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Dielectric Properties of ZrO_2/ PMMA Nanocomposites

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Abstract: *Poly (methyl methacrylate) (PMMA) / ZrO_2 nanocomposites were prepared by solution casting method. The dielectric properties of the composites were studied using LCR Meter and survey the effect of volume fraction concentration of ZrO_2 and frequency on the dielectric properties of these nanocomposites. The determination of its dielectric properties, were carried out using capacitance measurements of the above samples as a function of frequency, over the range 50 Hz - 5 MHz at room temperature. The dielectric constant, dissipation factor and dielectric loss of composites behaves nonlinearly as frequency increases over the range 50Hz -3 MHz, whereas above 3 MHz the values of dielectric constant remain constant. And it is observed that the dielectric properties depend on ZrO_2 Vp%.*

Keywords: *PMMA, ZrO_2 ,Dielectric properties, Polymer nanocomposite*

I. Introduction

Nanocomposite materials, based on a polymer matrix and inorganic nanoparticle fillers, have drawn considerable attention in recent years, due to improvements in various properties including electrical, thermal, optical and other mechanical properties [1-2]. The polymer nanocomposites material polymeric (PNCs) is important to the electronic industry for its dielectric properties when used in capacitors [3]. One of the most characteristic features is that of their dielectric properties and that can be widely changed by choice of shape, size and conductivity of mixed constituents in the polymeric matrix [4]. The study of dielectric constant, dielectric loss, a. c. conductivity and electrical modulus as function of frequency is one of the most convenient and sensitive methods of studying the polymeric structure [5-6].

Zirconia (ZrO_2) is an oxide which has a high tensile strength, high hardness and corrosion resistance. Zirconia based ceramics are routinely used in structural applications in engineering, such as manufacture of cutting tools, gas sensors, refractories and structural opacifiers [7]. The properties of the polymers and the ceramics could be exploited in the corrosion and gas sensing studies. Ceramic materials are typically brittle, possess low dielectric strength and in many cases are difficult to be processed requiring high temperature. On the other hand, polymers are flexible, can be easily processed at low temperatures. A conductivity study of PVDF/ ZrO_2 has been reported [8]. Poly (methyl-methacrylates) PMMA/Ferric oxide Fe2O3 composites dielectric properties were studied [9]. Dielectric properties of conventional particulate-filled microcomposites of ZrO_2 /PMMA composites prepared by different method have been investigated by other searcher [10-11].

The aim of this work is to study the dielectric properties of Zirconia (ZrO_2)/PMMA nanocomposites by changing fraction volume of Zirconia (ZrO_2) nanoparticles. For these experiments, we have prepared well dispersed, stable and homogeneous ZrO_2 nanoparticles in the polymer matrix PMMA.

II. Experimental

Poly (methyl methacrylate) (PMMA) (procured from Himedia company) and Zirconium dioxide (ZrO_2) powders from Hongwu (with sizes of nano 50-40nm) have been used as the raw materials in this work to prepare the polymer composites (PCs) using the solution cast technique.

In order to study the effect of ZrO_2 in the polymer matrix, pure PMMA, ZrO_2/PMMA composites were fabricated separately with different volume fraction of the ZrO2. For this purpose 1 g of PMMA was dissolved in 10mL of chloroform solution. The mixture was stirred continuously with a magnetic stirrer and ultrasonic for several hours at room temperature until the PMMA has completely dissolved. While the above systems were still in the liquid state, various amounts of ZrO_2 powder were added for the production of the composite samples. The ZrO_2 powder content in the prepared samples was varying from 0wt. % to 6wt. 0% in volume fraction and the mixtures were stirred continuously until homogeneous solutions were obtained. The solutions were then cast into clean and dry glass Petri dish and allowed to evaporate at room temperature until solvent free films were obtained. The samples were made in the form of circular discs and smooth surfaces. Samples with a diameter of (40 mm) and thicknesses (3 mm) were placed between two parallel plated electrodes, in order to examine dielectric properties of samples by LCR meter (Agilent impedance Analyzes 4294A). The LCR meter, was connected with the computer and the data was collected as a function different frequencies. The measurement was carried out at frequencies from 50 Hz to 5 MHz at room temperature.

III. Results and Discussion

The dielectric properties of (PMMA) / ZrO_2 composite are studied as a function of volume fraction of ZrO_2 and applied frequency at room temperature. The values of dielectric constant ε' and dissipation factor D (loss of tangent) and dielectric loss ε'' are obtained from the measured values of capacitance C and dissipation factor D using following equations [9]:

$$\varepsilon' = \frac{cd}{\varepsilon_0 A} \quad (1)$$

$$\tan\delta = D \quad (2)$$

$$\varepsilon'' = \varepsilon' \tan\delta \quad (3)$$

The variations of dielectric constant with respect to frequency for the PMMA composites with ZrO_2 at different concentrations are shown in Fig. (1). It can be seen from that the dielectric constant of pure PMMA and ZrO_2/PMMA composites decrease with increasing frequency. This is due to that at lower frequencies of applied voltage, all the free dipolar functional groups in the PMMA 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 orient at the same pace as the alternating field, so the contributions of these dipolar groups to the dielectric constant goes on reducing resulting in a continuously decreasing dielectric constant of the PMMA system at higher frequencies. On the other hand, the high value of dielectric constant at lower frequency might be due to the electrode effect and interfacial effects of the sample [9, 12]. Also we have noticed that the values of dielectric constant of PMMA composites have been found to be slowly increasing with Vp% of ZrO2and has peek at 2.5% for all frequencies, this may be due to dispersion fillers and interaction between filler and matrix. The results is very large than that reported by [10, 11] but the same behavior.

The dissipation factor D of PMMA and composite of ZrO_2/ PMMA is obtained as functions of Vp% ZrO_2 at different frequencies given in figure (3) and figure (4). it is found that dissipation factor D decreases as the frequency increases up to around 3 MHz for all samples whereas at higher frequencies the dissipation factor D remains same and is independent of the frequencies and we have noticed that the values of dissipation factor D of PMMA have been found to be slowly increasing with Vp% of ZrO2. Therefore the maximum dielectric constant is at 2.5Vp% with low dissipation factor D. Hence we observed the modification in dielectric loss of the PMMA composite.

The dielectric loss ε" of PMMA and its composites with different volume fraction of ZrO2 are obtained as functions of frequency using equation (3) and are given in figure(5). The Dielectric loss of all these composite decrease at low frequency range 50 Hz to 3 MHz and afterwards it nearly remains same at higher frequency range. As the weight percentage of ZrO_2 increases dielectric loss of composite films of PMMA increases as shown in figure (6). Hence we observed the modification in dielectric loss of the PMMA composite.

IV. Conclusion

PMMA / ZrO_2 composites were prepared by solution casting method. The dielectric properties of the polymer composites were measured. The dielectric loss and dielectric constant decreases with the increase of frequency. This is due to the electronic, ionic, dipolar and surface charge polarizations which depend on the frequencies. The large value of dielectric constant at lower frequency may be due space charge polarization arising at the grain boundary interfaces.

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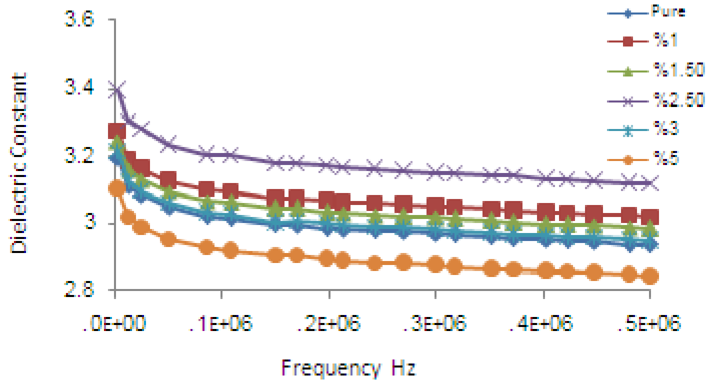

Fig. 1. Dielectric constant vs. frequency of composite of PMMA at different Vp% ZrO_2

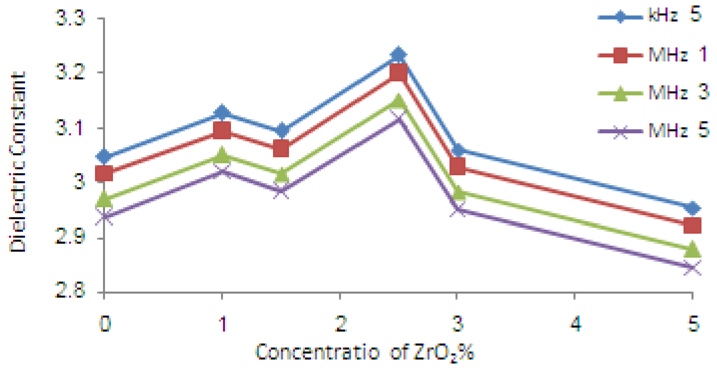

Fig. 2. Dielectric constant vs.Vp% of ZrO_2 composites of PMMA at different frequncy

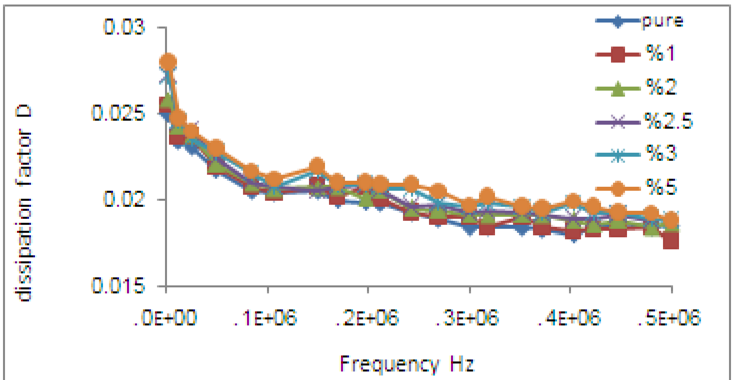

Fig. 3. Dissioation factor vs. frequency of composite of PMMA at different Vp% ZrO2

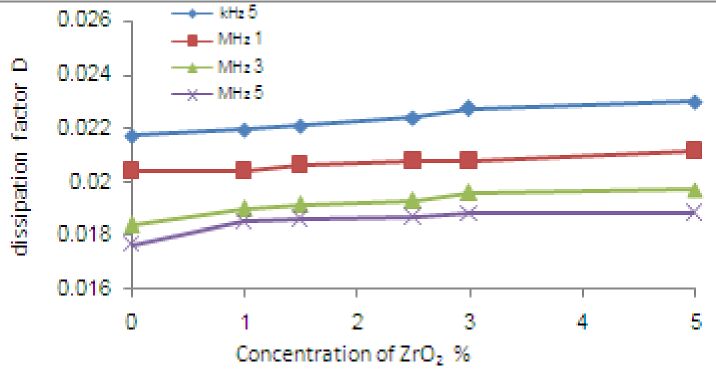

Fig. 4. Dissipation factor vs. Vp% of ZrO_2 of composite PMMA at different frequency

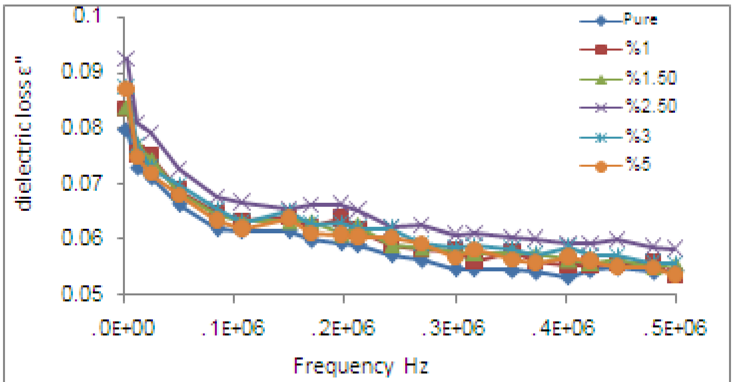

Figure 5 Dielectric loss vs. frequency of composite of PMMA at different Vp% of ZrO_2

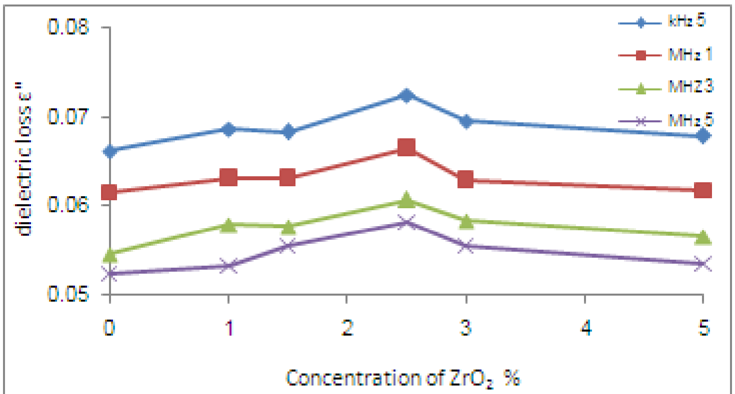

Fig. 5. Dielectric loss vs. Vp% of ZrO_2 composites of PMMA at different frequncy