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Investigation of the Dielectric Properties of PVA/PVP/SiC Nanostructures

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This work is aiming for a fabrication the polyvinyl alcohol/poly(N-vinyl-2-pyrrolidone)/SiC (PVA/PVP/SiC) nanostructures and studying their dielectric properties to use in different electrotechnical and electronic fields. The PVA/PVP/SiC nanostructures are prepared by using casting method with different concentrations of polymer blend and nanoparticles. The dielectric properties of PVA/PVP/SiC nanostructures are studied at frequency range from 100 Hz to 5 MHz. The results show that the dielectric constant, dielectric loss and A.C. electrical conductivity of PVA/PVP blend are increased with an increase in the SiC-nanoparticles' concentration. The dielectric constant, dielectric loss and A.C. electrical conductivity of PVA/PVP/SiC nanostructures are changed with an increase in the frequency.

Дану роботу спрямовано на виготовлення наноструктур полівініловий спирт/полі(N-вініл-2-піролідон)/SiC (PVA/PVP/SiC) і вивчення їхніх діелектричних властивостей для використання в різних електротехнічних та електронних областях. Наноструктури PVA/PVP/SiC одержано методом лиття з різними концентраціями полімерної суміші та наночастинок. Вивчено діелектричні властивості наноструктур PVA/PVP/SiC в діяпазоні частот від 100 Гц до 5 МГц. Результати показують, що діелектрична проникність, діелектричні втрати й електропровідність суміші PVA/PVP збільшуються зі збільшенням концентрації наночастинок SiC. Діелектрична проникність, діелектричні втрати й електропровідність наноструктур PVA/PVP/SiC змінюються зі збільшенням частоти.

Key words: nanostructures, SiC, blend, dielectric parameters, electrical conductivity.

Ключові слова: наноструктури, SiC, суміш, діелектричні параметри, електропровідність.

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1. INTRODUCTION

The production of novel polymeric nanocomposites have been widely studied by the current applications on nanosize inorganic fillers in the food packaging field, barrier applications, sensors, antimicrobial, conductive, coatings, antiballistic products and other materials [1]. Flexible electronics are attracting increased attention in the electronic industry day by day due to their compact nature and ease of handling. Along with other electronics, flexible dielectric materials are also getting popular for many applications like in field e ect transistors (FET), gate dielectrics, pulse power systems, sensors and energy storage devices, *etc.* [2].

Polymers are versatile materials that have certain unique properties such as low density, flexibility, toughness, easy processability, and low conductivity. However, these properties are still inadequate for efficient industrial applications. Hence, continuous research efforts are in progress to develop new polymeric materials with advanced properties. The desired properties can be obtained by adding filler (organic and inorganic materials) to the polymer matrix [3].

Polyvinyl alcohol (PVA) is an atactic, semi-crystalline polymeric material that possesses excellent biodegradability, biocompatibility, useful mechanical properties, excellent optical properties, and non-toxicity, hence its wide range of applications. Other excellent properties of polyvinyl alcohol include thermal stability, water solubility, excellent optical transmission, and non-corrosiveness. The hydrogen bonding between polyvinyl alcohol and other materials is facilitated by the presence of hydroxyl groups on the carbon backbone of polyvinyl alcohol, and these bonds help with composite formation. Polyvinyl alcohol is of significant interest because it is abundantly accessible, relatively cheap, contains many volatile functional groups, and has hydrophilic features. It has excellent charge storing capacity, has great dielectric strength, and gives uniform high-optical-quality films for nonlinear optical instruments and optical sensors [4].

Poly(N-vinyl-2-pyrrolidone) (PVP) is one of the synthetic polymers that find wide applications as a film former, stabilizer as well as suspending and complexing agent. PVP is used as a biomaterial because of its solubility in water, biocompatibility as well as its extremely low cytotoxicity. PVP hydrogel has excellent transparency but suffer from the inferior mechanical properties [5]. Silicon carbide (SiC) serves as an exclusive example of such non-oxide ceramics due to its superior characteristics such as good mechanical property, high level of thermal and electrical conductivity, excellent chemical stability, high radiation resistance, and so forth. Such distinctive properties have turned SiC to be a promising material to be applied as a nuclear, turbine, and furnace reactor, and a jet engine, or even for the needs of space exploration [6]. This paper deals with synthesis of PVA/PVP/SiC nanostructures and investigating their dielectric properties to employ in different electronics fields.

2. MATERIALS AND METHODS

The nanostructures films were prepared from PVA/PVP as matrix and SiC nanoparticles (NPs) as additive by using casting technique. The film of PVA/PVP blend was prepared with ratio 77% PVA/23% PVP by dissolving of 1 gm in 30 ml distilled water. The SiC NPs were added to the PVA/PVP blend with various concentrations are 0.5%, 1%, and 1.5%. The dielectric properties of PVA/PVP/SiC nanostructures were studied at frequency range 100 Hz–$5\cdot10^6$ Hz by using LCR meter (HIOKI 3532-50 LCR HI TESTER). The dielectric constant (ε') was determined by [7]:

$$\varepsilon' = \frac{C_p d}{\varepsilon_0 A}, \tag{1}$$

where C_p is matter capacitance, d is the thickness of sample; A is the area.

The dielectric loss (ε'') was calculated by [8]:

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

where D is the dispersion factor.

The A.C. electrical conductivity is given by [9]:

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

3. RESULTS AND DISCUSSION

Figures 1, 2 show the variation of dielectric constant and dielectric loss of PVA/PVP/SiC nanostructures with frequency. The dielectric constant and dielectric loss of PVA/PVP/SiC nanostructures are decreased with an increase in the frequency. This one could be explained by the electrode and interfacial effect of the materials studied, which induces dipoles to align themselves with the electric field.

When the electric field is reversed at high frequencies, the charge is unable to keep up with the changes in the field, resulting

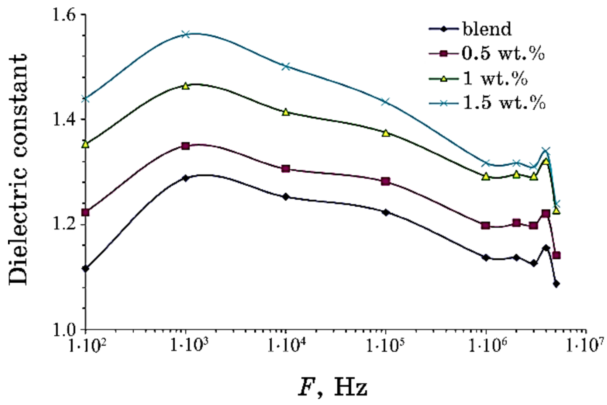

Fig. 1. Variation of dielectric constant for the PVA/PVP/SiC nanostructures with frequency.

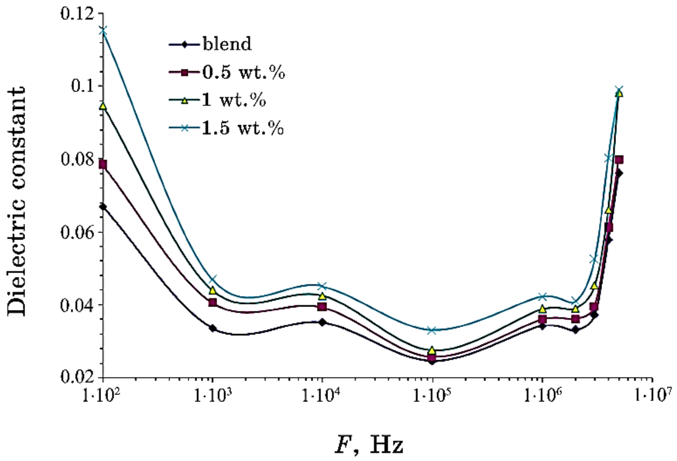

Fig. 2. Variation of dielectric loss for the PVA/PVP/SiC nanostructures with frequency.

in a delay in the charges behind the field, leading to a decrease in the values of ε' and ε'', because the polarization resulting from the accumulated charge decreases. The dielectric constant and dielectric loss of PVA/PVP are increased with an increase in the SiC-NPs' concentration, which may be related to increase in the charge-carriers' number [10–13].

Figure 3 demonstrates the behaviour of A.C. electrical conductivity of PVA/PVP/SiC nanostructures with frequency. Generally, the number of charge carriers, which have high relaxation time due to higher energy barrier and respond in low-frequency regime, might

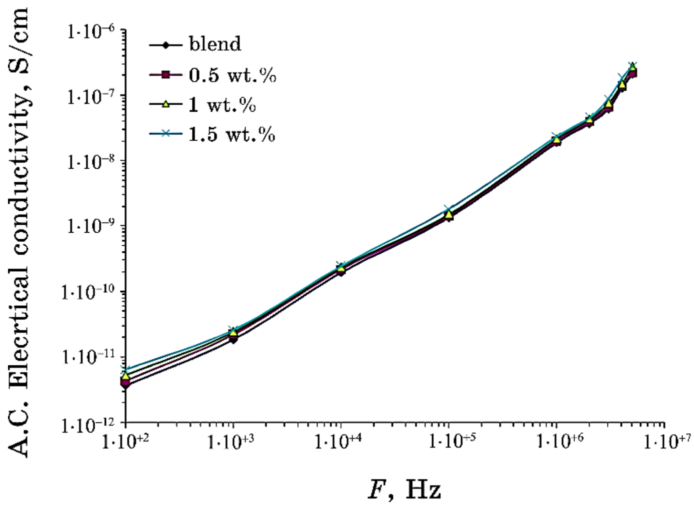

Fig. 3. Behaviour of A.C. electrical conductivity of the PVA/PVP/SiC nanostructures with frequency.

be less in number; hence, the conductivity is lower at lower frequencies. However, the number of charge carriers with low barrier heights is bigger, and they respond easily with high frequency and showed higher conductivity at higher frequencies. The A.C. electrical conductivity of PVA/PVP are increased with an increase in the SiC-NPs' content, which may be due to increase in the numbers of charge carriers [14–19].

4. CONCLUSIONS

This paper includes preparation of PVA/PVP/SiC nanostructures to use in various electrical and electronic fields. The dielectric properties of PVA/PVP/SiC nanostructures were tested at frequency range from 100 Hz to 5 MHz. The results showed that the dielectric constant, dielectric loss and A.C. electrical conductivity of PVA/PVP blend were enhanced with an increase in the SiC-NPs' content. The dielectric constant and dielectric loss of PVA/PVP/SiC nanostructures were decreased, while the A.C. electrical conductivity was reduced with an increase in the frequency.

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