Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2023, т. 21, № 3, сс. 561–567

PACS numbers: 77.22.Ch, 77.22.Gm, 77.55.dj, 77.84.Lf, 81.05.Qk, 81.07.Pr, 82.35.Np

Enhanced Dielectric Properties of CeO_2/SiC-Nanostructures-Doped PVA to Use in Various Electronics Devices

Ahmed Hashim[1], Aseel Hadi[2], and M. H. 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]*Department of Medical Physics,*
Al-Mustaqbal University College,
Babylon, Iraq

In present work, fabrication of poly(vinyl alcohol) (PVA)/CeO_2/SiC nanocomposites with lightweight and low cost is investigated. The dielectric properties of PVA/CeO_2/SiC nanocomposites are studied. The results show that both the dielectric constant and the dielectric loss of PVA/CeO_2/SiC nanocomposites are decreased with an increasing in the frequency, while the electrical conductivity is increased as frequency increases. Dielectric constant, dielectric loss and electrical conductivity of PVA are increased with an increasing in the CeO_2/SiC-nanoparticles' concentration. The results on dielectric properties show that the PVA/CeO_2/SiC nanocomposites can be useful in various electronics applications.

У даній роботі досліджується виготовлення нанокомпозитів полівініловий спирт (ПВС)/CeO_2/SiC з полегшеною вагою та низькою вартістю. Досліджено діелектричні властивості нанокомпозитів ПВС/CeO_2/SiC. Результати показують, що як діелектрична проникність, так і діелектричні втрати нанокомпозитів ПВС/CeO_2/SiC зменшуються зі збільшенням частоти, тоді як електропровідність збільшується зі збільшенням частоти. Діелектрична проникність, діелектричні втрати й електропровідність ПВС збільшуються зі збільшенням концентрації наночастинок CeO_2/SiC. Результати стосовно діелектричних властивостей показують, що нанокомпозити ПВС/CeO_2/SiC можуть бути корисними в різних електронних застосуваннях.

Key words: nanocomposites, PVA, CeO_2/SiC nanoparticles, dielectric properties.

Ключові слова: нанокомпозити, ПВС, наночастинки CeO_2/SiC, діелектричні властивості.

(Received 9 February, 2023)

1. INTRODUCTION

Flexible composite materials have been receiving a great deal of attention in optical energy applications due to their remarkable electrical, thermal, mechanical, dielectric and optical properties versus the other traditional materials. Currently, polymer composites are of high interest in different energy applications because of their pliable characteristics and their easy to use. Huge attention has been given to reveal the optical properties of polymers, and to potentiate their implementations in optical energy applications [1]. In the class of new materials, polymer nanocomposites have grabbed more attention due to their enhanced electrical, optical and magnetic properties. These materials possess increased modulus and flame resistance, and are capable to preclude oxidation and agglomeration. These enhancements in properties are due to interaction between nanoparticles (NPs) and polymer matrix. Addition of nanoparticles into polymer matrix improves lifetime of nanoparticles, modifies the surface of nanoparticles by passivation defect states, provide low cost, ease of device fabrication and tuneable optical and electronic properties.

Nanocomposites on base of semi-conductor nanoparticles and polymer matrix are prospective materials for application in optoelectronics, for creation of luminescent materials, sensor, *etc.* [2–11].

Silicon carbide (SiC) is a robust ceramic material, and one of the hardest materials available. Due to its excellent properties (oxidation resistance, hardness, high-temperature resistance, and high strength), it has been utilized in different applications, such as nuclear, batteries, optics, photonics, high temperature applications, semi-conductors and electronic devices, coatings, friction, defence applications, healthcare applications in medical implants and devices, and humidity sensors [12].

CeO_2 is an n-type semi-conductor metal oxide in which cerium belongs to the lanthanide group. In applications, CeO_2 provides electromagnetic screens for anti-reflection coverings and is used in colour TV tubes, glowing mantles, camera phone lenses, CD player lasers, ultra-modern chip systems and solar cells, vehicle exhaust catalysts, biomedicine and photocatalysis. Nanostructured CeO_2 poses as the best UV absorber and is used as a preservative in polishes and coverings for wood additives to improve their UV stability. CeO_2 has been considered as an excellent semi-conducting photocatalytic material due to its moderate band-gap energy of 3.19 eV [13].

Polymers are generally used relating to their cost, fast treatment, high manufacturability, lightweight, chemical resistance [14–16]. The poly(vinyl alcohol) (PVA) is water soluble, nontoxic semicrystalline material with high flexibility, which is generally used in the polymeric blends related to its excellent chemical and physical characteristics, good forming of film properties, non-carcinogenic, emulsifying capability, biocompatible and biodegradable characters. These exceptional properties allow it for pharmaceutical applications applicability, drug-coating agents, cosmetic and industries of surgical structures. PVA has found applications in number of fields including membranes, coatings, adhesives, sensors, batteries, fuel cells, textiles, papermaking, and biomedical frameworks [17–25].

The present work deals with fabrication of PVA/CeO_2/SiC nanocomposites and investigation of the dielectric properties to employ in various electrical and electronics fields.

2. MATERIALS AND METHODS

Films of PVA/CeO_2/SiC nanocomposites were prepared by using casting method. The PVA solution was fabricated by dissolving of 0.5 gm of PVA in distilled water (20 ml). The CeO_2/SiC NPs were added to the PVA solution with ratio 3:1 and different concentrations of 1.9 wt.%, 3.8 wt.%, and 5.7 wt.%.

The dielectric properties of PVA/CeO_2/SiC nanocomposites' films were measured within the frequency range 100 Hz–$5\cdot10^6$ Hz by LCR meter (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant (ε') was found by [26] as

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

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

Dielectric loss (ε'') was calculated by [27] as

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

where D is the dispersion factor.

The A.C. electrical conductivity was determined by [28] as

$$\sigma_{\text{A.C.}} = 2\pi\varepsilon' D\varepsilon_o. \quad (3)$$

3. RESULTS AND DISCUSSION

Figures 1 and 2 show the variation of dielectric constant and dielectric loss for PVA/CeO_2/SiC nanocomposites with frequency respectively. The dielectric constant values are high at low frequencies. This is due to a large number of charges accumulating on the surface area of the polymer electrode (interfacial polarization) and induced dipoles. Additionally, at high frequency, electrons and atoms

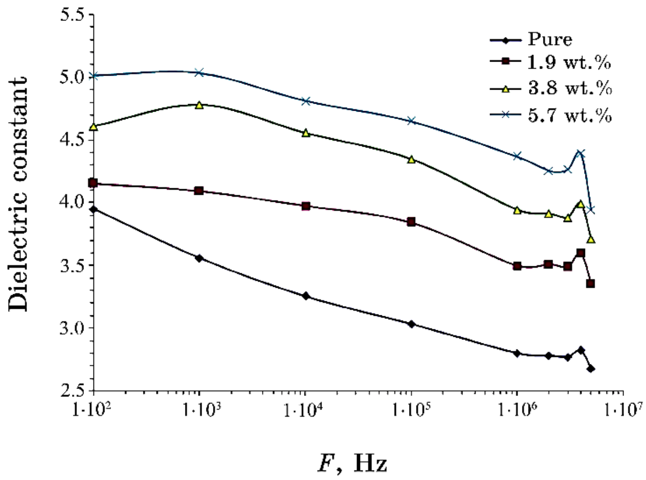

Fig. 1. Dielectric constant variation for the PVA/CeO_2/SiC nanocomposites with frequency.

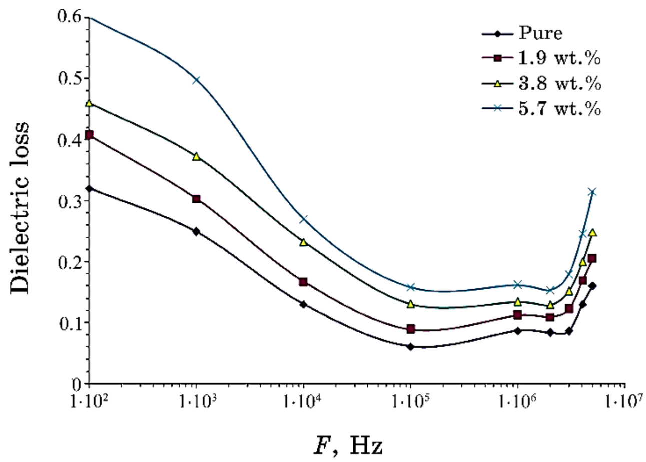

Fig. 2. Dielectric loss behaviour for the PVA/CeO_2/SiC nanocomposites with frequency.

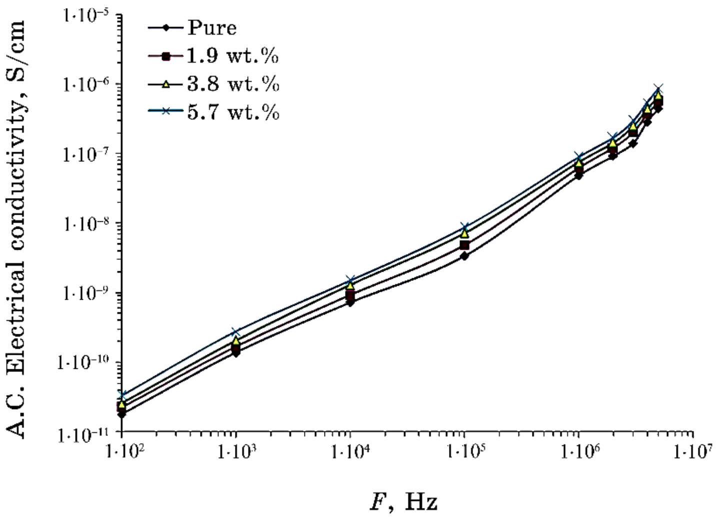

Fig. 3. Behaviour of A.C. electrical conductivity for the PVA/CeO_2/SiC nanocomposites with frequency.

exhibit displacement polarization, while interfacial and orientation polarization are restricted, resulting in a low charge on the films' surface [29].

From Figures 1 and 2, both the dielectric constant and the dielectric loss of PVA increase as CeO_2/SiC nanoparticles concentration increases. This result can be attributed to the increase in conductivity because of the increase charge-carrier density in polymer matrix [30].

Figure 3 represents the behaviour of AC electrical conductivity for PVA/CeO_2/SiC nanocomposites with frequency. The conductivity is low at low frequencies that could be related to space charge polarization, suggesting non-Debye properties of the prepared composites examined. The conductivity value increases, when the frequency F is increased. Furthermore, the conductivity values of the PVA/CeO_2/SiC NPs were found to be greater than those of PVA, which implying the insertion of CeO_2/SiC NPs into the examined polymeric blend could enhance the charge conduction mechanism significantly rapidly. Furthermore, such enhancement may indicate an increase in disorder degree that regulates charge carrier movement and obtains the formation of a linked percolating chain that is suitable for the charge transfer mechanism [31].

4. CONCLUSIONS

This work includes a fabrication of PVA/CeO_2/SiC nanocomposites and studying their dielectric properties to use in various electronics applications. The results showed that the dielectric constant and dielectric loss of PVA/CeO_2/SiC nanocomposites decreased while the electrical conductivity increased with an increase in the frequency. Dielectric constant, dielectric loss and electrical conductivity of PVA increased with an increase in the CeO_2/SiC nanoparticles concentrations. The results of dielectric properties show the PVA/CeO_2/SiC nanocomposites can be useful in various electronics applications.

REFERENCES

1. A. Atta, M.M. Abdelhamied, A. M. Abdelreheem, and M. R. Berber, *Polymers*, **13**: 1 (2021); https://doi.org/10.3390/polym13081225
2. A. Hashim, H. Ahmed, A. Yahya, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii,* **19**, No. 3: 681(2021); https://doi.org/10.15407/nnn.19.03.681
3. A. Hashim, A. J. Kadham, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 2: 327 (2021); https://doi.org/10.15407/nnn.19.02.327
4. A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 3: 647 (2021); https://doi.org/10.15407/nnn.19.03.647
5. M. Sajjad and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 831 (2021); https://doi.org/10.15407/nnn.19.04.831
6. H. Ahmed and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 841 (2021); https://doi.org/10.15407/nnn.19.04.841
7. A. G. Hadi, Z. Al-Ramadhan, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 865 (2021); https://doi.org/10.15407/nnn.19.04.865
8. A. Hashim and A. Jassim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 883 (2021); https://doi.org/10.15407/nnn.19.04.883
9. A. Hashim and Z. S. Hamad, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 893 (2021); https://doi.org/10.15407/nnn.19.04.893
10. A. Hashim and A. Jassim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 1: 177 (2022); https://doi.org/10.15407/nnn.20.01.177
11. A. Hashim, B. H. Rabee, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 2: 517 (2022); https://doi.org/10.15407/nnn.20.02.517
12. M. Petousis, N. Vidakis, N. Mountakis, S. Grammatikos, V. Papadakis, C. N. David, A. Moutsopoulou, and S. C. Das, *Polymers*, **14**: 1 (2022); https://doi.org/10.3390/polym14173492
13. A. Syed, L. S. R. Yadav, A. H. Bahkali, A. M. Elgorban, D. Abdul Hakeem, and N. Ganganagappa, *Crystals*, **10**: 1 (2020); doi:10.3390/cryst10090817
14. M. H. Rasheed, A. Hashim, and F. L. Rashid, *Nanosistemi, Nanomateriali, Nanotehnologii,* **19**, No. 2: 347(2021); https://doi.org/10.15407/nnn.19.02.347
15. A. Hashim and Z. S. Hamad, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 1: 165 (2022); https://doi.org/10.15407/nnn.20.01.165

16. A. G. Hadi, Z. Al-Ramadhan, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 2: 535 (2022); https://doi.org/10.15407/nnn.20.02.535
17. 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
18. A. Hashim, A. J. K. Algidsawi, H. Ahmed, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 2: 353 (2021); https://doi.org/10.15407/nnn.19.02.353
19. A. Yahya, H. Ahmed, A. Hashim, M. A. Habeeb, and A. Hadi, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 3: 673 (2021); https://doi.org/10.15407/nnn.19.03.673
20. A. Hashim, E. H. Abdullah, F. L. Rashid, and A. Hadi, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 3: 697 (2021); https://doi.org/10.15407/nnn.19.03.697
21. A. Hashim and Q. Hadi, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 873 (2021); https://doi.org/10.15407/nnn.19.04.873
22. Farhan Lafta Rashid, and Ahmed Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 905 (2021); https://doi.org/10.15407/nnn.19.04.905
23. Z. S. Hamad and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 1: 159 (2022); https://doi.org/10.15407/nnn.20.01.159
24. B. Mohammed, H. Ahmed, and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 1: 187 (2022); https://doi.org/10.15407/nnn.20.01.187
25. Y. Y. Mijbil and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 2: 497 (2022); https://doi.org/10.15407/nnn.20.02.497
26. S. Ishaq, F. Kanwal, S. Atiq, M. Moussa, U. Azhar, and D. Losic, *Materials*, **13**: 1 (2020); doi:10.3390/ma13010205
27. E. Elbayoumy, N. A. El-Ghamaz, F. Sh. Mohamed, M. A. Diab, and T. Nakano, *Polymers*, **13**: 1 (2021); https://doi.org/10.3390/polym13173005
28. H. M. Alhusaiki-Alghamdi, *Results in Physics*, **24**: 1 (2021); https://doi.org/10.1016/j.rinp.2021.104125
29. A. El Askary, M. El-Sharnouby, N. S. Awwad, H. A. Ibrahium, M. A. El-Morsy, M. O. Farea, and A. A. Menazea, *Physica B*, **637**: 1 (2022); https://doi.org/10.1016/j.physb.2022.413910
30. A. Hashim and Z. S. Hamad, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 2: 507 (2022); https://doi.org/10.15407/nnn.20.02.507
31. A. A. Alrehaili, A. F. Gharib, A. El Askary, M. A. El-Morsy, N. S. Awwad, H. A. Ibrahium, and A. A. Menazea, *Optical Materials*, **129**: 112497 (2022); https://doi.org/10.1016/j.optmat.2022.112497