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Dielectric Characteristics of PVA/ZrO_2–SiC Nanostructures for Electronics Applications

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Films of PVA and PVA doped with ZrO_2–SiC nanoparticles are prepared using the casting method. The structural and dielectric characteristics of PVA/ZrO_2–SiC nanocomposites are studied for the electronics applications. The experimental results indicate to improvement in dielectric parameters (dielectric constant, dielectric loss, and alternating-current electrical conductivity) of PVA with rise in ZrO_2–SiC nanoparticles' ratios. In addition, the dielectric constant and loss are decreased, while the alternating-current electrical conductivity of PVA/ZrO_2–SiC nanocomposites is increased with the rise in frequency.

Плівки полівінілалкоголю (ПВА) та ПВА, леґованого наночастинками ZrO_2–SiC, готуються методом лиття. Структурні та діелектричні характеристики нанокомпозитів ПВА/ZrO_2–SiC вивчаються для застосування їх в електроніці. Експериментальні результати свідчать про поліпшення діелектричних параметрів (діелектричної сталої, діелектричних втрат і електропровідности змінного струму) ПВА зі зростанням співвідношення наночастинок ZrO_2–SiC. Крім того, діелектричні стала та втрати зменшуються, в той час як електропровідність змінного струму у нанокомпозитів ПВА/ZrO_2–SiC збільшується зі зростанням його частоти.

Key words: dielectric parameters, SiC, conductivity, PVA, nanocomposites, ZrO_2.

Ключові слова: діелектричні параметри, SiC, провідність, полівінілалкоголь, нанокомпозити, ZrO_2.

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1. INTRODUCTION

Polymers are considered as organic materials having conjugating chain, which display good electric conduction; this is due to their characteristics as charges' carriers by means of the π-electrons, cause to mobility of charge along the polymers' chain. Polymers' characteristics are as good as with the inorganic matter but the polymers include many pros (and cons), such as good flexibility, corrosion resistance, processability, few cost and lightweight. The inorganics also contain important characteristics like stability to heat and good mechanical characteristics. Consequently, the polymer/inorganic system have huge applications in several fields [1]. The nanocomposite materials are promising in the fields of sensors, radiation shielding, antibacterial, thermal energy storage and release, piezoelectric, solar cells, diodes and other fields with low cost and lightweight [2]. Polymer matrix nanocomposites are becoming an essential part of today materials because of several advantages, such as low weight, simple fabrication methods, low cost, high fatigue strength, and good corrosion resistance.

Nanoparticles' incorporation into the polymer matrix considerably alters its physical properties, such as the electrical, structural, thermal, and optical properties [3]. The nanocomposites of organic and inorganic are very promising for fields in smart microelectronics, photodiodes, light-emitting diodes, gas sensors, photovoltaic cells, *etc.* [4]. Metal-oxide nanoparticles have explained their huge interest in applications of solar cells optoelectronics, sensing, catalysis and so on related to their exceptional chemical and physical characteristics varying from the bulk [5]. Polyvinyl alcohol (PVA) is semi-crystalline, with low electrical conductivity. PVA has certain physical characteristics resulted from crystal–amorphous interfacial effects. Its electrical characteristics may be modified to an exact requirement by the suitable doping substance addition [6].

2. MATERIALS AND METHODS

Nanocomposites films of PVA doped with ZrO_2–SiC nanoparticles (NPs) were fabricated by casting technique. The PVA solution was prepared by dissolving of 0.5 gm in 20 ml of distilled water. The ZrO_2–SiC NPs were added to PVA solution with ratio 1:1, and different contents are of 2, 4 and 6 wt.%. The dielectric characteristics measured in frequency 100 Hz–5 MHz by LCR meter type (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant ε' is defined by [7]:

$$\varepsilon' = C_p/C_o, \quad (1)$$

where C_p is capacitance and C_o is vacuum capacitor. The dielectric loss ε'' is given by [8]:

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

where D is dispersion factor. The a.c. conductivity is defined by [9]:

$$\sigma_{\text{a.c.}} = w\varepsilon''\varepsilon_o, \tag{3}$$

where w is angular frequency.

3. RESULTS AND DISCUSSION

Figures 1 and 2 represent the dielectric constant and loss of PVA/ZrO_2–SiC nanostructures with frequency, respectively. From these figures, the ε' of PVA/ZrO_2–SiC nanostructures reduces with the rise in frequency that is related to the dipoles' tendency in polymer to orient themselves in the applied field direction. The dielectric loss of PVA/ZrO_2–SiC nanostructures decrease with rising of frequency. This behaviour is related to the interfacial polarization in the PVA/ZrO_2–SiC nanostructures. The high value at low frequency of ε'' of PVA/ZrO_2–SiC nanostructures is related to the mobility of charges [9]. ε' and ε'' of PVA were rise with the of ZrO_2–SiC NPs content. This behaviour is related to a rise in the polariza-

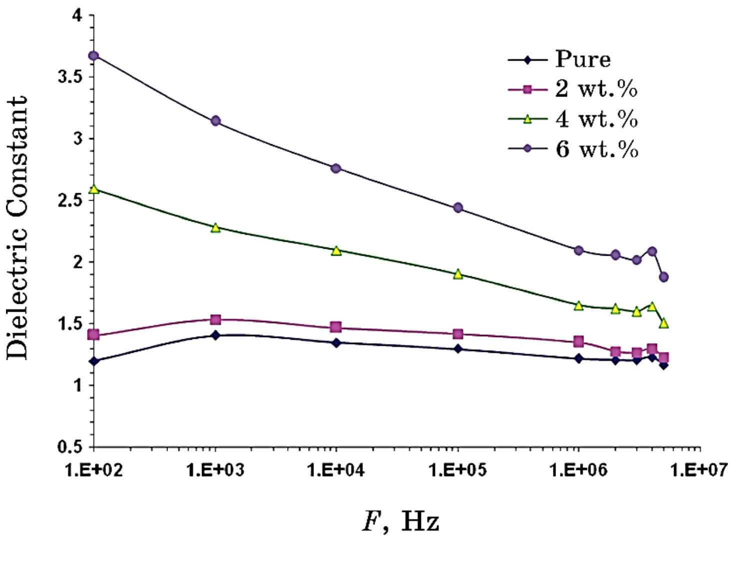

Fig. 1. Variation of dielectric constant of PVA/ZrO_2–SiC nanostructures with frequency.

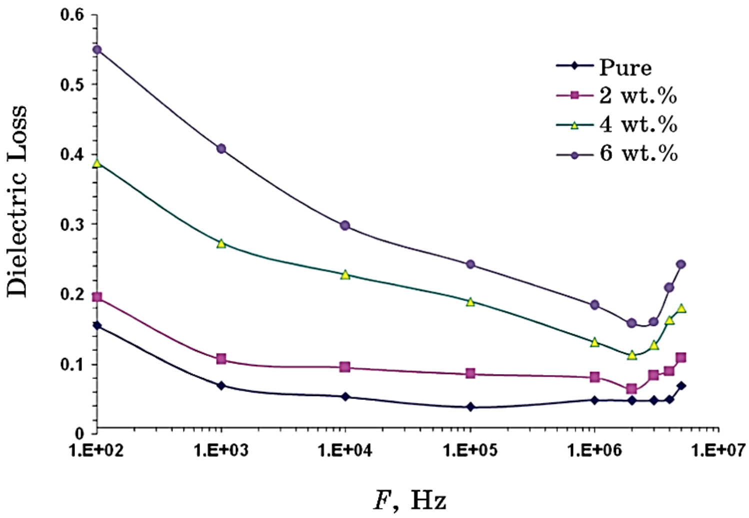

Fig. 2. Variation of dielectric loss of PVA/ZrO_2–SiC nanostructures with frequency.

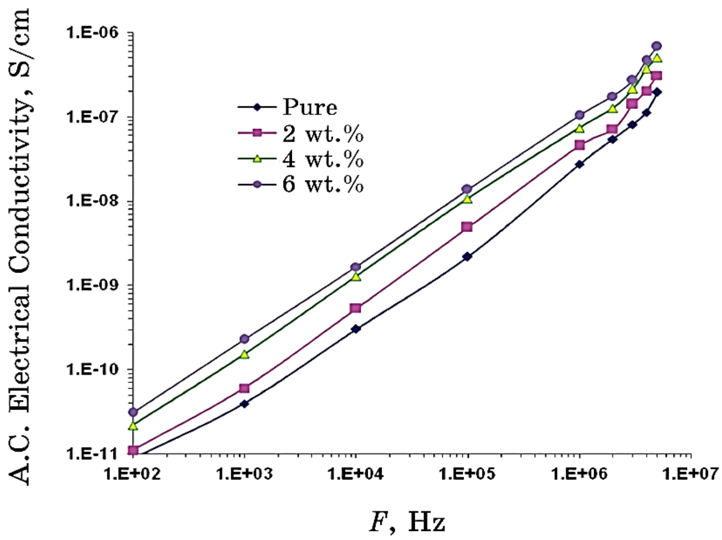

Fig. 3. Behaviour of conductivity of PVA/ZrO_2–SiC nanostructures with frequency.

tions of free electrons and space charges with raising the ZrO_2–SiC NPs ratio [10, 11].

Figure 3 shows the behaviour of conductivity of PVA/ZrO_2–SiC nanostructures with frequency. The conductivity rises with rising

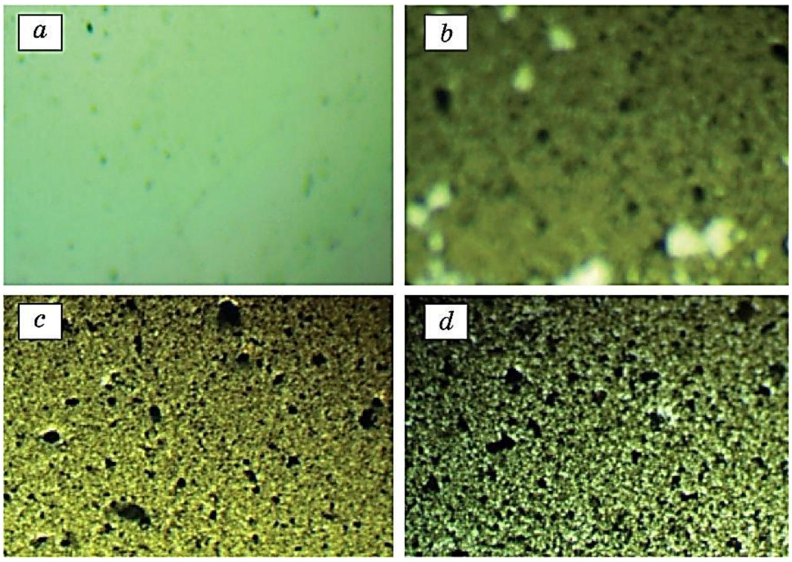

Fig. 4. Microscope images (4×): (*a*) PVA; (*b*) 2 wt.% ZrO_2–SiC NPs; (*c*) 4 wt.% ZrO_2–SiC NPs; (*d*) 6 wt.% ZrO_2–SiC NPs.

in frequency; this is related to the mobility of charge carriers and hopping of ions. The conductivity of PVA rises with raising the ZrO_2–SiC NPs content. This increase in conductivity is related to rise in charge carriers (as shown in Fig. 4) due to ZrO_2–SiC NPs composition with both the decrease in the resistance of nanocomposites and the rise in the conductivity [12–14].

4. CONCLUSIONS

The dielectric parameters of PVA are improved with the rise in ZrO_2–SiC NPs ratios.

The dielectric constant and loss (ε' and ε'') are reduced, while the conductivity is raised with the rise in the frequency.

Finally, the results showed that the PVA/ZrO_2–SiC nanostructures might be used for various field in the electrical and electronic approaches.

REFERENCES

1. M. H. A. Rehim and J. Alhamidi, *J. of Advancements in Food Technology*, **1**, No. 1: 1 (2018); https://dx.doi.org/10.15744/2639-3328.1.105
2. A. Hashim, A. J. Kadham, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, Iss. 1: 91 (2021);

https://doi.org/10.15407/nnn.19.01.091
3. E. Sheha, H. Khoder, T. S. Shanap, M. G. El-Shaarawy, and M. K. El Mansy, *Optik*, **123**, Iss. 13: 1161 (2012); https://doi.org/10.1016/j.ijleo.2011.06.066
4. R. K. Swarnkar, S. C. Singh, and R. Gopal, *ICOP 2009-International Conference on Optics and Photonics CSIO (30 Octomber–1 November, 2009, Chandigarh, India)*, p. 1.
5. T. H. Tran and V. T. Nguyen, *Int. Scholarly Research Notices*, **2014**, Article ID 856592: 14 pages (2014).
6. G. V. Kumar, *Int. J. of Res. Granthaalayah*, **5**, No. 4, RAST: 87 (2017); https://doi.org/10.5281/zenodo.803434
7. A. A. Abdelmalik, A. Sadiq, and U. Sadiq, *J. of Physical Science*, **31**, No. 1: 1 (2020).
8. S. M. Ambalagi, S. Nagaraja, V. T. Manjula, and Shrishail Hogade, *Int. J. of Innovative Res. in Sci., Eng. and Techno.*, **5**, Iss. 2 (2016).
9. A. Y. Yassin, A. Raouf Mohamed, A. M. Abdelghany, and E. M. Abdelrazek, *Journal of Materials Science: Materials in Electronics*, **29**: 15931 (2018); https://doi.org/10.1007/s10854-018-9679-7
10. A. Hashim and A. Hadi, *Sensor Letters*, **15**, No. 12: 1019 (2017); https://doi.org/10.1166/sl.2017.3910
11. A. Hashim, M. A. Habeeb, A. Hadi, Q. M. Jebur, and W. Hadi, *Sensor Letters*, **15**, No. 12: 998 (2017); https://doi.org/10.1166/sl.2017.3935
12. H. Ahmed and A. Hashim, *Egypt. J. Chem.*, **63**, No. 3: 805 (2020); doi: 10.21608/EJCHEM.2019.11109.1712
13. I. R. Agool, F. S. Mohammed, and A. Hashim, *Advances in Environmental Biology*, **9**, Iss. 11: 1 (2015).
14. A. Hashim and Q. Hadi, *Sensor Letters*, **15**, No. 11: 951 (2017); https://doi.org/10.1166/sl.2017.3892