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Exploring the Dielectric Properties of PVP/Ag/SiC Nanostructures to Use in Various Electronics Fields

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This work objects to fabrication of PVP/Ag/SiC nanostructures and investigation of the dielectric properties to use them in various electronics applications with lightweight and low cost. The results demonstrate that the dielectric constant and dielectric loss of PVP/Ag/SiC nanostructures are reduced, while the electrical conductivity is increased with an increase in the frequency. The dielectric constant, dielectric loss, and electrical conductivity are increased with an increase of the concentration. Finally, the results of dielectric properties indicate that the PVP/Ag/SiC nanostructures can be suitable in different electronics fields.

Цю роботу спрямовано на виготовлення наноструктур полівінілпіролідон/Ag/SiC та дослідження діелектричних властивостей для використання їх у різних електронних застосуваннях з легкою вагою та низькою ціною. Результати показують, що діелектрична проникність і діелектричні втрати наноструктур полівінілпіролідон/Ag/SiC зменшуються, а електропровідність зростає зі збільшенням частоти. Діелектрична проникність, діелектричні втрати й електропровідність зростають зі збільшенням концентрації. Нарешті, результати стосовно діелектричних властивостей показують, що наноструктури полівінілпіролідон/Ag/SiC можуть бути придатними у різних галузях електроніки.

Key words: polyvinylpyrrolidone, Ag/SiC, nanostructures, dielectric properties, electronics fields.

Ключові слова: полівінілпіролідон, Ag/SiC, наноструктури, діелектричні властивості, галузі електроніки.

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1. INTRODUCTION

Polymer nanocomposites are one of the most important materials in the academic and industrial areas, and are produced by dispersing nanofillers with one or more dimensions at nanoscale into the polymeric matrix.

Recently, researchers have been attracted to polymer nanocomposites over conventional microcomposites due to their wide applications in electromechanical systems and their large interfacial area per unit volume of the dispersion medium [1].

Organic/inorganic nanocomposites are extremely promising for applications in light-emitting diodes, photodiodes, photovoltaic cells, smart microelectronic device, and gas sensors among others. The properties of nanocomposites' films can be adjusted by varying the composition. Their fabrication shares the same advantages of organic device technology, such as low cost production and the possibility of device fabrication on large area and flexible substrates [2].

Among noble metal nanoparticles, silver has been extensively studied due to the possibilities for their use in different areas of nonlinear optics, optoelectronics, and laser physics. Silver nanoparticles are advantageous compared with nanoparticles of other noble metals (in particular, gold and copper) as the energy of the surface plasmon resonance lies far from the energy corresponding to interband transitions. This allows one to distinguish clearly the effect of surface plasmons on different optical properties.

Therefore, nanocomposites, in which the silver nanoparticles are dispersed in a dielectric matrix, have some advantages in this regard [3].

Silicon carbide (SiC) nanoparticles have high thermal conductivity, stability, purity, good wear resistance, and a low thermal expansion coefficient. At high temperatures, these particles are also resistant to oxidation [4].

Polyvinylpyrrolidone (PVP) has chosen because it has excellent characteristics such as optical, mechanical and electrical properties. PVP has ad-chive nature. Thus, it may be used in electronic circuit boards and display device applications. PVP has good compatibility and can easily form films with large internal area [5].

The nanocomposites materials were suggested to utilize in different applications such as optical fields [6–15], antibacterial [16–21], sensors [22, 23], radiation shielding and bioenvironmental [24–29], energy storage [30–32], electronics and optoelectronics [33–46].

This article aims to prepare of PVP/Ag/SiC nanostructures and studying the dielectric properties to utilize in different electronics fields.

2. MATERIALS AND METHODS

Nanocomposites films of PVP doped with Ag/SiC nanoparticles were fabricated using casting process with different concentrations ($C_1 = 12.5$ gm/L, $C_2 = 25$ gm/L, and $C_3 = 50$ gm/L). Ag–SiC nanoparticles (NPs) with a ratio of 6% were added to polymer with content of 50% Ag and 50% SiC. The dielectric properties of PVP/Ag/SiC nanostructures films were measured at frequency range 100 Hz–$5 \cdot 10^6$ Hz by LCR meter (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant (ε') was determined by [47]:

$$\varepsilon' = C_p/C_0, \tag{1}$$

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

Dielectric loss (ε'') was given by [47]:

$$\varepsilon'' = \varepsilon' D, \tag{2}$$

where D is the dispersion factor.

The A.C. electrical conductivity was found [48] as follows:

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

4. RESULTS AND DISCUSSION

The behaviours of dielectric constant and dielectric loss with frequency and concentration are shown in Figs. 1–4, respectively. It can be seen that with increasing frequency dielectric constant (ε'), dielectric loss (ε'') decreases. This is because of the available relaxation time of the polymer. At low frequencies, polymer molecules get sufficient time to orient themselves according to the applied field. However, as the frequency increases, molecules are not getting sufficient time to orient themselves according to the direction of the electrical field.

Therefore, the overall polarization effect decreases and, consequently, the value of dielectric constant decreases too, as it is directly proportional to the value of polarization. At high frequencies, as the polarization decreases, the dielectric loss and dissipation factor, also decreases as sufficient time is not provided to the polymer chain to generate phase angle. Thus, at high frequencies, the contribution of orientational or dipole polarization vanishes and the effect is only for electronic polarization, which is instantaneous. The dielectric constant and dielectric loss increase with rising concentration that relates to increase in charge carriers [49–60].

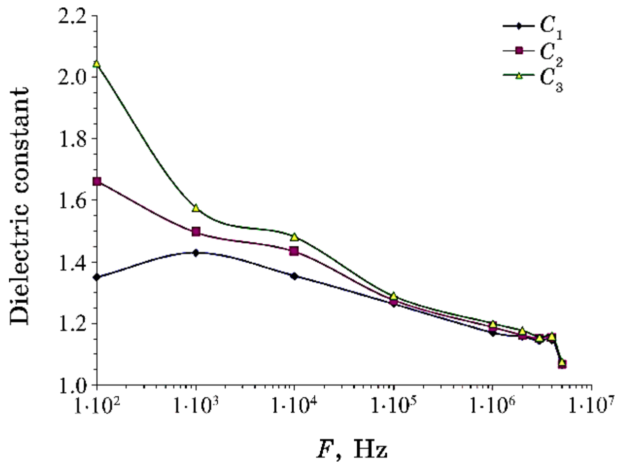

Fig. 1. Behaviour of dielectric constant with frequency for the PVP/Ag/SiC nanostructures.

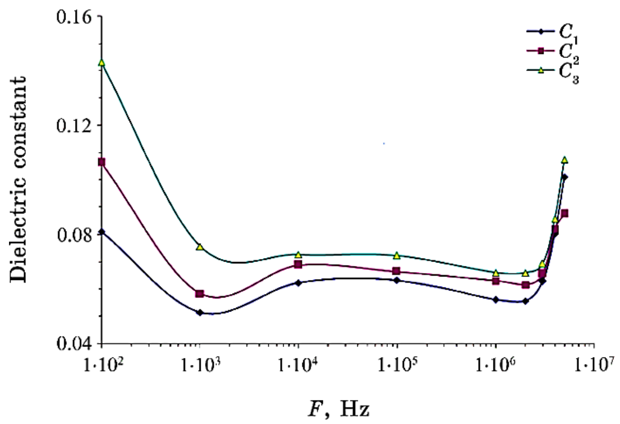

Fig. 2. Dielectric loss performance with frequency for the PVP/Ag/SiC nanostructures.

Figures 5 and 6 show the variation of A.C. conductivity for PVP/Ag/SiC nanostructures films with frequency for varied concentrations. As shown in these figures, the electrical conductivity increases with increasing the concentration, because the distributed Ag/SiC NPs in the polymer matrix has increased the number of conductive pathways and rise in the charge-carriers' numbers. In addition, the conductivity of PVP/Ag/SiC nanostructures films increases with rising of the frequency. The dependence of conductivity with the frequency is caused by the hopping of carriers of charge in the localized levels [61–68].

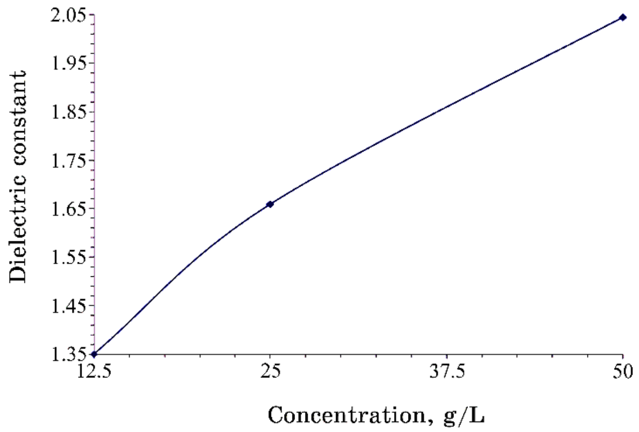

Fig. 3. Dielectric constant variation for the PVP/Ag/SiC nanostructures with concentration.

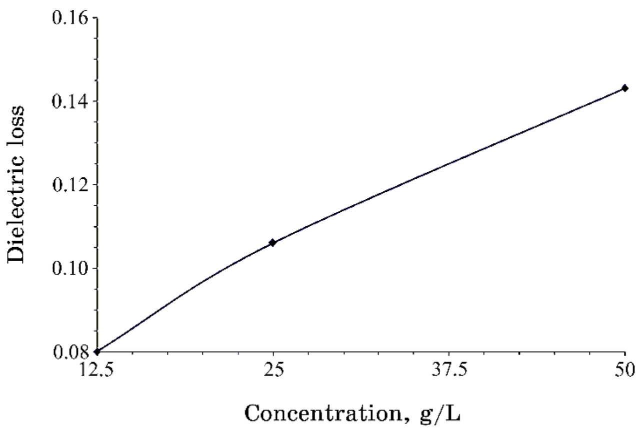

Fig. 4. Variation of dielectric loss for the PVP/Ag/SiC nanostructures with concentration.

5. CONCLUSIONS

This study comprises preparation of PVP/Ag/SiC nanostructures and examining the dielectric properties to use them in different electronics fields with lightweight and low cost. The results showed that the dielectric constant and dielectric loss of PVP/Ag/SiC nanostructures reduced while the electrical conductivity increased with an increase in the frequency. The dielectric constant, dielectric loss and electrical conductivity rise with increasing of the concentration. The final results indicated that the dielectric properties indicated that the PVP/Ag/SiC nanostructures could be suitable in

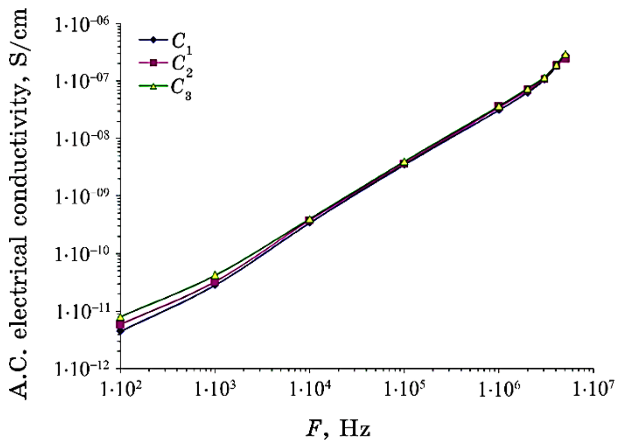

Fig. 5. Variation of A.C. conductivity for the PVP/Ag/SiC nanostructures with frequency.

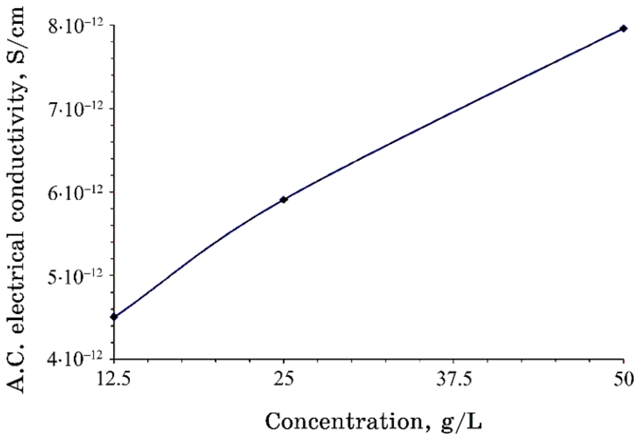

Fig. 6. Behaviour of A.C. conductivity for the PVP/Ag/SiC nanostructures with concentration.

various electronics applications.

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