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# Fabrication and Enhanced Dielectric Properties of PVA–$Cr_2O_3$–$Sb_2O_3$ Nanocomposites for Electrical and Electronics Applications

Ahmed Hashim and M. H. Abbas

*College of Education for Pure Sciences,*
*Department of Physics,*
*University of Babylon,*
*Hillah, Iraq*

In present work, nanocomposites films have been prepared from $Cr_2O_3$–$Sb_2O_3$-nanoparticles-doped PVA to exploit in different electrical and electronics applications. The dielectric properties of PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites were tested at frequency ranged from 100 Hz to 5 MHz. The experimental results confirmed that both the dielectric constant and the dielectric loss of PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites were reduced, whereas the electrical conductivity was increased with raising the frequency. The dielectric constant, dielectric loss, and A.C. electrical conductivity of PVA were increased with raising the $Cr_2O_3$–$Sb_2O_3$-nanoparticles' concentration. The results illustrated that the PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites can be suitable in different electrical and electronics applications.

У цій роботі нанокомпозитні плівки було виготовлено з полівінілового спирту (ПВС), леґованого наночастинками $Cr_2O_3$–$Sb_2O_3$, для використання в різних електричних та електронних застосуваннях. Діелектричні властивості нанокомпозитів ПВС–$Cr_2O_3$–$Sb_2O_3$ перевіряли в діяпазоні частот від 100 Гц до 5 МГц. Експериментальні результати підтвердили, що діелектрична проникність і діелектричні втрати нанокомпозитів ПВС–$Cr_2O_3$–$Sb_2O_3$ зменшуються, тоді як електропровідність зростає зі збільшенням частоти. Діелектрична проникність, діелектричні втрати й електропровідність змінного струму ПВС зростали зі збільшенням концентрації наночастинок $Cr_2O_3$–$Sb_2O_3$. Кінцеві результати показали, що нанокомпозити ПВС–$Cr_2O_3$–$Sb_2O_3$ можуть бути придатними для різних електричних та електронних застосувань.

**Key words:** $Cr_2O_3$, $Sb_2O_3$, PVA, nanocomposites, dielectric properties.

**Ключові слова:** $Cr_2O_3$, $Sb_2O_3$, полівініловий спирт, нанокомпозити, діелектричні властивості.

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## 1. INTRODUCTION

Today, intercalated polymer nanocomposites (NCs) with nanometal oxides are gaining significant interest in both academic and industrial scenarios. It involves the selection of polymers and metal oxides on the nanoscale from various numbers of polymers and nanomaterials available today for the desired properties. Metal oxides are well-known materials for sensors, photocatalytic, fuel cells, coatings, optoelectronic devices, *etc.* [1]. The substrate/matrix role of organic polymers, where the substantial dispersion of inorganic oxides results in the composite formation, finds enormous applicability. The various fields, where these heterostructures involving polymeric matrix find their applicability, include optoelectronics, automotive and aerospace industries, *etc*. Polymer composites have been found to be effective in dye degradation compared to other materials. The properties of these polymeric nanocomposites get affected by various factors like interfacial bonding, the embedding of nanoparticles (NPs), and the morphological behaviour of the dispersed nanoparticles in the polymeric substrate [2].

Organic–inorganic hybrid optical materials are extremely valuable for a technological perspective. Hybrid compositions with remarkable properties may emerge once the relationships between the properties of inorganic elements and polymer matrices are clarified. Polymeric nanocomposites, because of their interesting properties, are also a significant class in the field of applied materials science technology. Polymer composites display a variety of fascinating optical features, including a high/low refractive index, tailored absorption/emission spectra, and strong optical nonlinearities. Hybrids are eligible for potential optoelectronic applications because they possess such rare properties [3].

The new characteristics of PVA-based materials have made them appropriate for a range of applications, especially, optoelectronic technology. One might modify the behaviour of optoelectronic devices by dispersing one or more nanofiller (such as metal oxide, rare earth salt, *etc.*) inside the PVA matrix [4].

Metal-oxide materials have increasing demand in the scientific community due to their eco-friendliness, stability, natural abundance, ease of synthesis, and wider application purposes. Different types of metal oxides and their nanomaterials are being used in an extensive variety of fields like adsorbents, gas sensors, photovoltaics, photoelectronics, and electrochemical, fuel cells, ceramics and other biological applications [5]. Antimony trioxide ($Sb_2O_3$) is a semiconducting material and possesses excellent catalytic performance in photochemistry and superior chemical stability in flame retardation. So far, much attention has been focused on the synthesis of $Sb_2O_3$ films, and the exploration of their novel properties [6].

Nanocomposites materials of polymer as a matrix doped with nanoparticles have huge applications of optical, electronics and optoelectronics fields [7–33]. The present work deals with preparation and dielectric properties of PVA–$Cr_2O_3$–$Sb_2O_3$-nanocomposites' films to exploit in different electrical and electronics applications.

## 2. MATERIALS AND METHODS

The PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites films were prepared using casting process. The PVA film was fabricated by dissolving of 0.5 gm PVA in 30 ml of distilled water by using magnetic stirrer to mix the polymer for 1 hour to obtain more homogeneous solution. The $Cr_2O_3$ and $Sb_2O_3$ nanoparticles were added to PVA with constant ratio 1:1, and different contents are 2.2%, 4.4% and 6.6%. The dielectric properties of PVA–$Cr_2O_3$–$Sb_2O_3$-nanocomposites' films were measured at frequency range from 100 Hz to $5\cdot10^6$ Hz using LCR-meter type (HIOKI 3532-50 LCR HI TESTER). The dielectric constant ($\varepsilon'$) is calculated by [34] as follows:

$$\varepsilon' = C_p/C_0, \quad (2)$$

where $C_p$ is the capacitance of matter and $C_0$ is the capacitance of vacuum.

Dielectric loss ($\varepsilon''$) is determined by [35] as follows:

$$\varepsilon'' = \varepsilon' D, \quad (2)$$

where $D$ is the dispersion factor.

The A.C. electrical conductivity is obtained by [36] as follows:

$$\sigma_{\text{A.C.}} = 2\pi f \varepsilon' D \varepsilon_0. \quad (3)$$

## 3. RESULTS AND DISCUSSION

The performance of dielectric constant and dielectric loss for PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites with frequency and $Cr_2O_3$–$Sb_2O_3$-NPs' concentration are demonstrated in Figs. 1–4, respectively. Because the values of dielectric constant drop with increasing frequency, the dipole is difficult to spin accurately and easily, and its oscillation begins to occur after this field. This behaviour is because of the die-

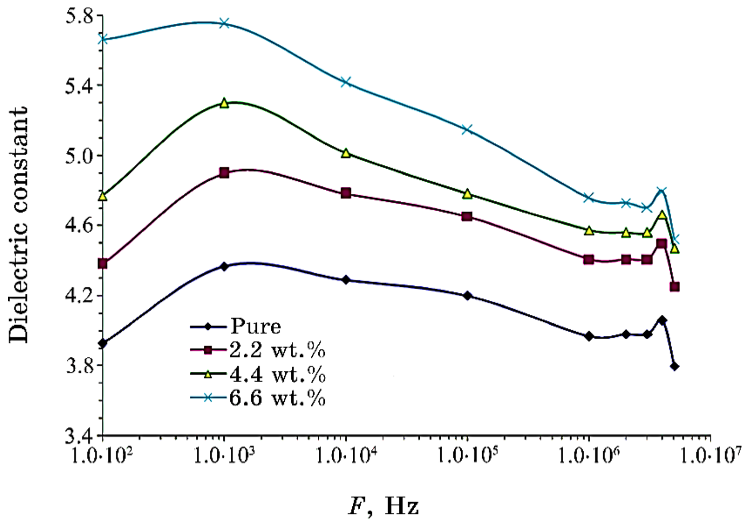


**Fig. 1.** Dielectric-constant variation for PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites with frequency.

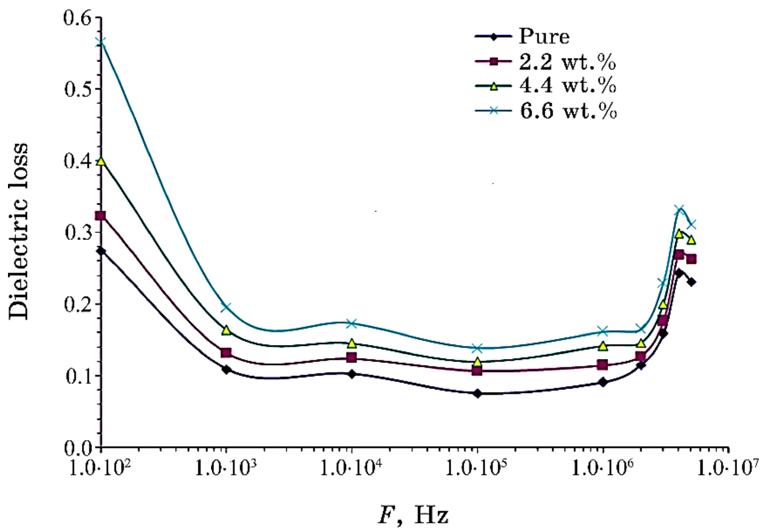


**Fig. 2.** Dielectric-loss behaviour for PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites with frequency.

lectric-constant values decrease. In addition, there was no evidence of relaxation peaks, which points to a non-Debye response.

These figures show that the motion of ions is recognized as the fundamental foundation of nanocomposite dielectric loss at lower frequencies, leading to a decrease in dielectric loss as a function of

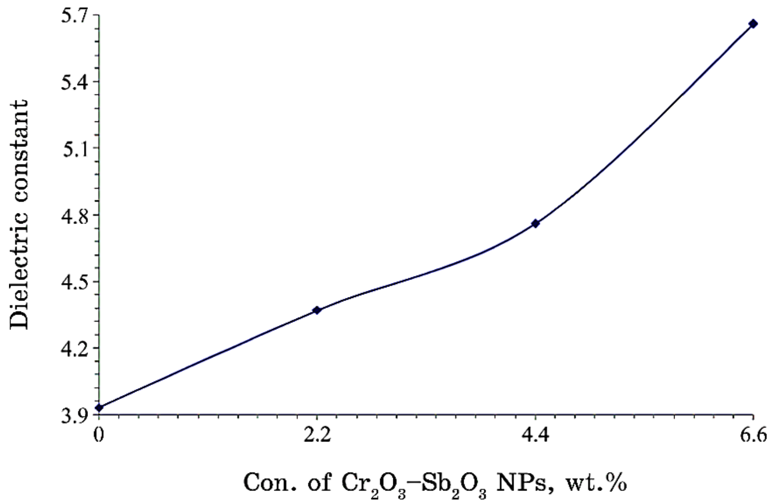


**Fig. 3.** Dielectric-constant performance of PVA with $Cr_2O_3$–$Sb_2O_3$-NPs' concentration.

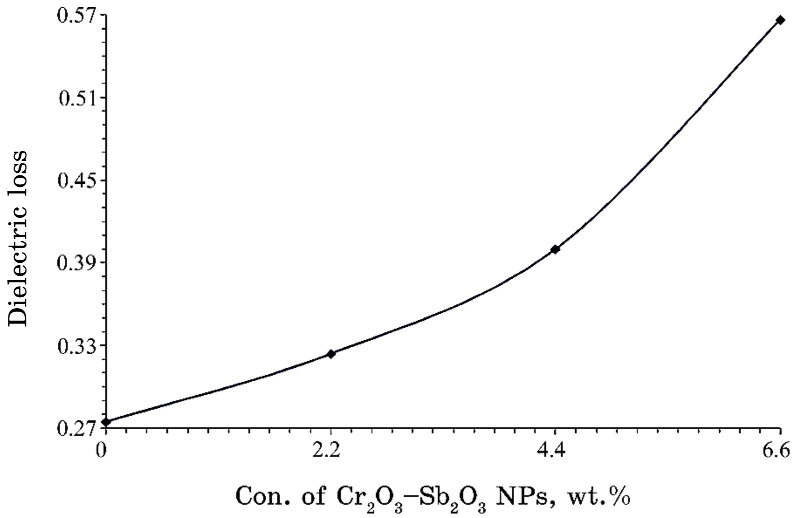


**Fig. 4.** Dielectric-loss behaviour of PVA with $Cr_2O_3$–$Sb_2O_3$-NPs' concentration.

raising frequency. Thus, the high value of the dielectric loss at low frequencies indicates the impact of ion jumping.

The dielectric constant and dielectric loss of PVA are increased with increasing $Cr_2O_3$–$Sb_2O_3$-NPs' concentration; this is due to increase in the charge-carriers' numbers [37–51].

Figures 5 and 6 conform the variation of electrical conductivity

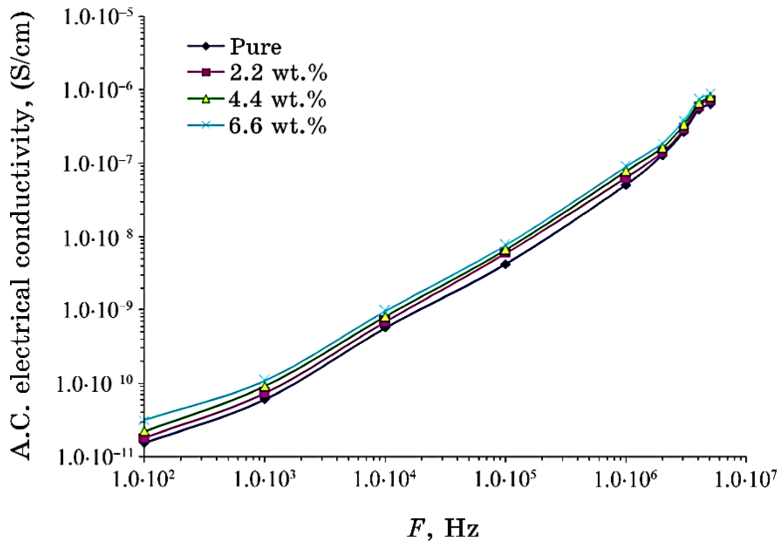


**Fig. 5.** Variation of electrical conductivity for PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites with frequency.

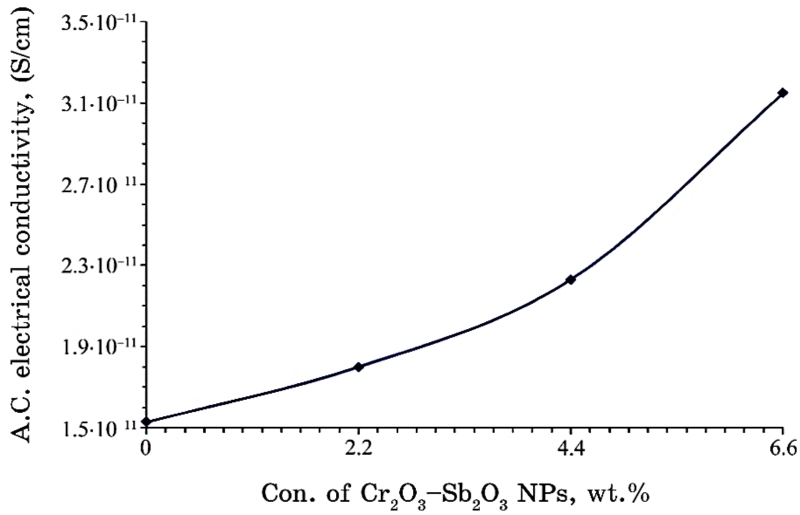


**Fig. 6.** Behaviour of electrical conductivity for PVA with $Cr_2O_3$–$Sb_2O_3$-NPs' concentration.

for PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites with frequency and $Cr_2O_3$–$Sb_2O_3$-NPs' concentration, respectively.

The electrical conductivity rises with increasing concentration and frequency. The increase of electrical conductivity, as the $Cr_2O_3$–

$Sb_2O_3$-NPs' concentration increases, is attributed to raising in the charge-carriers' numbers.

The frequency-dependent conductivity is caused by the hopping of electrons in the localized states near the Fermi level and due to the excitation of charge carriers to the states in the conduction band [52–60].

## 4. CONCLUSIONS

This study involved preparation of nanocomposites from $Cr_2O_3$–$Sb_2O_3$-nanoparticles-doped PVA to utilize them in various electrical and electronics fields. The results showed that the dielectric constant and dielectric loss of PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites are reduced, whereas the electrical conductivity is increased with raising frequency. The dielectric constant, dielectric loss, and A.C. electrical conductivity of PVA are increased with raising the $Cr_2O_3$–$Sb_2O_3$-NPs' content. Finally, the results demonstrated that the PVA–$Cr_2O_3$–$Sb_2O_3$ nanocomposites may be used in different electrical and electronics applications.

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