Linear attenuation coefficient measurement in polymer composite

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Abstract

Linear attenuation coefficient of polymer composite for beta particles and bremsstrahlung ray were investigated as a function of the absorber thickness and energy. The attenuation coefficient were obtained using NaI(Tl) energy selective scintillation counter with $^{90}Sr/^{90}Y$ beta source having an energy range from 0.1-1.1 MeV. The present results show the capability of this composite to absorber beta particles and bremsstrahlung ray that yield from it. That's mean it is useful to choice this composite for radiation shielding of beta ray with low thickness.

Key words

Attenuation,
polymer,
Beta particle.

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قياس معامل التوهين الخطي في مركب البوليمر

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الخلاصة

تمت دراسة معامل التوهين الخطي لجسيمات بيتا وأشعة الكبح في متراكب ذو أساس بوليمري كدالة للطاقة وسمك المادة الماصة. تم قياس معامل التوهين باستخدام منظومة الكاشف الوميضي NaI(Tl) مع مصدر بيتا $^{90}Sr/^{90}Y$ بمدى طاقة يتراوح بين 0.1 - 1.1 مليون الكترون فولت. بينت النتائج ان هذا المتراكب يملك قدرة عالية على امتصاص جسيمات بيتا واشعة الكبح الناتجة عنها. هذا يعني انه من المفيد اختيار هذا المتراكب من اجل الحماية من اشعة بيتا وبسمك قليل.

Introduction

The study of interaction of radiation with the materials of common and industrial use, as well as biological and commercial importance has become major area of interest in the radiation field science. The attenuation coefficient is an important parameter characterizing the penetration and diffusion of rays in composite materials, and the accurate values linear attenuation coefficient of beta and bremsstrahlung rays for various media especially composite materials are useful for dosimetry, radiation shielding to choice the suitable type of material to adequately stop various forms of radiations, as well as for many nuclear physics experiments.[1]

The probability occurrence of any particular category of interaction, and hence the penetrating power of the several radiations, depends on:

1- The type of radiation and its energy.
2- The nature of the absorbing medium.

An extensive data on mass attenuation coefficients of gamma rays in compound and mixtures of dosimetric interest have been studied by Hubbel [2]. Other scientists such as Bradley et al.[3], Chaudhari and

Girase [4] and Chaudhari and Rathod[5] measured mass attenuation coefficient for various absorber at different energies. In 1990 Dhaliwal et al.[6] studied the attenuation of bremsstrahlung from beta rays in Al, Cu, Sn, and Pb materials.

Measurements on attenuation coefficients and range energy relation of beta particles for various absorbers at different energies have been reported by various workers as Rocca et al. [7] and Mahajan [8], also the attenuation coefficient of beta by composite were investigated by Pujol et al. [9] and Alzubadi [10].

In this work the absorption of beta particles and bremsstrahlung ray in different thickness of polymer composite are studied and measured the linear attenuation coefficient as a function of the energy and absorber thickness.

The attenuation of radiation expressed as Eq.(1):

$$I = I_o \exp(-\mu d) \qquad (1)$$

where I_o is the number of particles counted during a certain time without any absorber, I is the number counted during the same time with a thickness d of absorber between the radiation source and the detector, and μ is the linear absorption coefficient in cm^{-1} .

This equation may be cast into the linear form, as Eq.(2):

$$\mu = (1/d) \log(I_o/I) \qquad (2)$$

Materials and methods

1. Absorber materials

The materials used in this work to prepare the composite samples as absorber with different thicknesses are; Epoxy Resin (EP), polyurethane (PU) and Lead powder with size of 200 µm.

1-1Preparation of EP/PU blend

To prepare the EP/PU Blend an exact amount of special hardener is added to the resin with weight ratio of hardener to resin 1:3. The content is mixed thoroughly by a fan type stirrer until the mixture becomes homogeneous.

A sufficient amount of isocyanate hardener is also added to resin (polyol) with weight ratio of hardener to resin 1:9. The content is also mixed thoroughly by a fan type stirrer before adding epoxy to the mixture.

The epoxy/ polyurethane blend are prepared with weight ratio of both polymers as (20%EP)/(80%PU). It is the best compatibility blend.

1-2 Preparation the composite

By the same manner of previous preparation using the ratio of blend (%20PU)+(%80EP), the lead/EP/PU composite are prepared with weight ratio of lead 70%.

To get the required thickness, pour the mixture in templates with thickness ranging from 0.16 to 1.2 cm, and the dimensions of 3×2.5 cm.

2. Experimental setup

The experimental arrangement with the electronic configuration is schematically shown in Fig.1. The assembly was placed in lead castle. Energy calibration was performed using a set of standard gamma sources.

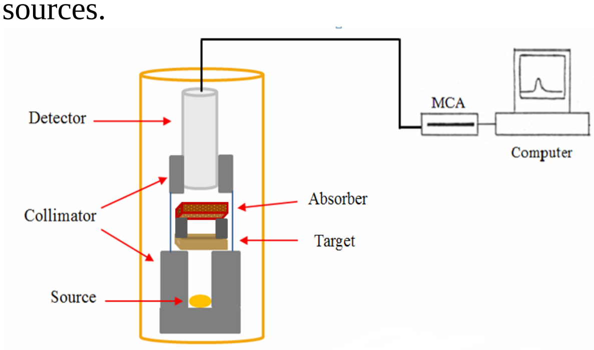


Fig.1: Schematic diagram of experimental setup.

Measurements have been carried out using a collimated beam of pure beta source $^{90}Sr/^{90}Y$ with energy (0.546-2.274) MeV. The beta-particles intensities behind the composite samples have been carried out by using sodium iodide crystal NaI(TI) scintillation detector. The incident and transmitted intensities were determined for fixed preset time at 600 sec in each measurement.

Beta-particles intensities without and with different thickness have been measured. Measurements have been carried out with energy range 0.1-1.1 MeV, and the linear attenuation coefficient was calculated.

3.Determination of beta-particles range

The range of beta-particles, for energy range $0.01 \leq E \leq 2.5$ MeV can be approximated by Baker and Katz[11]:

$$R(kg.m^{-2})=4.12\ E^{n}\ (MeV) \qquad (3)$$

where $n=1.265-0.0954\ \ln E_{max}$

E_{max} is the maximum beta-particles energy in MeV and, R is the range of beta-particles in $kg.m^{-2}$.

Therefore a composite sheet of thickness 0.2 cm, which is sufficient to stop all beta particles from $^{90}Sr/^{90}Y$ according to Eq.(3) was used as a beta stopper (target) to generate bremsstrahlung ray.

Bremsstrahlung ray count rate was recorded without and with different thicknesses of composite absorber and the linear attenuation coefficient was computed.

Results and discussion

The count rat as a function of energy in MeV without absorber material (d=0) and with absorber(d=0.16) was plotted as shown in Fig.2 and the absorption spectra for beta particles in different thickness of absorber from 0.16 to 1.2 cm was shown in Fig.3. It is clear that the intensity of beta decrease with increase the thickness of the absorber.

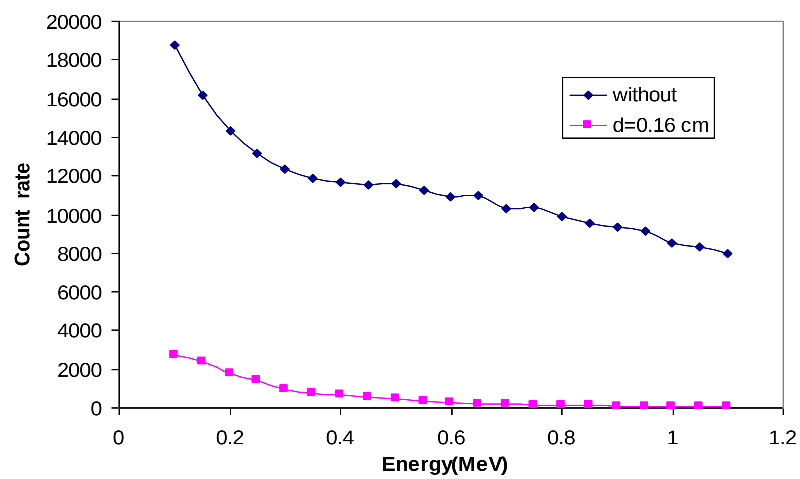


Fig.2: Absorption Spectra for Beta ray without and with absorber of Composite

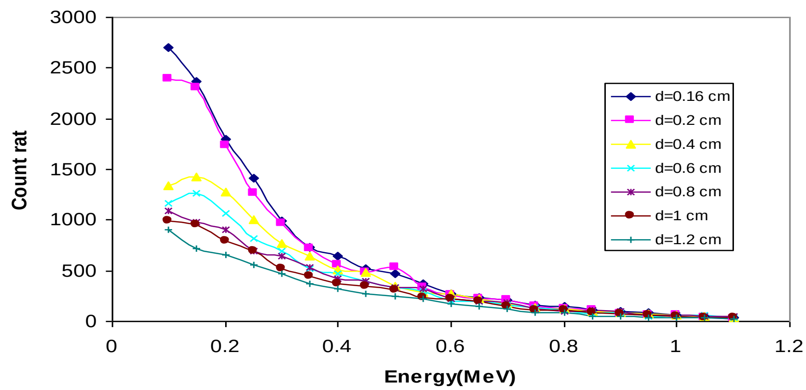


Fig.3:Absorption Spectra for beta particles in different thickness of absorber

Linear attenuation coefficients of beta particle of energy range 0.1-1.1MeV for different thickness of polymer composite obtained from Eq.2 are given in Table 1. It is shown that linear attenuation decrease with increase the thickness of absorber and increase with increase energy. These relations are shown in Figs.4 and 5.

Table 1: Linear attenuation coefficients for different thickness of polymer composite (cm^{-1}).

	Thickness						
	d=0.16cm	d=0.2cm	d=0.4cm	d=0.6cm	d=0.8cm	d=1cm	d=1.2cm
E(MeV)	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6	μ_7
0.1	12.1065	10.2819	6.5959	4.6276	3.5537	2.9410	2.5229
0.15	12.0283	9.7620	6.0813	4.2451	3.5030	2.8355	2.5925
0.2	12.9686	10.5416	6.0403	4.3320	3.4484	2.8992	2.5635
0.25	13.9594	11.7445	6.4380	4.6355	3.6806	2.9402	2.6325
0.3	15.7865	12.7728	6.9306	4.7929	3.6935	3.1706	2.7177
0.35	17.4071	13.9737	7.3025	5.2150	3.8850	3.2694	2.8761
0.4	18.0444	15.2359	7.8350	5.3390	4.1351	3.4303	2.9977
0.45	19.3886	15.8086	7.9559	5.6423	4.2285	3.5076	3.1174
0.5	19.9060	16.4340	8.7690	5.8753	4.4289	3.6117	3.2126
0.55	21.2791	17.4998	9.2175	6.0530	4.4507	3.8650	3.2718
0.6	23.0822	18.7472	9.2420	6.7307	4.8683	3.8901	3.4560
0.65	23.9709	19.5050	9.6745	6.6597	5.0456	4.0008	3.5906
0.7	24.3263	19.6052	10.3002	6.9481	5.0432	4.2267	3.6797
0.75	25.7714	21.0239	10.8597	7.2398	5.5068	4.5412	3.9516
0.8	26.3248	21.8704	10.8775	7.5032	5.7341	4.5202	3.9005
0.85	27.5152	22.1861	11.5006	7.6671	5.6030	4.7457	4.3285
0.9	28.2907	23.9891	11.5496	7.8513	5.7612	4.8241	4.3748
0.95	29.0206	24.5056	12.2163	8.5527	6.1828	5.0430	4.5475
1.0	30.5617	25.1170	12.0731	8.3428	6.2353	5.1986	4.5778
1.05	32.5086	27.0954	12.6025	8.3116	6.5017	5.5335	4.6112
1.1	33.6072	28.1038	13.3112	9.2030	6.3703	5.4915	4.9136

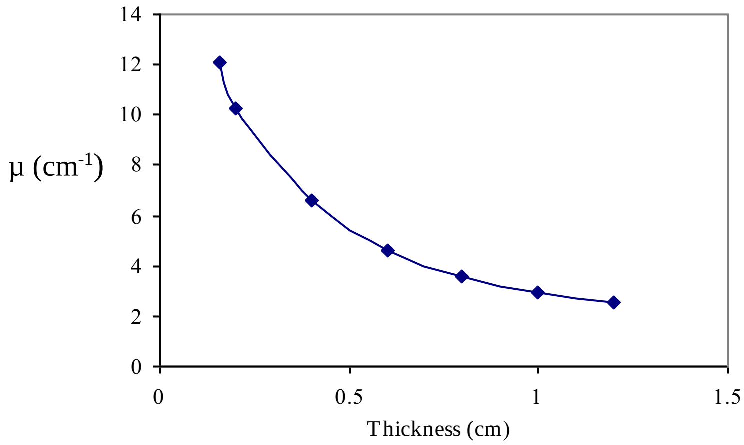


Fig.4: Linear attenuation coefficient (μ) of beta as a function of thickness in cm

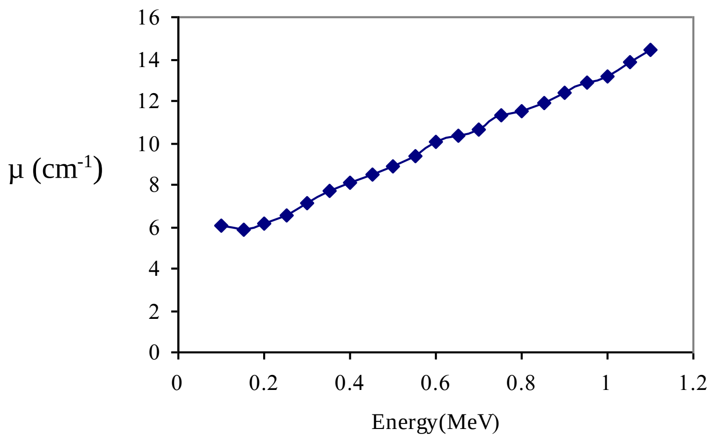


Fig.5: Linear attenuation coefficient (μ) of beta as function of energy in MeV

In Fig.6 the count rate as a function of energy in MeV without absorber material (d=0) and with different thicknesses of absorber was plotted to obtain the absorption spectra for bremsstrahlung ray. It is found that the intensity of bremsstrahulng ray decrease with increase the thickness of the absorber that is clear in low energy regions.

Fig.7 shows the intensity (ln I) as a function of thickness of absorber. The slope of this graph gives the value of linear attenuation coefficient.

In the same way we obtain the linear attenuation coefficients for the range of energies from 0.1 to 1.1 MeV, and plotted in Fig.8. It is found that the linear attenuation coefficient decreases with increase energy.

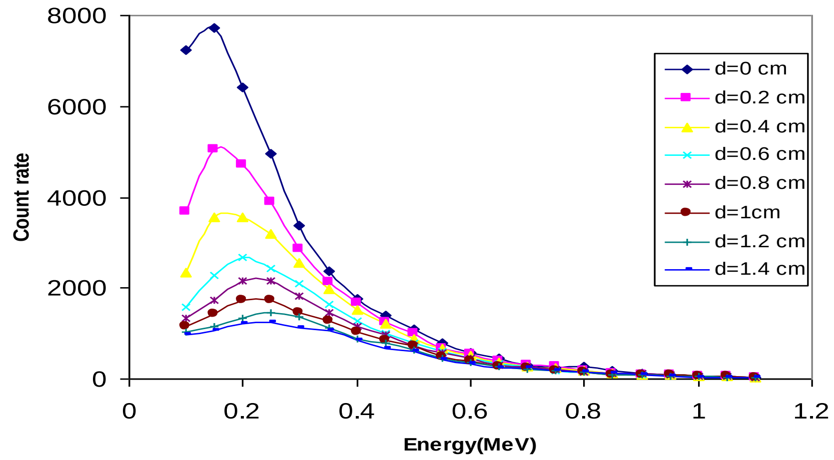
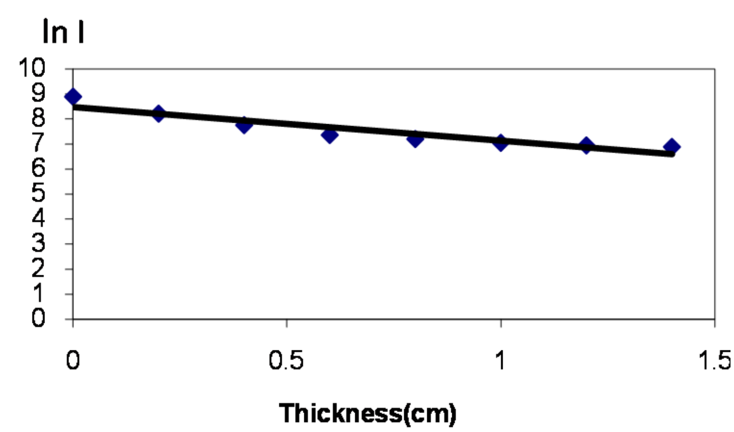


Fig.6: Absorption Spectra for bremsstrahlung ray in different thickness of absorber



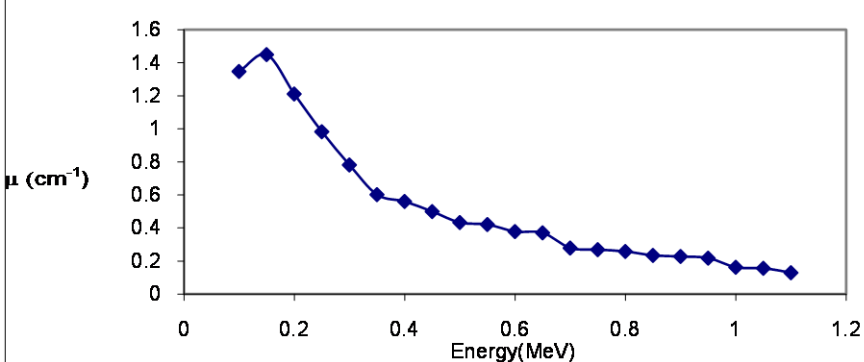


Fig.8: Linear Attenuation Coefficient (µ) as a function of Energys

Conclusions

The attenuation of radiation can be achieved using a wide range of materials and understanding the basic principles involved in the physical interaction of radiation with matter that can help in the choice of shielding for a given application.

Therefore from the above results obtained that the lead/EP/PU polymer composite material is good absorber of beta and bremsstrahulng ray. It can use as a shielding for beta sources instead of shield with two materials first with low Z and second with high Z. Also this material can be used to make radiation protective clothing and aprons for the medical, scientific and nuclear industries.

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