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Synthesis of PEO/Si_3N_4–CeO_2-Nanocomposites' Films for Radiation Shielding

Ahmed Kareem, Ahmed Hashim, and Huda Bukheet Hassan

College of Education for Pure Sciences,
Department of Physics,
University of Babylon,
34001 Hillah, Iraq

Films of PEO/Si_3N_4–CeO_2 nanocomposites (NCs) are fabricated by casting method with different contents of PEO-polymer matrix and Si_3N_4–CeO_2 nanoparticles (NPs). The PEO/Si_3N_4–CeO_2 NCs are examined for gamma ray shielding. The results show that the PEO/Si_3N_4–CeO_2 NCs have the high attenuation coefficients for gamma rays. The attenuation coefficients increase with the increase of the Si_3N_4–CeO_2-NPs' concentration.

Плівки нанокомпозитів поліетилен оксид (ПЕО)/Si_3N_4–CeO_2 було виготовлено методом лиття з різним вмістом полімерної матриці ПЕО та наночастинок Si_3N_4–CeO_2. Нанокомпозити ПЕО/Si_3N_4–CeO_2 було досліджено стосовно екранування гама-променів. Результати показали, що нанокомпозити ПЕО/Si_3N_4–CeO_2 мають високі коефіцієнти ослаблення гама-променів. Коефіцієнти ослаблення підвищуються зі збільшенням концентрації наночастинок Si_3N_4–CeO_2.

Key words: PEO, CeO_2, Si_3N_4, nanocomposites, radiation shielding.

Ключові слова: поліетилен оксид, CeO_2, Si_3N_4, нанокомпозити, радіаційний захист.

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1. INTRODUCTION

Polymer nanocomposites (PNCs) contain typically one or more nanoparticles (NPs) components within the polymer matrix [1]. The enhancement of the properties with the addition of nanoparticles can be achieved due to different factors; one of the most important of them is a corresponding interfacial interaction between the nanoparticles and the matrix with good dispersion of particles within the matrix [2]. Polymer nanocomposite materials are of great scientific and technological interest due to their unique mechanical, electronic, and optical properties [3]. The important properties of polymer nanocomposites cause a wide range of applications in various technologies such as advanced materials and goods, sensors, energy devices, and medicines [4]. Polyethylene oxide (PEO) is known as semi-crystalline, water-soluble, non-ionic, biodegradable and biocompatible polymer of considerable industrial significance, which finds applications in many different branches of industry [5], such as cosmetology (personal lubricants, emulsions, skin creams), pharmaceutical products, gene therapy, *etc.* [6].

Si_3N_4 nanoparticles exhibit high potential for the reinforcement of polymers. Si_3N_4 is a ceramic material with high strength and toughness. It has been used in many industrial applications, such as cutting tools, high temperature automobile components, springs, bearings and engine components. Si_3N_4 nanoparticles have also been used for enhancing the thermal conductivity of polyethylene composites and the wear resistance of polymer materials [7]. Cerium oxides have recently attracted much interest due to their unique properties, which make them suitable for various applications [8]. Cerium oxide (CeO_2) is a typical rare-earth element oxide [9]. Commercially, CeO_2 has numerous applications including fuel cells (as summarized by (EPA, 2009)), coatings, polishing agent (for glass mirrors, electronic wafers, precision optics, ophthalmic lenses, television tubes, plate glass) and petroleum refining (cracking catalysts). CeO_2 is applied in a variety of consumer products including semiconductors and as an additive in cigarettes. CeO_2 nanoparticles are predominantly employed as diesel-fuel additive [10]. There are many studies on properties of nanocomposites like optical properties [11–19] and electrical properties [20–31] to apply for radiation shielding [32, 33]. The present work aims to fabrication of PEO/Si_3N_4–CeO_2 nanocomposites for radiation shielding.

2. MATERIALS AND METHODS

The silicon nitride (Si_3N_4, 15–30 nm, purity 99.9%) and cerium dioxide (CeO_2, 99.97, 50 nm) nanopowders were obtained from US Research Nanomaterials, Inc. The PEO/Si_3N_4–CeO_2 nanocomposites (NCs) were prepared by casting method. The 1 g of the poly(ethylene oxide) (PEO) was dissolved in 60 ml of distilled water, and then the solution was thoroughly mixed for one hour with a magnetic stirrer. The nanoparticles (NPs), namely, from 50% Si_3N_4 and 50% CeO_2, are added to the PEO solution with contents of 1.9%, 3.8%, 5.7%, and 7.6%. The nanocomposites were casted in a template, namely, a Petri dish measuring 10 cm in diameter. The PEO/Si_3N_4–CeO_2 nanocomposite films were tested by using the optical microscope (supplied from Olympus name (ToupView) type (Nikon-73346)) with magnification ×10.

The attenuation of radiation is characterized by relationship [34] $N = N_0 e^{-\mu x}$, where N_0 is the number of particles of radiation counted during a certain time duration without any absorber; μ is the attenuation coefficient of gamma radiation, and N is the number counted during the same time, with a thickness of sample x.

3. RESULTS AND DISCUSSION

Figure 1 indicates microscopic images of PEO/Si_3N_4–CeO_2 nanocom-

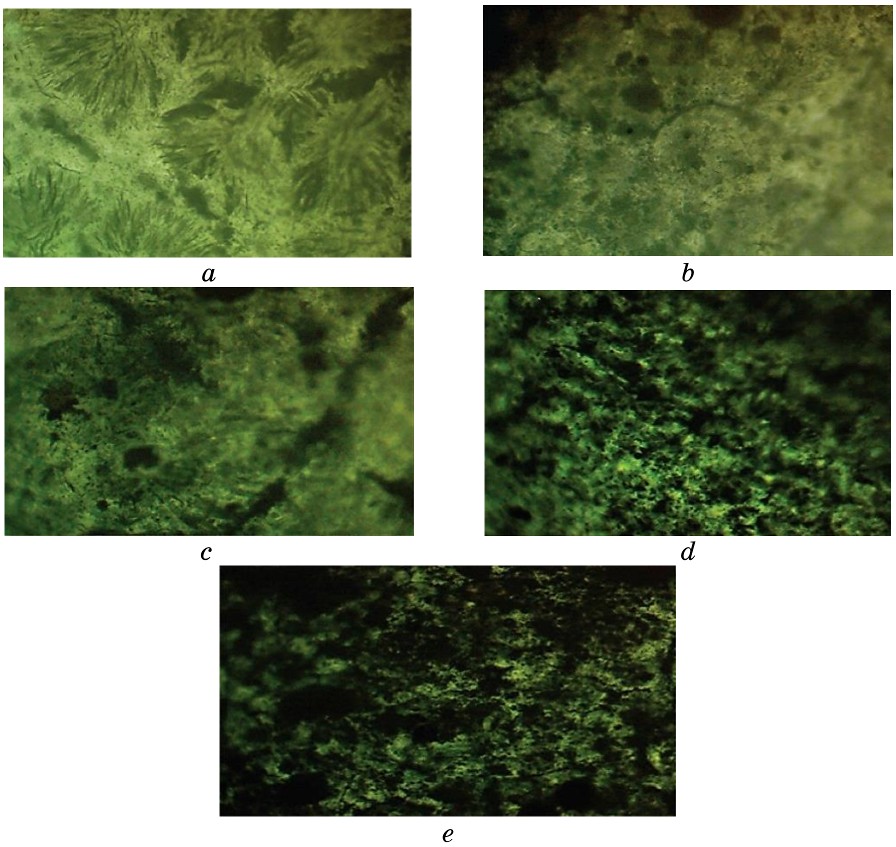

Fig. 1. Photomicrographs (×10) for PEO/Si_3N_4–CeO_2 NCs: (*a*) for PEO pure; (*b*) 1.9 wt.% Si_3N_4–CeO_2 NPs; (*c*) 3.8 wt.% Si_3N_4–CeO_2 NPs; (*d*) 5.7 wt.% Si_3N_4–CeO_2 NPs, and (*e*) 7.6 wt.% Si_3N_4–CeO_2 NPs.

posite at magnification power ×10. This figure shows that the Si_3N_4–CeO_2 nanoparticles are aggregated as clusters at low concentrations. When increasing the concentration of nanoparticles, the nanoparticles form a paths' network inside the polymer matrix [35–46].

Figure 2 shows the variation of (N/N_0) for PEO with different

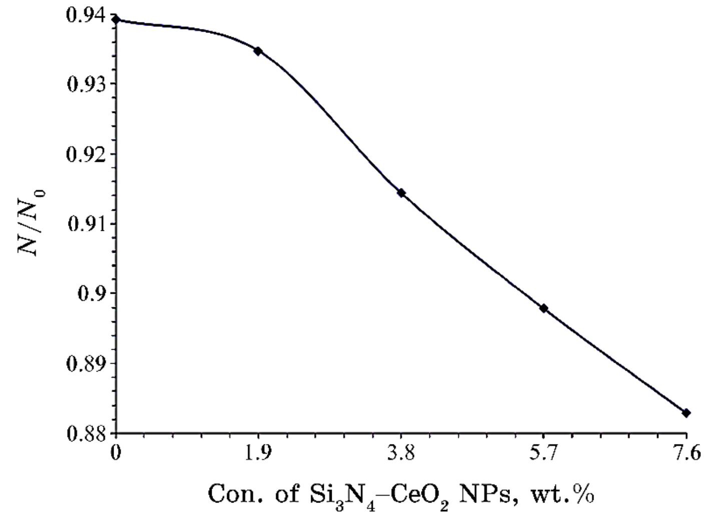

Fig. 2. Variation of N/N_0 for PEO with different concentrations of Si_3N_4–CeO_2 nanoparticles.

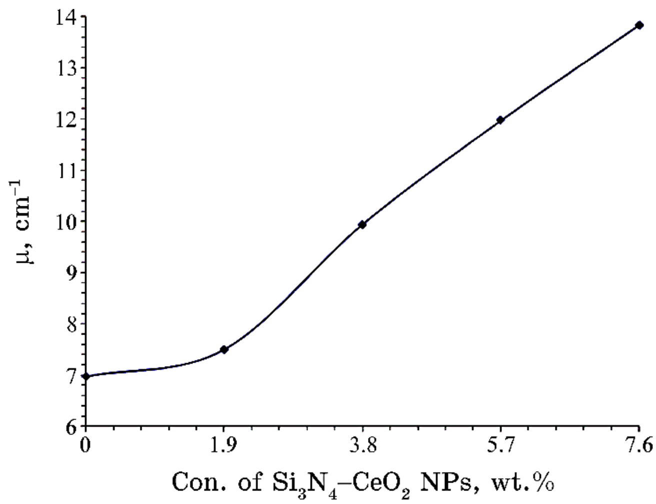

Fig. 3. Variation of attenuation coefficient of gamma radiation for PEO as a function of Si_3N_4–CeO_2-nanoparticles' concentration.

concentrations of Si_3N_4–CeO_2 nanoparticles. The transmission radiation decreases with the increasing of the concentrations of Si_3N_4–CeO_2 nanoparticles that is attributed to the increase of the attenuation radiation [47].

Figure 3 shows the variation of attenuation coefficients of gamma radiation for PEO as a function of Si_3N_4–CeO_2-nanoparticles' concentration. The attenuation coefficients increase with the increase of nanoparticles' concentration; this is due to the absorption or reflection of gamma radiation by shielding nanocomposite materials [48–50].

4. CONCLUSIONS

This work included the fabrication of PEO/Si_3N_4–CeO_2-nanocomposite films with various concentrations of polymer matrix and nanoparticles. The gamma-ray shielding application for PEO/Si_3N_4–CeO_2 nanocomposites was tested. (Incidentally, the results indicated that the PS/SiO_2–$SrTiO_3$ nanocomposites have the high attenuation coefficients of gamma rays.) The attenuation coefficients were rising with the increase of Si_3N_4–CeO_2-nanoparticles' concentration.

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