Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2024, т. 22, № 2, сс. 427–436
https://doi.org/10.15407/nnn.22.02.427

PACS numbers: 77.22.Ch, 77.22.Gm, 78.20.Ci, 78.67.Sc, 81.07.Pr, 82.35.Np, 85.35.Ds

Developing the Dielectric Properties of PVP/SiC/Ti Nanocomposites

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Films of PVP/SiC/Ti nanocomposites (PVP—polyvinyl pyrrolidine) are fabricated to employ in various electrical and electronics applications. The dielectric properties of PVP/SiC/Ti nanocomposites are tested in frequency range from 100 Hz to 5 MHz. The results confirm that the dielectric constant, dielectric loss and electrical conductivity of PVP/SiC/Ti nanocomposites are rising with rising concentration. The dielectric constant and dielectric loss of PVP/SiC/Ti nanocomposites decrease, but the conductivity is raised, with increasing of frequency. The final results show that PVP/SiC/Ti nanocomposites may be suitable in various electronics applications.

Плівки з нанокомпозитів ПВП/SiC/Ti (ПВП — полівінілпіролідин) виготовляються для використання в різних електричних та електронних застосуваннях. Діелектричні властивості нанокомпозитів ПВП/SiC/Ti перевіряються в діяпазоні частот від 100 Гц до 5 МГц. Результати підтверджують, що діелектрична проникність, діелектричні втрати й електропровідність нанокомпозитів ПВП/SiC/Ti зростають зі збільшенням концентрації. Діелектрична проникність і діелектричні втрати нанокомпозитів ПВП/SiC/Ti зменшуються, але провідність підвищується зі збільшенням частоти. Остаточні результати показують, що ПВП/SiC/Ti-нанокомпозити можуть бути придатними для різних застосувань електроніки.

Key words: polyvinyl pyrrolidine, SiC/Ti, nanocomposites, dielectric properties, electronics applications.

Ключові слова: полівінілпіролідин, SiC/Ti, нанокомпозити, діелектричні властивості, застосування в електроніці.

(Received 28 June, 2023; in revised form, 26 August, 2023)

1. INTRODUCTION

Nanocomposite materials are increasingly used in different areas. Since the requirements for such materials are permanently increasing, there is a need to create new functional materials with superior properties. In particular, the development of flexible conductive materials for electronics, optics, and devices for energy conversion and storage, much attention is paid to the creation of electrically conductive polymer-based nanocomposites [1].

Recent years have seen a rise in the use of nanocomposite materials in scientific research, with the promotion of physical properties and changes in energy storage technologies as essential components for practical applications.

The current applications of nanocomposites include high-energy batteries, fuel cells, microwave absorbers, optoelectronics, gas sensors, and UV filters. Many microelectronic devices require flexible, lightweight, dielectric/conductive polymer materials. By adding a few nanofillers, electrical conduction networks can be successfully formed in insulating polymers, leading to better optical and thermal properties [2].

Silicon carbide (SiC) is used as inorganic materials due to its have a well thermal and chemical stability, high strength and hardness [3].

Titanium is a highly attractive material in the production of components for various applications ranging from biomedical implants to automotive fuel injectors due to its low density, high strength, good corrosion resistance, and biocompatibility. At the same time, the high strength to weight ratio and high resistance to corrosion make titanium and its alloys ideal materials for many applications [4].

Polyvinyl pyrrolidine (PVP) has a moderately conductive electrical conductivity and is suitable for a wide range of materials, since it has great stability. Polyvinyl pyrrolidine has rich charge transport and is considered as low-toxicity polymer [5].

There are many investigations on nanocomposites field to make use in different approaches such as optical fields [6–15], radiation shielding and bioenvironmental [16–21], energy storage [22–24],sensors [25, 26], antibacterial [27–32], electronics and optoelectronics [33–47].

This study aims to fabricate the PVP/SiC/Ti nanocomposites and to examine the dielectric properties to employ in various electrical and electronics applications.

2. MATERIALS AND METHODS

Nanocomposite films of PVP biopolymer doped with SiC/Ti nanoparticles (NPs) were synthesized by using casting technique. The PVP/SiC/Ti nanocomposite films were fabricated with various concentrations: $C_1 = 12.5$ gm/L, $C_2 = 25$ gm/L, $C_3 = 50$ gm/L, and constant weight percentage of SiC/Ti NPs (6%) with content of 50% SiC and 50% Ti. The dielectric properties of PVP/SiC/Ti nanocomposite films were tested at frequency (F) range from 100 Hz to 5 MHz by using LCR meter (HIOKI 3532-50 LCR HI TESTER).

The dielectric constant (ε') is calculated by [48]:

$$\varepsilon' = C_p/C_0, \tag{1}$$

wherever C_p is the capacitance of matter and C_0 is the vacuum capacitance.

Dielectric loss (ε'') is determined by [49]:

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

where D is the dispersion factor.

The A.C. electrical conductivity is obtained by [50]:

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

3. RESULTS AND DISCUSSION

The variation of dielectric constant and dielectric loss with frequency and concentration for PVP/SiC/Ti nanocomposites films are shown in Figs. 1–4, respectively. The dielectric constant rises at lower frequencies. This increased dielectric constant is due to Maxwell–Wagner polarization, which is primarily produced by conductor-insulator interactions. Furthermore, this interfacial polarization is caused by the accumulation of space charge polarization at the interfaces. Space charges acquire ample time to adapt to an applied electric field in the low-frequency region; however, in the higher frequency range, changes towards an electric field eventuate rapidly for space charges to adjust, and the polarization consequence could not exist.

The dielectric loss reduces as the frequency increases. Higher frequencies hinder the ability for space charges that respond towards the applied field, therefore charge accumulation due to polarization reduces, and hence dielectric loss decreases. The dielectric constant and dielectric loss are increased with an increase in the concentration; this is due to raise in the number of charges carriers

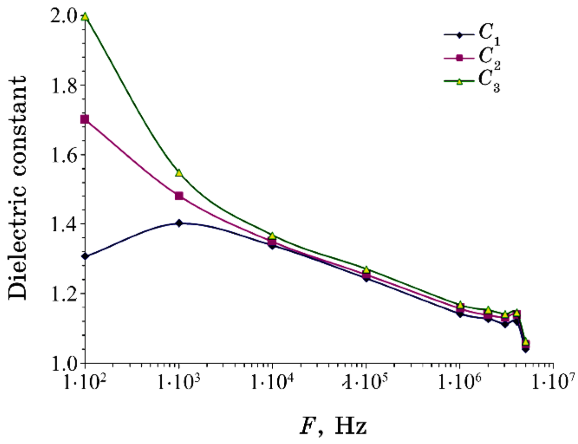

Fig. 1. Variation of dielectric constant with frequency for PVP/SiC/Ti nanocomposites.

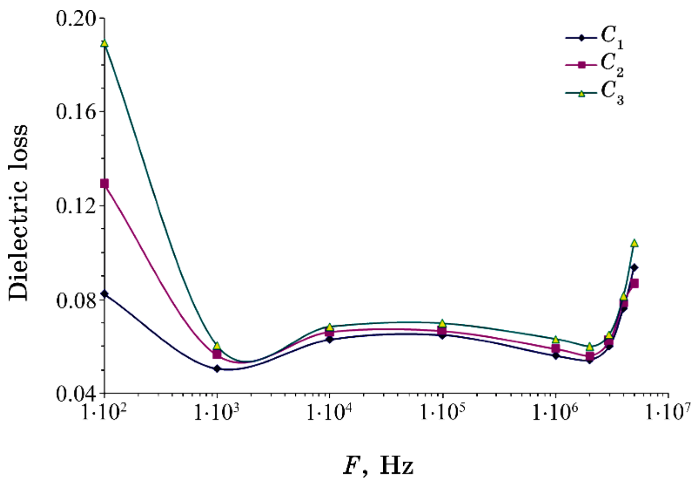

Fig. 2. Dielectric loss variation with frequency for PVP/SiC/Ti nanocomposites.

[51–64].

Figures 5 and 6 illustrate the behaviour of electrical conductivity for PVP/SiC/Ti nanocomposites with frequency and concentration, respectively. The electrical conductivity increases with an increase in the frequency and concentration.

At low-frequency levels, conductivity is poor due to interfacial impedance or space charge polarization. This one indicates that the thin films, which have been investigated, have non-Debye properties. Conductivity increases with a rise in frequency, when operat-

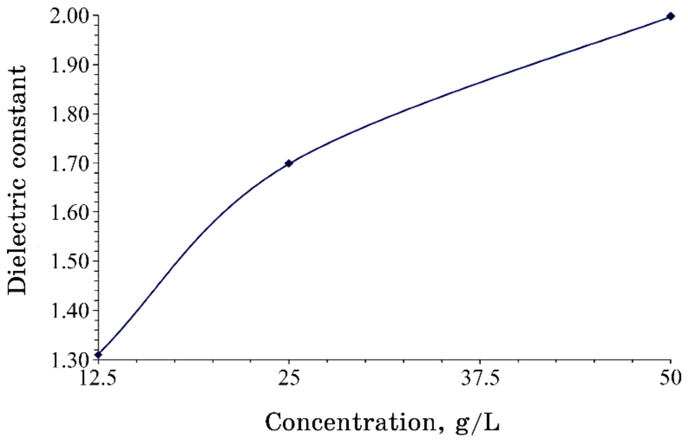

Fig. 3. Dielectric constant behaviour with concentration for PVP/SiC/Ti nanocomposites.

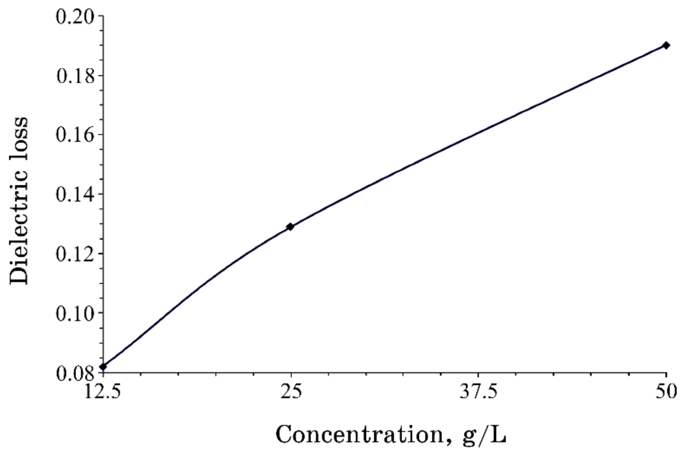

Fig. 4. Variation of dielectric loss for PVP/SiC/Ti L nanocomposites with concentration.

ing at higher frequencies.

The increase of conductivity with rising concentration can be related to increase in the charge carriers [65–70].

4. CONCLUSIONS

The current study involves fabrication of PVP/SiC/Ti nanocomposites films to utilize in many electrical and electronics fields. The dielectric properties of PVP/SiC/Ti nanocomposites were tested in

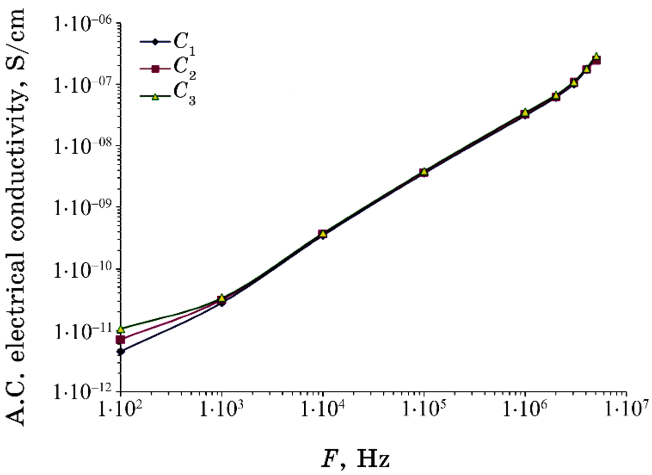

Fig. 5. Behaviour of electrical conductivity for PVP/SiC/Ti nanocomposites with frequency.

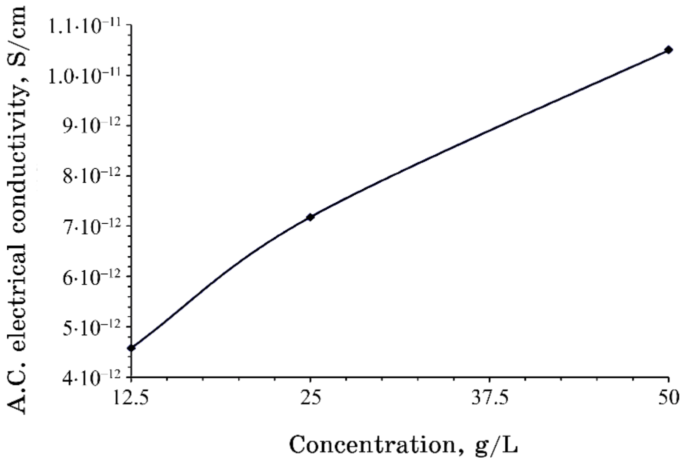

Fig. 6. Performance of electrical conductivity for PVP/SiC/Ti nanocomposites with concentration.

frequency ranged of 100 Hz–5 MHz. The results confirmed that the dielectric constant, dielectric loss and electrical conductivity of PVP/SiC/Ti nanocomposites are increased with rising concentration. The dielectric constant and dielectric loss of PVP/SiC/Ti nanocomposites are decreased, while the conductivity rises, with increasing frequency. Finally, the results show that the PVP/SiC/Ti nanocomposites may be appropriate in various electronics fields.

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