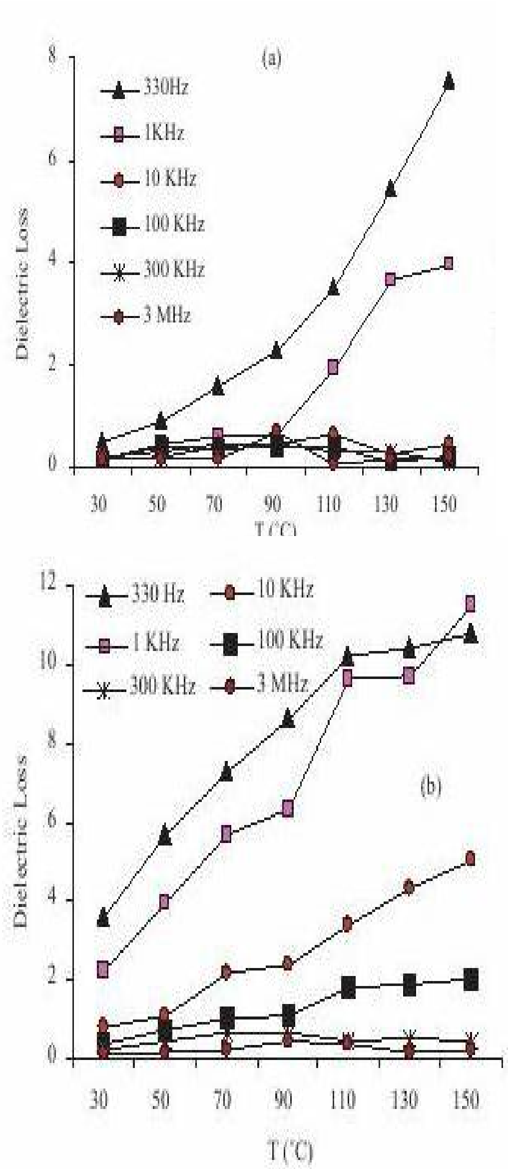

Fig. (5):Temperature dependence of dielectric loss at different frequencies for (a) sample A, (b) sample B.

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الخلاصة

تم في هذا البحث دراسة الخصائص العزلية بدلالة تغير التردد من 40Hz-110MHz وتغير درجة لحرارة من $(25\text{-}150)^0C$ باستخدام اختبار ثابت العزل الكهربائي لنماذج راتنجي الايبوكسي ومتراكبات الايبوكسي المدعمة بالياف الزجاج نوع (E-glass) المحضرة بطريقة التشكيل اليدوي تشير نتائج ثابت العزل الكهربائي وفقدان العزل الى الزيادة لنماذج الايبوكسي المدعمة بالالياف الزجاجية ولقد اظهرت النتائج إلى نقصان العزل بزيادة التردد وانه يزداد مع زيادة درجة الحرارة وذلك بسبب حركة الدايبولات الجزيئة بارتفاع الحرارة لراتنج الايبوكسي اعتمادا على درجة الانتقال الزجاجي لراتنج الايبوكسي.