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Exploring the A.C. Electrical Characteristics of ZrC-Nanoparticles-Doped PVA/PEG Blend

Ahmed Hashim[1], Aseel Hadi[2], Bahaa H. Rabee[1], Majeed Ali Habeeb[1], Musaab Khudhur Mohammed[1], and Mohammed Hashim Abbas[3]

[1]*College of Education for Pure Sciences, Department of Physics, University of Babylon, Hillah, Iraq*
[2]*College of Materials Engineering, Department of Ceramic and Building Materials, University of Babylon, Hillah, Iraq*
[3]*Al-Mustaqbal University College, Medical Physics Department, Babylon, Iraq*

Nanocomposites of PVA/PEG blend doped with ZrC nanoparticles (NPs) are fabricated by using casting process with various contents of PVA/PEG blend and ZrC NPs. The A.C. electrical properties of PVA/PEG/ZrC nanocomposites are investigated at frequencies from 100 Hz to 5 MHz. The experimental results show that the A.C. electrical properties (dielectric constant, dielectric loss and A.C. electrical conductivity) of PVA/PEG blend are increased with increase in the ZrC NPs' ratio. In addition, dielectric parameters of PVA/PEG/ZrC nanocomposites are changed with rise in the frequency from 100 Hz to 5 MHz.

Нанокомпозити суміші полівінілалкоголь/поліетиленгліколь (PVA/PEG), леґованої наночастинками (НЧ) ZrC, виготовляються за допомогою процесу лиття з різним вмістом суміші PVA/PEG і НЧ ZrC. Досліджено електричні властивості нанокомпозитів PVA/PEG/ZrC на частотах від 100 Гц до 5 МГц. Результати експериментів показують, що електричні властивості за змінного струму (діелектрична проникність, діелектричні втрати й електропровідність змінного струму) суміші PVA/PEG збільшуються зі збільшенням пропорції НЧ ZrC. Крім того, змінюються діелектричні параметри нанокомпозитів PVA/PEG/ZRC з підвищенням частоти від 100 Гц до 5 МГц.

Key words: ZrC, blend, nanocomposites, conductivity, dielectric parame-

ters.

Ключові слова: ZrC, суміш, нанокомпозити, провідність, діелектричні параметри.

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1. INTRODUCTION

In recent years, synthesis of novel materials having high dielectric constant (*k*), low dielectric loss for embedded microelectronic applications is in great and urgent demand. Polymer composites are active materials, which provide an ideal solution to combine the dielectric or electrical properties for the microelectronic applications. Moreover, these can be used in a wide range of low-cost dielectric applications. Strong efforts are being invested to find a suitable material with *k* of low-cost materials [1].

Polymer nanocomposites have been widely investigated not for their numerous applications, but to understand their physical properties. In light of these studies, it was observed that adding a small fraction of the nanoparticles to the polymer matrix develop considerable properties for several applications such as electromagnetic shielding, electrostatic dissipation, charge storage capacitor systems and microwave absorbers [2].

Combining organic polymers with inorganic nanomaterials opens new applications for the host polymer [3]. In recent years polymers have been a subject of considerable interest because of their physical and chemical properties. Polymers are widely used in insulation, electrical industries as well as in microelectronics. Different polymers films, *i.e.*, pure and doped with different additives is used in various medical, biological and technological applications. Among polymer PVA films (doped and undoped) have been the subjects of several investigators, because it has many applications in industry due its low cost and excellent durability. It is used in various applications including polymerization aid to make polyvinyl acetate dispersion for the preparation of glues, paper coating, paper adhesives, thickener, protective chemical resistant gloves, eye treatment, polymer in capsulated nanobeads and in food products [4].

PVA can be blended with other polymers to form polymer complexes by hydrogen bonding. Hydroxyl groups located on the carbon chain backbone of the polymer are considered as the main source of the hydrogen bonding. On the other hand, polyethylene glycol (PEG) is a highly water soluble and nontoxic material, besides, its solubility in most organic solvents is considerably high. Moreover, when PEG mixed with other polymeric material, most of these properties can be shared within the resulting blend. Introducing metal oxide nanoparticles into polymers varies the physical and chemical properties of the resulting nanocomposite material. Of course, these properties depend on the type of the nanoparticles used and their preparation method [5]. The work aims to prepare of nanocomposites films of PVA/PEG blend doped with ZrC nanoparticles and studying their A.C. electrical properties.

2. MATERIALS AND METHODS

Nanocomposites films of PVA/PEG blend doped with ZrC nanoparticles were prepared by using casting method. The PVA/PEG blend was fabricated by dissolving of 1 gm of polymers in distilled water (30 ml) with ratio 81 wt.% PVA and 19 wt.% PEG. The ZrC NPs were added to the blend with concentrations of 1.5 wt.%, 3 wt.%, and 4.5 wt.%. The A.C. electrical properties of PVA/PEG/ZrC nanocomposites 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′) of PVA/PEG/ZrC nanocomposites was found by [6]:

$$\varepsilon' = C_p d/\varepsilon_0 A, \quad (1)$$

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

Dielectric loss (ε″) of nanocomposites was calculated by [6]:

$$\varepsilon'' = \varepsilon' D, \quad (2)$$

where D is the dispersion factor.

The A.C. electrical conductivity was determined by [7]:

$$\sigma_{\text{A.C.}} = \omega\varepsilon' D\varepsilon_0. \quad (3)$$

3. RESULTS AND DISCUSSION

The variations of dielectric constant and dielectric loss of PVA/PEG/ZrC nanocomposites with frequency and ZrC NPs' content are represented in Figs. 1–4. It was observed that, only at the lower frequency, the dielectric constant values are high that might be due to the existence of interfacial polarization. Interfacial polarization exists at the low frequencies only and diminishes as the frequency is increased. When the frequencies are higher, the polar molecular rotational motion of material may not quick enough to obtain equilibrium by means of an applied electric field. The higher

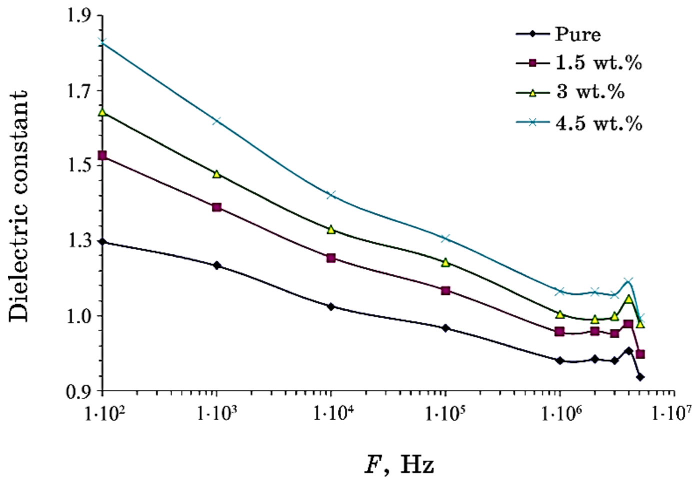

Fig. 1. Variation of dielectric constant of PVA/PEG/ZrC nanocomposites with frequency.

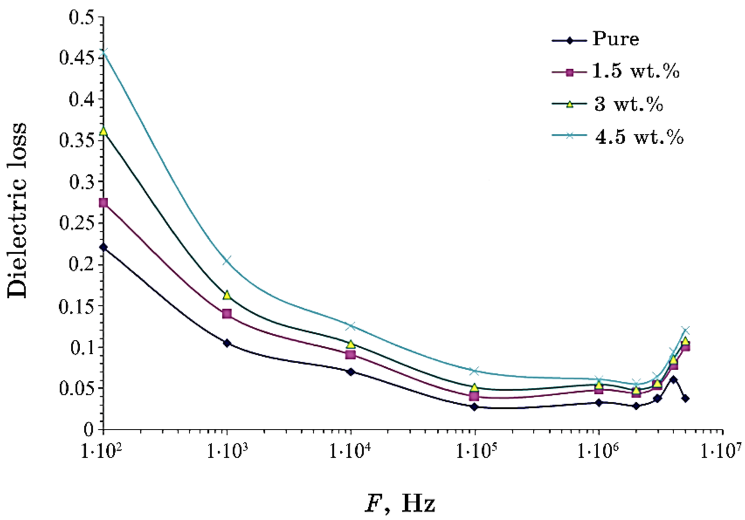

Fig. 2. Variation of dielectric loss of PVA/PEG/ZrC nanocomposites with frequency.

values of dielectric loss were noticed at lower frequencies that may be due to Maxwell–Wagner effect ensuing from immigration of charge carriers at the interface or sensitive mobile ionic impurities and polar radicals having dipole moments [8–12].

The behaviours of A.C. electrical conductivity of PVA/PEG/ZrC nanocomposites with frequency and ZrC NPs' content are shown in

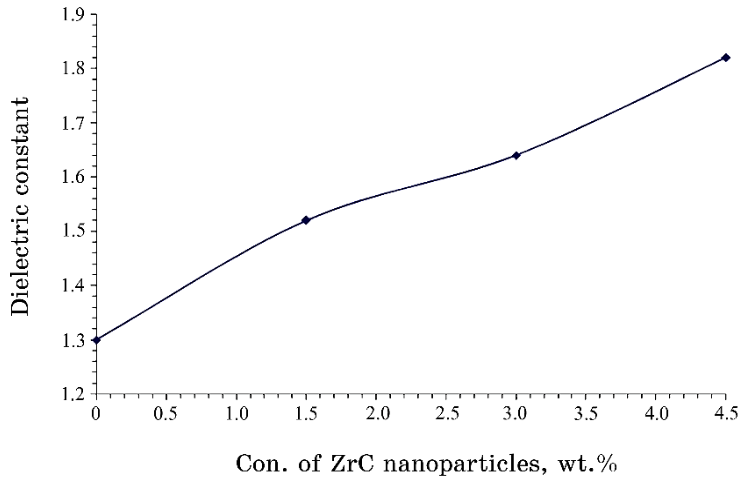

Fig. 3. Behaviour of dielectric constant of PVA/PEG blend with ZrC NPs' content.

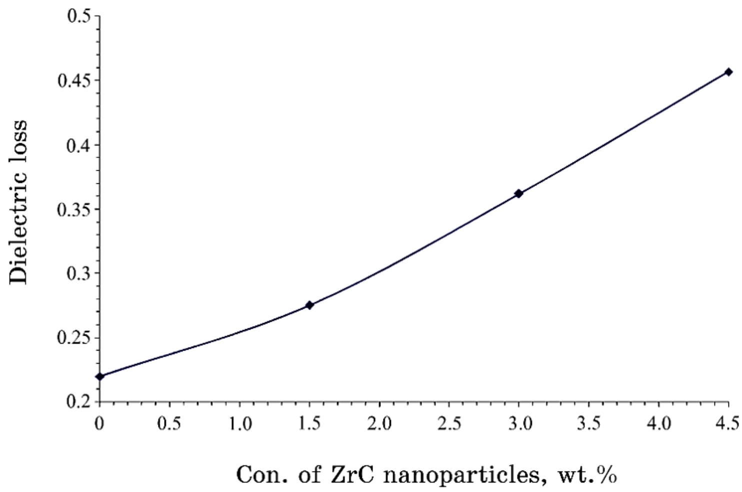

Fig. 4. Behaviour of dielectric loss of PVA/PEG blend with ZrC NPs' content.

Fig. 5 and Fig. 6, respectively. From these figures, the conductivity rises with the rise in the frequency. This indicates that there may be charge carriers, which can be transported by hopping through the defect sites along the polymer chain [13–16].

With increase in the ZrC NPs' content, the electrical conductivity of PVA/PEG blend increases that relates to form a network paths inside polymer matrix and increase in the charges carriers [17–21].

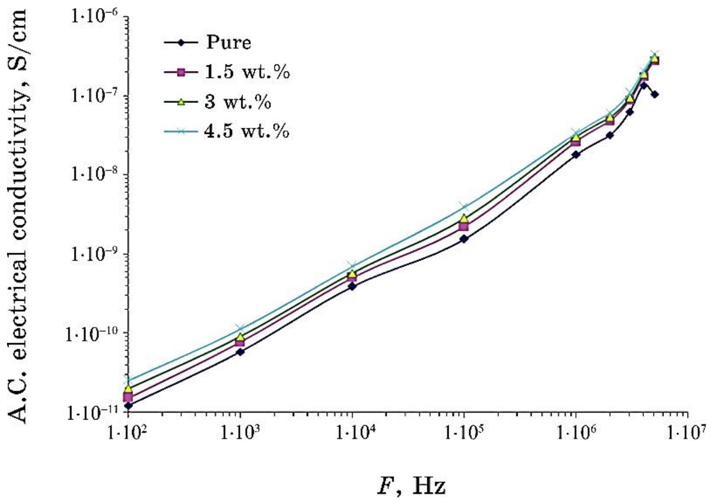

Fig. 5. Behaviour of A.C. electrical conductivity of PVA/PEG/ZrC nanocomposites with frequency.

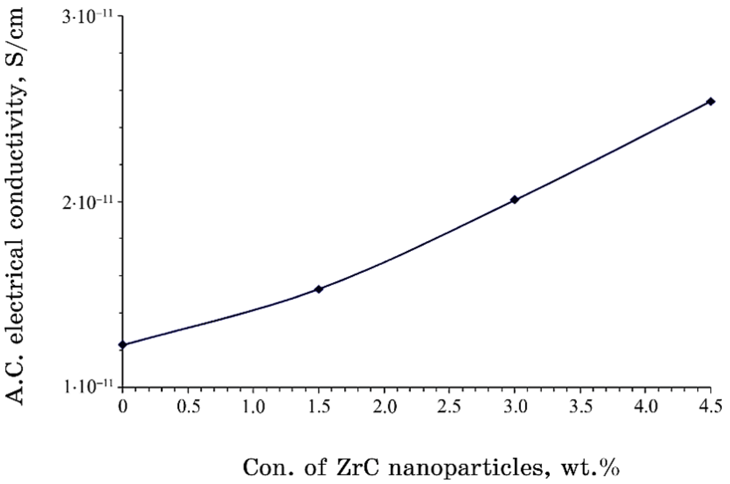

Fig. 6. Behaviour of A.C. electrical conductivity of PVA/PEG blend with ZrC NPs' content.

4. CONCLUSIONS

The PVA/PEG/ZrC nanocomposites films were fabricated by casting method. The dielectric properties of PVA/PEG/ZrC nanocomposites films are examined in the range of frequency from 100 Hz to 5 MHz. The experimental results showed that the dielectric constant, dielectric loss and A.C. electrical conductivity of PVA/PEG blend are increased with the increase in ZrC NPs' ratio. The dielectric constant and dielectric loss of PVA/PEG/ZrC nanocomposite films are decreased, while the A.C. electrical conductivity increases as the frequency increases.

REFERENCES

1. S. G. Rathod, R. F. Bhajantri, V. Ravindrachary, P. K. Pujari, and T. Sheela, *J. of Adv. Dielectrics*, **4**, No. 4: 1450033 (2014); doi:10.1142/S2010135X14500337
2. T. A. Taha, A. Hassona, S. Elrabaie, and M. T. Attia, *J. of Asian Ceramic Societies*, **8**, Iss. 4: 1 (2020); doi:10.1080/21870764.2020.1812839
3. Z. K. Heiba, M. B. Mohamed, and S. I. Ahmed, *Alexandria Engineering Journal*, **61**, No. 5: 3375 (2021); https://doi.org/10.1016/j.aej.2021.08.051
4. V. P. Meshram and B. M. Suryavanshi, *International Journal of Advances in Science Engineering and Technology*, Special Issue-1: 171 (2015).
5. A. A. Alhazime, *J. Inorg. Organomet. Polym.*, **30**: 4459 (2020); https://doi.org/10.1007/s10904-020-01577-8
6. S. Ishaq, F. Kanwal, S. Atiq, M. Moussa, U. Azhar, and D. Losic, *Materials*, **13**: 205 (2020); doi:10.3390/ma13010205
7. H. M. Alhusaiki-Alghamdi, *Results in Physics*, **24**: 104125 (2021); https://doi.org/10.1016/j.rinp.2021.104125
8. P. L. Reddy, K. Deshmukh, K. Chidambaram, M. M. Nazeer Ali, K. K. Sadasivuni, Y. Ravi Kumar, R. Lakshmipathy, and S. K. K. Pasha, *Journal of Materials Science: Materials in Electronics*, **30**: 4676 (2019); https://doi.org/10.1007/s10854-019-00761-y
9. D. Hassan and A. Hashim, *Bulletin of Electrical Engineering and Informatics*, **7**, Iss. 4: 547 (2018); doi:10.11591/eei.v7i4.969
10. A. J. K. Algidsawi, A. Hashim, A. Hadi, M. A. Habeeb, and H. H. Abed, *Physics and Chemistry of Solid State*, **23**, No. 2: 353 (2022); doi:10.15330/pcss.23.2.353-360
11. Z. S. Hamad and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii,* **20**, Iss. 1: 159 (2022); https://doi.org/10.15407/nnn.20.01.159
12. D. Hassan and A. H. Ah-Yasari, *Bulletin of Electrical Engineering and Informatics*, **8**, Iss. 1: 52 (2019); doi:10.11591/eei.v8i1.1019
13. S. M. Reda and Sheikha M. Al-Ghannam, *Advances in Materials Physics and Chemistry*, **2**: 75 (2012).
14. N. Al-Huda Al-Aaraji, A. Hashim, A. Hadi, and H. M. Abduljalil, *Silicon*, **14**: 4699 (2021); https://doi.org/10.1007/s12633-021-01265-3
15. A. J. K. Algidsawi, A. Hashim, A. Hadi, and M. A. Habeeb, *Semiconductor Physics, Quantum Electronics & Optoelectronics*, **24**, No. 4: 472: (2021); https://doi.org/10.15407/spqeo24.04.472
16. A. Hashim, A. J. K. Algidsawi, H. Ahmed, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 1: 91 (2021); https://doi.org/10.15407/nnn.19.01.091
17. A. Hashim, H. M. Abduljalil, and H. Ahmed, *Egypt. J. Chem.*, **63**, No. 1: 71 (2020); doi:10.21608/EJCHEM.2019.10712.1695
18. B. Hussien, A. K. Algidsawi, and A. Hashim, *Australian Journal of Basic*

and Applied Sciences, **5**, No. 7: 933 (2011).
19. H. Abduljalil, A. Hashim, and A. Jewad, *European Journal of Scientific Research*, **63**, No. 2: 231 (2011).
20. A. Hashim, *J. Mater. Sci.: Mater. Electron.*, **32**: 2796 (2021); https://doi.org/10.1007/s10854-020-05032-9
21. Q. M. Jebur, A. Hashim, and M. A. Habeeb, *Egypt. J. Chem.*, **63**, No. 2: 611 (2020); doi:10.21608/ejchem.2019.10197.1669