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Synthesis and Morphology Characteristics of PMMA/CeO_2/SiO_2 Nanostructures for Antibacterial Application

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In this work, nanocomposite films are prepared by casting method from polymethyl methacrylate (PMMA) with various ratios of nanomaterials (SiO_2–CeO_2): 1.4, 2.8, 4.2 and 5.6 wt.%. The structural properties are investigated by means of the optical and field emission scanning electron microscopies. The results show that there is a good-homogeneity distribution of SiO_2/CeO_2 nanoparticles within the polymeric mixture. The PMMA/SiO_2/CeO_2 nanocomposites are tested for antibacterial application. The results show that the inhibition-zone diameter increases with increase in the SiO_2/CeO_2 nanoparticles' concentrations.

У цій роботі нанокомпозитні плівки готуються методом лиття з поліметилметакрилату (ПММА) за різних співвідношень наноматеріялів (SiO_2–CeO_2): 1,4, 2,8, 4,2 і 5,6 мас.%. Структурні властивості досліджуються за допомогою оптичної й автоемісійної сканувальної мікроскопій. Результати показують, що є розподіл наночастинок SiO_2/CeO_2 з хорошою однорідністю в полімерній суміші. Нанокомпозити ПММА/SiO_2/CeO_2 тестуються на антибактеріяльне застосування. Результати показують, що діяметер зони інгібування збільшується зі збільшенням концентрації наночастинок SiO_2/CeO_2.

Key words: nanocomposites, polymethyl methacrylate, SiO_2, CeO_2, structural properties, antibacterial agents.

Ключові слова: нанокомпозити, поліметилметакрилат, SiO_2, CeO_2, структурні властивості, антибактеріяльні засоби.

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1. INTRODUCTION

Nanocomposites of polymers and inorganic nanoparticles (NPs) have attracted increasing interest due to their value-added applications derived from their unique optical, magnetic, electrical, thermal, and antibacterial properties [1]. Polymers have played a very important role in many areas of daily life as traditional materials [2, 3]. Polymers are characterized by their resistance to abrasion, flexibility, colour fastness, ease of processing, lightness, *etc.* [4].

Polymethyl methacrylate (PMMA) was chosen in this study because it is non-toxic, cost-effective, and effortless to get. PMMA has appropriate material properties such as distinguished mechanical quality, hardness, excessive rigidity, transparency, and good insulation residences [5]. Cerium oxide nanoparticles (CeO_2 NPs) have attracted much attention for their high stability, surface chemistry, and biocompatibility. CeO_2 NPs are transparent in the visible region and have a refractive index of 2.2 at a wavelength of 632 nm. Pure CeO_2 exhibits a wide indirect optical band gap and energy-wide band gap that operates effectively in the ultraviolet region, and thus, it could be an excellent choice for different optical and electronic applications [6]. Silicon dioxide (SiO_2) commonly referred to as silica, which may exist in the amorphous and crystalline structure, was found to be useful filler for improving the mechanical performance of polymeric materials. The silica, as an additive, is used in coatings, food, and biomedical applications [7]. The oxides' nanostructures and nanooxides-doped polymers were included many applications in different industrial approaches such as sensors, electronics and optoelectronics [8–32], and bioenvironmental fields [33–39].

The present work deals with preparation of PMMA/SiO_2/CeO_2 nanocomposites for antibacterial applications.

2. MATERIALS AND METHODS

Films of PMMA/SiO_2/CeO_2 nanocomposites were prepared from PMMA and PMMA doped with SiO_2 and CeO_2 nanoparticles using casting method by dissolving 1.5 g of PMMA in 30 ml of chloroform; then, the SiO_2/CeO_2 NPs were added to PMMA with different ratios: 1.4, 2.8, 2.8, 4.2, 5.6 wt.%. Microscopic images of the pure polymer and the nanocomposites were measured using optical microscopy with a magnification of ×10. Field emission scanning electron microscopy (FE-SEM) was used to examine the surfaces' nature of the polymer and PMMA/SiO_2/CeO_2 nanocomposites. These nanocomposites were tested for antibacterial activity against gram-positive (*Staphylococcus aureus*) and gram-negative (*Proteus*) bacteria by diffusion method.

3. RESULTS AND DISCUSSION

The SiO_2/CeO_2 NPs distribution inside the PMMA matrix are shown in Figs. 1 and 2.

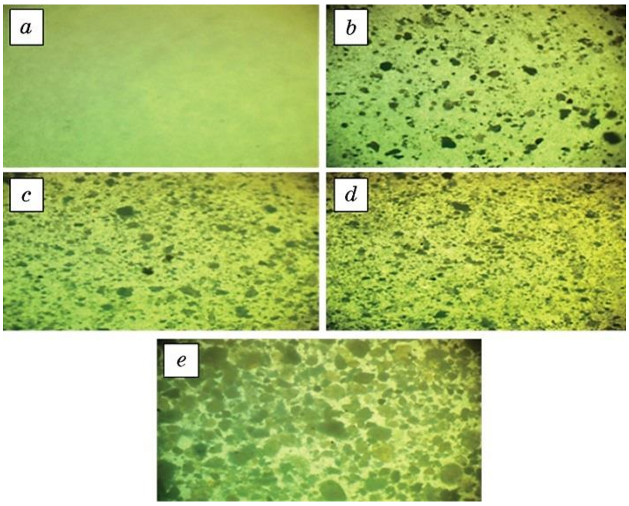

Fig. 1. Microscope images (×10): *a*—pure polymer; *b*—1.4 wt.% SiO_2/CeO_2 NPs; *c*—2.8 wt.% SiO_2/CeO_2 NPs; *d*—4.2 wt.% SiO_2/CeO_2 NPs; *e*—5.6 wt.% SiO_2/CeO_2 NPs.

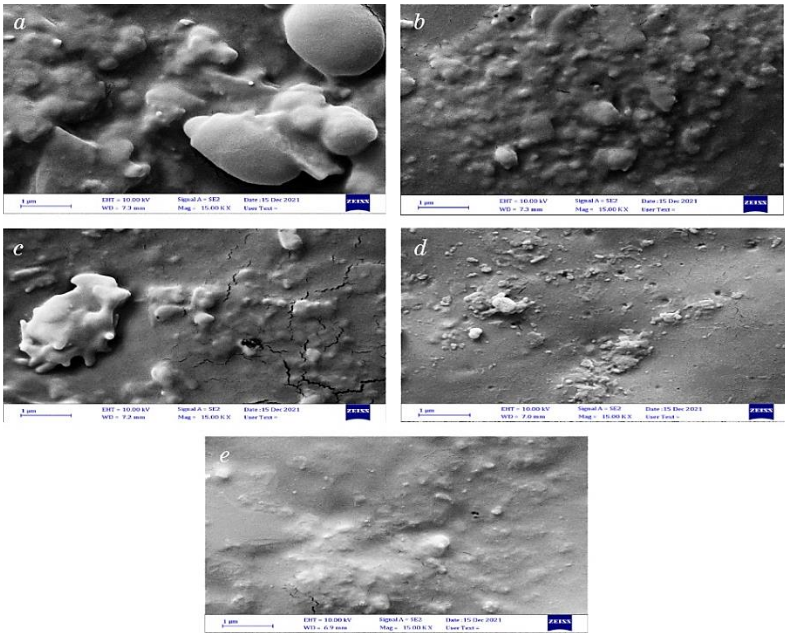

Fig. 2. FE-SEM images: *a*—pure polymer; *b*—1.4 wt.% SiO_2/CeO_2 NPs; *c*—2.8 wt.% SiO_2/CeO_2 NPs; *d*—4.2 wt.% SiO_2/CeO_2 NPs; *e*—5.6 wt.% SiO_2/CeO_2 NPs.

The figures demonstrate that the images of optical microscopy and FE-SEM for PMMA/SiO_2/CeO_2 nanocomposites. From these figures, the SiO_2/CeO_2 nanoparticles are aggregated as clusters at low concentrations, but they form a paths network inside the polymer matrix at high concentration [40].

Figures 3 and 4 illustrate the antibacterial activity of PMMA/SiO_2/CeO_2 nanocomposites against gram-positive (*Staphylococcus aureus*) and gram-negative (*Proteus*) bacteria. From these figures, the inhibition-zone diameter increases with increasing SiO_2/CeO_2-nanoparticles' concentrations. The major mechanism that caused the antibacterial activity by the metal-oxide NPs might be through oxidative stress caused by ROS. ROS includes radicals like

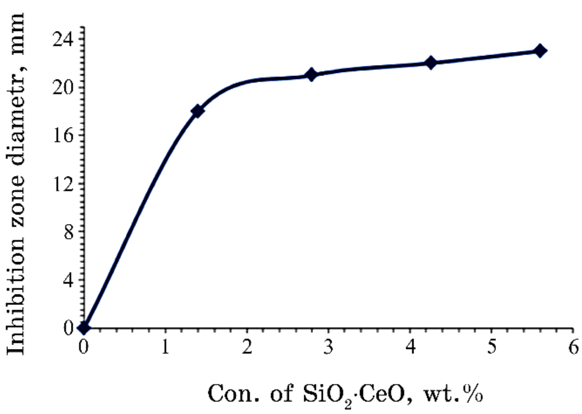

Fig. 3. Antibacterial activity of PMMA/SiO_2/CeO_2 nanocomposites against gram-positive (*Staphylococcus aureus*) bacteria.

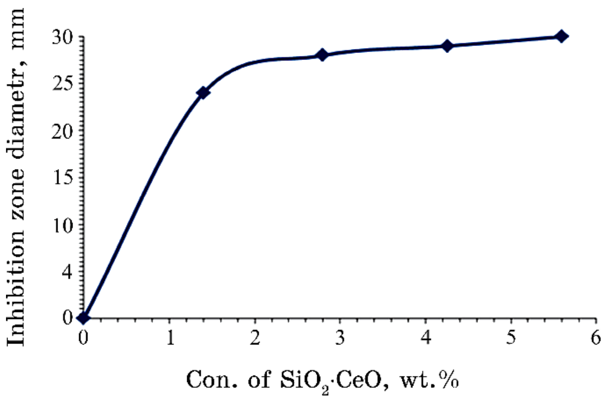

Fig. 4. Antibacterial activity of PMMA/SiO_2/CeO_2 nanocomposites against gram negative (Proteus) bacteria.

superoxide radicals (O^{-2}), hydroxyl radicals (^{-}OH), hydrogen peroxide (H_2O_2) and singlet oxygen ($^1O_2$), which could be the reason of damaging the proteins and DNA in the bacteria. ROS could be produced by the present nanocomposites leading to the inhibition of most pathogenic bacteria [41, 42].

4. CONCLUSION

This work includes of fabricating the PMMA/SiO_2/CeO_2 nanocomposites' films for antibacterial applications. The morphology properties of PMMA/SiO_2/CeO_2 nanocomposites were tested to use for antibacterial applications. The results of antibacterial activity of PMMA/SiO_2/CeO_2 nanocomposites demonstrate that the inhibition-zone diameter increases with increase in the SiO_2/CeO_2 concentrations against gram-positive (*Staphylococcus aureus*) and gram-negative (*Proteus*) bacteria.

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