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Fabrication and Tailored Structural and Dielectric characteristics of (SrTiO₃/ NiO) Nanostructure Doped (PEO/PVA) polymeric Blend for Electronics Fields

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Films are prepared from (PEO/PVA) blend with various ratios of (SrTiO₃/NiO) by using casting method. SEM images of (PEO/PVA/SrTiO₃/NiO) nanocomposites show that many aggregates or chunks on the upper surface that are homogeneous and coherent. The (PEO/PVA/SrTiO₃/NiO) nanocomposites contribute to tiny vibrational molecular movement, according to the (FTIR) analysis. Several polymer chains were also disrupted once (SrTiO₃/NiO) nanoparticles were introduced. Instead, several additional chains were produced. Dielectric constant and dielectric loss decreases with increasing of frequency ,while conductivity increases, as well as dielectric constant increases from 4.73 to 5.99 and dielectric loss rise from 0.85 to 1.80 ,while the conductivity increases from 4.7×10^{-11} S/cm to 1.10×10^{-10} S/cm when (SrTiO₃/NiO) NPs reached 4wt.%. The results of structural and electrical properties show that the (PEO/PVA/SrTiO₃/NiO) NCs may be used for various electronics fields.

Keywords: polymer blend, electrical properties, (SrTiO₃/NiO) nanoparticles, structural properties.

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Introduction

Nanocomposites have recently sparked a lot of attention, and there are a lot of initiatives underway to regulate nanostructures using novel synthetic techniques. Nanocomposite materials' qualities are determined not only by their morphology and interfacial properties, as well as their particular parents' characteristics [1]. Individual atoms and molecules, as well as bulk matter, have different physical, chemical, and biological properties than nanomaterials. Melting temperature, magnetic characteristics, charge capacity, and even color are all fundamental attributes of materials that may be changed. by making nanoparticles without changing the materials' chemical makeup. Dielectric characteristics of polymers are becoming more important because they help us understand how molecular chains move and how they might be used in electrical and electronic engineering [2,3]. The electronegativity of a substance was studied as part of the A.C impedance search. It is related to the structure of charge carriers, which helps to restrict the

(A.C) impedance of polymers. Nanocomposites of organic inorganic have gotten a lot of interest in the world of material technology and research. When nanoparticles have a shorter wavelength than visible light, nanocomposite has a high optical transparency, which reduces scattering loss [4,5,6]. Electrolytes made of poly(ethylene oxide) (PEO) polymer have been extensively studied in order to get more knowledge [7]. Polyvinyl alcohol (PVA) polymers have gained popularity in recent years because of their diverse variety of applications PVA is a promising material because of its strong dielectric strength, high charges-to-rage capacity, and pant-dependent electrical and optical characteristics. It has a carbon chain backbone with hydroxyl groups connected to methane carbons, which can aid in the formation of polymer complexes by providing a hydrogen bonding source [8]. Nickel oxide is a mineral composed of nickel and oxygen NiO is a transition metal oxide with a cubic lattice structure that is widely used. It has gained popularity as a result of its potential applications in a range of fields, including: substrate for the lanthanum aluminate-strontium titanate interface. Strontium titanate

can be made electrically conductive by doping it with niobium, making it one of the few commercially available conductive single crystal substrates for the formation of perovskite oxides. Its bulk lattice parameter of 3.905 makes it a good substrate for the formation of a variety of different oxides, such as rare-earth manganite's catalysis [9]. SrTiO₃ is an effective epitaxial growth substrate for high-temperature superconductors and a variety of oxide-based thin films. It's well known for being the growth and titanates [10]. This work deal with preparation and characteristics of nanocomposites for electrical and electronics applications.

I. Materials and Methods

By casting nickel oxide (NiO) nanoparticles and strontium titanate (SrTiO₃) into polyvinyl alcohol (PVA) and poly(ethylene oxide) (PEO) with varied concentrations are (0,1%,2%, 3%, and 4%) in 50 ml of water, polymers nanocomposites were created. Dielectric characteristics of (PEO/PVA/SrTiO₃/NiO) nanocomposites (dielectric constant, dielectric loss, and conductivity) were measured at room temperature using a (LCR Meter) in the range of frequency (f) (100Hz -5MHz)

The following formula is used to compute the dielectric constant (ε') [11,12,13]

$$\epsilon' = C_p / C_0 \tag{1}$$

C_p denotes capacitance and (C₀) denotes a vacuum capacitor. Dielectric loss (ε'') is given by [14,15]

$$\epsilon'' = \epsilon' \cdot D \tag{2}$$

The dispersion factor (D) is used here. The conductivity is calculated as follows [16,17]

$$\sigma a. c = \omega \epsilon'' \cdot \epsilon' \tag{3}$$

II. Results and Discussion

2.1. Scanning Electron Microscope (SEM) Measurements

Scanning electron micrographs of pure (PEO/PVA) blend and (1,2,3,4) wt. percent of (SrTiO₃/NiO) NPs are displayed in figure 1 (A-B-C-D-E). Different alterations Pure (PEO/PVA) to low, moderate, and high concentrations of (SrTiO₃/NiO) nanoparticles have been observed. In the pure (PEO/PVA) mixture, the smooth surface of the (PEO/PVA) blend can be seen. Tiny and few agglomerations of (SrTiO₃/NiO) nanoparticles were observed in (figure 1 B), which contains 1wt% of (SrTiO₃/NiO) nanoparticles, implying that (SrTiO₃/NiO) nanoparticles can be well disseminated in a (PEO/PVA) blend, resulting in a homogenous, dense film with no visible phase separation. With a concentration of (SrTiO₃/NiO) NPs of 2%, agglomerations were formed (figure1C), while certain semi-tori of various sizes appeared as bright spots in all of them with varying degrees of roughness in (PEO/PVA) 3wt% of (SrTiO₃/NiO) NPs generated samples (figure1D), these bright spots appear to be agglomerates of (SrTiO₃/NiO) NPs that grow in size as the concentration of (SrTiO₃/NiO)

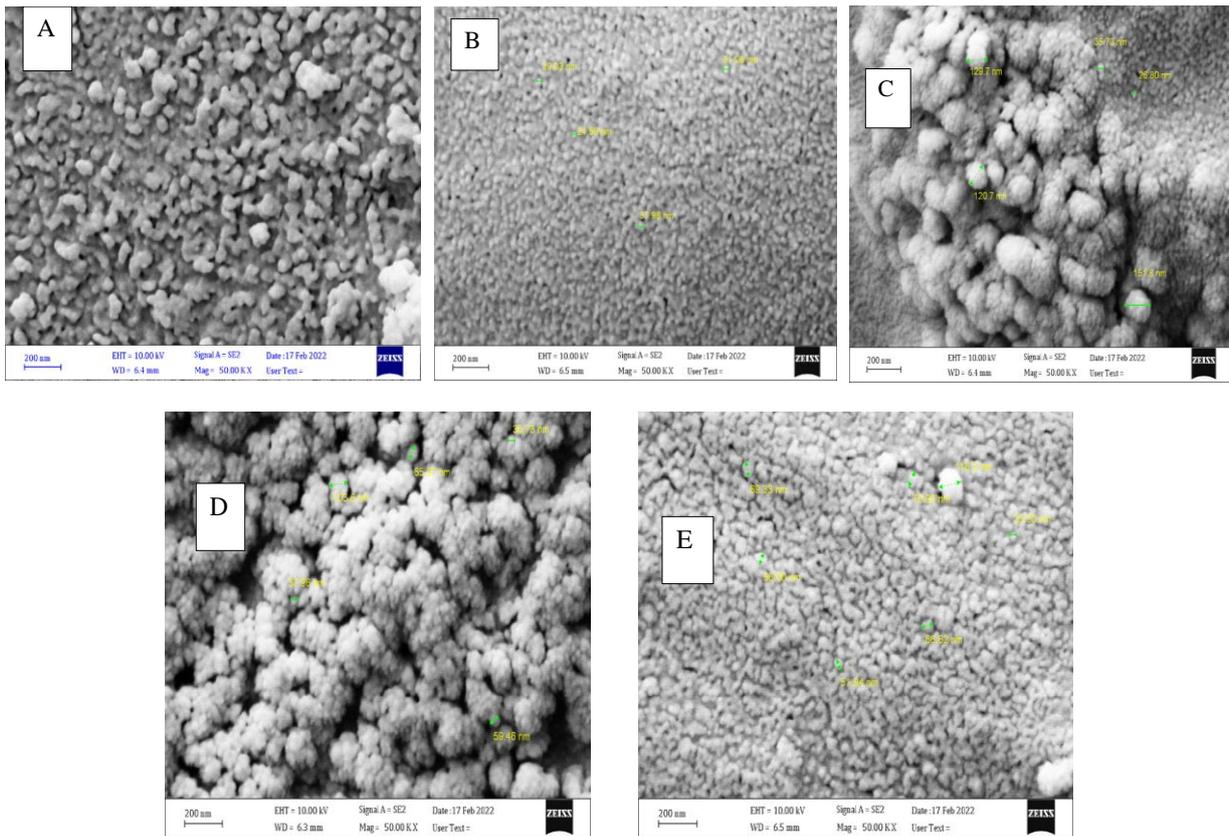


Fig. 1. SEM images for (PEO/PVA/SrTiO₃/NiO) NCs: (A) for (PEO/PVA) pure, (B) for 1 wt% SrTiO₃/NiO, (C) for 2 wt% SrTiO₃/NiO, (D) for 3 wt% SrTiO₃/NiO (E) for 4 wt% SrTiO₃/NiO.

nanoparticles increases. As seen in (figure 1E) 4wt percent, the degree of roughness of the film surface increases. This could indicate filler segregation in the host matrix, implying additive-polymer interaction and complications. It may also refer to the formation of (SrTiO₃/NiO) nanoparticles in a (PEO/PVA) blend matrix [18,19,20].

2.2. Fourier Transform Infrared Ray (FT-IR) Analysis

The FT-IR spectra of (PEO/PVA/SrTiO₃/NiO) NCs are shown in figure 2. At ambient temperature, FT-IR spectra of pure (PEO/ PVA) blend and doped by (SrTiO₃/NiO) nanoparticles in the range 4000–500 cm⁻¹ were collected. The presence of the stretching vibration of the hydroxyl group OH of (PEO/PVA) is responsible for the prominent peaks in the spectra at (2881) cm⁻¹. The

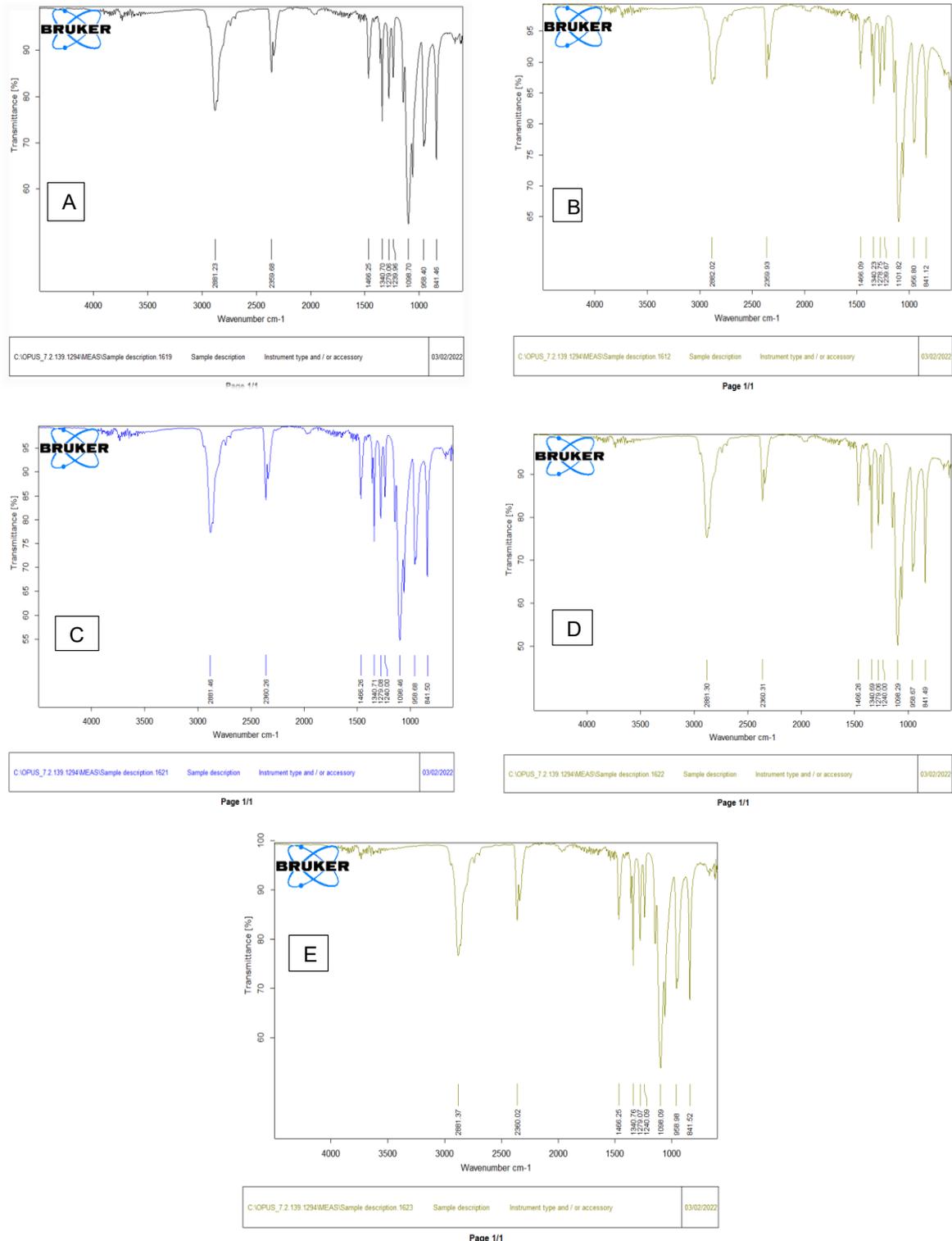


Fig. 2. FT-IR spectra for (PEO/PVA/SrTiO₃/NiO) NCs. (A) for (PEO/PVA) blend, (B) (b) for 1 wt% SrTiO₃/NiO, (C) for 2 wt% SrTiO₃/NiO, (D) for 3 wt% SrTiO₃/NiO (E) for 4 wt% SrTiO₃/NiO.

C=O stretching mode is thought to be responsible for the absorbent peak at $(2359) \text{ cm}^{-1}$. Asymmetric stretching and scissoring bending vibrations of the CH_2 group appear at $(1098) \text{ cm}^{-1}$. The photos demonstrate the bonding nature of (PEO/PVA/SrTiO₃/NiO) nanocomposites with polymers. According to the FT-IR analysis, there are no interactions between the (PEO/PVA) blend and the (SrTiO₃/NiO) NPs. Furthermore, we can see in these data that when the concentration of (SrTiO₃/NiO) nanoparticles increases, the transmittance decreases dramatically due to the increased density of nanocomposites [21,22,23].

2.3. The A.C Electrical Characteristics of (PEO/PVA/SrTiO₃/NiO) NCs

Figure. 3. The dielectric constant of (PEO/PVA/SrTiO₃/NiO) NCs films (0,1,2,3,4) wt. % is plotted as a function of frequency. Dielectric constant fall with increasing frequency; this phenomenon is due to the presence of multiple types of polarizations in the composites. Composite materials are well recognized for having a large number of interfaces, and the large number of defects present at these interfaces can cause a shift in the distribution of positive or negative space charges. When these charges are exposed to an electric field, they move and become trapped by the defects, creating dipole

moments. This is referred to as interfacial or space charge polarization. When these dipoles are exposed to an electric field, they rotate, causing a current to flow through them. The diminishing tendency appears to be less prominent in the high frequency region ($1 \cdot 10^3$ to $1 \cdot 10^7$ Hz) than in the lower frequency zone. The dipole's difficulty to orient itself in a rapidly changing electric field [20] could explain it. The accumulation of charges at the interfaces causes the interfacial polarization effect, which happens in a heterogeneous system composed of phases with different dielectric permittivity and conductivities. In any case, the dipole moment exists because there are many particles per unit volume [24,25,26].

Figure. 4. illustrates the variation in dielectric constant for varying content of (SrTiO₃/NiO) nanoparticle in (PEO/PVA) mixture at a specific frequency of 100 Hz. At 4wt%, the dielectric constant grew monotonically as the additive amount climbed from 4.73 to 5.99. As the (SrTiO₃/NiO) concentration increase, the number of defects at grain borders, dangling bonds, and vacancies rises, these flaws will cause an increasing number of dipole moments. As a result, raising the dipole moment raises the dielectric constant of the nanocomposites [27,28,29].

Figure. 5. As a function of frequency, plot dielectric loss of (PEO/PVA/SrTiO₃/NiO) NCs. Because of a

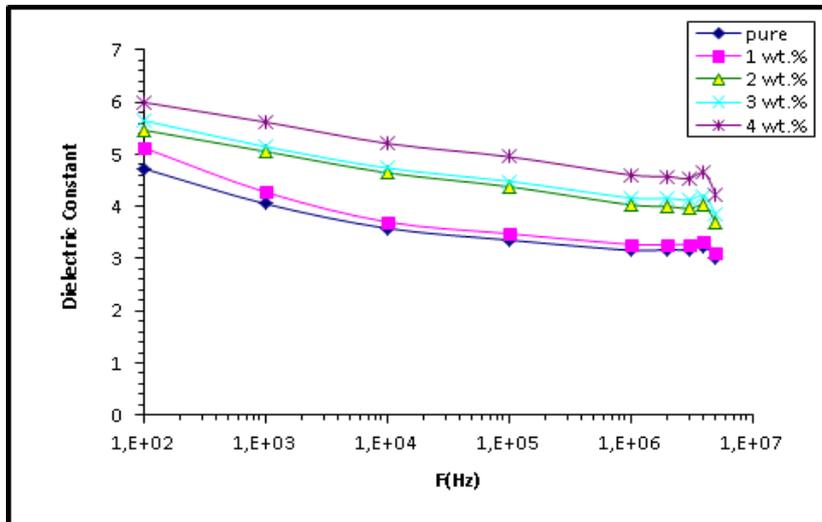


Fig. 3. For (PEO/ PVA /SrTiO₃/NiO) NCs, the dielectric constant varies with frequency.

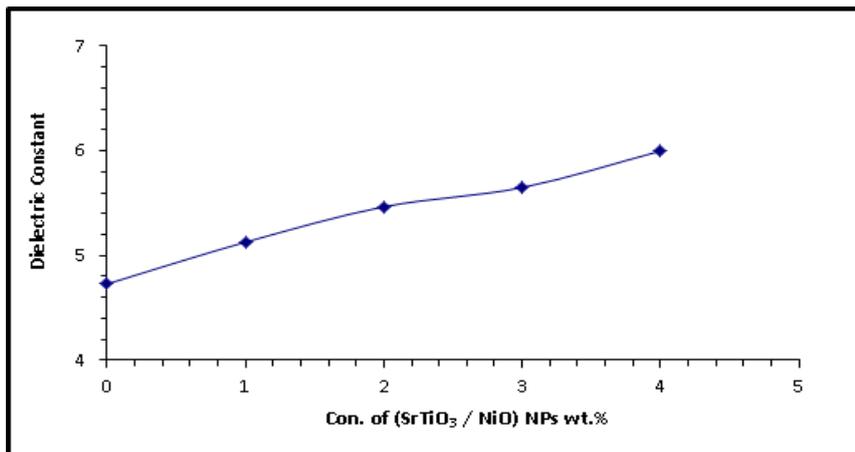


Fig. 4. Difference of dielectric constant with concentration of (SrTiO₃/NiO) NPs for (PEO/ PVA /SrTiO₃/ NiO) NCs.

decrease in the space charge polarization contribution and the inability of dipoles to rotate quickly, as the frequency of the applied electric field increases, the dielectric loss of all NCs samples decreases, resulting in a frequency gap between the oscillating dipole and the applied field. Due to free charge motion inside the material, the dielectric loss for (PEO/PVA/SrTiO₃/NiO) NCs becomes quite significant at lower frequencies. Furthermore, these NCs have a significant dielectric loss because electric dipoles have ample time to align with the applied electric field before their orientation changes [30,31,32].

At 100 Hz, figure. (6) shows how dielectric loss varies with concentrations of (SrTiO₃/NiO) NPs in a (PEO/PVA) blend. A dielectric loss of (PEO/PVA/SrTiO₃/NiO) NCs increases as the NP concentration rises from 0.85 to 1.80 at 4wt%, which is due to an increase in the number of charge carriers in the material. When the concentration of (SrTiO₃/NiO) NPs is low, they form clusters, but when the concentration reaches 4 wt. percent, they form a path network in the (PEO/PVA/SrTiO₃/NiO) NCs. [33,34].

Figure. 7. illustrates the A.C conductivity of (PEO/PVA/ SrTiO₃/NiO) NCs as a function of frequency. The conductivity of alternating current increases with frequency, and the increase in NCs conductivity with frequency is a common response for polymeric and

semiconductor materials. It's because composite systems have significantly improved charge carrier mobility [35]. As the additive concentration increases, the additive molecules begin to bridge the gap between the two localized states and lower the potential barrier between them, allowing charge carriers to move between them more freely [36]. The polymer's segmental mobility also aids the translational ionic action. The fact that translational motion causes ionic motion is self-evident. [37,38].

Figure. 8. displays the A.C electrical conductivity of NCs made of (PEO/PVA/SrTiO₃/NiO). vs nanoparticle concentrations at 100Hz. A.C electrical conductivity increases from 4.710^{-11} S/cm to 1.1010^{-10} S/cm when (SrTiO₃/NiO) nanoparticle concentrations are increased by 4wt%. This is due to the dopant nanoparticles composition increasing the quantity of charge carriers, lowering the resistance of NCs and increasing the conductivity. Furthermore, (SrTiO₃/NiO) nanoparticles form a route network in nanocomposites, particularly at nanoparticle concentrations of 4 wt.% for (PEO/PVA /SrTiO₃/NiO) NCs [39,40,41].

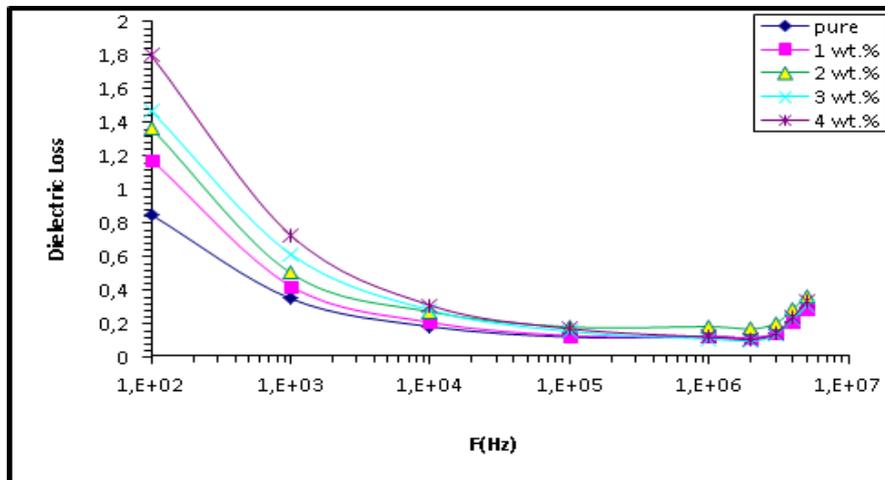


Fig. 5. Dielectric loss difference with frequency for (PEO/ PVA/SrTiO₃/NiO) NCs.

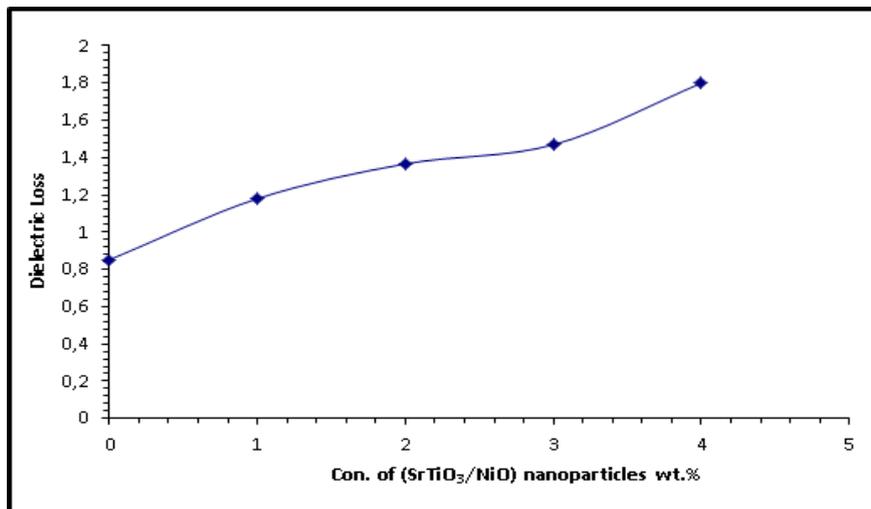


Fig. 6. Difference of dielectric loss with concentration of (SrTiO₃/NiO) NPs for (PEO/ PVA /SrTiO₃/NiO) NCs.

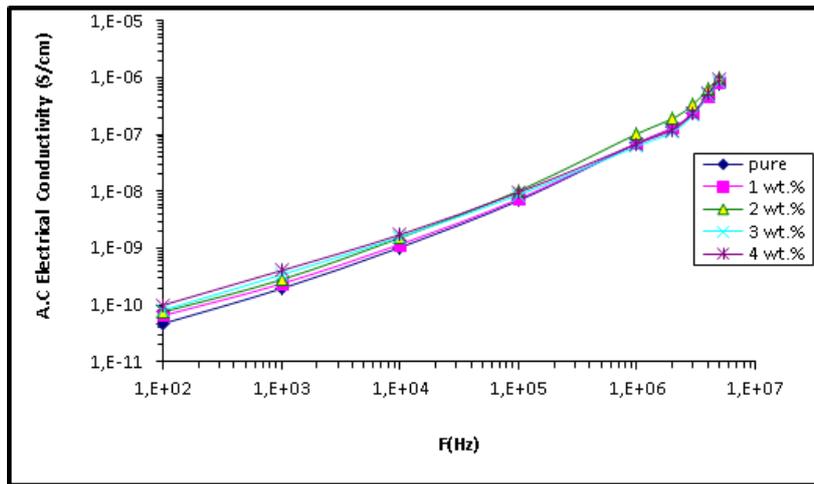


Fig. 7. Difference of conductivity for (PEO/ PVA/SrTiO₃/NiO) NCs with frequency.

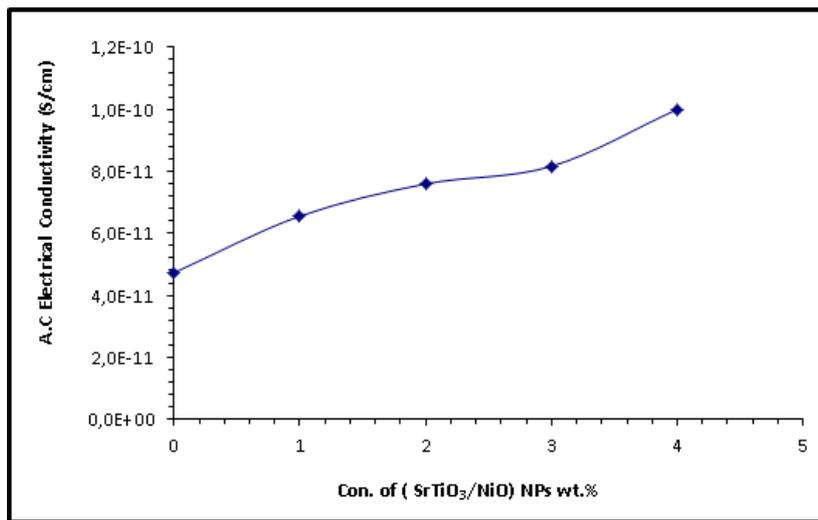


Fig. 8. Difference of conductivity with (SrTiO₃/NiO) nanoparticles concentration for (PEO/ PVA /SrTiO₃/ NiO) NCs.

Conclusion

The surface morphology of the (PVA/PEO/SrTiO₃/NiO) NCs films is depicted by scanning electron microscopy (SEM), which exhibits various pieces or aggregates randomly spread throughout the top surface that are uniform and consistent. The (FT-IR) study demonstrated that the (PVA/PEO/SrTiO₃/NiO) NCs allow for small vibrational molecular mobility, and that the inclusion of (SrTiO₃/NiO) nanoparticles shattered specific polymer manacles. Instead, a slew of new chains sprouted. When the frequency is increased, the dielectric constant and dielectric loss decreases, while conductivity

increases. When the concentration of (SrTiO₃/NiO) NPs is increased, the dielectric constant, dielectric loss, and conductivity increases. As a result, the ratio of (SrTiO₃/NiO) NPs reach 4wt% shows dramatic changes in dielectric properties. According to these results can be used the (PVA/PEO/SrTiO₃/NiO) NCs in the electrical and electronics devices.

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Виготовлення та дослідження структурних і діелектричних характеристик наноструктур (SrTiO₃/NiO), легованих полімерною сумішшю (PEO/PVA) для електроніки

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Плівки виготовляли із суміші (PEO/PVA) у різних співвідношеннях (SrTiO₃/NiO) методом лиття. SEM-зображення нанокомпозитів (PEO/PVA/SrTiO₃/NiO) показали, що більшість частин на верхній поверхні є однорідними та когерентними. Відповідно до аналізу FTIR, нанокомпозити (PEO/PVA/SrTiO₃/NiO) сприяють незначному коливальному руху молекул. Кілька полімерних ланцюжків були розірваними після введення наночастинок (SrTiO₃/NiO). Замість них виготовляли кілька додаткових ланцюжків. Показано, що діелектрична проникність і діелектричні втрати зменшуються зі збільшенням частоти, тоді як провідність зростає, а також діелектрична проникність збільшується з 4,73 до 5,99, а діелектричні втрати збільшуються з 0,85 до 1,80, тоді як провідність збільшується з $4,7 \times 10^{-11}$ См/см до $1,10 \times 10^{-10}$ См/см, коли НЧ (SrTiO₃/NiO) досягають 4 мас.%. Результати структурних та електричних властивостей показують, що НК (PEO/PVA/SrTiO₃/NiO) мають перспективу використання для різних галузей електроніки.

Ключові слова: полімерна суміш, електричні властивості, наночастинки (SrTiO₃/NiO), структурні властивості.