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Tailoring the Dielectric Properties of PMMA–SiC–Cr_2O_3 Nanocomposites for Nanoelectronics Applications

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Films of PMMA–SiC–Cr_2O_3 nanocomposites are prepared to utilize in various electronics applications. The dielectric properties of PMMA–SiC–Cr_2O_3 nanocomposites are studied in frequency range from 100 Hz to 5 MHz. The results illustrate both the dielectric constant and the dielectric loss of PMMA–SiC–Cr_2O_3 nanocomposites reduced, while the conductivity rises with rising of frequency. Dielectric constant, dielectric loss, and electrical conductivity of PMMA are rising with rising in the SiC–Cr_2O_3 nanoparticles' ratio. The results on dielectric properties demonstrate that the PMMA–SiC–Cr_2O_3 nanocomposites may be useful for electronics applications.

Плівки нанокомпозитів поліметилметакрилат (ПММА)–SiC–Cr_2O_3 підготовлено для використання в різних застосуваннях електроніки. Досліджено діелектричні властивості нанокомпозитів ПММА–SiC–Cr_2O_3 у діяпазоні частот від 100 Гц до 5 МГц. Одержані результати свідчать про те, що діелектрична проникність і діелектричні втрати нанокомпозитів ПММА–SiC–Cr_2O_3 зменшуються, тоді як провідність зростає зі зростанням частоти. Діелектрична проникність, діелектричні втрати й електропровідність ПММА зростають зі збільшенням (спів)відношення наночастинок SiC–Cr_2O_3. Результати щодо діелектричних властивостей демонструють, що нанокомпозити ПММА–SiC–Cr_2O_3 можуть бути корисними для застосування в електроніці.

Key words: poly(methyl methacrylate), $SiC–Cr_2O_3$, nanocomposites, dielectric constant, conductivity.

Ключові слова: полі(метилметакрилат), $SiC–Cr_2O_3$, нанокомпозити, діелектрична проникність, провідність.

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1. INTRODUCTION

Recently, the improvement of polymeric materials by modification of their physical properties has become of concern in order to fulfil the increasing requirements in various industrial applications such as cables, materials of electronic packaging, jackets, and films of capacitors [1].

Chromium oxide (Cr_2O_3) is one of the most important wide band gap ($E_g \approx 3$ eV) *p*-type semiconductor, transition metal-oxide material. This kind of *p*-type wide band-gap oxide semiconductors may be a good candidate material for UV-light emitter using nanolasers, and optical storage system. It has wide variety of applications such as catalysts, hydrogen storage, wear resistance materials, dye and pigment, advanced colorants, digital recording system, black matrix films, solar energy application, coating materials for thermal protection, and electrochromic material. It expresses high electrical conductivity with partial or complete electron transfer. It is treated as an important refractory material because of its high melting temperature (≈ 2300°C) and high-temperature oxidation resistance, although it shows poor sintering ability, which is possibly because of low density factor [2].

Silicon carbide (SiC) is used as inorganic materials due to its have a well thermal and chemical stability, high strength and hardness. Some researchers have studied the addition of SiC to the polymer with improving thermal stability and dielectric properties [3]. Nanocomposites with silicon carbide may be utilized in different electronics, optical, optoelectronics and photonics fields [4–12].

Poly(methyl methacrylate) (PMMA) polymer has an excellent optical, electrical, mechanical, and thermal characteristic. The exceptional properties of PMMA such as, high transparency, environmental stability, low cost, easy preparation and shaping at low temperature make it an excellent candidate for fabricating thin films [13]. PMMA doped with different materials may be employed for various electronics and optoelectronics fields [14–16]. The organic–inorganic nanocomposites' applications are promising in the fields of optical and electronic devices, sensors, microelectronic packaging, membranes, aerospace, packaging materials, medicine, drug delivery, automobiles, coatings, injection moulded products, consumer goods, fire-retardants, adhesives, *etc.* [17–28].

2. MATERIALS AND METHODS

The samples of PMMA–SiC–Cr_2O_3 nanocomposites films were prepared using the dissolving of 0.5 gm of PMMA in 20 ml of chloroform by using magnetic. The SiC–Cr_2O_3 nanoparticles (NPs) were added to the PMMA with concentration 1:3, and different ratios are as follow: 1.9, 3.8 and 5.7 wt.%. The casting technique was employed to fabricate the PMMA–SiC–Cr_2O_3 nanocomposites. The dielectric properties of PMMA–SiC–Cr_2O_3 nanocomposites' films were tested in the frequency range from 100 Hz to $5\cdot10^6$ Hz, using LCR meter type (HIOKI 3532-50 LCR HI TESTER). The dielectric constant (ε') is calculated by Ref. [29]

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

where C_p is parallel capacitance and C_0 is vacuum capacitor. The dielectric loss (ε'') is calculated by Ref. [30]

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

where D is dispersion factor. The A.C. electrical conductivity is defined by Ref. [30]

$$\sigma_{\text{A.C.}} = \omega\varepsilon''\varepsilon_0, \tag{3}$$

where ω is the angular frequency.

3. RESULTS AND DISCUSSION

The variations of dielectric constant and dielectric loss for PMMA–SiC–Cr_2O_3 nanocomposites' films with frequency (F) are represented in Figs. 1 and 2, respectively. These figures show that both the dielectric constant and the dielectric loss rise sharply towards low frequencies due to the tendency of dipoles in the sample to orient themselves in the direction of the applied field [32]. The dielectric constant and dielectric loss of PMMA rise with increase in SiC–Cr_2O_3 NPs' ratio; this is due to the rise of the charge carriers [33, 34].

The performance of A.C. electrical conductivity with frequency for PMMA–SiC–Cr_2O_3 nanocomposites' films is shown in Fig. 3. As the frequency decreases, the more and more charge is accumulated

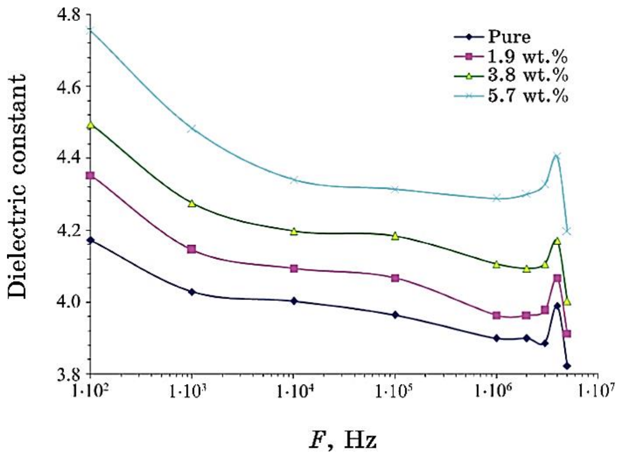

Fig. 1. Variation of dielectric constant for PMMA–SiC–Cr_2O_3 nanocomposites' films with frequency F.

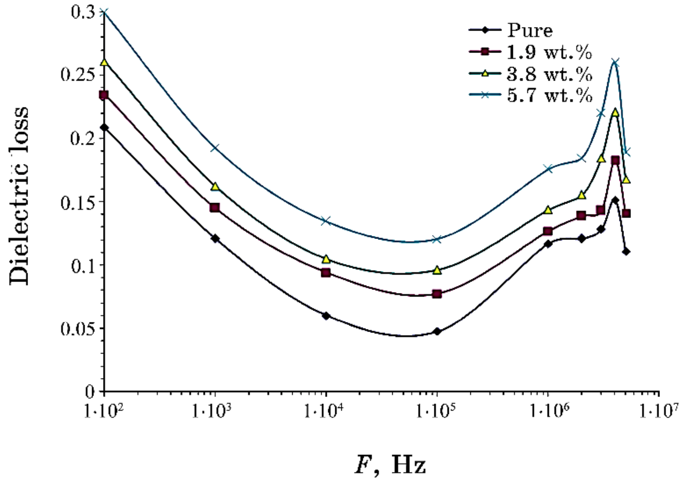

Fig. 2. Dielectric loss variation of PMMA–SiC–Cr_2O_3 nanocomposites' films with frequency F.

at the electrode and electrode interface that leads to a decrease in the number of mobile ions and, eventually, to a drop in the conductivity at low frequencies. In the high-frequency region, the conductivity increases with the frequency due to the mobility of charge carriers and the hopping of ions from the infinite cluster.

As a result, the ion exchange process occurs effectively in the high-frequency region [35]. The A.C. electrical conductivity of PMMA is increasing with an increase in the SiC–Cr_2O_3 NPs' con-

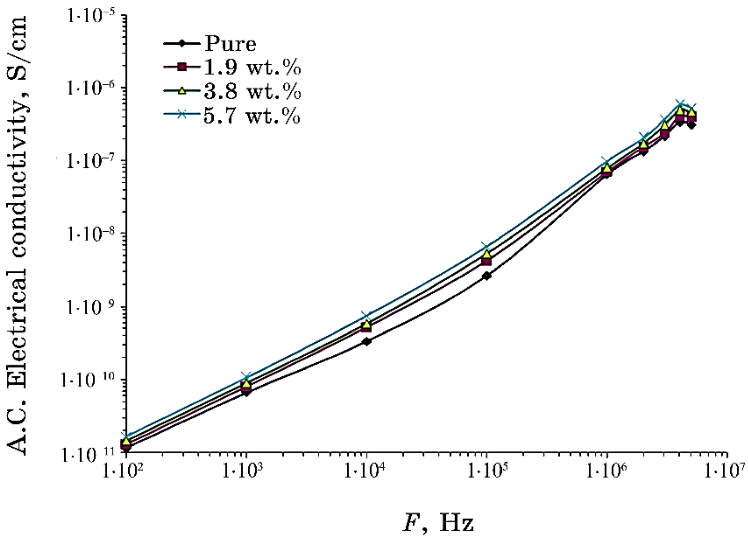

Fig. 3. Performance of A.C. electrical conductivity with frequency F for PMMA–SiC–Cr_2O_3 nanocomposites' films.

tent; this behaviour relate to the enhancement of the mobility of charge ions and the larger number of charge carriers in polymer matrix [36].

CONCLUSIONS

This work includes the fabrication and investigation of dielectric properties for PMMA–SiC–Cr_2O_3 nanocomposites' films to employ in various electronics applications. The results show that both the dielectric constant and the dielectric loss of PMMA–SiC–Cr_2O_3 nanocomposites are reduced, while the conductivity rises with rising of frequency. Dielectric constant, dielectric loss and electrical conductivity of PMMA were rising with rising in the SiC–Cr_2O_3 NPs' ratio about 12.2%, 30.4% and 30.4%, respectively at 100 Hz. The results on dielectric properties indicate that the PMMA–SiC–Cr_2O_3 nanocomposites may be suitable for electronics fields.

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