New Fabrication (PVA-CMC -PbO) Nanocomposites Structural and Electrical Properties

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Abstract

This paper presents the work conducted on preparing (PbO PVA-PEG) nanocomposites through adding the different weight concentrations of lead oxide (0,1,3,5,7 wt%). The structural aspects such as optical microscope, FTIR and electrical features of nanocomposites (PVA-CMC/PbO) were examined. The resulting data shows that the dielectric constant decreased along with the decline of dielectric loss, whereas the frequency value rose while applying of an electric field. As for the electrical conductivity AC, the dielectric loss and dielectric constant of all samples rose along with the increase in lead oxide concentration.

Key Words: Lead Oxide Nano-particles, Dielectric Constant, Dielectric Loss, Carboxy-Methyl Cellulose (CMC) Poly-Vinyl Alcohol (PVA).

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Introduction

Nanocomposite polymers can be defined as homogenous or heterogeneous, two-phase systems that consist of polymers and fillers with at least one dimension within the nano-range (1-100) nm. The fillers can be Nano fibres, two dimensional clay platelets, one dimensional nanotubes, or three dimensional spherical particles. Polymers are the most popular materials used in the manufacturing of nanocomposites, such as thermoplastics, thermosets or elastomers. Over the past decades, polymer nanocomposites (PNCs) have drawn significant attention in both academia and industry, and they have become a crucial factor in the production of innovative advanced materials suitable for a range of uses, including electrical engineering (Sun, 2010). Nano-composites are composed of synthetic and natural polymers, and nano materials. The latter refers to materials with nano sizes or are comprised from nano-sized building components (Doulabi *et al*, 2014). The mechanical, electrical, thermal, electronic, and electro-chemical properties of nanocomposites can vary greatly from those of their component materials (Mariselvi *et*, 2015). The basic theory of nanocomposites focuses on providing a huge interface between nano-sized building blocks and polymer matrices (1Naheed *et al*, 2014). Nanotechnology is widely regarded as the next industrial revolution (Ali *et al*, 2013; Qais *et al*, 2019) Combining nanoparticles in polymer matrix provides the opportunity of substantially enhancing the optical properties of the substance with individual small quantities on the nanoparticle (Abdel Amir *et al*, 2019).

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They can have a significant impact on physical properties, as one advantage of nanoparticles as polymer additives is that the loading specifications are relatively low as compared to conventional additives (Bhaiswar *et al*, 2014; Abbas *et al,* 2017).

Polyvinyl alcohol (PVA) is a synthetic polymer employed since 1930 within a broad range of commercial, industrial, food, and medical applications involving surgical threads, lacquers, food-contact and resins applications (Demerlis-Schoneker *et al,* 2003). Carboxy-methyl Cellulose (CMC) is a fundamental industrial polymer that can be applied in a number of uses, including flocculation, textiles, paper, medicine and food (Al-Bermany *et al*, 2004). Some of its characteristics include a relatively higher viscosity, and being non-toxic and non-allergenic. Many hydroxyl and carboxylic groups enable water binding and moisture absorption. CMC hydro-gel is used in different applications because it has a good biodegradability and a high water content, and it is relatively less costly (Nie *et al*, 2004). PbOs (Lead monoxides) are the TCOs (transparent conducting oxide) with the dielectric constant of έ =25.9. PbO has a lot of potential in applications as a surface modification layer in polymer solar inverted cells of photo-voltaic because of their low band gap, whereas β -PbOs can be applied as such a layer with the aim of reducing work functions (Gamal2 *et al*, 2008). PbO has attracted a great deal of interest due to its strong electro-chemical efficiency and stability in the medium of acid (Hu, 2015). The electrical properties considered as part of the present study, such as the dielectric constant (ε'), can be defined as follows (Abdul- Al-bermany *et al*, 2020; Blythe-Bloor *et al*, 2005).

$$C_P = \varepsilon_o \varepsilon' A / d \qquad (1)$$

Where d, Cp, $\boldsymbol{\varepsilon_o}$ and A represent the thickness, sample capacity, vacuum permittivity, and surface area, respectively. In contrast, the dielectric loss is expressed by (Blythe-Bloor *et al*, 2005).

$$\tan\delta = I_p / I_q = \varepsilon'' / \varepsilon \qquad (2)$$

Where: **ε''** represents the dielectric loss, and tan δ represents dielectric loss tangent. The following equation is applied to measure the A.C conductivity (Nahida, 2012):

$$\sigma_{a.c} = w\varepsilon''\varepsilon_\circ \qquad (3)$$

Experimental Work

The Materials Used

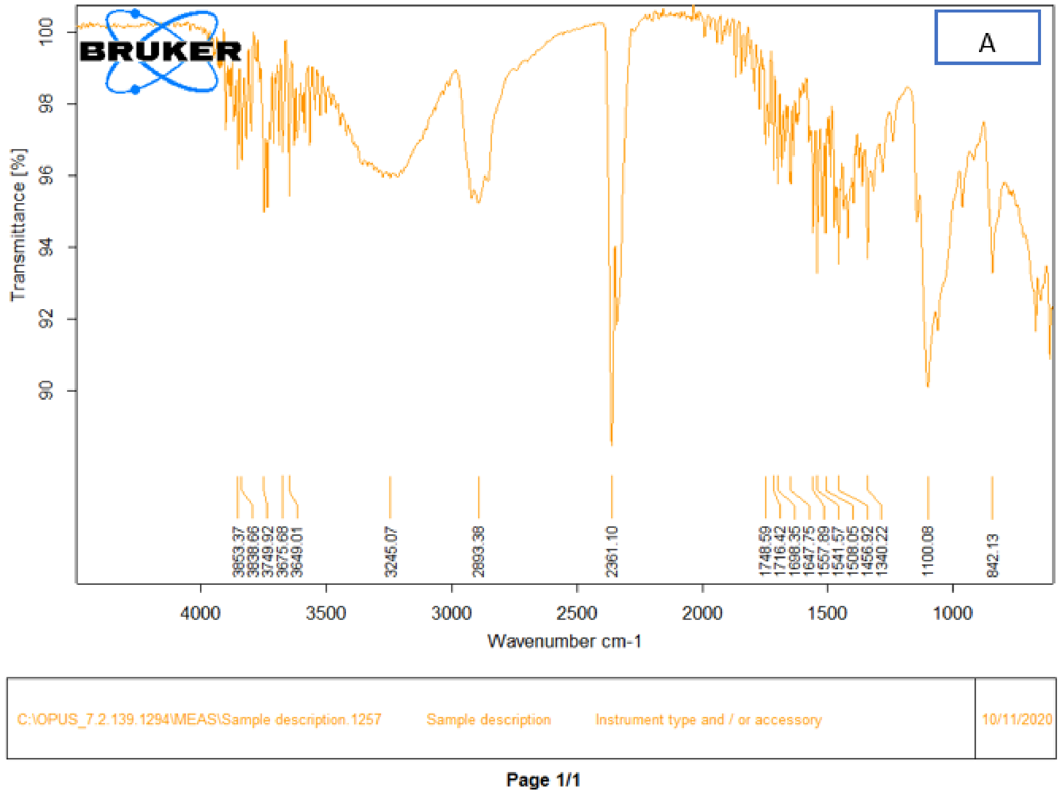
PVA is the largest water-soluble polymer. It was created an commonly adopted on the basis of its size. Its molecular weight is (1200-1800g/ mol), and it has a melting point of (230 C). CMC is found in form of a powder that is obtained from the local market in high purity degrees (99.8%). The melting point of CMC is (50-90) ^{0}C. The nanocomposites were prepared (PVA-CMC /PbO) from a mixture (PVA-PEG) in different concentrations. The decanting method was used in this preparation. The blend (PVA-CMC) sample were prepared with PVA and CMC. The PbO nano-particles were combined with the (PVA-CMC) according to a blending concentration of (0,1,3,5 and7) wt%. For obtaining a uniform solutions, the polymers are liquefied using magnetic stirrers in water distillation during the mixing process for prepare (PVA-CMC/PbO). Finally, the samples are ready for the appropriate measurements to be performed.

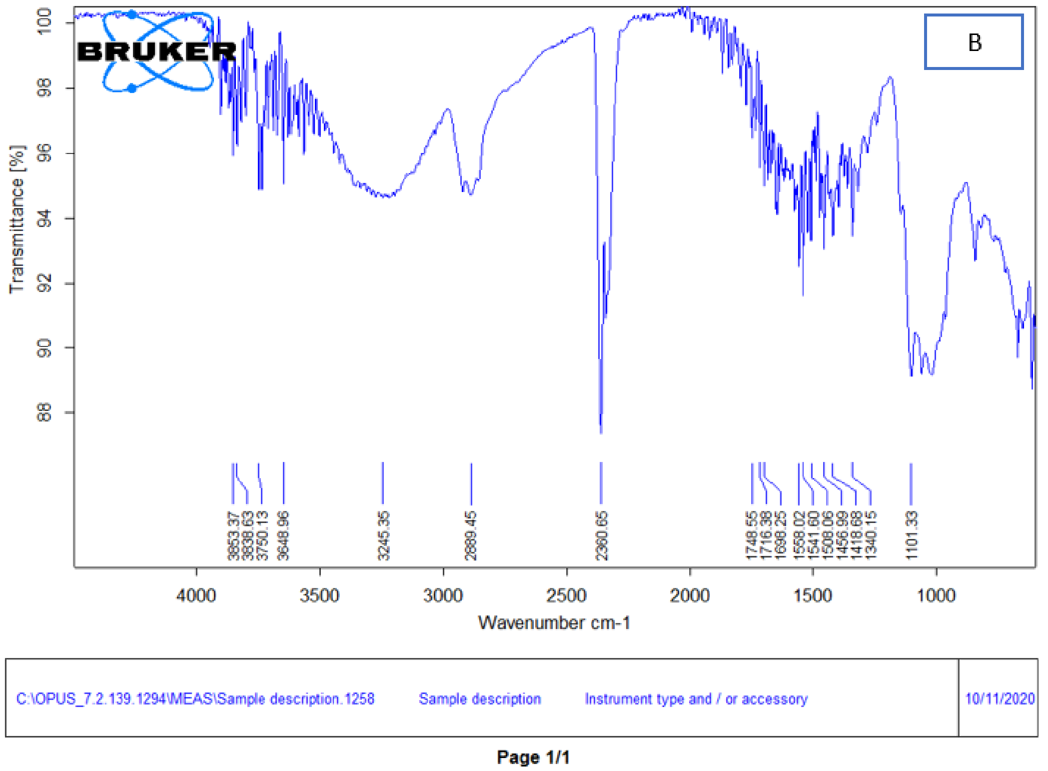
Results and Discussions

Figure (1) illustrates the several peaks in FT-IR spectrums of (PVA-CMC/PbO) nano-composites at different concentrations (pure,1,3,5,7 wt%) of (PbO), that fall within a range of (4000 - 1000) cm^{-1}. In Figure (1-a), the FTIR spectrum of (PVA-CMC/PbO) nano composites indicates a broadband peak at 3245 cm^{-1} for the stretching vibrations of (O – H), and a peak at 2893 cm^{-1} recognized as the stretching vibrations of (C- H). The peak at 1698 cm^{-1} belong to the (C=O) group, whereas the bending vibrations of (-CH_2) found at 1456 cm^{-1} and 1100 cm^{-1} are related to the (C- O) groups.

Figure (1-b) also presents several peaks, such as the ones observed at 1456 and 1101 cm^{-1} which belongs to CH_2 bending and (C- O), respectively. The peak seen at 1698 cm^{-1} is for the (C=O), while the broadband peak at 3245 cm^{-1} is related to the (O–H) groups. At 2889 cm^{-1}, a peak is found to be attributed to the stretching vibrations of (C-H). Moving to the spectrums illustrates in Figure (1-c), the stretching vibrations of (O-H) are shown at 3219 cm^{-1}, and the (C-H) bond is seen at the peak of 2895 cm^{-1}. As for the other peaks observed, the one at 1698 cm^{-1} is for the (C=O), whereas the ones at 1456 and 1099 cm^{-1} are related to the CH_2 and C-O bonds, respectively.

The FT-IR spectrums illustrated in Figure (1-d) show a broadband peak at 3213 cm^{-1} for the(O–H), whereas the peak at 2880 cm^{-1} represents the stretching vibrations of (C-H). The point at 1698 cm^{-1} belongs to the (C=O). Different peaks were presented for the CH_2 bending and C-O stretching, like the ones observed at 1457 and 1099 cm^{-1}, respectively. Finally, Figure (1-e) shows a broadband peak at 3253 cm^{-1} for the (O–H), whereas the peak at 2904 cm^{-1} belongs to the stretching vibrations of (C-H). The peaks found at 1690, 1418, and 1082 cm^{-1} belong to the (C=O), ($-CH_2$) bending and C-O group, respectively. From the FT-IR results, it can be observed that no chemical reaction occurs, but rather physical bonding or physical reactions (Chivukula Srikanth- Chakradhar Sridhar *et al*, 2016 ; Krishnamoorthy *et al*, 2009).





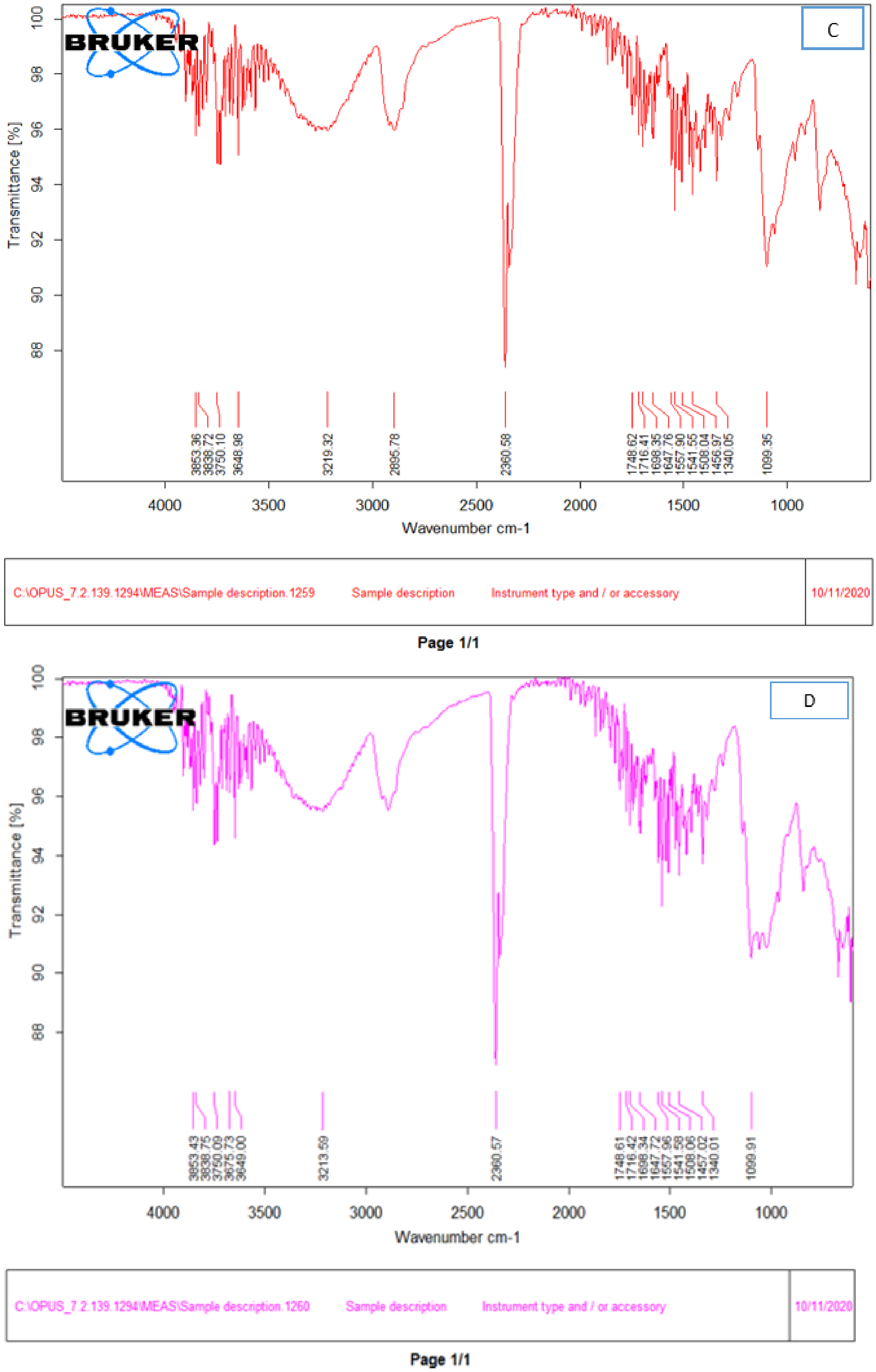
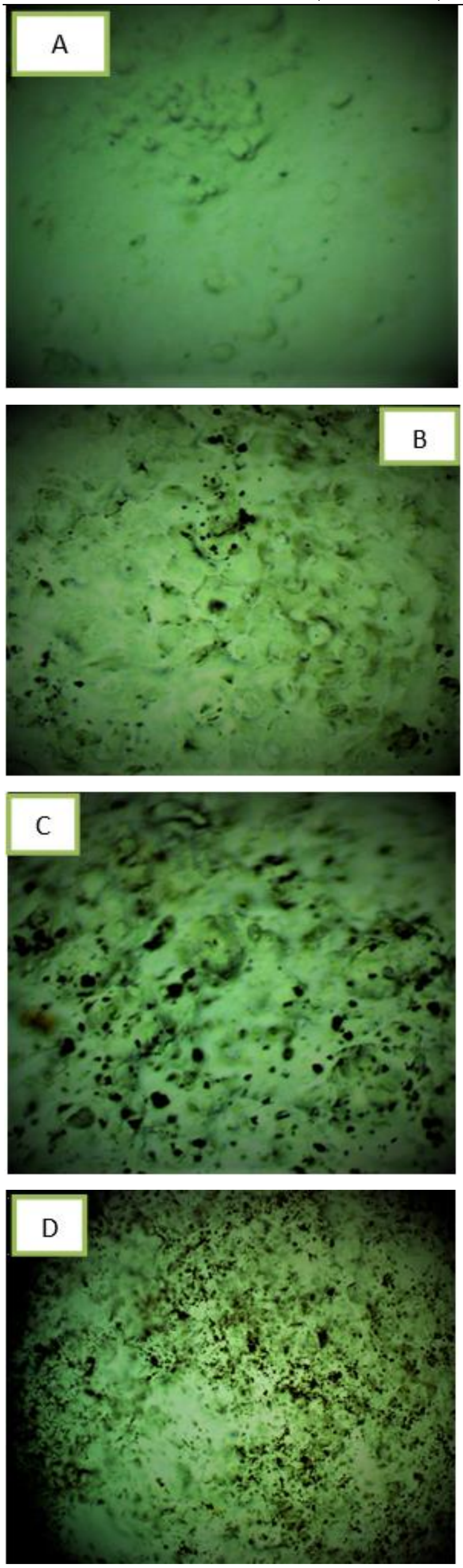


Figure 1. FTIR spectra for (PVA-CMC /PbO) nanocomposite: (A) (PVA-PEG) blend, (B) 1wt% PbO, (C) 3wt% PbO, (D) 5wt% PbO, (E)7 wt% PbO

The OM images of the pure (PVA-PEG) polymer blend surface and its nano-composites film at magnification strength (10X) are shown in Figure (2). It indicates good homogeneity and fine incorporation of PbO particles in the polymer (Babu- Vijay *et al*, 2015).



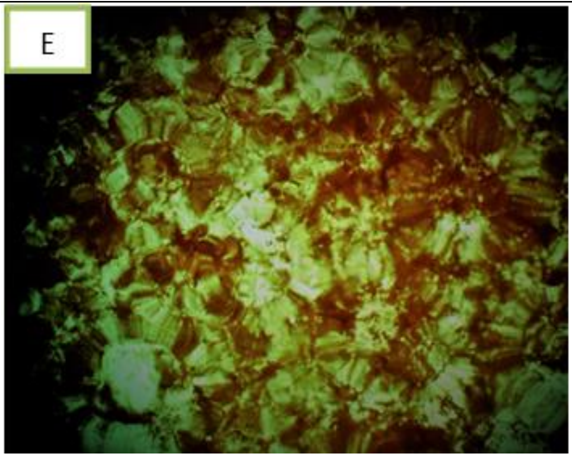


Figure 2. Photomicrographs (10x) for (PVA-CMC /PbO) nanocomposites

A) (PVA-CMC) blend B) 1 wt%, C) 3 wt%, D) 5 wt%, E) 7 wt% (PbO)

Figure (3) illustrates the effect of adding lead oxide (PbO) on the dielectric constant. It has been observed that a positive correlation exists between the dielectric constant and the lead oxide nano-particles, as both tend to increase simultaneously. This aspect can be traced back to the creation of a continuous network of lead oxide nano-particles within the nano-composites. This is well illustrated in microscopic images taken for samples of (PVA-PEG/PbO) and (PVA-CMC/PbO) nanocomposites at various concentrations (Agool, 2012).

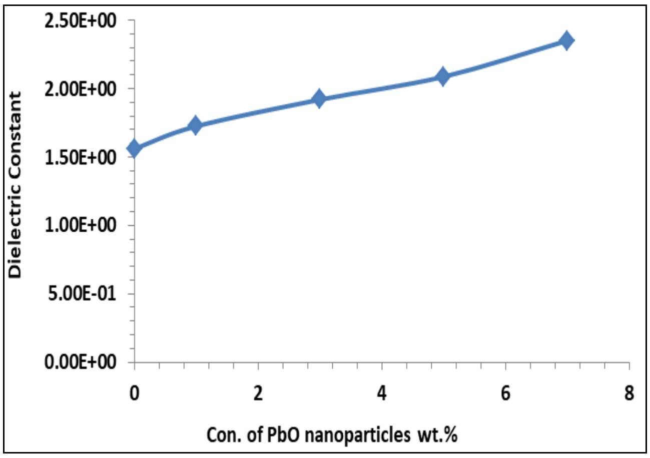


Figure 3. Variations in dielectric constant at different concentrations of (PbO) nano-particles at 100Hz of (PVA-CMC/PbO) nano-composites

Figure (4) illustrates the variation in dielectric constant for the (PVA-CMC/PbO) nano-composites of the samples at different frequencies. It is apparent from the figures that the ε' rate declines when applied frequency increases, as a result of the forms of polarization (ionic and electronic, dipolar, space charge) at low frequencies. The polarization of the space charge plays a significant role in increasing the dielectric constant, as it becomes less contributing to the rise in frequency and more contributing of polarization. This action induces the decrease in the **ε'** values for the samples with a rise in the frequency of electrical field. The alternative forms of polarizations take place at a subsequent frequency (Go swami *et al*, 2018; Rajesh *et al,* 2019).

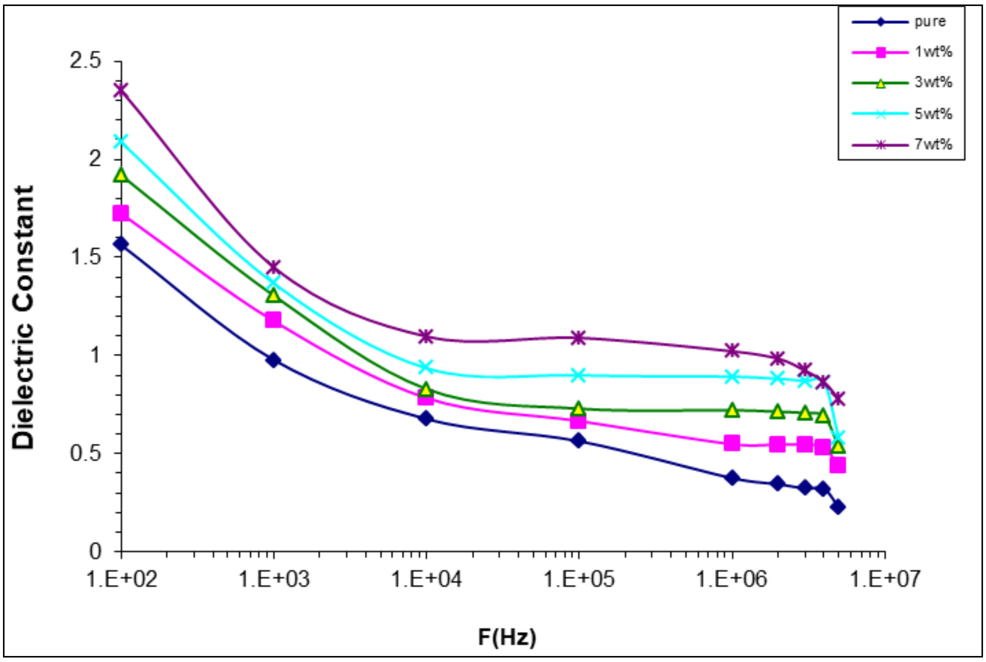


Figure 4. Variations in dielectric constant of (PVA-CMC/PbO) nano-composites at different frequencies

Figures (5) and (6) show the **ε''** values as a function of frequency of nano-composites. The loss of nano-composites (PVA-CMC/PbO) seems to decrease when the applied electric field increases. This behaviour is due to a decline in the contribution of space charge polarization, as well as a high value of dielectric loss for (PVA-CMC/PbO) nanocomposites at lower frequencies. The dielectric loss of (PVA-CMC/PbO) nano-composites increases with the rise in PbO nano-particle concentrations. When the frequency is increased the dielectric loss is approximately constant for (PVA-CMC/PbO) nano-composites (Go swami *et al*, 2018; Rajesh *et al,* 2019).

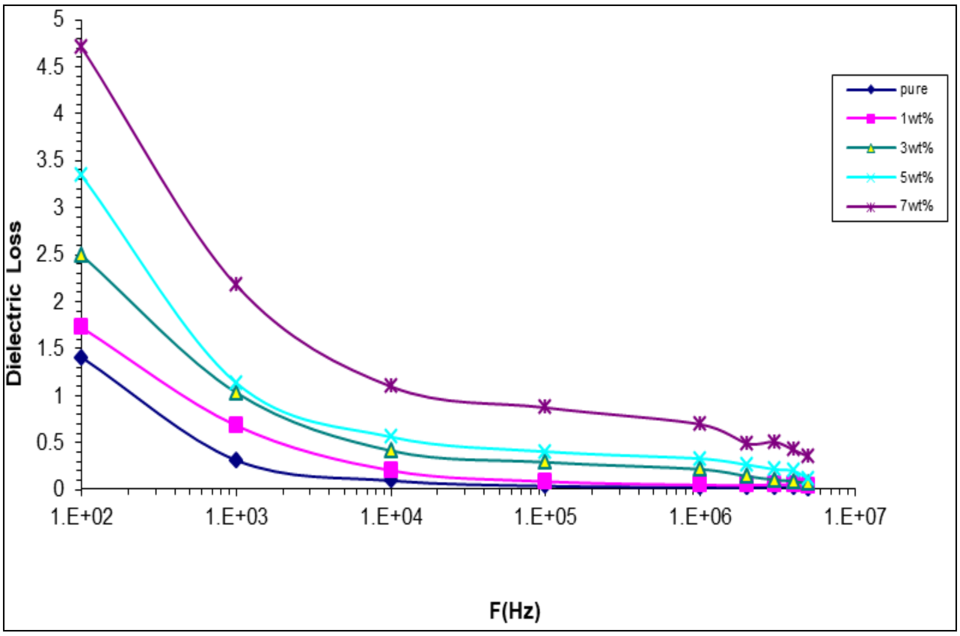


Figure 5. Variations in ε'' for (PVA-CMC/PbO) nano-composites at different frequencies

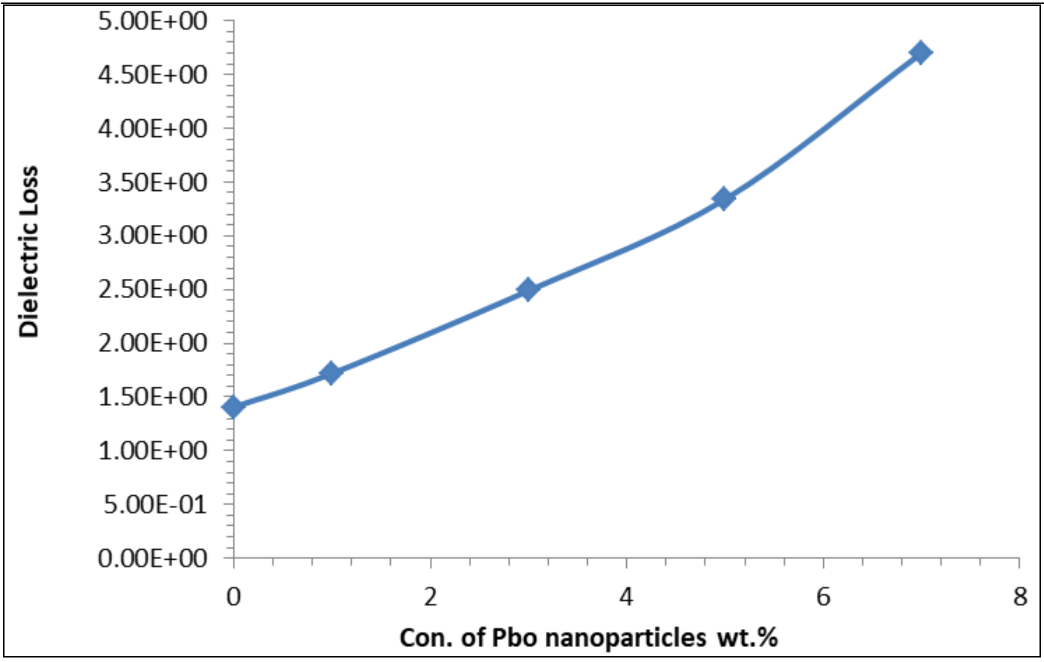


Figure 6. Variations in ε'' at different (PbO) nano-particle concentrations for (PVA-CMC /PbO)

The variations in AC electrical conductivity as a function of frequency for (PVA-CMC/PbO) nano-composites at 100Hz, is depicted in Figure (7). It is demonstrated that the σ a. c. of nano-composites rises whenever the frequency increases in (low, moderate and higher) frequency regions. This is due to the hop-up of charge carriers and also to the excitation of charge carriers within the conduction band in the upper regions. Figure (8) demonstrates that the conductivity of nanocomposites has increased with increasing the (PbO) nano-particle concentrations, as a consequence of the rise in ionic charge carriers and forming a continuous network of (PbO) nano-particles within the composites (Go swami *et al*, 2018; Rajesh *et al,* 2019).

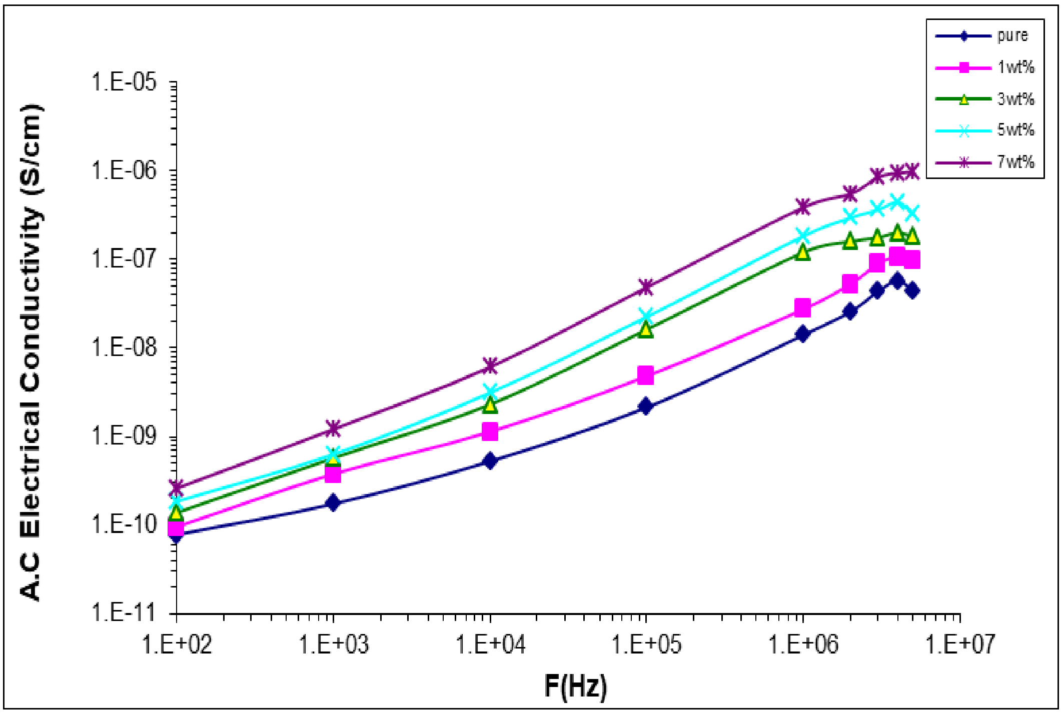


Figure 7. Variations in A.C electrical conductivity at different frequencies for (PVA-CMC /PbO)

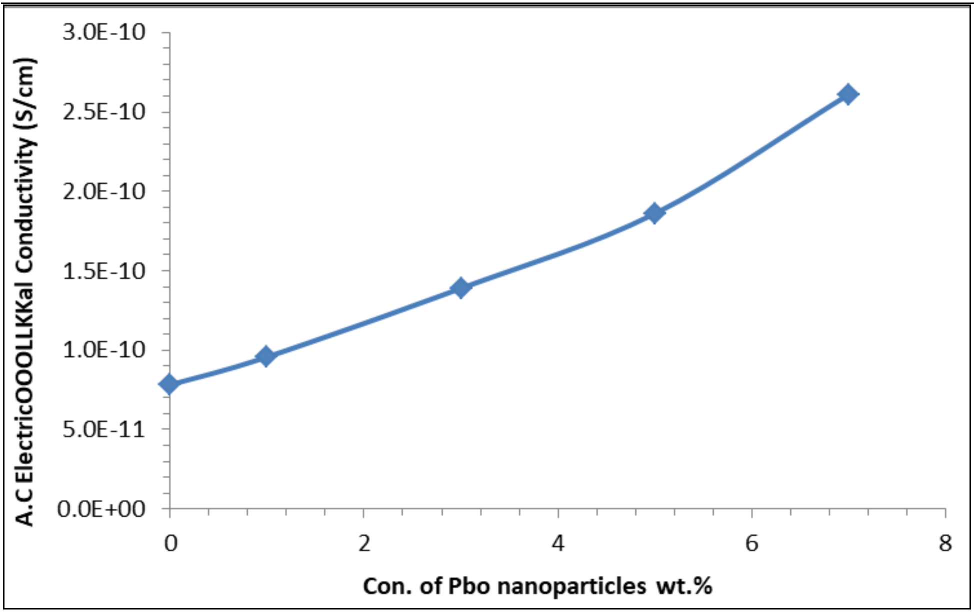


Figure 8. Variations in A.C electrical conductivity at different concentrations for (PVA-CMC PbO)

Conclusion

Throughout conducting the present experiment, is has been noticed that the dielectric constant ε' of the samples decreased as the frequency of the applied electric field increased, which is the same behaviour observed with the dielectric loss ε''. After increasing the frequency value, the AC electrical conductivity of (PVA-CMC/PbO) nano-composites improved. In addition, the dielectric constant and loss values increased at all ratios of concentration, along with the increase in lead oxide rates.

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