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The effect of Gamma radiation on The Dielectric Properties of SiO_2\ Ep: TiO_2 \ Ep Nanocomposite

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Abstract
This research investigates the dielectric properties (impedance, dielectric constant and dielectric loss) of SiO_2\ Ep :TiO_2 \ Ep nanocomposite over the frequency range of (10^2-10^6 Hz) at room temperature. The dielectric material used is epoxy resin, while nano-sized titanium dioxide (TiO_2) with grain size (30nm) , oxide silicon (SiO_2) with grain size (12nm) in state volume ratio (0,0.05 ,0.1) .The effect of gamma by using (CS137) for period time (17) day was studied Radiation caused decreasing in real and imaginary parts of dielectric constant and impedance .

Keywords: Polymer-Matrix Composites, Dielectric Properties, Epoxy.

تأثير أشعة كاما على الخصائص العزلية لمتراكبات الايبوكسيSio_2; Tio_2 النانوية

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الخلاصة
تم في هذا البحث دراسة الخواص الكهربائية (الممانعة، ثابت العزل بجزأيه الحقيقي و الخيالي) ولمدى من الترددات(10^2–10^6 Hz)وبدرجة حرارة الغرفة .المادة العزليه المستخدمة هي راتنج الايبوكسي بينما المادة المالئة هي ثنائي أوكسيد التيتانيوم ذو الحجم النانوي (30nm) و ثنائي اوكسيد السيليكون ذو الحجم النانوي (12nm) وبنسب حجميه (0.1, 0,0.05) وتم دراسة تأثير التشعيع بأشعة كاما المنبعثة من مصدرالسيزيوم (137) و لمدة (17) يوم وقد أظهرت النتائج الحالية أن التشعيع يؤدي الى نقصان في قيمة ثابت العزل بجزأيه الحقيقي والخيالي وكذلك الممانعة .

Introduction

In recent years, radiation is used for polymer processing and modification. The irradiation of polymeric materials with ionizing radiation (e.g. gamma rays, X-rays, accelerated electrons and ion beams) leads to the formation of very reactive intermediates, free radicals, ions and excited states. These intermediates can follow several reaction paths that result in disproportion, hydrogen abstraction, arrangements and/or the formation of new bonds [1]. The high surface to volume ratio of the grains, enhanced contribution from the interfacial region, possibilityof high defect density are some of the major factors determining the electric response of nanostructure materials[2]. Generally, cross-linking and chain scission occur simultaneously but one of them may dominant over the other

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[3]. Many industries are based on polymer radiation crosslinking technologies such as wire and cable insulation, applications in rubber tires and radiation vulcanization of rubber latex [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].

Experimental

1. Materials

The materials used to prepare the composite samples of this work are; Epoxy Resin (EP) EUXIT 50 supplied from (Swiss Chem.),silicon dioxide (SiO_2) with particle size (12 nm) and titanium dioxide (TiO_2) with particle size (30 nm).

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 1300 ^oC to reduce the moisture, and then weighted. Nanoparticles with epoxy resin were mixed by magnetic stirrer at 700 rpm at 600 ^oC 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/SiO_2 nanocomposites required so we used vacuum system (10^2 bar) 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. 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/SiO_2 nanocomposites so, we used the final preparation method for preparation the specimens and then tested it.

3. Irradiation Process

The samples exposed to gamma radiation by using gamma rays to irradiate all polymer composites samples for aperiods of (408) hour using Cs^{137} with energy (0.662) MeV, activity 8µCi and dose 11.2Gy. The irradiation process was performed in air at room temperature.

Electric Measurements

Studying the A.C. electrical properties may provide valuable information about the conduction mechanisms in specimens . The information can be obtained from the variation of the capacitance, and A.C. conductivity with frequency. The range of the frequencies in this work was 50Hz–5MHz. The measurements have been done using a computerized sensitive impedance analyzer. The electrode diameter of the holder is 0.5 cm. D.C. bias ranging from 250-750 mV across the sample pellet was used for measuring the variation of capacitance, dielectric constant and dielectric loss [7].

AC Measurements

Measurements of the dielectric parameters for samples were carried out, to find dielectric constant (ε'), dielectric loss (ε'') and loss factor (tan δ) by applying equations:

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

C_P = Capacitor containing an insulator material

$C_{\circ}$ =Capacitance of vacuum

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

R_P = Resistance

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

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

Impedance was found using equation

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

j = is imaginary number (√-1) [8, 9].

Results and Discussion

Figures-1 and 2 show the variation of the dielectric constant (ε`) and dielectric loss (ε") with frequency for the nanocomposite with over the frequency range (50 Hz–5 MHz)at room temperature, respectively. From the obtained results one can notice that the dielectric constant and loss increase under the effect of gamma rays. The increase of ε` and ε" value, due to the irradiation of the polymer in air is attributed to the increase of the number of dipoles in the polymer matrix where may be resulted from the increase of the number of C = O double bonds and C–H bonds in the polymer matrix. On the other hand, the increase of the irradiation may increase the number of free radicals that may react to decrease the number of dipoles in the samples [10].

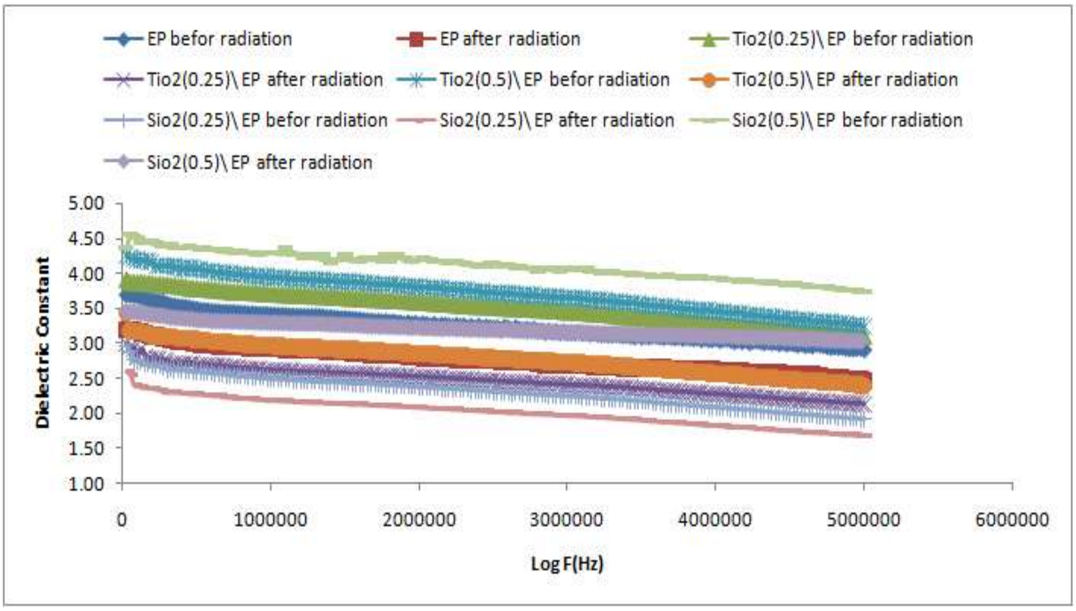

Figure 1- The variation of the Dielectric constant (ε′) with frequency of the Sio2/EP nanocomposite.

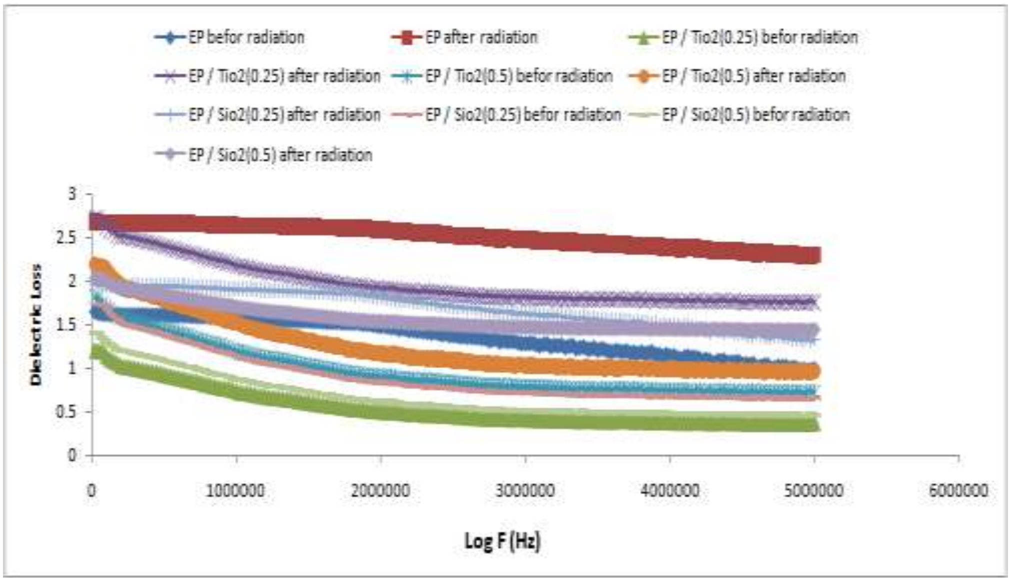

Figure 2-The variation of the fitted dielectric loss (ε") with frequency for the Sio2/EP nanocomposite.

The variation of impedance as a function of applied frequency at different compositions of unirradiated and irradiated samples at room temperature are presented in Figure-3. It can be seen that the value of Z decreased with increasing the frequency due to the degradation process.

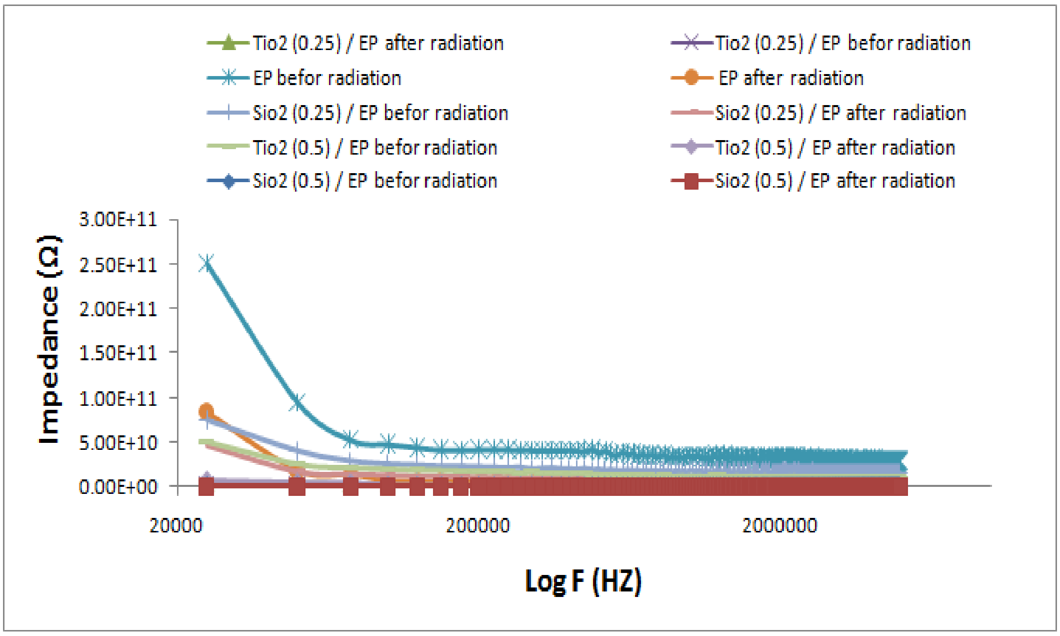

Figure3- The variation of the fitted Impedance (Z) with frequency for the Sio2/EP nanocomposite.

Conclusion

The values of the dielectric parameters were found to increase with irradiation dose. These results indicate that the irradiated nanocomposit**e** with dose may be suitable for applications such as cable and wire isolation for electronic systems.

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