Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2023, т. 21, № 3, сс. 505–511

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

Fabrication of PVA–Fe_2O_3/Co_2O_3 Nanocomposites and Improved Dielectric Properties for Flexible Electronics Fields

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

Films of PVA and PVA doped with Fe_2O_3/Co_2O_3 nanoparticles are fabricated to employ in different electronics fields. The dielectric properties of (PVA–Fe_2O_3/Co_2O_3) nanocomposites are investigated in frequency range from 100 Hz to 5 MHz. The results show that both the dielectric constant and the dielectric loss of (PVA–Fe_2O_3/Co_2O_3) nanocomposites are reduced, while the A.C. electrical conductivity increases with increasing of the frequency of applied electric field. The dielectric constant, the dielectric loss and the A.C. electrical conductivity of PVA increases with increasing of the Fe_2O_3/Co_2O_3-nanoparticles' content. The dielectric-properties' results show that the (PVA–Fe_2O_3/Co_2O_3) nanocomposites can be suitable for different electronics fields.

Плівки ПВС і ПВС, леґовані наночастинками Fe_2O_3/Co_2O_3, виготовляються для використання в різних галузях електроніки. Досліджено діелектричні властивості нанокомпозитів (ПВС–Fe_2O_3/Co_2O_3) в діяпазоні частот від 100 Гц до 5 МГц. Результати показують, що як діелектрична проникність, так і діелектричні втрати нанокомпозитів (ПВС–Fe_2O_3/Co_2O_3) зменшуються, тоді як електропровідність змінного струму зростає зі збільшенням частоти прикладеного електричного поля. Діелектрична проникність, діелектричні втрати й електропровідність змінного струму ПВС зростають із збільшенням вмісту наночастинок

Fe_2O_3/Co_2O_3. Результати діелектричних властивостей показують, що нанокомпозити (ПВС–Fe_2O_3/Co_2O_3) можуть бути придатними для різних галузей електроніки.

Key words: PVA, Fe_2O_3/Co_2O_3 nanoparticles, nanocomposites, dielectric properties.

Ключові слова: полівініловий спирт, наночастинки Fe_2O_3/Co_2O_3, нанокомпозити, діелектричні властивості.

(Received 8 February, 2023)

1. INTRODUCTION

Polymers have limited application in the manufacturing of goods and buildings on their own since their qualities are inferior to those of other materials, such as most metals. Polymers are materials with low-density flexible, fast treatment, easy to synthesized, lightweight and superior in dielectric breakdown strength. When a polymer system (matrix) is coupled with reinforcing material (filler), the characteristics of the composite are enhanced. In terms of matrix properties, the features of the composite are heavily influenced by filler features, with the size of the filler playing the most important impact. The polymer nanocomposites (PNC) in the associated technology (nanotechnology) are polymer composites with filler sizes in the nanoscale domain [1–4].

In the type of new substances, nanocomposites with polymer matrix 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 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 semiconductor nanoparticles and polymer matrix are prospective materials for application in optoelectronics, for creation of luminescent materials, sensor, *etc.* [5–14].

Fe_2O_3 nanoparticles (NPs) have special properties like good electron mobility, magnetic ability, and a 2.2 eV optical energy band gap, which are useful for optoelectronic applications. Fe_2O_3 NPs have potential applications in the fields of medicine, life sciences and computer technology like magnetic resonance imaging (MRI), drug carriers in delivery, gene carriers in gene therapy, nanofertilizers, non-fungicides, nanopesticides, nanofood, food packing, nanocoatings, nanosensors, nanoscale memory, nanowires, spintronics, *etc.* They can be used as filters in sunscreens, biosensors [15].

The great interest in cobalt oxides and the derived compounds is due to their exceptional physical and chemical properties, which make them promising materials widely applied in different fields, such as ceramics, optics or catalysis [16]. Polyvinyl alcohol (PVA) is nontoxic, semi-crystalline material, high flexibility and water soluble with excellent mechanical and thermal characterizations. PVA has wide uses in fields such as building, electronics, medicine and other industries. PVA has found applications in number of fields including fuel cells, membranes, papermaking, coatings, adhesives, sensors, batteries, textiles, and biomedical frameworks [17–25]. This work aims to prepare of (PVA–Fe_2O_3/Co_2O_3) nanocomposites to use in the electronics devices.

2. MATERIALS AND METHODS

Nanocomposites of PVA doped with iron oxide nanoparticles (Fe_2O_3 NPs) and cobalt oxide nanoparticles (Co_2O_3 NPs) were fabricated by casting method. The PVA film was prepared by dissolving of 0.5 gm in distilled water (20 ml). The Fe_2O_3/Co_2O_3 NPs were added to the PVA solution with ratio 1:1 and different concentrations: 1.9%, 3.8%, and 5.7%. The dielectric characteristics of PVA–Fe_2O_3/Co_2O_3 nanocomposites films measured at frequency range from 100 Hz to $5\cdot10^6$ Hz by LCR meter (HIOKI 3532-50 LCR HI TESTER). The dielectric constant ε' was determined [26] as

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

where C_p is the capacitance of matter, d is the thickness, A is the area. Dielectric loss ε'' was found [27] as

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

where D represents the dispersion factor. The A.C. electrical conductivity was calculated [28] as

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

3. RESULTS AND DISCUSSION

Figures 1 and 2 demonstrate the variation of dielectric constant and dielectric loss for PVA–Fe_2O_3/Co_2O_3 nanocomposites with frequency, respectively. With increasing frequency, the ε' values decrease,

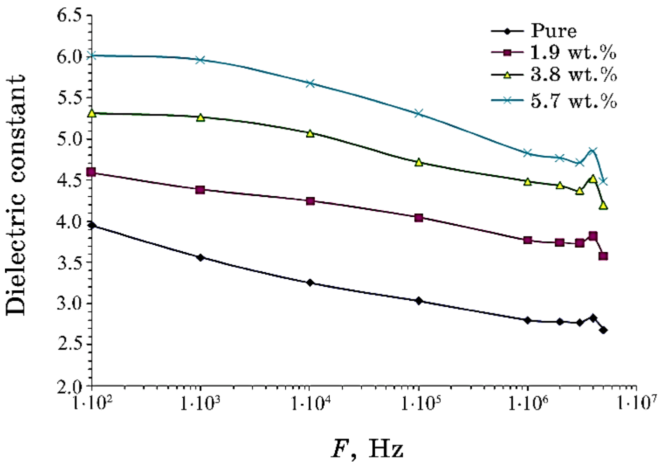

Fig. 1. Variation of dielectric constant for PVA–Fe_2O_3/Co_2O_3 nanocomposites with frequency.

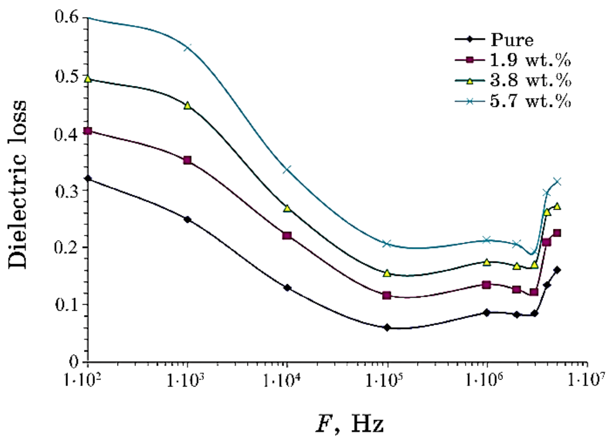

Fig. 2. Dielectric loss performance for PVA–Fe_2O_3/Co_2O_3 nanocomposites with frequency.

causing the dipole to lose its ability to spin, and its oscillation to begin to lie after this field.

Because of the mobility of ions, which is the fundamental basis of nanocomposite, dielectric loss has a reduction in high frequency as shown in Fig. 2; the dielectric loss has reduction in high frequency. As a result, at lower frequency values, a large dielectric loss value implies the effect of ion hopping and the loss of ion movement conduction, as well as the loss of ion polarization [29]. The dielectric constant and dielectric loss of PVA increase with an increase in the

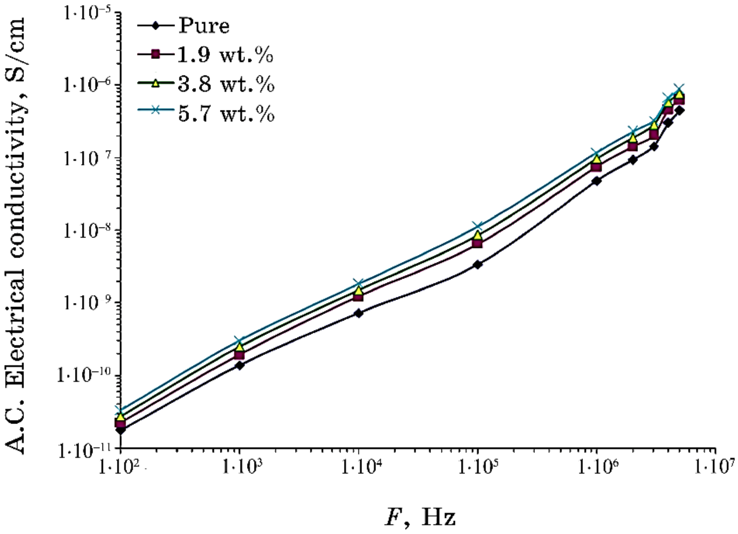

Fig. 3. Behaviour of A.C. electrical conductivity for PVA–Fe_2O_3/Co_2O_3 nanocomposites with frequency.

Fe_2O_3/Co_2O_3 NPs' content due to the rise of the charge carriers [30, 31].

The performance of A.C. electrical conductivity for PVA–Fe_2O_3/Co_2O_3 nanocomposites with frequency is shown in Fig. 3. At high frequency, the A.C. conductivity increases due to the excess charge carriers produced, which are assigned to the trapped charge activation in the polymeric material that undergoes localized motion. The highest value of conductivity was at highest content of Fe_2O_3/Co_2O_3 NPs, which can be assigned efficient conductive networks created, when Fe_2O_3/Co_2O_3 is loaded in polymeric matrix [32].

4. CONCLUSIONS

The present work involves preparation of (PVA–Fe_2O_3/Co_2O_3) nanocomposites films to employ in different electronics fields.

The results show that the dielectric constant and dielectric loss of (PVA–Fe_2O_3/Co_2O_3) nanocomposites is reduced, while the A.C. electrical conductivity increases with increasing of the frequency of applied electric field.

The dielectric constant, the dielectric loss and the A.C. electrical conductivity of PVA is increased with an increase in the Fe_2O_3/Co_2O_3 nanoparticles' content.

Finally, the dielectric properties results show that the (PVA–Fe_2O_3/Co_2O_3) nanocomposites can be suitable for different electronics fields.

REFERENCES

1. 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**: 1 (2022); https://doi.org/10.1016/j.optmat.2022.112497
2. M. H. Rasheed, A. Hashim, and F. L. Rashid, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, Iss. 2: 347(2021); https://doi.org/10.15407/nnn.19.02.347
3. A. Hashim and Z. S. Hamad, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 1: 165 (2022); https://doi.org/10.15407/nnn.20.01.165
4. 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
5. A. Hashim, H. Ahmed, A. Yahya, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, Iss. 3: 681(2021); https://doi.org/10.15407/nnn.19.03.681
6. 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
7. A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 3: 647 (2021); https://doi.org/10.15407/nnn.19.03.647
8. M. Sajjad and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 831 (2021); https://doi.org/10.15407/nnn.19.04.831
9. H. Ahmed and A. Hashim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 841 (2021); https://doi.org/10.15407/nnn.19.04.841
10. 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
11. A. Hashim and A. Jassim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 883 (2021); https://doi.org/10.15407/nnn.19.04.883
12. A. Hashim and Z. S. Hamad, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, No. 4: 893 (2021); https://doi.org/10.15407/nnn.19.04.893
13. A. Hashim and A. Jassim, *Nanosistemi, Nanomateriali, Nanotehnologii*, **20**, No. 1: 177 (2022); https://doi.org/10.15407/nnn.20.01.177
14. 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
15. J. S. Goud and N. Narsimlu, *Indian Journal of Chemical Technology*, **29**: 737 (2022); doi:10.56042/ijct.v29i6
16. M. F. Gazulla, M. J. Ventura, C. Andreu, J. Gilabert, M. Orduna, and M. Rodrigo, *Int. J. of Chem. Sci.*, **17**, No. 3: 1 (2019).
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. C. Srikanth, G. M. Madhu, H. Bhamidipati, and S. Srinivas, *AIMS Materials Science*, **6**, No. 6: 1107 (2019).
27. A. A. Abdelmalik, A. Sadiq, and U. Sadiq, *J. Phys. Sci.*, **31**, No. 1: 1 (2020); https://doi.org/10.21315/jps2020.31.1.1
28. K. Prabha and H. S. Jayanna, *Open Journal of Polymer Chemistry*, **5**: 47 (2015).
29. 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**: (2022); https://doi.org/10.1016/j.optmat.2022.112497
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. N. Al-H. Al-Aaraji, A. Hashim, A. Hadi, and H. M. Abduljalil, *Silicon*, **14**: 4699 (2022); https://doi.org/10.1007/s12633-021-01265-3
32. A. E. Tarabiah, Hisham A. Alhadlaq, Z. M. Alaizeri, A. A. A. Ahmed, G. M. Asnag, and M. Ahamed, *Journal of Polymer Research*, **29**: 1 (2022); https://doi.org/10.1007/s10965-022-03011-8