Dielectric properties of Ep\TiO_2;Ep\MgO nano composites

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Abstract

The Dielectric properties of EP/TiO_2 and MgO nanocomposite at a frequency range of (10^2-10^6 Hz) were studied. The composite were prepared with the state volume ratio (0, 0.05, 0.1) for EP/TiO_2 and MgO respectively. The impedance, dielectric constant and dielectric loss were found decrease with frequency increase.

Key words
Polymer-Matrix Composites, Dielectric Properties, Epoxy.

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الخصائص العزلية لمتراكبات الايبوكسي- TiO_2; MgO النانوية

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الخلاصة

تم دراسة الخواص العزليه للمتراكبات النانويه الايبوكسي - TiO_2 ; MgO ولمدى من الترددات (10^2-10^6 Hz) وبدرجة حرارة الغرفة المتراكبات تم تحضيرها بنسب حجميه (0،05.0،1.0). وقد أظهرت الدراسة أن قيمة الممانعة تقل بزيادة التردد وكذلك ثابت العزل بجزأيه الحقيقي والخيالي.

Introduction

Composites which are made of polymer with inorganic filler have been successfully used in electrical and electronic industries. These systems are considered heterogeneous and their electrical characteristics depend on several factors such as volume fraction, size, shape, conductivity of the filler, the adhesion between the filler and the polymer and the method of processing. The advantage of such composites is that it can be produced to exhibit enhanced and compatible properties that the constituent materials may not exhibit [1, 2].

The use of nanostructured fillers in epoxy systems has gained significant importance in the development of thermosetting composites [3]. Non conductive fillers increase the dielectric permittivity due to interfacial polarization (Maxwell-Wagner-Sillars polarization) For con fillers, electrical conductivity and dielectric permittivity increase with increasing the filler volume fraction until drastic changes in these properties reach a critical range of filler concentration called percolation threshold. The effective use of composites strongly depends on the ability to disperse the fillers homogeneously throughout the material [4]. Epoxy composite which consists of an epoxy resin and conductive or nonconductive filler, has been reported to possess interesting properties and is used in a verity of applications such as encapsulating, thin film coating, packing of electronic circuits protective coatings, electromagnetic frequency interference shields, antistatic devices and thermistors [5, 6]. Research in epoxy based composite dielectric systems is gathering momentum for their preferred electrical properties [7, 8]. Since interesting properties of polymer attributable to complex motion within their molecular matrix, therefore, the study of dielectric constant, dielectric loss as a function of temperature and frequency is one of the most convenient and sensitive methods of studying polymer structure. In this study, (EP/ TiO_2; EP /MgO) composites were prepared and their dielectric properties were investigated as a function of filler volume fraction (0.5ml and 0.25 ml), frequency in the range (10^2 -10^6 Hz). real and imaginary parts of the dielectric constant and impedance were also studied.

Experiment

1. Materials

The materials used to prepare the composite samples of this work are; Epoxy Resin (EP) EUXIT 50 supplied from (Swiss Chem.), magnesium oxide (MgO) with particle size is(100-90nm) and titanium oxide (TiO_2) with particle size is (30nm).

2. Sample preparation

There are many techniques which can be used to incorporate the nanoparticles into the polymer matrix. However, in this study we used two preparation methods.

The first method without nitrogen flow included: nanoparticles heating in an oven at 1300C to reduce the moisture, and then weighted. Nanoparticles with epoxy resin were mixed by magnetic stirrer at 700 rpm 600C for 30 minutes, used the homogenizer devices 3 min for separate nanoparticles and broken up the agglomeration of its to improve compatibility of the filler with host material. The hardener was mixed for 10 minutes by magnetic stirrer, using homogenizer device for 3 min again to get better homogeneity. During the preparation, air bubbles can get trapped in the material, especially during the mixing processes. To negate the influence of air bubbles on mechanical and dielectrical measurements, degassing of the epoxy/TiO_2; epoxy/MgO nanocomposites required so we used vacuum system (10^{-2} bar) as shown in Fig. 1 to remove the bubbles before molding the composites.

We found the shape some of specimen is not perfect because it is contains some intended matter that is come from atmosphere.

The second method with nitrogen flow included: after heating the nanoparticles in an oven as in the first method, the nanoparticles are weighted and manually mixed with epoxy resin under gloves in nitrogen atmosphere which is shown in Fig. 2. Then followed the same procedure of the first method, we found the shape of specimens are very perfect and do not contain on any intended matter.

The second preparation method is preferred because it is not very complicated from laboratory processing point of view, commercially available polymers and particles could be mixed with ease to prepare a composite, and it's not contain on air bubbles, dust or other unintended matter in polymer matrix can act as defects, which in turn can significantly influence on the mechanical and dielectrical properties of EP/TiO_2 ;EP/MgO nanocomposites So, we used the final preparation method for preparation the specimens and then tested it.

Fig.1: Gloves box.

Fig.2: Vacuum system.

Fig. 3: Homogenizer device.

3. Characterization and measurements

The samples capacitance and the loss tangent (tan δ) as a function of the alternating electric field frequency using by (HIOKI 3532-50 LRC Hi tester Japan). For continuous frequencies in the range (10^2- 10^6 Hz). at room temperature. The relative complex permittivity (ε*) can be expressed as follows

$\varepsilon^* = \varepsilon' - i\varepsilon$

where, $i = -1$. The real part (ε') and the imaginary part (ε'') of relative permittivity.

Dielectric loss of permittivity can be calculated from the measured capacitance and loss tangent [10, 11];

$$\varepsilon' = \frac{C_P}{C_\circ} \quad (1)$$

C_P= Capacitor containing an insulator material

$C_\circ$ =Capacitance vacuum

$$\varepsilon'' = \frac{1}{R_P C_\circ \omega} \quad (2)$$

R_P = Resistance

ω = The angular frequency of the applied field (ω =2πf)

$$\tan\delta = \frac{\varepsilon'}{\varepsilon''} = \frac{1}{R_P C_p \omega} \quad (3)$$

The impedance (Z) can be expressed as follows:

$$Z = \frac{R}{1 + j\omega R C_P} \quad (4)$$

j = is imaginary number (√-1)

Results and discussion

Fig. 4 shows the variation of the real part of permittivity (ε') of epoxy composite as a function of filler content in the room temperature at frequencies, (10^2 - 10^6Hz). It may be seen that the real part of permittivity ε' depends on filler content, and increased with increasing the filler content. It is also seen that the (ε') values are higher when the frequency is lower (10^2 Hz).The increase in ε' with increasing filler content or decreasing frequency is an expected behavior attributed to Maxwell-Wagner Sillars (MWS)/ or interfacial effect that appears in heterophase systems [12].

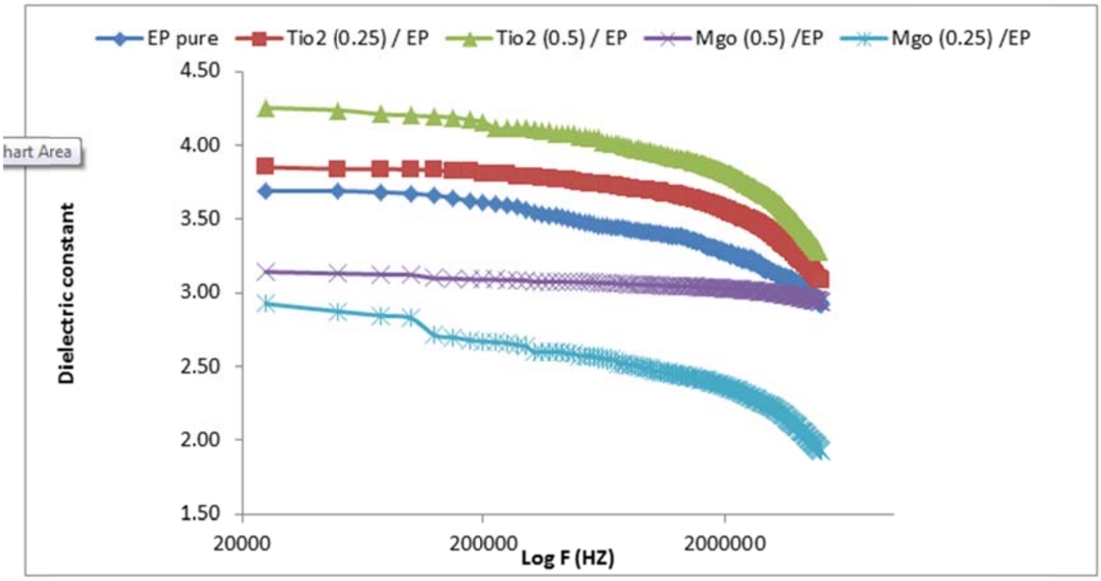

Fig.4: Dielectric constant &frequency of epoxy pure, EP/MgO and EP/TiO_2 nanocomposite.

Fig.5 shows the variation of (dielectric loss ε") as a function of frequency for pure epoxy and epoxy composites, at room temperature. It is clear that (ε") decreases with frequency, the large value of (ε") at low frequency could be due to mobile charge within the polymer backbone and dielectric loss which decreases with the frequency. This is attributed to the decreasing of the space charge polarization (interfacial polarization) contribution when increasing the frequency, that is highest absorption of applied field [13].

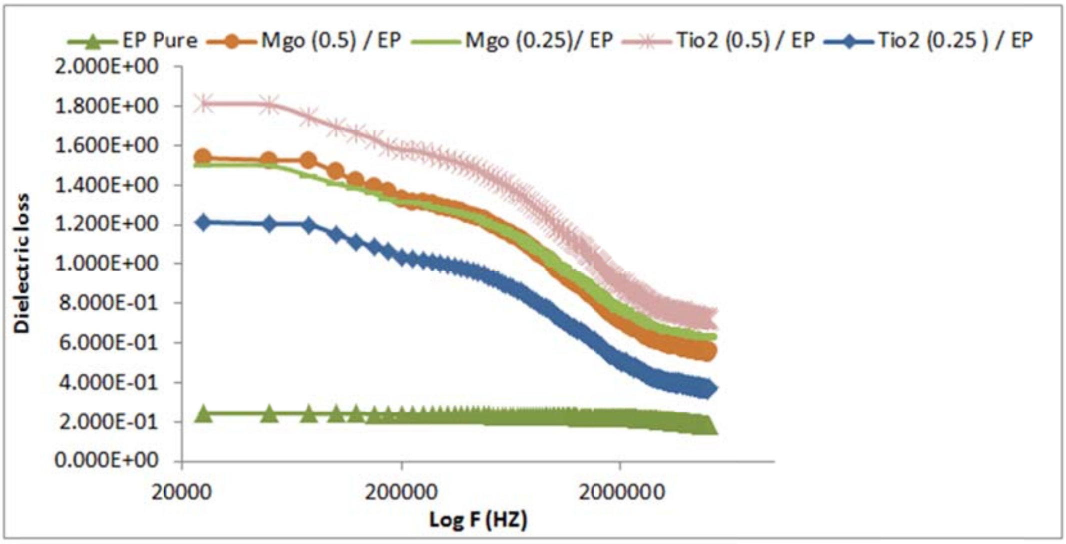

Fig.5: Dielectric loss &frequency of epoxy pure, EP/MgO and EP/TiO_2 nanocomposite.

Fig.6 shows the impedance (*Z*) frequency dependence for epoxy composites. There is an obvious decrease in *Z* with increasing filler content at each measured frequency due to the increasing of interfacial polarization.

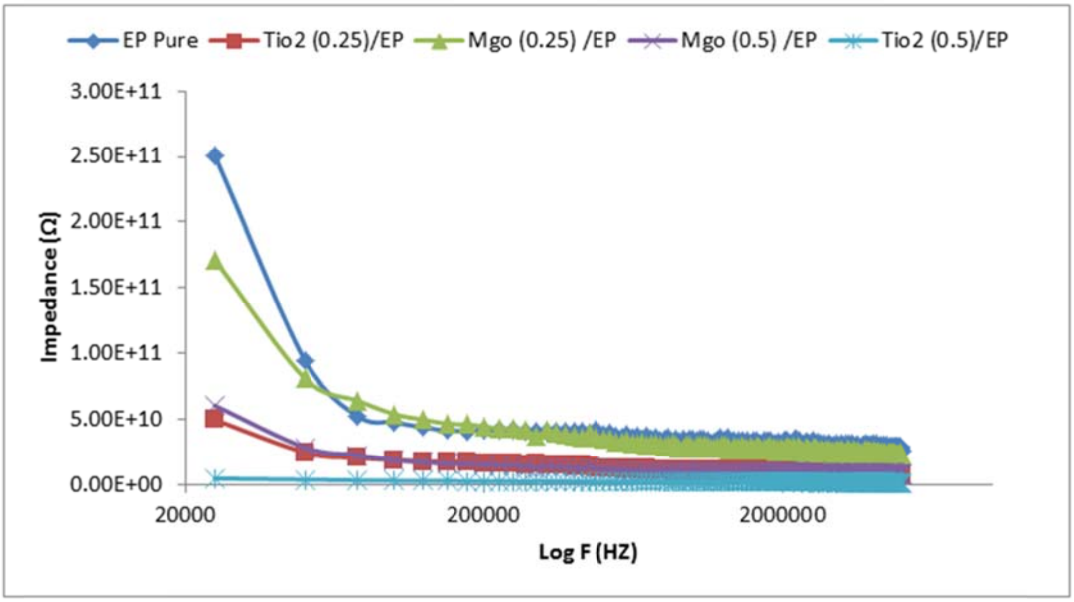

Fig.6: Impedance &frequency of epoxy pure, EP/MgO and EP/TiO_2 nanocomposite.

Conclusion

It is found that the permittivity, dielectric loss and loss tangent for all composites increase with increasing of the (EP/MgO; EP/TiO_2) filler content which has been attributed to interfacial polarization and segmental mobility of the polymer molecules, respectively. The permittivity decreases with the increasing of frequency because interfacial and segmental mobility polarizations cannot keep up orientation in the direction of the alternating field. The impedance *Z* of the composite decreases with the increase of filler volume content and frequency.

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