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Synthesis of Polymer Blend/Ag Nanocomposites: Morphological and Structural Properties for Gamma-Ray Shielding

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In order to use the nanocomposites (NCs) in a variety of optoelectronic nanodevices, this work attempts to create unique nanocomposite films by incorporating silver (Ag) nanostructures into polyvinyl alcohol (PVA) and polyethylene glycol (PEG). When compared with other nanosystems, PVA/PEG–Ag nanostructures have favourable properties: low weight, improved corrosion resistance, and low cost. The purpose of this work is to examine the structural properties of nanostructures made of PVA/PEG–Ag NCs. As suggested, from FTIR spectra, there is a physical contact between the polymer blend and the nanoparticles (NPs), which leads to a physical interaction between the nanocomposites and the polymer. With the optical microscope, it is observed that a continuous network is formed for the nanoparticles inside the polymer. The nanocomposites created are tested to see, if they could block gamma radiation. According to the experimental results, when exposed by gamma rays, the nanocomposite films of PVA–PEG/Ag NCs exhibit remarkable attenuation coefficients. Thus, it is clear that the addition of Ag NPs improves the final nanocomposite, and this material is believed to be a promising material for gamma-ray shielding and flexible optoelectronic applications.

Для використання нанокомпозитів у різноманітних оптоелектронних нанопристроях, у цій роботі зроблено спробу створити унікальні нанокомпозитні плівки шляхом втілення наноструктур срібла (Ag) у полівініловий спирт (PVA) та поліетиленгліколь (PEG). Порівняно з іншими наносистемами, наноструктури PVA/PEG–Ag мають сприятливі властивості: малу вагу, поліпшену стійкість до корозії та низьку вартість. Метою цієї роботи було вивчення структурних властивостей наноструктур, виготовлених з наночастинок PVA/PEG–Ag. За допомогою ІЧ-спектрів на основі Фур'є-перетвору передбачається, що між полімерною сумішшю та наночастинками є фізичний контакт, що приводить до фізичного взаємочину між нанокомпозитами та полімером. Із оптичним мікроскопом було помічено, що всередині полімеру утворюється безперервна мережа для наночастинок. Створені нанокомпозити було протестовані на предмет можливости блокування гамма-променів. Згідно з експериментальними результатами, щодо гамма-променів нанокомпозитні плівки PVA–PEG/Ag демонструють значні коефіцієнти загасання. Таким чином, очевидно, що додавання наночастинок Ag поліпшило кінцевий нанокомпозит, і цей матеріял вважається перспективним для екранування гамма-променів і гнучким для оптоелектронних застосувань.

Key words: PVA/PEG–Ag nanostructures, FTIR spectra, attenuation coefficient.

Ключові слова: наноструктури PVA/PEG–Ag, ІЧ-спектри на основі Фур'є-перетвору, коефіцієнт загасання.

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1. INTRODUCTION

The materials known as nanocomposite films, which possess a polymer matrix, have gained considerable attention from scientists in several fields [1, 2]. Optical, magnetic, thermal, electrical, and mechanical characteristics are only a few of their noteworthy qualities. Recent developments have concentrated on the creation and characteristics of these polymer films based on nanocomposites (NCs), especially for use in solar cells, optical sensors, and light-stable colour filters [3, 4]. The flexible nature and simplicity of production of composite materials, particularly, those comprising a polymer matrix, have led to substantial exploration of these materials for electrical applications [5, 6].

Polymer-based composites have developed at a rapid pace thanks to recent developments in the field of material science. Because of these materials' adaptability, affordability, and simplicity of manufacture, they have been thoroughly investigated [7, 8]. Historically seen as cheap and easily pliable materials, polymers have been used extensively, especially, in the field of composites. Combining ceramic additives with polymer matrices has produced composites with increased reflectivity, which is advantageous for a range of electrical and electronic applications [9–12]. These composite materials have been utilized in several fields, such as the production of angular acceleration accelerometers, integrated decoupling capacitors, and acoustic emission sensors [13, 14]. PVA is acknowledged for its exceptional barrier qualities, biodegradability, and biocompatibility. Because of its adaptability, it is used as a carrier for medicine delivery systems and in a variety of sectors, including food and textiles [15–19]. PVA is well known for its biodegradability, non-toxicity, and high physical qualities [20]. PEG is regarded highly for its low toxicity and water solubility, which makes it a favoured substance in biotechnological applications [21, 22].

2. MATERIALS AND METHOD

In order to obtain a more homogeneous solution, PVA–PEG was combined in 40 ml of distillate water using a magnetic stirrer at 70°C for 45 min to develop the nanocomposites by means of Ag-NPs' addition *via* casting technique at concentrations of 0, 2, 4, and 6 wt.%. The microscopic study was focused using an optical microscope (Olympus Nikon-73346 model, 10× magnification), and a microscopic camera was used to examine samples with different concentrations. Moreover, to know the attenuation characteristics of gamma rays with different concentrations of Ag NPs using nanocomposites to protect against gamma rays, samples were placed in front of a collimated beam produced by Cs-137 gamma-ray sources 5mci. There are two centimetres of separation between the detector and the gamma rays, and using Geiger-counter measurements of the gamma-ray fluxes transmitted through nanocomposites consisting of PVA–PEG/Ag NCs, linear attenuation coefficients were calculated [23, 24]:

$$N = N_0 e^{-\mu x}, \quad (1)$$

where N is the gamma-ray attenuation, x is the sample thickness, and N_0 is a gamma-ray incidence.

3. RESULTS AND DISCUSSION

3.1. Fourier Transform Infrared (FTIR) Spectroscopy Analysis of PVA–PEG/Ag NCs

Figure 1 displays the room-temperature FTIR spectra of PVA–PEG/Ag NCs. The response between the Ag nanoparticle-grafted pure PVA–-PEG cluster and FTIR spectra falls within the 4000–500 cm^{-1} area. At 3242.72 cm^{-1}, the spectral peak areas are seen due to the PVA–PVP stretching vibrations' OH-hydroxyl group [25–28]. The absorption peak at 1086.60 cm^{-1} is thought to originate from asymmetric stretching and bending vibrations of the CH_2 group, which are visible at 2906.32 cm^{-1}. The pictures demonstrate the bonding between the polymers and PVA–PEG/Ag NCs [29, 30]. Ag NPs and PVA–PEG mix do not react chemically, according to FTIR

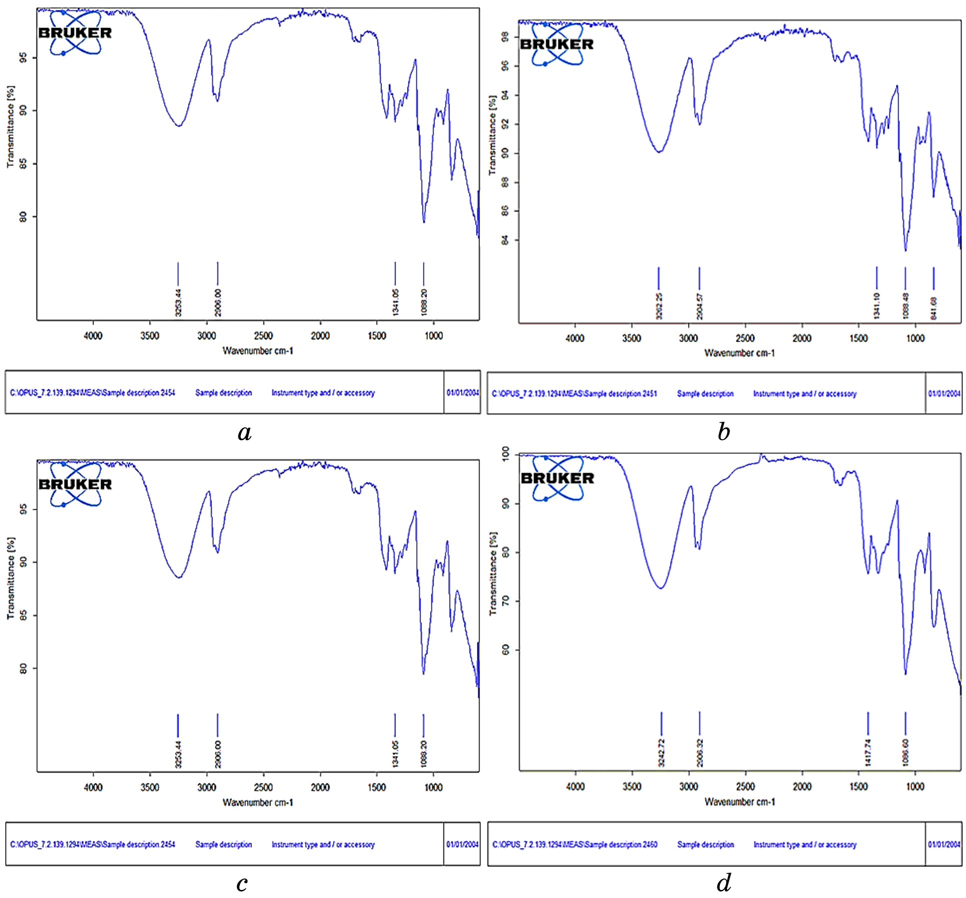

Fig. 1. FTIR spectra of PVA–PEG/Ag NCs: *a*—pure PVA–PEG; *b*—2 wt.% Ag; *c*—4 wt.% Ag; *d*—6 wt.% Ag.

studies. Moreover, our findings demonstrate that the increased concentration of the density of nanocomposites results in a considerable reduction in permeability as Ag-nanoparticles' rise [31, 32].

3.2. Optical Microscopy for PVA–PEG/Ag Nanocomposites

Microscopic images of the PVA–PEG/Ag nanocomposites at ×10 power magnification are shown in Fig. 2. As shown, the Ag NPs and the PVA–PEG blend are separable within the nanocomposites. The sponge-like shape of the filler causes Ag NPs to form a ring-linked network in a PVA–PEG matrix. This indicates that all three dimensions of the matrix are uniformly occupied by nanoparticles. The PVA–PEG assembly completely filled the interfacial space of

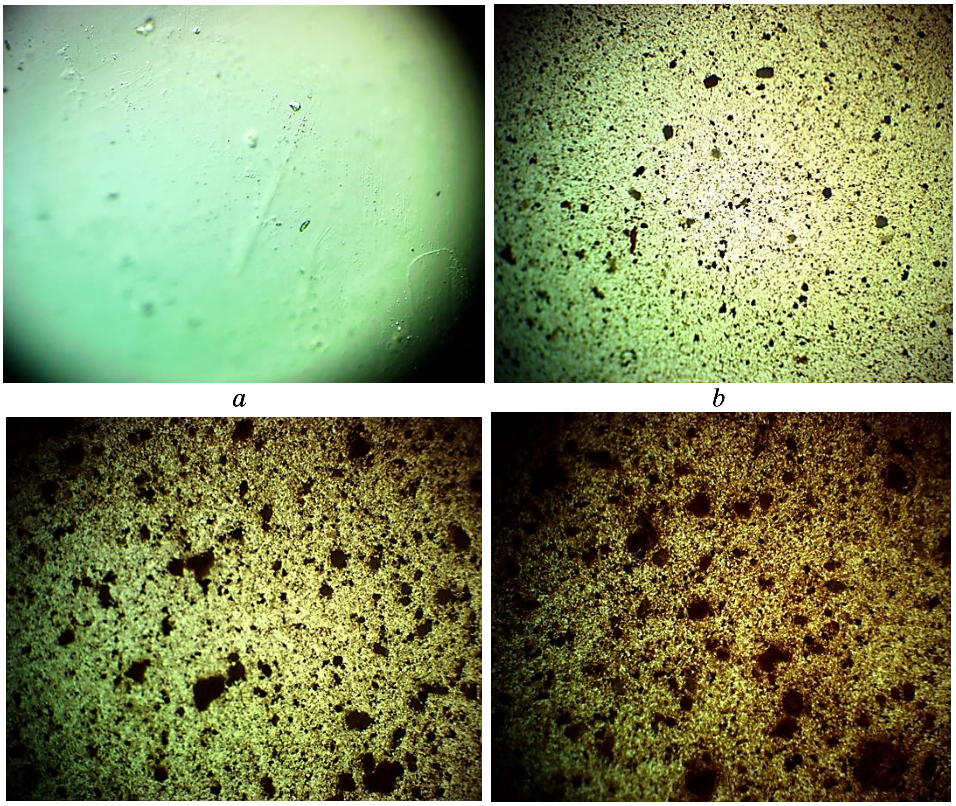

Fig. 2. Photomicrographs for PVA–PEG/Ag NCs: *a*—PVA–PVP pure; *b*—2 wt.% Ag; *c*—4 wt.% Ag; *d*—6 wt.% Ag (magnification—×10).

the Ag NPs sponges, as shown by the detailed microscopic images in Fig. 2. This is a notable distinction from the tests in Refs. [33–36]. The strong bonds, devoid of any obvious cracks or holes, holding the Ag-NPs' structure and the matrix mixture together serve as proof of this. In nanocomposites, the shape is easily distinguishable. When the Ag-NPs' concentration reaches 6 wt.%, a continuous network of nanoparticles' connections begins. The charge carrier network transmitted through the NPs bound to the PVA–PEG mixture may cause changes in the properties of the films [37, 38].

3.3. Application of PVA/PEG–Ag for Gamma-Rays' Shielding

In Figure 3, the N/N_0 fluctuation for a PVA/PEG mixture with different amounts of Ag nanoparticles is displayed. Because of an increase in attenuation radiation, transmission radiation decreases as

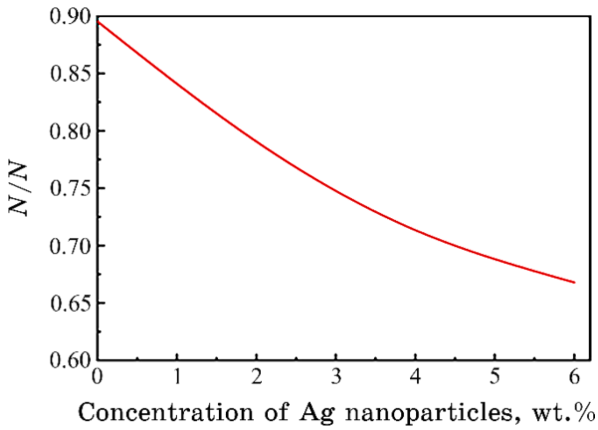

Fig. 3. Change of N/N_0 for PVA/PEG mixture with changed concentrations of Ag NPs.

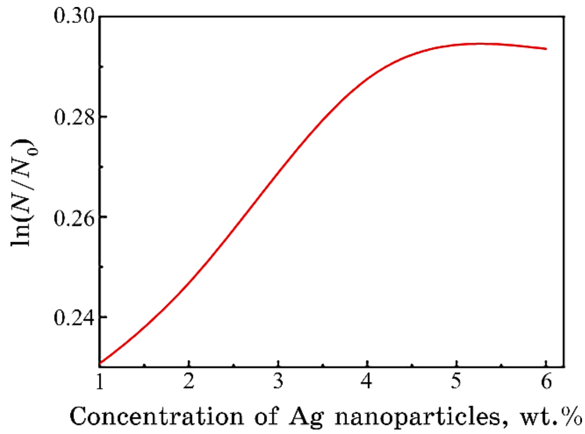

Fig. 4. Variation of $\ln(N/N_0)$ for PVA/PEG mixture with varied Ag-nanoparticles' concentration.

Ag-nanoparticles' concentration rises [39, 40]. Increasing $\ln(N/N_0)$ of the PVA/PEG combination is seen in Fig. 4 along with rising Ag-NPs' concentration.

Figure 5 shows the range of gamma-radiation attenuation coefficients for the PVA/PEG combination, depending on the amount of Ag nanoparticles. The results for polymeric nanocomposites and concrete in the following figure were found to be quite similar. The attenuation increases with the increase of nanoparticles [41]. However, polymer composites were superior to concrete due to their increased mobility, lack of electrical properties, and ability to prevent

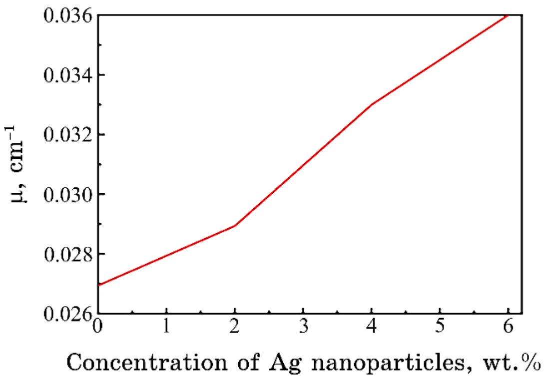

Fig. 5. Differences in the gamma-radiation attenuation coefficients for PVA/PEG blends with varied Ag-nanoparticles' concentration.

neutrons from leaving [42, 43].

4. CONCLUSION

In this work, solution casting was used to create polymer nanocomposites based on PVA/PEG blend. Using an optical microscope, images were obtained, which showed that the Ag-NPs' additions were uniformly distributed throughout the PEO/PVA mixture, forming a continuous network. FTIR images showed that there was a physical reaction, when reaching 6 wt.% of Ag NPs in the mixture. The results show that the attenuation coefficient increases with NPs' content. Based on these results, it can be suggested that these nanocomposites are good building blocks for attenuating gamma rays.

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