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Fabrication of PVA/NiO/SiC Nanocomposites and Studying their Dielectric Properties for Antibacterial Applications

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PREPARATION of PVA/NiO/SiC nanocomposites and studying their dielectric properties for antibacterial applications have been investigated. The A.C electrical properties of nanocomposites were studied in frequency ranging (100-5×106) Hz at room temperature. The experimental results showed that the dielectric constant and dielectric loss of (PVA-NiO-SiC) nanocomposites were decreased with an increasing the frequency of applied electric field. The A.C electrical conductivity increases with increasing of frequency. The dielectric constant, dielectric loss and A.C electrical conductivity of (PVA-NiO) nanocomposites were increased with increasing of SiC nanoparticles concentrations. The antibacterial applications for (PVA-NiO-SiC) nanocomposites tested against gram-positive (*S. aureus*) and gram-negative (*E. coli*). The results showed that the inhibition zone was increased with increase the concentrations of SiC nanoparticles.

Keywords: Antibacterial, Conductivity, Dielectric properties, Nanocomposites.

Introduction

The studies of metal oxide nanoparticles / Polymer nanocomposites are creating increasing attentionowing to their possible applications in memory, recording heads, microwave devices and household electronics [1]. Nanoparticles on the base of the polymer matrix and semiconductor nanoparticles are future materials for application in optoelectronics [2], sensor electronics, For making of luminescent materials [3]. The physicochemical properties of the system changes whenintroducing semiconductor nanoparticles into polymer matrix volume. The properties of the obtained structures depend on dimensions of the particles,semiconductor particle kind. Also, the physicochemical properties of the system will be under influenceof the effects of interaction of nanoparticles with polymer matrix [4]. The formation of nanocomposites can be formation inseveralmethods[5].Technology of obtaining nanocomposites can effect on polymer matrixvolume, distribution of nanoparticles in adimensions of nanoparticles and etc [6]. Due the good dispersibility in the polymeric system, nickel oxide (NiO) is considered as the potential candidates in the fabrication of engineering nanomaterials for multifunctional applications. NiO nanofillers is being incorporated into the polymeric matrix for developing polymer nanocomposites with improved electrical and dielectric properties. Nickel based transition metal oxides with remarkable electrochemical properties have become a new kind of energy-storing materials [7]. Silicon Carbide (SiC) is one of promising filter ceramics for elevatedtemperature structural components because of its excellent mechanical, electrical and thermal properties likefracture strength, high elastic modulus, hardness and toughness, chemical stability, relatively low density and good thermal conductivity as well as low thermal expansion co-efficient and high resistivity [8]. A blend of SiC with metals/metal oxides recompensesit'san expands inbrittleness and engineering applications [9]. Without adding of any metal oxide or metal as sintering aids, be actual difficult to sinter pure form SiC through conventional heating technique because SiC needs a higher temperature above 2000°C to be sintered. The oxide phase improves the fracture toughness of the materialsand really decreases the sintering temperature [10]. The addition of NiO nanoparticles into polyvinyl alcohol (PVA) matrix is expected to achieve conductive polymer nanocomposites with unique properties, which can be used as multifunctional material for

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different applications [11]. Organic compounds used for disinfection have some disadvantages, including toxicity to the human body, therefore, the interest in inorganic disinfectants such as metal oxide nanoparticles (NPs) is increasing [12]. Highly ionic nanoparticles metal oxides may be particularly important antimicrobial agents as they can be prepared with unusual crystal morphologies and extremely high surface areas [13]. Metal oxide nanoparticles (e.g., ZnO, CuO, and NiO) have good antibacterial activities but they are not highly effective against foodborne illnesses [14]. The effect of Silicon Carbide (SiC) nanoparticles on A.C Electrical Propertiesof (PVA–NiO–SiC) nanocomposites and their application has been treated in this paper this paper.

Experimental

Polyvinyl alcohol-Silicon Carbide-nickel oxidenanocomposites were prepared throughutilize casting technique withweight percentage of polymer PVA is (98.5 wt.%) and (1.5 wt.%) nickel oxide nanoparticles .Nanocomposites of (PVA-NiO-SiC) were prepared with altered weight percentages of Silicon Carbide nanoparticles which was add up to (PVA-NiO) are (1.5, 3, 4.5 and 6wt.%).

Dielectric materials can be used to store electrical energy in the form of charge separation when the electron distributions around constituent atoms or molecules are polarized by an external electric field. The complex permittivity of a material can be expressed as [15]:

$$\varepsilon^{*} = \varepsilon_a - j\varepsilon_b \qquad \text{……….(1)}$$

Where ε_a and ε_b are the real and imaginary parts of the complex permittivity and j = √-1.

The real part of the permittivity is given by [15]:

$$\varepsilon_a = \varepsilon_0 \varepsilon^{-} \qquad \text{……..(2)}$$

The magnitude of ε_a (or the dielectric constant) indicates the ability of the material to store energy from the applied electric field [15]. The capacitance of a capacitor constructed of two parallel plates is given by the equation [16]:

$$C = \varepsilon^{-} \varepsilon_o \frac{A}{t} \qquad \text{………… (3)}$$

Where ε^{-} is dielectric constant, t is thickness of the sample and ε_o is vacuum permittivity. The dielectric constant is given by [17]:

$$\varepsilon^{-} = \frac{C_p}{C_o} \qquad \text{………… (4)}$$

Where C_p is parallel capacitance and C_o is vacuum capacitor.

As the polarization of a material under an electric field varies, some of the applied electric field energy is dissipated due to charge migration (i.e., conduction) or conversion into thermal energy (e.g., molecular vibration). Ceramic capacitors based on highly polarizable inorganic materials have traditionally been used to meet the need for pulse power applications [18]. The dielectric loss (ε″) is given by [19]:

$$\varepsilon'' = \varepsilon^{-} D \qquad \text{……….(5)}$$

Where D is dispersion factor. And this measures the lost electrical energy in the sample from the applied field which is transformed to thermal energy in the sample. The dissipated power in the insulator is represented by the existence of alternating potential as a function of the alternating conductivity is given by [20]:

$$\sigma_{ac} = \omega\, \varepsilon''\, \varepsilon_0 \qquad \text{……… (6)}$$

Where ω is the angular frequency.

Results and Discussion

Figure 1 shows the variation of dielectric constant with concentrations of nanaparticles for (PVA-NiO-SiC) nanocomposites at 100 Hz. As shown in the figure, the dielectric constant of nanocomposites increases with the increasing of the concentration of SiC nanoparticles, this behavior could be interpreted from interfacial polarization inside the nanocomposites in applied alternating electric field and increasing of the charge carriers [21]. The variation of dielectric constant of (PVA-NiO-SiC) nanocomposites with frequency are shown in Fig. 2. The figure shows that the dielectric constant of the samples of nanocomposites decreases with the increasing of the frequency of applied field, this may be attributed to the tendency of dipoles in nanocomposites samples to orient themselves in the direction of the electric applied field and decreasing of space charge polarization to the total polarization [22].

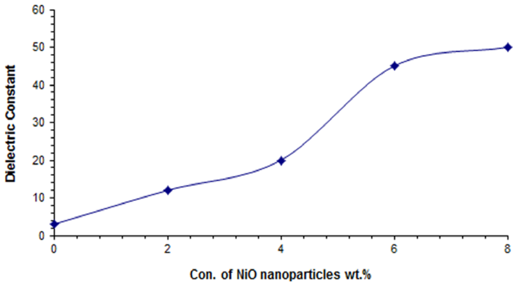

Fig. 1. Effect of SiC nanoparticles concentrations on dielectric constant for (PVA-NiO-SiC) nanocomposites at 100 Hz.

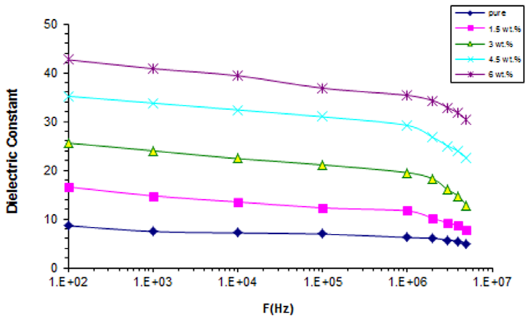

Fig. 2. Variation of dielectric constant for (PVA-NiO-SiC) nanocomposites with frequency at room temperature.

Figure 3 shows the effect of concentrations for SiC nanoparticles on dielectric loss of (PVA-NiO) nanocomposites at 100 Hz. The figure shows that the dielectric loss of (PVA-NiO-SiC) nanocomposites increases with the increasing of the concentrations for SiC nanoparticles. The increases of dielectric loss of (PVA-NiO) with the increasing of concentrations for SiC nanoparticles related to the increases of the charge carriers number.The variation of dielectric loss of (PVA-NiO-SiC) nanocomposites with frequency are shown in Fig. 4. The dielectric loss of the samples for nanocomposites decreases with the increasing of the frequency of applied electric field, this behavior attributed to the decreases of the space charge polarization contribution. From the figures, the dielectric loss has high value for (PVA-NiO-SiC) nanocomposites at low frequency, and it is decreasing when increasing the frequency, this is due to the electric dipoles have sufficient time to align with the applied electric field before the electric field changes its direction; consequently the dielectric constant of nanocomposites is high. At high frequencies, the dielectric constant value decreases due to the shorter time available for the dipoles to align [23].

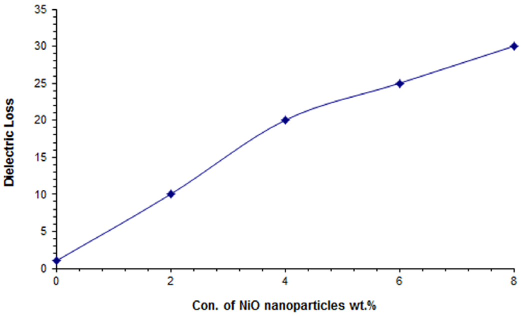

Fig. 3. Effect of SiC nanoparticles concentrations on dielectric loss for (PVA-NiO) nanocomposites at 100 Hz.

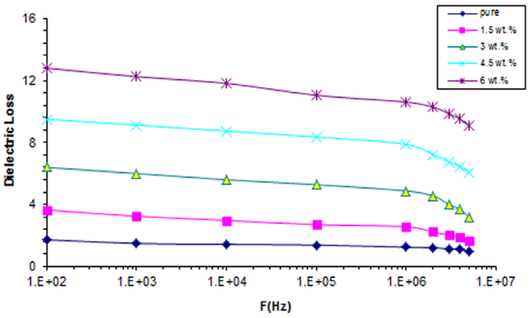

Fig. 4. Variation of dielectric loss for (PVA-NiO-SiC) nanocomposites with frequency at room temperature..

The variation of A.C electrical conductivity for (PVA-NiO) nanocomposites with concentrations of SiC nanoparticles are shown in Fig. 5, respectively at 100 Hz. As is shown in the figure, the A.C electrical conductivity of nanocomposites increases with the increasing of the SiC nanoparticles concentrations. This is increases of the conductivity caused by the increase in the number of charge carriers due to dopant nanoparticles composition which reduces the resistance of nanocomposite and increases the A.C electrical conductivity [24-29]. Figure 6 shows the variation of A.C electrical conductivity of(PVA-NiO-SiC) nanocomposites with frequency respectively at room temperature. The A.C electrical conductivity increases with increasing of the frequency of electric field for two samples of nanocomposites, this behavior attributed to the mobility of charge carriers and the hopping of ions from the cluster. In the low frequency, more charge accumulation occurred at the electrode and electrolyte interface, leading to a decrease in the number of mobile ions and electrical conductivity [30].The mobility of charge carriers was higher in the high-frequency region; hence the electrical conductivity increases with frequency for (PVA-NiO-SiC) nanocomposites [31].

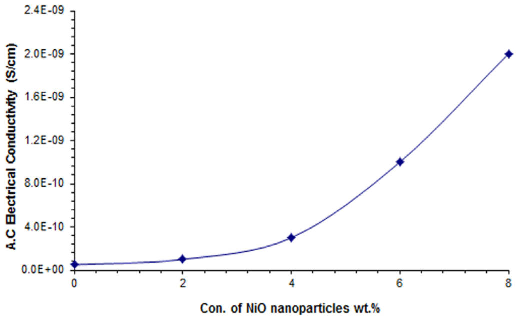

Fig. 5. Effect of SiC nanoparticles concentrations on A.C electrical conductivity for (PVA-NiO) nanocomposites at 100 Hz.

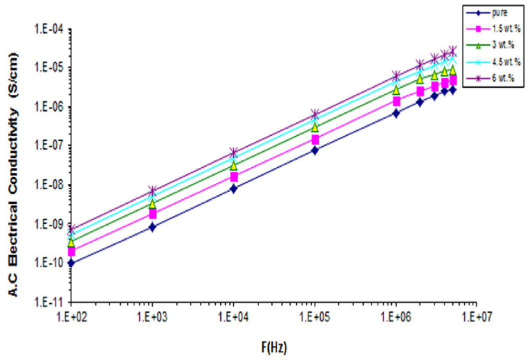

Fig. 6. Variation of A.C electrical conductivity for (PVA-NiO-SiC) nanocomposites with frequency at room temperature.

The antibacterial properties of the (PVA-NiO-SiC) nanocomposites were examined against gram-positive (Staphylococcus aureus) and gram-negative (*Escherichia coli*) and the get data are show in Fig. 7 and 8.

There are some methods to make polymersantibacterial such as ionizing radiation, but they can be still infected by microorganisms during usage of them .The best and easy way to obtain antibacterial polymers is melt mixing of polymers with antibacterial agents [32]. In this study, NanoNiO and SiC particles were mixed withpolymer (PVA).NiO nanoparticles have large surface area available to facilitate the interactions that increases bactericidal effect compared to large sized particles; hence they impartincrementin cytotoxicity to the microorganisms [33]. The synthesized NiO nanomaterial has reduced particle size accompanied with large surface to volume ratio, it facilitates the interaction and enhances the antibacterial activity than the micron sized particles.When the light is incident on NiO nanomaterial, whose photon energy is higher than the band gap Eg, because of the photoexcitation there will be a formation of holes (h+) in the valence band and electrons (e−) in the conduction band. They have high redox properties and hence react with molecular oxygen (O_2) and hydroxyl ions (%OH) to generate various ROS%. When molecular oxygen traps the electron, it generates superoxide anion (O_2 %−), hydrogen peroxide (H_2O_2%) and hydroxyl radicals (•OH). Superoxide anion reacts with water molecules and there will be absorption of electrons from water and hydroxyl ions from the holes for the mineralization of bacterial cells. The production of ROS% is mandatory and they are the dominant species to decide the cell death, since it induces oxidative stress, and lead to the damage of cell membrane, protein deactivation, interrupt in the electron transport, damages DNA and mitochondria, and thus results in cell death,because of the use of NiO having high stability, smaller size and spherical morphology [34-39].

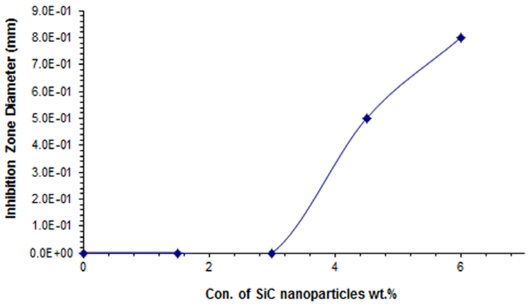

Fig. 7. Antibacterial effect of (PVA-NiO) blend as a function of SiC nanoparticles concentrations on *S. aureus*.

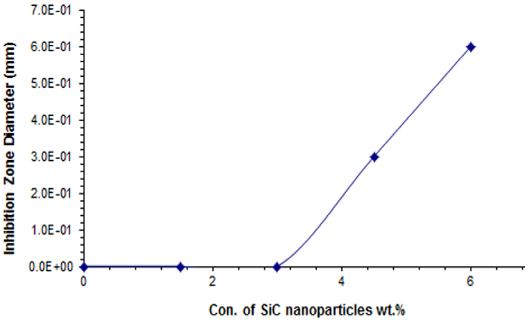

Fig. 8. Antibacterial effect of (PVA-NiO) blend as a function of SiC nanoparticles concentrations on *E. coli.*

Conclusions

The dielectric constant, dielectric loss and A.C electrical conductivity of (PVA-NiO) nanocomposites increase with increasing SiC nanoparticles concentrations. The dielectric constant and dielectric loss of nanocomposites are decreased with increase the frequency. The A.C electrical conductivity is increased with increase the frequency. The inhibition zones for S.aureus and E.coli are increased with an increase the concentration of SiC nanoparticles .

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تصنيع متراكبات PVA/NiO/SiC النانوية ودراسة خصائصها العزلية للتطبيقات المضادة للبكتريا

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تم تحضير متراكبات PVA/NiO/SiC النانوية ودراسة خصائصها العزلية للتطبيقات المضادة للبكتريا. الخصائص الكهربائية المتناوبة للمتراكبات النانوية درست ضمن مدى تردد (5-100×10^6) هرتز عند درجة حرارة الغزفة. النتائج التجريبية بينت أن ثابت العزل والفقدان العزلي لمتراكبات (PVA-NiO-SiC) النانوية يقلان مع زيادة تردد المجال الكهربائي المسلط. التوصيلية الكهربائية المتناوبة تزداد مع زيادة التردد. أن ثابت العزل، والفقدان العزلي والتوصيلية الكهربائية المتناوبة لمتراكبات (PVA-NiO) النانوية تزداد مع زيادة تراكيز جسيمات SiC النانوية. التطبيقات المضادة للبكتريا لمتراكبات (PVA-NiO-SiC) النانوية اختبرت ضد بكتريا موجبة الغرام (*S. aureus*) وسالبة الغرام (*E. coli*). النتائج بينت أن منطقة التثبيط تزداد مع زيادة تراكيز جسيمات SiC النانوية.