

ISSN: 1991-8941

## Study the enhancement of the radiation shielding afforded to epoxy /lead composites.

Dhameer A. Mutlak                      Ahmed .H. Ali  
 University of Anbar - College of Science.

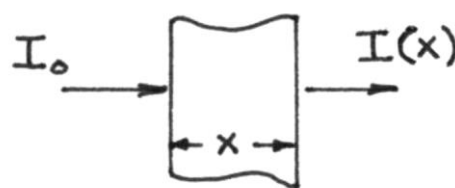
**Abstract:** At present the research aims to individuate right formulations suitable to realize the “cure” process through ionizing radiations to get shielding with applicative properties similar if not better than that obtained with traditional thermal processes. It is worth noting that material properties, on the same formulation, are strongly dependent also on the choice of the process parameters. Additionally a shield absorbs for radiation is a function for the material it is made of, its thickness, type the material and energy of the radiation it is exposed to. Where , as the energy of the radiation increases, the thickness of the shielding must increase or a material with a higher attenuation coefficient must be used. And the results show that the linear absorption coefficient of lead powder increase with increase thickness of lead powder . That linear absorption coefficient as a function of different thickness from (0.0 to 2.5cm.) of lead powder and lead shots where complete its test . No significant changes in linear absorption coefficient behavior of lead powder, lead shots and thickness. Although values of linear absorption coefficient of lead shots will slightly increase as in that for value of lead powder.

### Introduction

The use of ionizing radiation for the synthesis and/or the modification of polymers have received more and more interests in the last years. Due to the advantages in terms of both final properties of the material and environmentally the sustainable process[1]. In particular radiation curing of epoxy resins for the production of advanced composites allows operating at room temperature and in reduced times, with respect to thermal processes. Technical characteristics lead is often used because of its excellent attenuation properties and its relatively low material cost and low processing (molding, machining, etc.) costs. In many applications, lead attenuates x-rays more efficiently than any other material commercially available. High energy gamma damage mostly for organic materials, and polymers. Low effect on metals, moderate on ceramic[2]. Gamma rays are just short wavelength waves that usually follow (by a few picoseconds) beta particle or alpha particle emission, Gamma radiation may ionize atoms but the interaction with one atom usually consumes all or a large fraction of the energy. However, the gamma radiation interacts with atoms with a much smaller probability than either alpha or beta particles.

### Theoretical Concepts of Gamma Interactions:

These are typically photons with energies in the range of 0.1 – 10 MeV. The attenuation of the intensity of a beam of gamma rays in an absorber, sketched in Figure(1.1), follows a true exponential variation with the distance of penetration, which is unlike that of charged particles as shown in equation (1.1)[3].



**Fig.1.1: Attenuation of a beam of gamma radiation through an absorber of thickness x.**

$$I(x) = I_0 e^{-\mu x} \quad (1.1)$$

Where : $I_0$  incident gamma ray

$I(X)$ :attenuated gamma ray

$X$ : thickness

$\mu$ : attenuation coefficient

The interaction is expressed through the linear attenuation

coefficient  $\mu$ , which does not depend on  $x$  but does depend on the energy of the incident gamma. By attenuation one means either scattering or absorption. Since either process will remove the photon from the beam, the probability of penetrating a distance  $x$  is the same as the probability of traveling a distance  $x$  without any interaction,  $e^{-\mu x}$ . The attenuation coefficient is therefore the probability per unit path of interaction; it is what we would call the macroscopic cross section  $\Sigma$  in the case of neutron interaction. There are several different processes of gamma interaction. Each process can be treated as occurring independently of each other; for this reason  $\mu$  is the sum of the individual contributions. These contributions, of course, are not equally important at any given energy. Each process has its own energy variation as well as dependence on the atomic number of the absorber. We will focus our discussions on the three most important processes of gamma

interaction, photoelectric effect, Compton scattering and pair production. These can be classified by object with which the photon interacts and the type of process (absorption or scattering). As shown in the matrix below table (1), photoelectric is the absorption of a photon followed by the ejection of an atomic electron. Compton scattering is inelastic (photon loses energy) relativistic scattering by a free electron. Implication here is that the photon energy is at least comparable to the rest mass energy of the electron. When the photon energy is much lower than the rest mass energy, the scattering by a free electron becomes elastic (no energy loss). This is the low-energy limit of Compton scattering, a process known as Thomson scattering. When the photon energy is greater than twice the rest mass energy of electron, the photon can be absorbed and an electron-positron pair is emitted. This process is called pair production. Other combinations of interaction and process in the matrix (marked x) could be discussed.

**Table (1) : Interaction gamma rays with matter**

Interaction with	absorption	elastic scattering	inelastic scattering
atomic electron	photoelectric	Thomson	Compton
nucleus	x	x	X
electric field around the nucleus	pair production	x	X

Given what we have just said. The sum of the probability of interaction by photoelectric  $\mu_c$ , Compton scattering  $\mu_\tau$  and pair produce  $\mu_k$  is attenuation coefficient  $\mu$  equation (1-2)

$$\mu = \mu_c + \mu_\tau + \mu_k \quad (1.2)$$

where the subscripts C,  $\tau$ , and  $\kappa$  denote Compton scattering C, photoelectric effect  $\tau$ , and pair production, respectively. The half-value thickness  $D_{1/2}$  of a material is defined as the thickness at

which the impulse counting rate is reduced by half, and can be calculated from the absorption coefficient in accordance the equation below  $D_{1/2} = 0.693 / \mu$  [4].

## **Experimental methods**

### **Sample Preparation**

#### **Preparation of the epoxy:**

The mixing ratio is approximate 3:1 by weight. After the compounds were completely dissolved in the hardener, the hardener solution was mixed. The epoxy solution was then placed in a container of glass with dimensions of 20 mm in length, 6 mm in thickness, and 15

mm in width. Initial curing takes 24 hours at room temperature. The identical samples dimensions are (12.5, 1, 6 cm.) for all tests.

#### **Preparation of the lead powder/ epoxy composites:**

By the same manner of the previous Preparation were prepared the lead/epoxy composites with five different weights (10,20,30,40,50)gm.

#### **Preparation of the lead shots/ epoxy composites:**

The lead shots/epoxy composites were prepared as in above with the same procedure, same weight.

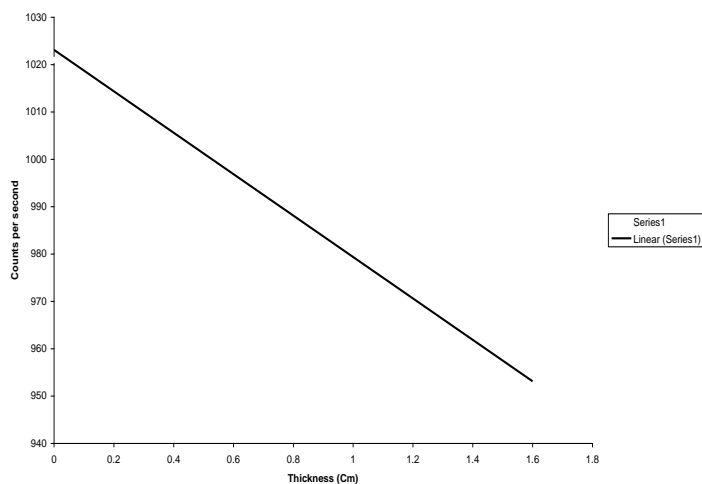
#### **Gamma irradiation tests Irradiation tests of lead powder and lead shots:**

All the samples of lead powders and lead shots were exposed to the gamma source Co-60 type (Gamma cell 900) to find the linear absorption coefficient  $\mu$  for all different samples as shown table (4),table(5).

## Results and Discussion

Table (2) includes the values of linear absorption coefficient, thickness and half-value thickness D1/2 of lead powder. The results in this table (2) show that the linear absorption coefficient of lead powder increases with increase thickness of lead powder as shown in Fig.1.2. These confirm the results observed in [4].

The linear absorption coefficient as a function of different thickness from (0.0 to 2.5cm.) of lead powder and lead shots were tested as shown in table (3). No significant changes in linear absorption coefficient behavior of lead powder, lead shots and thickness as shown in table (3) and fig.1.3.



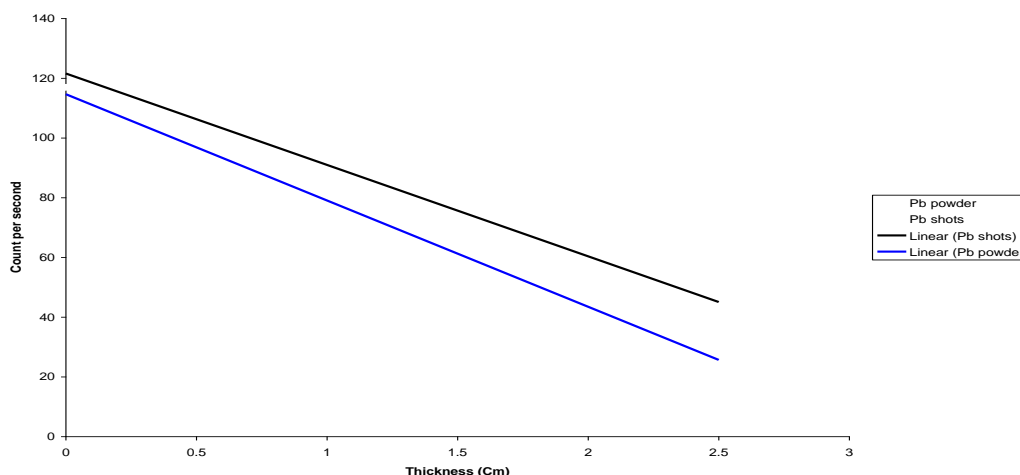
**Fig. 1.2: Relation between thickness of epoxy/Pb powder composites and counts per second**

**Table (2): Linear absorption coefficient of lead powder and thickness**

Thickness Cm.	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6
linear absorption coefficient 1/Cm.	0.0196	0.0121	0.048	0.0537	0.044	0.0401	0.0402	0.0424
half-value thickness d1/2	35.3646	5.7284	14.4405	12.8077	15.7533	17.2854	17.2425	16.3478

**Table (3): Linear absorption coefficient of lead powder, lead shots and thickness.**

Thickness Cm.	Counts/Sec. Pb powder	Counts/Sec. Pb shots	$\mu$ Pb powder	half-value thickness d1/2	$\mu$ Pb shots	half-value thickness d1/2
0.0	117	117				
0.5	90	111	0.32	12.3329	0.12	5.7762
1	81	92	0.367	1.8886	0.238	2.9123
1.5	69	80	0.352	1.9692	0.251	2.7615
2	38	53	0.561	1.2355	0.394	1.7592
2.5	26	47	0.6	1.1552	0.363	1.9094



**Fig.1.3: Relation between thickness of Pb powder, Pb shots and count per second**

Linear absorption coefficient as function masses of lead powder and lead shots were tested in Epoxy composites with 0.6 cm. thicknesses as tabulated in table (4) and table (5). The results in this table (5) with respect to the values of linear absorption coefficient of lead shots slightly increases as in the results of linear absorption coefficient of lead powder which tabulated in table (4). The half-thickness was found by assuming exponential absorption as shown in tables (2),(3),(4), and table (5)[5]. Lead is particularly as an absorber good of gamma rays of low or high energy. The attenuation of gamma rays therefore takes place predominantly in the electron shell of the absorber atoms. The absorption coefficient should therefore be proportional to the number of electrons in the shell per unit volume, or approximately proportional to the density of the material.

Linear absorption coefficient of pure Epoxy exposes to gamma source of Co- 60 for thickness (0.6 cm.) = 0.141 1/cm.

Because for light elements  $Z/A=1/2$  implies that mass absorption coefficient for a given photon energy is practically constant for light elements [6]. Pair formation is also possible in the field of light particles, but the thresholds in such cases are higher, for example, the pair production in the field of electron has a threshold of  $4mc^2$  i.e. it will take place only if the gamma rays have energies greater than 2.04 MeV.

Many of the test and measurement instruments that are used to measure ionizing radiation rely on the attenuation properties of lead and other materials as a basic operating principle. The interaction of gamma rays with epoxy/lead composites mainly occurs by means of

electronic excitation, electronic ionization and primarily, atomic displacement of the orbital electrons the influence of radiation on the material depends on dose rate and the parameters of the composites, including their thickness and composition. Thick high-strength epoxy/lead composites to shield any accompanying radiation [7]. Radiation can extract hydrogen atoms from the epoxy chain and thus generate hydrocarbon radicals. Two of these radicals combine to form an extended epoxy molecule. As this process repeats, a polymer network is formed. The industrial applications of cross linking by irradiation with gamma rays irradiation doses do not require catalysts, so there are no catalyst residues in the final product to interfere with physical properties. There is no heat treatment to degrade thermally sensitive components, and the dosage of irradiation can be controlled easily. The main chains may be degraded or cross linked by the gamma-ray irradiation, with both processes usually taking place concurrently [8]. The lead uses in this study because its inter atomic bonding forces are weak and its melting point is very low, low mass number materials, such as hydrogen in epoxy are best for slowing down neutrons. Materials containing hydrogen are known as hydrogenous material, and their value as a neutron shield is determined by their hydrogen content [9]. Epoxy ranks high and is probably the best neutron shield material, although it is a poor absorber of gamma radiation. Making shields composed of lead and epoxy, it is possible to utilize the properties of both of these materials, resulting in a neutron-gamma ( $n, \gamma$ ) reaction, lead has an extremely low level of neutron absorption and hence

practically no secondary gamma radiation. Lead itself cannot become radioactive under bombardment by neutrons [10].

The half-value thickness  $D_{1/2}$  of a material is defined as the thickness at which the impulse counting rate is reduced by half, and calculated from the absorption coefficient as shown in tables 1, 2, 3, and 4 for the lead and epoxy and their composites. These confirm the results observed in [4]. Absorption of gamma rays by leads as a function of the energy ( $m_{Co}$  = fraction due to Compton effect,  $m_{Ph}$  = fraction due to photoelectric effect,  $m_{Pa}$  = fraction due to pair formation). The total absorption coefficient (attenuation coefficient)

is  $m = m_{Co} + m_{Ph} + m_{Pa}$  pair formation). The total absorption coefficient (attenuation coefficient) is  $m = m_{Co} + m_{Ph} + m_{Pa}$ . High energy radiation is scattered principally by electrons, and so are best shielded by elements with high atomic number. Thus Pb, with an atomic number of 82, is expected to shield better than epoxy alone. Lead/epoxy composites would be expected to increase the radiation shielding characteristics for other radiations. Thus, the object of this work was to study the enhancement of the radiation shielding afforded to epoxy /lead composites [5].

**Table (4): Linear absorption coefficient and masses of lead powder in Epoxy composites with 0.6 cm. thickness.**

masses of lead powder (gm)	linear absorption coefficient(1/cm)	half-value thickness $d_{1/2}$ (cm)
10	0.073	9.4952
20	0.086	8.0598
30	0.1014	6.8357
40	0.1157	5.9909
50	0.2375	2.9185

**Table (5): Linear absorption coefficient and masses of lead shots in Epoxy composites with 0.6 Cm. thickness**

masses of lead shots (gm)	linear absorption coefficient (1/cm)	half-value thickness $d_{1/2}$ (cm)
10	0.171	4.0535
20	0.151	4.5904
30	0.202	3.4314
40	0.243	2.8525
50	0.308	2.2505

## References

- [1]:Nasa Space vehicle design criteria (structures). "nuclear and spacer addition effects on materials ".1970.
- [2]:Markley F., Forster G. A., R. Booth Argonne National Laboratory "Radiation damage studies of zero gradient synchrotron magnet insulation and related materials". 1969.
- [3]: Robley D. Evans, "The Atomic Nucleus", McGraw-Hill New York, Chaps 24, 25, 1955.
- [4]: PHYWE series of publications • Laboratory Experiments • Physics • phywe systeme GMBH • 37070 Göttingen, Germany.
- [5]: James R. Gaier "Effect of Intercalation in Graphite Epoxy Composites on the Shielding of High Energy Radiation "National Aeronautics and Space Administration.July 1997.
- [6]: Atam P.Arya "Fundamentals of nuclear physics" Boston, Toronto Allyn and Bacon1970.
- [7]: Khalil I. Arshak, Member, IEEE, and Olga Korostynska "Gamma Radiation Nose System Based on  $In_2O_3=SiO_2$  Thick-Film Sensors" IEEE sensors journal , Vol. 6, No. 2, April 2006.
- [8]:In Jae Lee,<sup>1</sup> Ho Wook Choi,<sup>1</sup> Young Chang Nho,<sup>2</sup> Dong Hack

- Suhl "Gamma-Ray Irradiation Effect of Polyethylene on Dimaleimides as a Class of New Multifunctional Monomers" 2002.
- [9]: McLaughlin and N.W. Holm: "Physical Characteristics of Ionizing Radiation," in Manual on Radiation Sterilization of Medical and Biological Materials: Technical Reports Series No. 149, Chapter 1: 5-12, (1973).
- [10]: IAEA-TECDOC-1422, Radiation processing of polysaccharides November 2004

### دراسة تحسين إنتاج الدروع الإشعاعية لمتراكبات الايبوكسي / رصاص

ضمير عبد مطلق العبيدي      أحمد حسين علي عواد

[E-mail.: dhameer35@yahoo.com](mailto:dhameer35@yahoo.com)

#### الخلاصة:

الغاية من البحث هي تشخيص صيغ جديدة وصحيحة تنتج من خلال عمل عمليات الإشعاع المؤين للحصول على دروع بخواص عملية مماثلة إذا لم تكون أفضل من تلك التي حصلنا عليها من العمليات حرارية التقليدية. ومن الجدير بالذكر أن خواص تلك المادة، على نفس الصيغة تعتمد بشده على اختيار المعاملات عملية. بالإضافة لذلك الدرع الماص للإشعاع ويكون كدالة للمواد المصنوعة منها، سمكها، نوع المادة و طاقة الإشعاع المعرض عليها حيث عندما تزداد طاقة الإشعاع فيجب زيادة سمك الدروع أو استعمال مواد ذات معامل توهين عالية و النتائج أظهرت بأن معامل الامتصاص الخطي يزداد مع زيادة سمك مسحوق الرصاص. أن معامل الامتصاص الخطي كان كدالة لتباين في السمك من (0 إلى 2.5 سنتيمتر) من مسحوق الرصاص وكرات الرصاص حيث تم اختبارها. لا توجد تغيرات مهمة بين معامل الامتصاص الخطي لمسحوق الرصاص وكرات الرصاص والسمك وان قيم معامل الامتصاص الخطي لكرات الرصاص سوف تزداد بعض شئ عن قيم معامل الامتصاص الخطي لمسحوق الرصاص.