Fabrication of SrTiO$_3$ NPs Doped Polymer Blend and Studying their AC Electrical Characteristics for Piezoelectric Fields

Abeer Ghalib Hadi$^1$, Zainab Al-Ramadhan$^2$, Ahmed Hashim$^3$

$^{1,2}$University of Mustansiriyah, College of Education, Department of Physics, Iraq.
$^3$University of Babylon, College of Education for Pure Sciences, Department of Physics, Iraq.

E-mail: abeer.ghaleb2020@gmail.com

Abstract. Nanocomposite films of PVA/PAA/SrTiO$_3$ NPs were fabricated for electronic and optic approaches using a low cost method. The AC electrical characteristics of PVA/PAA/SrTiO$_3$ films were investigated. The results showed that the dielectric constant of polymeric blend increases from 5.39 to 7.25, and the dielectric loss increases from 1 to 30. While, the electrical conductivity increases from $5.00 \times 10^{-11}$ to $2.00 \times 10^{-9}$ with increasing the SrTiO$_3$ NPs content. Also, the dielectric constant of polymeric blend increased from 5.39 to 8.04, and the dielectric loss increased from 0.377 to 1.21. While, the electrical conductivity increased from $2.09 \times 10^{-11}$ to $6.70 \times 10^{-11}$ with increasing the frequency.

Keywords: PAA, nanocomposites, SrTiO$_3$, dielectric constant, electronic applications.

1. Introduction

Polymers are known to be a conjugating chain of organic materials that show strong electrical conduction, which induces charge mobility along the polymers chain due to their characteristics as charges borne by the $\pi$-electron. Characteristics of Polymers are as good as with the inorganic matter, but the polymers include many pros, such as good flexibility, corrosion resistance, processability, low cost and light-weight. The inorganic also contains important characteristics like stability to heat, and good mechanical characteristics. Consequently, the polymer/inorganic system have huge applications in several fields [1]. Polymer nanocomposites have expected much interest related to their several industrial fields in water treatment, aerospace food structures industry, drug delivery and aeronautical [2]. The nanocomposites combine useful characteristics of Polymers and other characteristics of nanoparticles [3]. The polyvinyl alcohol/ PVA is a Water/synthetic polymer soluble, non-toxic, and it is generally used in the mixtures owing to its excellent chemical and physics characteristics, good film formation properties, noncarcinogenic, emulsifying capability, biocompatible and biodegradable qualities [4]. The PAA is a hydrophilic Polymer, non-toxic, biocompatible [5]. This work aims to prepare new types of nanocomposites to be used in pressure sensors and piezoelectric fields.
2. Materials and methods
Using the casting process, the nanocomposite films of PVA/PAA blend as a matrix and SrTiO$_3$ NPs as an additive were manufactured.
The PVA/PAA film was prepared using a magnetic stirrer by dissolving 1gm of 4:1 ratio polymers in 30 ml of distilled water.
The nanocomposite films were prepared by adding the SrTiO$_3$ NPs to different concentrations of PVA/PAA solutions (1.8%, 3.6%, 5.4% and 7.2%).
The dielectric properties were calculated in a frequency range of (100 Hz - 5M Hz) using the LCR meter.
The dielectric constant ($\varepsilon$) is determined with the aid of [6]:
$$\varepsilon = \frac{C_p}{C_o}$$
(1)
The $C_o$ and $C_p$ are vacuum and capacitance in parallel capacitors.
The dielectric loss ($\varepsilon''$) is determined by [7]:
$$\varepsilon'' = \varepsilon \cdot D$$
(2)
D is a dispersion factor.
The AC conductivity was determined by the following relation [8].
$$\sigma_{A.C} = \varepsilon'' \varepsilon_0$$
(3)
W: The angular frequency representation

3. Results and Debate
Figures 1 and 2 represent the dielectric constant and the loss of nanocomposites with PVA/PAA/SrTiO$_3$ and frequency respectively. From these figures, the $\varepsilon'$ of PVA/PAA/SrTiO$_3$ nanocomposite reduces with increasing the frequency, which is related to the dipoles tendency in the polymer to orient themselves in the applied field direction. The dielectric loss of PVA/PAA/SrTiO$_3$ decreases with increasing the frequency. This behavior is related to the interfacial polarization in the PVA/PAA/SrTiO$_3$ nanocomposites. The high value at low frequency of $\varepsilon''$ for PVA/PAA/SrTiO$_3$ nanocomposite is related to the mobility of the charges [9]. Figures 1 and 2 show the $\varepsilon'$ and $\varepsilon''$ of a (PVA–PAA) blend, which increase with increasing the SrTiO$_3$ NPs content. This behavior is related to increase the polarizations of the free electrons and the space charges [10,11].

Figure 1. Variation of $\varepsilon'$ with frequency of PVA/PAA/SrTiO$_3$ samples.
Figure 2. Variation of $\varepsilon''$ frequency of PVA/PAA/SrTiO$_3$ samples.

Figure 3 shows the AC electrical conductivity with frequency for PVA/PAA/SrTiO$_3$ nanocomposite. This figure indicates that the conductivity increases with increasing the frequency, which attributed to the influence of the polarization and hopping. The conductivity of PVA/PAA increases with increasing SrTiO$_3$ NPs ratio. This is due to the hopping mechanism of conducting charge carriers [12].

Figure 3. Variation of $\sigma_{AC}$ with a frequency for PVA/PAA/SrTiO$_3$ samples.

4. Conclusions

The dielectric constant of PVA/PAA increased from 5.39 to 7.25 and the dielectric loss increased from 1 to 30 while the electrical conductivity increased from $5.00 \times 10^{-11}$ to $2.00 \times 10^{-9}$ with the addition of SrTiO$_3$ NPs. The PVA/PAA/SrTiO$_3$ dielectric constant increased from 5.39 to 8.04 and the dielectric
loss increased from 0.377 to 1.21 while the AC conductivity increased from $2.09 \times 10^{-11}$ to $6.70 \times 10^{-11}$ with increasing the frequency. The results indicated that the PVA/PAA/SrTiO$_3$ nanocomposite may be used in various piezoelectric and electronic applications like capacitors, pressure sensors, diode, transistors, etc.

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