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Exploring the A.C. Electrical Properties of PMMA/SiC/CdS Nanocomposites to Use in Electronics Fields

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This work aims to fabricate the PMMA/SiC/CdS nanocomposites to use in lightweight and low-cost electronics applications. The A.C. electrical properties of PMMA/SiC/CdS nanocomposites are investigated. The results show that both the dielectric constant and the dielectric loss of PMMA/SiC/CdS nanocomposites are reduced, while the electrical conductivity is increased as frequency is increased. Dielectric constant, dielectric loss and electrical conductivity of PMMA are enhanced with increasing in SiC/CdS nanoparticles' content. The obtained results on A.C. electrical properties show that the PMMA/SiC/CdS nanocomposites are suitable for various nanoelectronics fields.

Цю роботу спрямовано на виготовлення нанокомпозитів поліметилметакрилат (ПММА)/SiC/CdS для використання у легковагих і недорогих застосуваннях електроніки. Досліджено електричні властивості нанокомпозитів ПММА/SiC/CdS. Результати показують, що як діелектрична проникність, так і діелектричні втрати нанокомпозитів ПММА/SiC/CdS зменшуються, тоді як електропровідність збільшується зі збільшенням частоти. Діелектрична проникність, діелектричні втрати й електропровідність ПММА збільшуються зі збільшенням вмісту наночастинок SiC/CdS. Одержані результати стосовно електричних властивостей змінного струму показують, що нанокомпозити ПММА/SiC/CdS придатні для різних галузей наноелектроніки.

Key words: nanocomposites, poly(methyl methacrylate), SiC/CdS, dielectric properties.

Ключові слова: нанокомпозити, поліметилметакрилат, SiC/CdS, діелектричні властивості.

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1. INTRODUCTION

Polymer nanocomposites are one of the most important materials in the academic and industrial areas, and are produced by dispersing nanofillers with one or more dimensions at nanoscale into the polymeric matrix. Recently, researchers have been attracted to polymer nanocomposites over conventional microcomposites due to their wide applications in electromechanical systems and their large interfacial area per unit volume of the dispersion medium [1]. Poly(methyl methacrylate) (PMMA) is classified as acrylate polymers. It is an optically transparent thermoplastic, and it is widely used as a substitute for inorganic glass due to high impact strength, weather resistance and scratch resistance. Intrinsically, it is an insulator but with doping and mixing with metallic nanoparticles (NPs), it starts conduct electric charges. The drastic change in the properties of polymer nanocomposites are influenced by the type of integrated nanoparticles, their size, shape, their concentration and interaction with polymer matrix. PMMA as a conducting polymer has attracted attention for use in many applications as optical components, optical sensors and in optoelectronics devices due to their low cost and excellent physical and chemical properties [2]. The nanocomposites with PMMA matrix may be applied for optoelectronics and electronics applications [3–5].

CdS is a semiconductor capable of absorbing visible light. Metal sulphides are potential candidates for photocatalysis applications. The valence band of such materials usually consists of sulphur 3*p* orbitals that leads to more negative values of the conduction band in comparison with metal oxides (MO). There is a wide range of methods for the synthesis of narrow-gap semiconducting CdS of various forms—nanoparticles, nanospheres, nanorods, and nanoplates [6]. Silicon carbide (SiC) is the main candidate material for spatial optical mirrors due to its excellent thermal dimensional stability, low density and high strength. In order to reduce the launch cost and ensure the imaging accuracy, the SiC mirrors should be designed with optimal topological structures to achieve a high degree of lightweight [7]. SiC nanocomposites were studied for various optical, photonics, electronics and optoelectronics applications

[8–16].

The applications of nanocomposites (organic and inorganic) are promising in the approaches of sensors, microelectronic packaging, packaging materials, medicine, optical and electronic devices, drug delivery, automobiles, membranes, aerospace, coatings, injection moulded products, adhesives, consumer goods, fire-retardants, *etc.* [17–27]. The present work deals with fabrication of PMMA/SiC/CdS nanocomposites and investigating their A.C. electrical properties to use different nanoelectronics fields.

2. MATERIALS AND METHODS

The nanocomposites films of PMMA/SiC/CdS were fabricated by dissolving 0.5 gm of PMMA in 20 ml of chloroform by using magnetic. The SiC/CdS nanoparticles added to PMMA mixture with ratio 1:3 and different contents are 1.9, 3.8 and 5.7 wt.%. The casting method was used to prepare the samples of PMMA/SiC/CdS nanocomposites. The A.C. electrical properties of PMMA/SiC/CdS nanocomposites samples studied with frequency range from 100 Hz to $5\cdot10^6$ Hz by using LCR meter type (HIOKI 3532-50 LCR HI TESTER). The dielectric constant ε' is given by the equation [28]

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

where C_p is parallel capacitance and C_0 is vacuum capacitor. The dielectric loss ε'' is calculated by [29]

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

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

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

where w is the angular frequency.

3. RESULTS AND DISCUSSION

Figure 1 and Figure 2 show the behaviours of dielectric constant and dielectric loss of PMMA/SiC/CdS nanocomposites with frequency respectively. As shown in these figures, the dielectric constant has high values at low frequency. The high value of dielectric constant at lower frequency might be due to the electrode effect and interfacial effect of the sample [31]. The high value at low frequen-

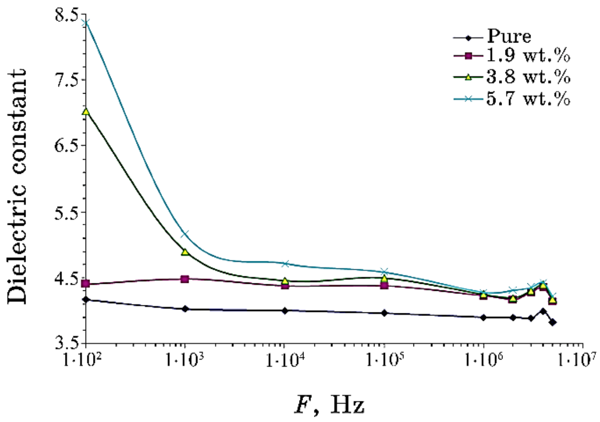

Fig. 1. Behaviour of dielectric constant for PMMA/SiC/CdS nanocomposites with frequency.

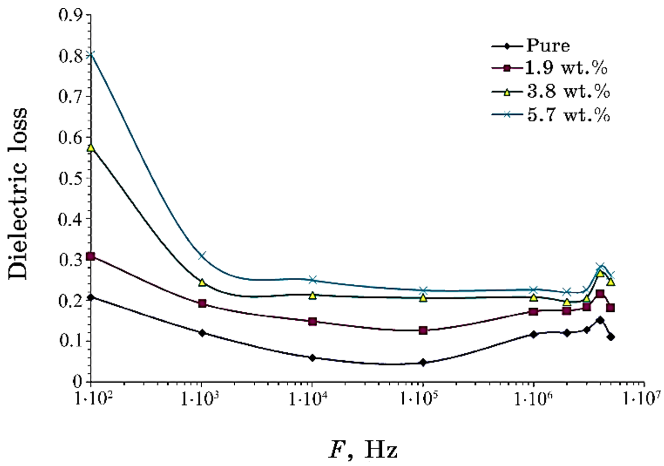

Fig. 2. Dielectric loss behaviour of PMMA/SiC/CdS nanocomposites with frequency.

cy of dielectric loss of PMMA/SiC/CdS nanocomposites is related to the charges mobility [32]. The dielectric constant and dielectric loss are increased with an increase in the SiC/CdS nanoparticles content, this result can be attributed to the increase in conductivity because of the increase charge carriers density in polymer matrix [33, 34].

Figure 3 demonstrates the variation of A.C. electrical conductivity for the PMMA/SiC/CdS nanocomposites with frequency. As shown in this figure, it can be noticed that the conductivity rises with the increase in frequency that relates to the polarization effect and hopping mechanism [35]. As the SiC/CdS NPs' content is in-

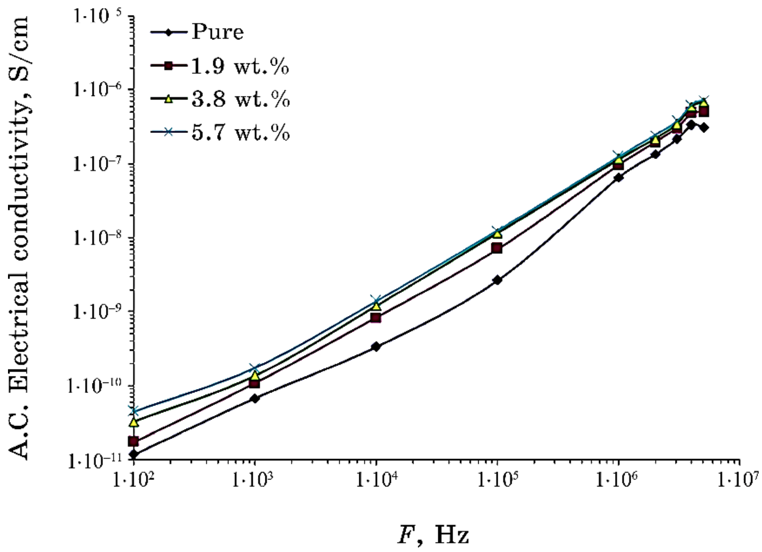

Fig. 3. Variation of A.C. electrical conductivity for PMMA/SiC/CdS nanocomposites with frequency.

creased, the inorganic filler molecules start bridging the gap separating two the localized states and lowering the potential barrier between them, thereby, facilitating the transfer of charge carriers between two localized states [36, 37].

4. CONCLUSIONS

This study involves synthesis of PMMA/SiC/CdS nanocomposites and studying their A.C. electrical properties to employ in lightweight and low cost electronics fields. The results showed that the dielectric constant and dielectric loss of PMMA/SiC/CdS nanocomposites reduced while the electrical conductivity increased as frequency increases. The dielectric constant, dielectric loss and electrical conductivity of PMMA enhanced with a rise in the SiC/CdS NPs' content. The obtained results on A.C. electrical properties showed that the PMMA/SiC/CdS nanocomposites are appropriate for different nanoelectronics applications.

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