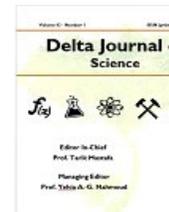


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Research Article

PHYSICS

USING NANO TUNGSTEN OXIDE POLYMER COMPOSITE AS A GAMMA RADIATION SHIELDING

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ABSTRACT

Lead is a traditional shielding material for gamma radiation protection, in spite of its disadvantages such as high density, toxicity and high cost. New shielding materials that have the same effective attenuation and have more advantages are studied. The aim of this work is to prepare new nano-composite material shield (nontoxic, light, and environmental friendly) that minimize the radiation hazards. Polymers are safe and light materials but on their own aren't effective in radiation shielding. The idea is to use a high-density metal which is the most effective materials in shielding with polymers which have the property of lightness and flexibility. A new nano-composite will be produced with improved advantage in shielding materials.

In this study, high-density metal is the nano tungsten oxide powder that can be mixed with poly vinyl alcohol. Using a certain amount with different concentrations of nano tungsten oxide powder in the polymer matrix. The composite sheets have been obtained by casting method with different thickness for each concentration. The nano-composite can be tested by Geiger-Muller counter for attenuation measurements. According to results, a new shielding material is efficient for gamma radiation protection.

1. Introduction

Unwanted exposures to high energy ionizing radiation cause hazards to health. Protection ways are required to minimize hazards from the ionizing radiation. There are three arms of protection from radiation which are time, distance and shielding. The amount of radiation exposure is reduced if the time of the exposure decreased, also the distance from the radiation source is becoming longer. The longer the distance from the radiation source, the lower the dose to the square of the distance based on inverse square law. Shielding is one of the best methods for radiation protection. There is no special shielding material for alpha particles because of their big size. Even thin paper or human skin could easily block alpha particles. On the other hand, beta particles are smaller than alpha particles so they penetrate human body easily, that is why using aluminum shield is required. But gamma rays are waves and they have no mass and high energy. So, materials with high density could block gamma rays. When gamma energy is increased the thickness of materials should be increased in order to maximize the probability of blocking the gamma rays [1].

Nowadays, lead plays an important role in radiation shielding regardless its cost and toxicity. Lead is used frequently in the fields of nuclear medicine [2]; however, lead is a highly toxic metal and very heavy for personal shielding [3].

For this reason, non-toxic and light materials are required for radiation shielding. Polymers are very light materials and they have no toxic effect. But they are inadequate and they cannot stop gamma rays because of their low density. Tungsten is an element with a high

atomic number and high density and also tungsten is non-toxic [4], [5].

In recent days researchers looked to use other materials that is lower cost, light-weight and flexible shielding for protection against radiation.

Yue *et al.*, studied a wolfram and styrene-butadiene-styrene copolymer and have obtained a new shielding material by mixing metal and copolymer [6].

In the study by Ivanova *et al.*, [7] high density polymer metal composites are used for radiation protection in radiotherapy. In the preparation of this composite, wolfram powder and polymer were created by mixing high-density and low X-ray transmittance.

Soylu *et al.*, [8] had been investigating the efficiency of wolfram carbide-doped polymer on gamma ray shielding. In his study 50%, 60%, and 70% wolfram carbide - doped polymer composite discs had produced and exposed to I-131, Am-241, and C-137 gamma sources, respectively. According to the results, the best efficiency of composite materials was determined against the Cs-137 source.

Eder [9] studied tin, bismuth, and wolfram instead of lead alternatively. In this study, he mixed metals with polymers in different ratios and obtained materials that were exposed to X-rays. He found that the ability of absorption decreased depending on the increase of the voltage of the tube.

McAlister [10] had been studying a polymer that was named T-Flex which was mixed with wolfram and iron powders and he produced a shielding material. This shielding material was exposed to various radiation sources and he

compared the theoretical results that were obtained with X - COM and experimental results.

Erol *et al.*, [11] have used shielding which contains boron and wolfram carbide. Four different samples were prepared in this context. The shielding ability of these samples was tested with a Geiger–Müller (GM) detector with Cs-137 and I-131 radioisotopes where the best results of the products were obtained.

The target in this study is testing durable, healthy, flexible, light - shielding materials, which contain nano tungsten oxide and poly vinyl alcohol polymer. Five Samples with different concentrations from these materials were being prepared and characterized by XRD to confirm the composite. The linear attenuation coefficient of these samples was measured by Geiger-Muller counter with I-131 point source.

2. Material and methods

2.1. Preparation of samples

The composite sheets were produced using different concentrations of nano tungsten oxide (WO_3) powder (<100nm.) prepared by using precipitation method [12], PVA polymer from NICE chemicals company. The materials of the composite should be mixed homogenously so first a solution from the tungsten oxide is made by using sonication method and at the same time a solution from PVA with 15% concentration is prepared, then the two solutions mixing homogenously by using magnetic stirrer with slight heat. After completely mixing thin sheets were made using casting method by pouring the mixture in petri dish and let it dry in clear box at room temperature for about five days depending on

the temperature of the room. Repeat these steps with different concentrations of nano tungsten oxide powder in PVA 0%, 25%, 50%, 70% and 80% by weight. The obtained sheets are with different thickness from zero to 5mm. for each concentration.

2.2. Measurements

The structure of the prepared sheet composition was confirmed by using X-ray diffractometer type GNR $\text{CuK}\alpha$ radiation ($\lambda=1.540598 \text{ \AA}$) with Θ range from 20° to 60° . The attenuation coefficient for these materials was determined by working with I-131 with energy 364 keV a point source for gamma energy. Using collimation system fixed on the Geiger Muller counter detector. Then, polymer composite sheets were placed separately on the collimators each concentration with different thickness from zero to 5mm then register the counts.

The attenuation of gamma radiation shielding can be determined experimentally from the mass attenuation coefficient formula:

$$I = I_0 e^{-\mu \rho t}$$

Where I = intensity after shielding, I_0 = incident intensity, μ = mass absorption coefficient (cm^2 / g), ρ = density of the shielding material (g/cm^3), and t = physical thickness of the shielding material (cm)

3. Results

3.1. XRD analysis

X-ray diffraction (XRD) analysis for sheets was used to characterize the composite and show the change in the crystal structure if it happened and also illustrate the stability of the composite after mixing conditions.

The X-ray diffraction patterns of the prepared WO₃/PVA composite films illustrated in the figures (1, 2, 3, 4) for nano composite sheets show that the intense characteristics peaks of WO₃ is gradually increase due to increasing the concentration of tungsten oxide nanoparticles. It was noticed from the figures that the patterns of the prepared composites feature weak peaks for WO₃ in curves (1) and (2) due to the low concentration of tungsten oxide nanoparticles, (25% and 50%). The peaks of WO₃ became sharper by increasing the percentage of the tungsten oxide nanoparticles in curves (3) and (4) (70% and 80%). The variation in the doped WO₃ concentration to the PVA matrix leads to the changes in sharp diffraction peaks.

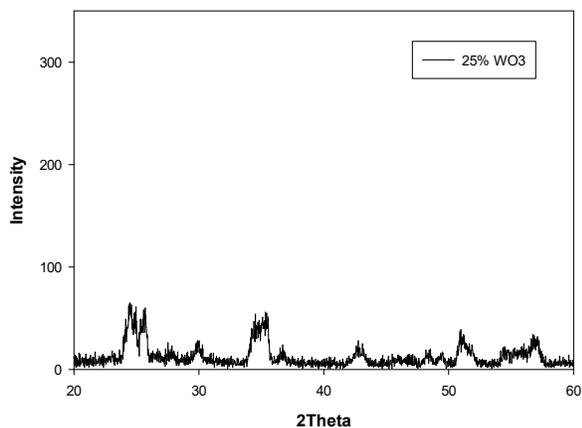


Fig.1: XRD for WO₃ 25% with 75% PVA

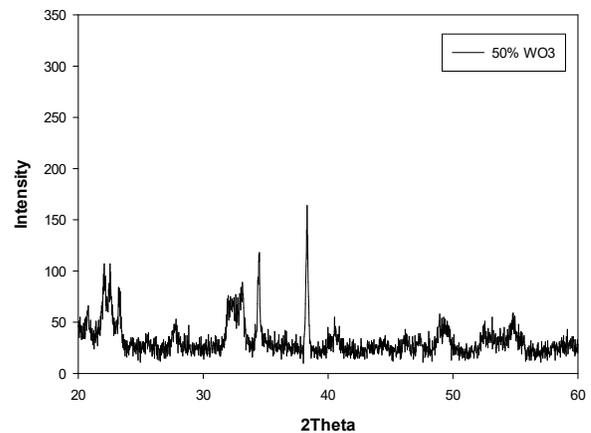


Fig. 1: XRD for WO₃ 50% with 50% PVA

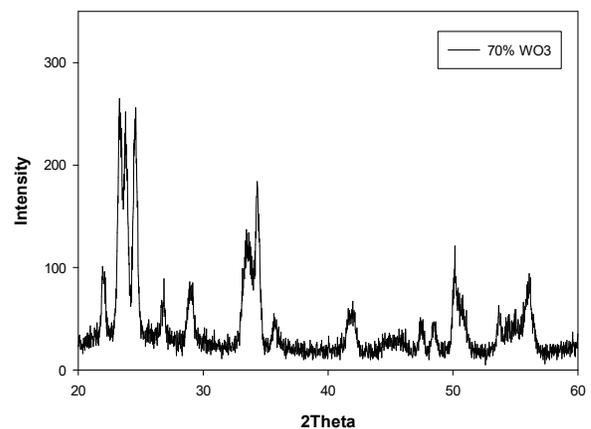


Fig. 2: XRD for WO₃ 70% with 30% PVA

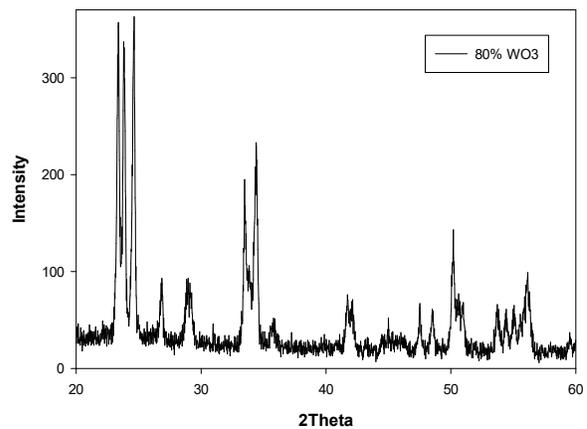


Fig. 3: XRD for WO₃ 80% with 20% PVA

3.2. Gamma ray attenuation results

To investigate the experimental shielding property for WO₃/PVA nanocomposite sheets we studied the relationship between the concentration of nano WO₃ in sheets and count rate of photon energy [I-131(364keV) by using GM detector with different thickness of sheets that illustrated in Table (1).

Table 1: I-131 counts for the different samples.

Concentration %	Linear Attenuation Coefficient
0	0.051
25	0.181
50	0.256
70	0.387
80	0.513

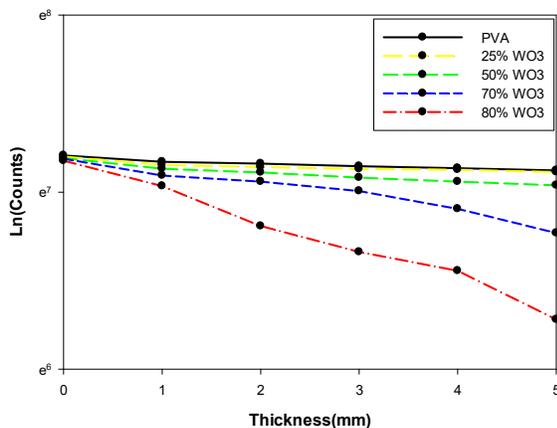


Fig. 5: total counts versus thickness for different concentrations.

It's obvious that the linear attenuation coefficient increasing by increasing the concentration of the filler high atomic number material and thickness of sheets.

From plot (5) we can deduce the linear attenuation coefficient according to the following equation:

$$I=I_0 e^{-\mu x}$$

Table 2: The results of attenuation coefficient of each concentration

Thickness (mm)	Count 0%	Count 25%	Count 50%	Count 70%	Count 80%
0	1350	1341	1330	1325	1310
1	1302	1280	1252	1205	1135
2	1289	1264	1226	1164	905
3	1270	1250	1191	1104	782
4	1256	1245	1164	998	703
5	1240	1229	1140	870	534

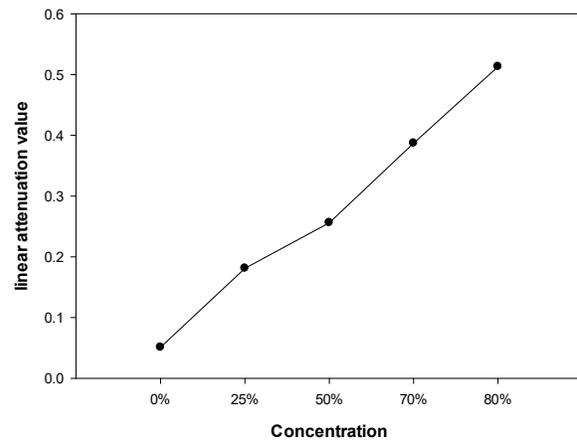


Fig. 6: Attenuation coefficient for different concentrations.

4. Conclusion

By studying the effect of tungsten oxide nano-polymer composite for gamma radiation shielding shows acceptable results of linear attenuation coefficient. The most impressive material for gamma radiation protection purposes is the addition of high Z materials which is tungsten oxide nano-powder in this study. The study shows improving in radiation protective properties for the energy of Iodine (I-131 364keV). The results show increasing the linear attenuation coefficient from 0.05 to

0.51 by increasing the concentration of the filler material WO_3 from 25 to 80%. The Nano tungsten oxide polymer shield is elastic, soft, and easily shapeable. The use of a composite material based on a matrix of poly vinyl ethylene with the addition of nano powders tungsten oxide is lighter than lead so, it can be used in radiation protection shielding which could be used in aprons cover in radiology filed.

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استخدام مركب نانو أكسيد التنغستن مع البوليمر كواقى من أشعة جاما

ميسون محمد مراد⁽¹⁾, ياسر محمد عبده⁽¹⁾, محمد رضا بربر⁽²⁾, فتحي أحمد الحسيني⁽¹⁾

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الرصاص هو مادة التدرىع التقلدىة للحمایة من أشعة جاما. بالرغم من عيوبه مثل الكثافة العالیه والسمة والتكلفة العالیه. لذلك نحتاج إلى مادة تدرىع جدىة لها نفس التوهین الفعال والمزايا الجدىة. نهدف إلى تحضیر مادة مركبة نانویة جدىة غیر سامة وخفیفة وصدیقة للبیئة. تعد البولیمرات مواد أمنة وخفیفة ولكنها لیست فعالة بمفردها فی الحمایة من الإشعاع. كما تعد المعادن العالیه الكثافة أكثر المواد فعالیه لهذه المهمة. إذا تمكنا من مزج البولیمرات مع المعدن الثقیل يمكننا الحصول على مادة جدىة لها مزايا کلیهما.

فی هذه الدراسة، المعدن عالی الكثافة هو مسحوق أكسید التنغستن النانوی الذی يمكن خلطه مع أحد أنواع البولیمرات وهو البولی فینیل الكحولی بكمیات معینة بتركیزات مختلفة من مسحوق أكسید التنغستن النانوی فی مصفوفة البولیمر. ويمكن الحصول على الألواح المركبة بطریقة الصب بسمك مختلف لكل تركیز ويمكن اختبارها بواسطة كاشف عداد جیجر مولر لقیاس التوهین. وفقاً للنتائج، فإن مادة التدرىع الجدىة فعالة للوقایة من إشعاع جاما.