Manufacture of Shielding for Attenuation Ionization Ray by the Preparation of Nano Gadolinium Oxide with PMMA

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Abstract

In this research, the coefficient of linear absorption, Half-value layer and Effective atomic number of the composite material for gamma ray of gadolinium oxide with PMMA (Gd_2O_3- PMMA) for shields made with varying concentrations (10%, 20%, 30%, 40%) and varied thicknesses The impact of raising the shield thickness when the concentration of each thickness is increased. The gamma ray radiation source was Cs-137and Co-60 which have (activity 10 µci and energy of 0.662 MeV, activity 1µci and energies 1.173 -1.332 (MeV) were used in measurement, As an electrical system, a scinatelaion detector (NaI (Tl)) was utilized with a (2x2)" for ORTEC software program (Scintivision-Buffer) with an integrated measurement system. The results reveal that when the concentration of nano particle-gadolinium oxides raised and the thickness of the produced layer increased, the attenuation coefficient and effective atomic number values increased of the prepared composite However, as the concentration and thickness of the composite increased, the Half-value layer values dropped.

Key Words: Manufacture of Shielding, Nano Gadolinium, Half Value Layer (HVL).

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Introduction

Gamma-ray attenuation coefficients are very significant in both basic sciences. They are required in several fields, for example, Radiotherapy, radiation diagnostics, radiation oncology, and radiation dosimetry are all fields that deal with radiation. Every health physicist understands the need of protecting the body from excessive radiation exposure. [Al-Saadi 2017]. Since, the last researches have been studied the linear attenuation coefficient, for concrete including zeolite as a composite with different concentrations (0%, 10%, 30% and 50%) showed that the measured with four concrete pattern, decreased with increasing zeolite concentration that's mean the addition of zeolite as an aggregate in concrete is not a replacement for used of radiation shielding [Zhong, 2009]. In 2012, have been prepared two samples of WO_3-Epoxy with different sizes of tungsten oxide materials. The effect of functional material size on radiation absorption and radiation shielding material mechanical characteristics. In epoxy resin-based radiation shielding materials, WO_3 nanoparticles are more effective than WO_3 microparticles. [Yu, D., Shu-Quan 2012]. In 2013, this work has been prepared from Pb_3O_4-Epoxy composite materials proved the availability for using the Pb_3O_4 composite as a gamma ray shielding [Eid, 2013]. At the same additive volume fractions, tungsten, bismuth, tin, and copper powders have been used as additives coating to collect lead-free and flexible x-ray shielding materials. The tungsten, additives with silicone rubber coating had the best absorption ratios than the samples that enclosed tungsten – bismuth, copper, and tungsten–in. [Aral 2016].

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The higher probability of interaction between radiation and nano particles are effective in a small concentration When compared to microparticles - Gd_2O_3-epoxy composite materials, nanoparticles Gd_2O_3-epoxy composite materials have similar flexural strength and up to 15% greater flexural modulus. Based on these findings, nanoparticles-Gd_2O_3 reinforced epoxy composites are thought to be a potential radiation shielding material. [Li, R., Gu, 2017]. The shielding characteristics such as coefficient of linear absorption, the effective atomic number (Z_{eff}), and the half value layer (HVL) for nano gadolinium oxide (Gd_2O_3) as reinforcement materials with varied concentrations of (10%, 20%, 30%, and 40%) were computed in this study.

Theoretical Part

The theoretical relations of the attenuation of collimated beam of mono-energetic gamma ray is attenuated in matters according to the Lambert-Beer law [Meyerhof 1967]:

$$I = I_0 e^{-\mu * x} \qquad (1)$$

Where I_0 and I represents the incident and transmitted rays Intensity respectively x, μ is the attenuation coefficient and Is the thickness shield in cm. The thickness of a substance that decreases the intensity of a photon beam to half of its original value. I_0, i.e. (½)I_0, is called the half value layer (HVL) and is given by [Akkaş 2016]:

$$x_{1/2} = \frac{0.693}{\mu} \qquad (2)$$

The atomic number that is in effect. (Z_{eff}) is definable as [Biswas 2016, Pawar 2011].

$$\sigma_m = \mu_m \frac{\sum_i n_i A_i}{N_A} \qquad (3)$$

$$\sigma_a = \frac{\sigma_m}{\sum_i n_i} \qquad (4)$$

$$\sigma_e = \frac{1}{N_A} \sum_i \frac{f_i A_i}{Z_i} \mu_i \qquad (5)$$

$$Z_{matrix} = \frac{\sigma_a}{\sigma_e} \qquad (6)$$

$$Z_{eff} = \sum_{i=1}^{2} w_i Z_i \qquad (7)$$

Where n_i :The number of atom each element in the base material, A_i: are the mass number of each element in the base material, N_A: is Avogadro's number, σ_m the molecular cross section, σ_a : the atomic cross section, f_i: is the fractional abundance of element i : with respect to the number of atoms, Z_i: the atomic number of each element in the base material, σ_e : the electronic cross-section, Z_{matrix}: the atomic number of Polymer and w_i: weight fraction shield.

Experimental Part

The pre-polymerized PMMA beads, gadolinium oxide nanopowder (Gd2O3) as reinforcement in different concentrations (10%, 20%, 30%, 40%) were mixed together and poured into the PMMA monomer liquid, then stirred slowly for several minutes to reduce the inclusion of the air bubble. The mixing process takes place with a mechanical fan, then it is transferred to an ultrasound machine to complete the mixing process through this device and for a period of time, after that the mixed solutions were poured into certain molds.

Results and Discussion

Table (1) depicts the linear attenuation coefficient of a Gd_2O_3- PMMA shield at various concentrations, thicknesses, and energies. It is obvious that as the concentration of reinforcement materials increased, so did the values of the linear attenuation coefficient. As a result of the increased distribution of reinforcing materials in the structure, absorption processes will increase. in the base material, resulting in an improvement in shield density, gamma ray attenuation, and, as a result, the linear attenuation coefficient. Draw the relationship between linear attenuation coefficient and different composite material thicknesses for different reinforcement material concentrations as shown in the figure (1) and the values of the coefficient of linear absorption increase as the concentration thickness of the composite material increases, as seen in the figure (2). This is in consistent with the study [Mohammad 2018, Korkut 2013].

The table shows the nose mentioned the relationship between linear attenuation coefficients and gamma photon energy for various thicknesses and concentrations of reinforcement material. In figure (3) These graphs show how the attenuation coefficient is affected by energy, and how increasing energy lowers the attenuation coefficient. This is due to the fact that the mechanism of gamma radiation interaction with the material differs depending on the energy values used. The highest values of attenuation coefficients are observed in the low energy zone, which can be explained by the dominance of the photoelectric effect, which has a large cross section in this area. We can see that as the energy level rises, the most important factor is computant absorption, so the attenuation coefficient gradually decreases until it reaches the high energy range, where the signal is strongest. where the pair's influence is dominant Within this area, there is no significant change in attenuation values [El-Fiki

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2015, Shirmardi 2013].

The table shows the nose mentioned the relationship between half-value layer and gamma photon energy for various thicknesses and concentrations of reinforcement material. In figure (4) draw a relationship between the half value layer and the concentration of reinforcement materials. The half value layer reduces as the concentration of reinforcing materials increases. This is because increasing the concentration of reinforcing materials increases the properties of the base material in terms of gamma ray attenuation, thus assisting in the selection of the thickest appropriate for these engineered shields. In terms of the relationship between the half value layer and the thickness of the manufactured shields, Figure (5) shows that as the thickness of the manufactured shields increases, the half value layer decreases, resulting in an increase in the linear attenuation coefficient, which is inversely proportional to the half layer thickness. the relationship between the Half value layer and incident photon energy The Half value layer increases as the energy level rises, as seen in the table. This can be demonstrated by the fact that low-energy gamma rays need a thinner half-layer than high-energy gamma rays, which need a thicker half-layer to attenuate to half the original value [Al-Saadi 2014].

The effective atomic number's values of shields were calculated using equation (7) for all concentrations as shown in Table (2). The relationship between the atomic effect and the concentration of the additive and the figure (6) shows the relationship. It can be observed that the increasing atomic number increases by increasing the concentration of the composite material. This can be explained by increasing the concentration of additives this will increase the number of atomic shields, ie, there is an improvement in the properties of the PMMA towards the properties of the reinforcement material. Therefore, by increasing the concentration of the reinforcement materials, it is possible to obtain large atomic material that makes it suitable for use as a shield against gamma radiation [Abdala 2014].

Table 1. The Value of Linear Attenuation Coefficients and Half Value Layer

Comp.	WO_3 Concentrations	Thi. (cm)	662 Kev Energy		1172 Kev Energy		1332 Kev Energy	
			$\mu(cm^{-1})$	$HVL(cm)$	$\mu(cm^{-1})$	$HVL(cm)$	$\mu(cm^{-1})$	$HVL(cm)$
Ep (pure)	0	1	0.06992	9.911327	0.06767	10.24087	0.06172	11.22813
Group (1)	10%	1	0.09695	7.148014	0.07697	9.003508	0.0687	10.08734
	20%		0.10287	6.736658	0.08465	8.186651	0.07478	9.267184
	30%		0.11353	6.104113	0.09024	7.679521	0.08216	8.434761
	40%		0.11994	5.459272	0.09779	7.086614	0.09175	7.553134
Group (2)	10%	2	0.0989	7.007078	0.07939	8.729059	0.07545	9.184891
	20%		0.10537	6.576825	0.0865	8.011561	0.08242	8.408153
	30%		0.11644	5.951563	0.0959	7.226277	0.09199	7.533428
	40%		0.12817	5.291288	0.1049	6.606292	0.09997	6.93208
Group (3)	10%	3	0.11037	6.27888	0.07978	8.686388	0.07878	8.796649
	20%		0.11594	5.97723	0.08758	7.912765	0.08588	8.069399
	30%		0.1265	5.478261	0.09589	7.227031	0.0929	7.459634
	40%		0.13635	5.082508	0.10481	6.611965	0.10159	6.821538
Group (4)	10%	4	0.11237	6.167126	0.08774	7.898336	0.08475	8.176991
	20%		0.1211	5.722543	0.09239	7.500812	0.08848	7.832278
	30%		0.13094	5.2925	0.09958	6.959229	0.0938	7.38806
	40%		0.14651	4.730053	0.10577	6.551952	0.10387	6.671801

Table 2. The Values of Effective Atomic Number of the Composite Material

Concentration of reinforcement (%)	**Concentration of Polymer (%)**	Z_{eff}
0	100	2.0451
10	90	17.0405
20	80	32.036
30	70	47.0315
40	60	62.027

Conclusions

According to the current research, nanotechnology opens up new possibilities for the development of radiation safety materials that are both customizable and effective as photon attenuators. The integration of high-atomic-number nanomaterials into polymer materials enables the development of radiation shielding materials that can substitute lead as the dominant material. in the field of radiation protection, the study's key finding confirms current knowledge that nanocomposites based on nanoparticles may greatly attenuate photons, allowing them to be used effectively in medical radiation applications. Particle size, the support ratio used in the shielding material, and other variables all play a role. The amount of photon energy used has a direct impact on the efficacy of every radiation protection system. To promote the full utilization of nanoparticles' ability in radiation protection technology.

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