Crystal Structural, Morphological and Gamma Ray Shielding (γ -S) Efficiency of PVA/PAAm/PAA Polymer Blend Loaded With Silver Nanoparticles via Casting Method

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Ministry of Education

Research Article

Keywords: PVA, AgNPs, Polymer composites, Radiation shields

Posted Date: November 11th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-1050050/v1>

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Abstract

Cost, weightiness, vacuum, and absorption power of the matters applied for radiological preservation are significant points which challenge scientists and researchers to preparation and improve suitable γ -S materials. A perfect γ -S is one which can absorb, attenuate, or prevent the ultimate part of incident γ -radiation. The major purpose of this study is to evaluation the effect of silver nanoparticles (AgNPs) additions on the γ -S characteristics of polyvinyl alcohol PVA, polyacrylamide PAAm and polyacrylic acid PAA polymeric blend (PB). In the current research, PVA/PAAm/PAA (70:20:10) wt./wt.% matrix PB with 0, 0.03, 0.06 and 0.08 wt% of AgNPs were synthesized via Petri dish casting technique as a polymer nanocomposites (PNCs). The specimen were categorized as h0,h1,h2 and h3 depending on the addition of AgNPs. Crystal structure involves X-ray diffraction (X-ray), the Fourier transformation infrared spectrum (FT-IR), ultraviolet-visible light spectrum (UV-V) and optical microscopy (OPM) were studied. The **coefficients** of attenuation were also computed utilizing **caesium** (Cs^{137}) source. Results showed which increasing of AgNPs from 0% to 0.08% leads to increasing in the attenuation coefficient values and decreasing the ratio of radiation counts (N/N_0), also 0.08% of AgNPs loaded is the essential optimum consist of this additive. The γ -S properties conducted using γ -rays has explained which PNCs with 8% of AgNPs and only 0.090 cm thickness, can attenuate 80% of the γ - ray.

1. Introduction

PNCs show promising appropriate alternate candidates to concrete and Pb^{204} in the field of γ -S because its strength, lightweight, elasticity over with excellent mechanical, physical, optical and radiation impedance characteristics [1]. The loading of NPs improves the properties of the PB such as increased flexible toughness and durability, heat and obstruction resistance, decreased the permeability of gas, and flaming. The magnetic, optical and electrical characteristics are also improved [2, 3]. Second aspect which indicates the utilize of NPs as fillers to the polymer basis is which the doping requirements are perfectly low compared to another. Different kinds of inorganic NPs such as silicon dioxide SiO_2 , zinc oxide ZnO and titanium oxide TiO_2 , were utilized with nanoclay matters to fabrication NCs film that is active in separate salts and metals from seawater [4]. In the previous years, use of PNCs as the γ -S against γ -radiation, is very popular [5]. The application of γ -radiation is quickly growing in several fields [6]. Researchers have investigated various γ -S materials to conserve life from the radiation exposure hazarding [6–10]. Excellent γ -S is one which can absorbs, attenuate maximum of the incident γ -ray [11]. PVA has a appropriate high tensile hardness and suitable elasticity. PVA is commonly annealed via a large range of low molecular weight compositions which predominatingly include polarized groups, that form H-bonds with the hydroxyl groups of the PVA chain, reduction direct H-bonding between PVA molecules [12, 13]. PAAm and PAA are polymers which have the same basis but with various functional groups that are acid and amide. These two polymers are water soluble polymer (WSP) and have different characteristics of not being like to non-toxic and monomers [14–16]. AgNPs is closely used in various industrial, medical and mechanical applications due to of its metallic characteristics, such as electrical conductivity and ability to absorbs the UV-V spectrum [17].

2. Experimental Part

2.1. Materials

Three matrix polymers were purchased from DIDACTIC and utilized without any changes or modifications: PVA powder (99% assay purity) with an average Mw of 18k, PAAm powder (99.9% assay purity) with average Mw of 5000k and PAA powder (99.9% assay purity) with average Mw of 450k. The doped AgNPs (99.95% assay purity) were purchased from sky spring NMs, Inc., with an average grain size of (20~30) nm.

2.2. Synthesis of PNCs

The composite films were fabricated from PVA, PAAm and PAA with different (70:20:10) wt./wt.% as matrix polymers via the solution casting technique as offers in Table 1. All polymers were dissolved in deionized water, the blend was thereafter stirred for 1.5 hrs. using a hot plate magnetic stirrer, and preserve at a temperature of about 55°C. Then, this blend was leaved to cool to 5 days. In the incorporation operation, 3 portions of AgNPs were added to the PVA/PAAM/PAA homogenous sol in steps of 30 mL from 0–35 mL sol. To homogenize these PNCs, stirring was made for about 20 min. The PNCs were categorized as h0, h1, h2 and h3 identical to PVA/PAAM/PAA wt.% with 0, 0.03, 0.06 and 0.08 wt.% from AgNPs. The solution casting technique was performed via casting these PNCs solution to 5 cm Petri dishes and leaving them to dry for 7 days and before properties were completed. The thicknesses of PVA/PAAM/PAA film and its PNCs were evaluated to be between 0.085 and 0.090 cm.

Table 1
The (PVA/PAAm/PAA)/AgNPs wt.%.

Sample code	wt.%			
	PVA	PAAm	PAA	AgNPs
h0	0.700	0.200	0.100	0.00
h1	0.679	0.194	0.097	0.03
h2	0.658	0.188	0.094	0.06
h3	0.644	0.184	0.092	0.08

2.3. X-ray pattern analysis

X-ray patterns were used to investigate the generated phases. It was completed on an x'-pert high score diffractometer, V=45 kV, I=45 mA, CuK_α and $\lambda = 1.540 \text{ \AA}$. The resulted data was computed between 5° and 60°.

2.4. FT-IR spectrophotometer

To compute the type of the interaction between the NPCs, Vertex 701, Bruker spectrophotometer was utilized in the optical range between 400 to 4000 cm^{-1} .

2.5. UV-V spectroscopy

A double-beam, shemadzo 1800 spectrophotometer, in the optical range between 180-1100 nm was utilized to record the UV-V spectrum.

2.6. OM images

Morphological images were showed using Nikon Olympus 73346.

2.7. Radiation system

The radiation accounts were calculated using IEC. PTY. LTD. Geiger counter ratemeter source efficiency=5 μCi , voltage=440V, time of counts=100s and background ray count=33 count/100s), Australia.

3. Results And Discussion

3.1. X-ray pattern analysis

Figure 1 represents the X-ray peaks of PVA/PAAM/PAA PB film with different AgNPs contents. The X-ray peak of PVA/PAAM/PAA matrix polymers of shows one peak describe the semi crystalline structure of the matrix polymers at 2θ of 20° . AgNPs addition leads to appear an important decline in peak sharpness due to the interaction that resulted between the PNCs contents. Also, AgNPs addition was found by the appearance of a low intense peak at 2θ of 40° . The Bragg patterns occur at $2\theta = 20^\circ$ (110), and 40° (101) are known for the face-centered cubic (FCC) structure of AgNPs. The peaks of AgNPs were compared with [18], and without any shifting. X-ray patterns were detected a hardly observed increase of the crystalline structure with increasing AgNPs.

3.2. Analysis of FT-IR spectrum

The certain functional groups of matrix PVA/PAAM/PAA, PB with different AgNPs contents were computed from FT-IR spectrum, as investigated in (Fig. 2. and Table 2). Fig. 2, shows clear peaks at 3750.13, 3748.16, 3754.13 and 3741.68 cm^{-1} of O–H stretching bond [19, 20], whereas the N–H stretching bonds were appeared at 2889.97, 2890.26, 2889.19 and 2885.43 cm^{-1} [21, 22, 23]. The C=O starching were referred to the intense peaks at 1733.38, 1716.41, 1713.34 and 1718.32 cm^{-1} [24]. The peaks were located at 1340.90, 1340.54, 1342.17 and 1343.13 cm^{-1} reflect the S=O stretching bond [25]. The peaks were located at the 1240.31, 1239.52, 1237.14 and 1238.13 cm^{-1} reflect the C-O stretching bonds [25]. The peaks were located at the 1098.40, 1097.62, 1096.46 and 1096.53 cm^{-1} reflect the C-O stretching, 960.90, 960.90, 960.91 and 960.93 cm^{-1} and 841.15, 840.75, 840.78 and 840.81 cm^{-1} reflect the C=C stretching bond [25]. The new bonds approved the formation of PVA/PAAM/PAA PB, while the

loaded of AgNPs lead to raising in intensity of peak, due to network disposal between AgNPs and matrix functional groups. Also, AgNPs reasoned a minor variation in the peak situ of FT-IR, then, Table 2 refers, there is no important variance in matrix material chemical nature after loaded reported as [26], thus, there are new peaks caused by the C=O stretching bond at 1540 cm^{-1} , that clearly referred which AgNPs were successfully doped.

Table 2
Characteristics chemical bands of ho, h1, h2 and h3 samples.

h0	h1	h2	h3	Group	Comp. class	Reference
3750.13	3748.16	3754.13	3741.68	O–H Stretching	alcohol	[19, 20]
2889.97	2890.26	2889.19	2885.43	N–H stretching	amine salt	[21, 22, 23]
1733.38	1716.41	1713.34	1718.32	C=O stretching	ester	[24]
-	1541.50	1548.46	1544.38	C=C stretching	cyclic alkene	[25]
1340.90	1340.54	1342.17	1343.13	S=O stretching	sulfate	[25]
1240.31	1239.52	1237.14	1238.13	C-O stretching	alkyl aryl ether	[25]
1098.40	1097.62	1096.46	1096.53	C-O stretching	secondary alcohol	[26]
960.90	960.90	960.91	960.93	C=C bending	alkene	[26]
841.15	840.75	840.78	840.81	C=C bending	alkene	[26]

3.3. UV-V spectrum analysis

Figure 2 represent the UV-V spectrum of raw material blend after and before doping with AgNPs in spectrum range of 200-800 nm, from figure can notice that one band appear at 350 nm assigned to ($n \rightarrow \pi^*$, $N=N$) related to raw material and another band which appear at 290 nm assigned to ($n \rightarrow \pi^*$, $C=O$) related to the wavelength shifting which happens after doping, furthermore the UV-V spectrum for the ho,h1,h2 and h3 samples showed one broadband between 300-400 nm. The addition AgNPs to the polymeric blend improved the UV absorbance spectrum, due to to the good diffusion and homogeneity of AgNPs in the matrix as shown in Fig. 3, furthermore Figure 2 refers to increasing the amount of AgNPs which decreased the function of polymer because network formulations [27, 28]. Hence the absorbance were increased after doping and the h3 sample has greatest absorbance value.

3.4. OM morphology

Figure 3 illustrates the OM images of matrix polymer blend film, with different AgNPs contents at power of magnification 40X. Fig. 3-ho offers which the PVA/PAAM/PAA PB has acceptable dissolving and homogenous. The h1, h2, and h3 morphological images in the same figure refer to the diffusion of AgNPs in the matrix. AgNPs were perfectly propagated inside the PB. The images also exhibit which no any aggregation occurred in the PNCs film. The reason of that associated to the interaction which missing

between the matrix and additives. The images also show which when the doped of AgNPs increase, the consistency of the surface increase due to the cross linking created between the matrix polymers and AgNPs. These behaviors are good agreement with previous OM images reported with [29]. The amorphous structure or nature of surfaces were improved after the doped of AgNPs.

3.5. The efficiency of γ -S

The significant nature of the interaction between γ -radiation and materials is a limited case to examination to compute the efficiency of these type of radiations to diffuse in the mediums that because the nature of reaction helped to choose the more applicable γ -S. Materials which are assumed to be applied as shields against γ -radiation should have higher thickness and atomic number and as such materials assess a larger probability of interactions that indicate highest energy transfer with γ -radiation [30]. The matters with lower density and atomic number can manufacture of raised thickness as significantly as high atomic number materials in γ -radiation protection [31, 32]. The polymer blend and PNCs show encouraging proper alternate selector to concrete and others in the field of γ -S due to its lightweight, durability, elasticity over with acceptable physical, mechanical, and γ -S [33, 34]. The polymer matrixes can easily be loaded with different great amounts of high atomic number matters to fabricate their PNCs that are more respective γ -S [35]. Figure 4 shows that the N/No values were decreased with the increasing of AgNPs. The distance between the source and sample was 5 cm and between the detector and sample was 10 cm. The values of PNCs attenuation coefficient showed in figure 5 were increased with increasing of AgNPs. These findings offer a very close results if comparing with the attained results via PCs with concrete, furthermore, PCs have an characteristic over lead and concrete because of its minimum mobility properties, conductivity and the capability to prevent γ -radiation shot [36, 37]. The loaded of AgNPs improves the physical properties of matrix material such as flexibility, density and attenuation coefficient and create it more appropriate for using in γ -S.

4. Conclusion

Low cost, eco efficiency, environmentally friendly and novel PNCs films from PVA/PAAM/PAA encapsulated by AgNPs were successfully synthesized by casting technique at thickness about 0.085 to 0.090 cm. The X-ray patterns of matrix polymers and PNCs films show two peaks indicate the FCC structure, one peak appears at 2θ of 20° (110) related to matrix materials and other appears at 2θ of 40° (101) related to NPs contents. SiO_2 NPs capsulation was detected by the appearance of a sharp peak at 2θ of 19.4° . FT-IR spectrums shows shift in the some bands and variance in the sharpness of others in comparison with polymer matrix film, furthermore many interactions were occurred between the matrix and AgNPs. The OM images were showed that the AgNPs form a continuous cross linking or networks inside the PB with a good and strong diffusion of NPs in the matrix. The results of γ -S were indicated which the N/No decrease with the increasing of AgNPs. The values of attenuation coefficient were increased with the increasing of AgNPs. These results make the NCs films is suitable for applied in γ -S purposes.

Declarations

Data Availability

All data resulted in this article were included in this published paper.

Declaration of Competing Interest

The authors declare which they have no known competing financial interests or personal relations that could have appeared to influence the work reported in this article.

Acknowledgments

The author would like to thanks the department of physics, college of education for pure sciences, university of Babylon, Iraq for their support.

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Figures

Figure 1

X-ray pattern of PVA/PAAM/PAA blend films with different AgNPs loads.

Figure 2

FT-IR spectrum of ho, h1, h2 and h3 samples.

Figure 3

UV-V spectrum of ho, h1, h2 and h3 samples

Figure 4

Morphological images of ho, h1, h2 and h3 samples.

Figure 5

N/N_0 versus AgNPs contents of h0, h1, h2 and h3 samples.

Figure 6

Attenuation coefficient versus AgNPs contents of h0, h1, h2 and h3 samples.