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Study on Lead Iodide-Polyvinyl Alcohol Polymer Composites as an X-ray Shielding Material

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ABSTRACT
Now-a-days, the importance of x-rays is increasing in fields like medical diagnosis, cancer treatment, nuclear fission energy, x-ray scanning machines for airport and railway station entry and in treatment of food for preservation. But the exposure to x-rays will be harmful for the users of such facilities. Doctors, operators and researchers are required to be protected from the high energy ionizing radiations like x-rays and gamma rays.So to protect them, proper shielding is necessary. Numbers of shielding materials are used at workplaces of high radiation regions at nuclear installations. Most commonly used, shielding material is lead glasses due to its high atomic number (Z=82). This insures high absorption by the shielding material. Recently light polymer sheets of polyvinyl alcohol (PVA) are replacing heavy glass sheets. To prepare lead polymer sheets lead compounds are mixed with polymer. In the present work, we selected to mix lead iodide in polymer composite to analyze its X-ray shielding capability. Polymer composites sheets of lead iodide with PVA were prepared by solution method. These sheets of Polymer composites were subjected to soft x-rays (30 KeV- 60KeV) switching studies at room temperature. These sheets found to provide the x-ray absorption69.6% higher than conventional shielding material like lead and are light in weight too.
Key words: X-rays, Polyvinyl Alcohol, Shielding material, Polymer composite material, Lead iodide.

I. INTRODUCTION
X- Rays are widely used for medical, industrial, biological, agricultural and environmental applications. Use of nuclear methods for medical diagnostic and elementary particle research is growing at faster pace. The harmful effects of incident X-rays cause damage to human cells by skin burn, loss of hair and can also cause risk of cancer. So, it is required to protect people from the high energy ionizing radiations like X-rays[1-7] by using suitable materials [8,9,10]. Radiation Shield is one of the methods for protection. It creates a barrier between a person and source of radiation and block the radiation through photo emission and scattering by a barrier material. People working near X-rays are required to wear protective clothing to avoid radiations. Lead has been used to shield X- rays because of its high atomic number and high density also having high attenuation coefficient and suitable for used as radiation shield [11,12].

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Lead shielding products like lead apron are very useful for protection from X-rays radiation during medical operations [13-16]. As lead is a heavy metal so use of lead protective garments for a long time can lead to back pain [17]. Moreover, due to its high toxicity [18] it has environmental disadvantages and its disposal creates environmental hazards [19]. Lead also has low melting point causing high risk at the time of sudden risk like fire etc.

Most recently research work focuses on reducing the weight of protective garments by using composite materials. Lead Iodide is a poisonous material which is harmful for the environment if it is used directly. Polymer composites are heterogeneous substances consisting of two or more materials that have their individual characteristics. The combination of materials brings about new physical, chemical, and mechanical desirable properties. Therefore, its toxic nature can be reduced to no harmful level by making its polymer composites and it can be used without any adverse health effects. So to have a better material of physical and chemical properties it was planned to blend Lead Iodide with polymer Polyvinyl Alcohol. Polyvinyl Alcohol (PVA) is a well-known polymer.

In this paper, formation of light polymer sheets of PVA with lead iodide. PVA replaces heavy glass sheet to lighten the material and it has low toxicity and high flexibility also. Lead iodide is preferred in comparison to metallic lead as it is very much suitable and has favourable properties also it is a quite stable compound. The ability of shielding materials in decreasing the intensity of radiation is expressed by linear and mass attenuation coefficient. Mass attenuation coefficient depends on the incident X-ray energy, the effective atomic number of material and the density of shielding material [20-23]. The accurate attenuation coefficient values of materials are very important parameter in nuclear and radiation physics, radiation dosimetry, crystallography, radiography, spectrometry, biological, medical, agricultural, environmental and industrial.

II. MATERIAL PREPARATION

To prepare the sample, PVA was dissolved in water and fine powder of 99.999% pure Lead Iodide was mixed with that. The properly dissolved material was let to settle down for period of 24 days to form sheets of sample (PVA + PbI_2) [24,25]. Prepared samples (Fig 1.) were cut in the form of rectangular sheets and electrodes were made by using silver paste. During sensor development, silver pasting was done at the top and bottom of the rectangular sheets such that a longitudinal configuration is obtained. Samples were then subjected to microscope studies to find out any possibility of cracks etc. Only those samples were used for studies those were found free from any crack. These prepared sheets were of the order of 1mm thickness.

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Fig. 1 Sample of PbI_2 with PVA

X-RAY SWITCHING STUDIES:

X-ray switching studies have been performed on composites of Lead Iodide with PVA to knowabout the variation of current with thickness of samples. The experimental setup used for x-ray switching studies consists of:

- X-ray source
- Time controller device
- Sensor holder
- Software/hardware to record photocurrent.

The voltage applied to the sheets is of the order of 50V and the variations in (I_{max}-I_{min}) were observed for different thickness.

Table-1: variations in (I_{max}-I_{min})

Sample No.	Thickness of samples (mm)	Comulative (mm)	I_{max} -I_{min}
	0	0	3.81E-09
1	0.71	0.71	2.70E-09
2	0.45	1.16	2.18E-09
3	1.206	2.366	1.48E-09
4	0.69	3.056	8.76E-10
5	1.05	4.106	6.18E-10

III. EXPERIMENTAL RESULTS AND DISCUSSION

Prepared sheets of polymer composites were subjected to soft x-ray of energy up to 60 KeV at room temperature. Radiations after crossing the sample sheets were detected using BiI_3 sensor.

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(Fig.2)

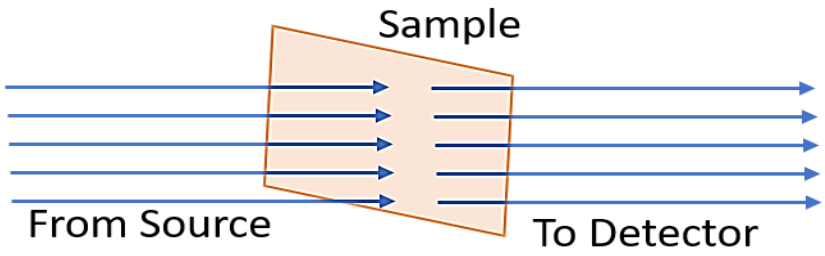

Fig.2 Set-up for X-ray absorption

X-rays were obtained from copper target X-ray tube operating at 30-60 kV with maximum current of 10 mA. The samples were placed in the path of x-ray beam coming perpendicularly on the sample sheets. Sheet number is increased to increase the thickness. The intensity of x-ray coming after the samples was allowed to fall on the detector. Detector current which is proportional to the intensity of x-rays was recorded.Difference in photoelectric current I_p and dark current I_d was plotted against thickness (Fig.3).

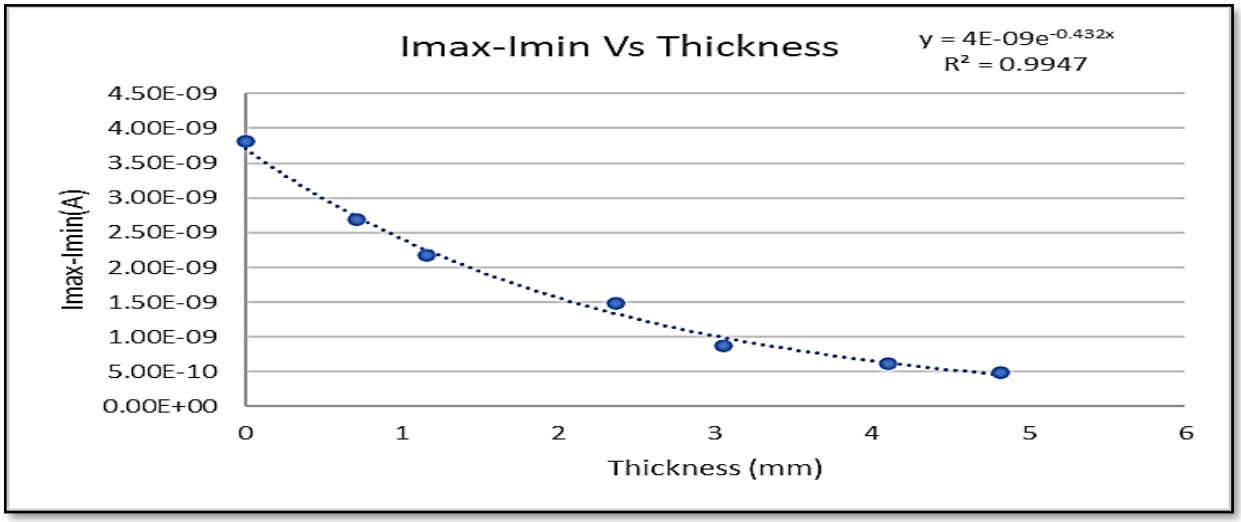

Fig. 3: Difference in photocurrent (I_p) and dark current (I_d) Vs Thickness

So, the obtained value of μ will be 0.432 $mm^{-1}$from graphical representation and density of PbI_2 with PVA according to their concentration in sampleby taking their weights is 1.29 g/cm^3.Therefore,their ratio is called mass attenuation coefficient(μ/ρ) = 17.944 cm^2/g.

According to Beer-Lambert Law

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

Where,

- I is the intensity after crossing the sample
- I_0 is the initial intensity

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- x is thickness of sample
- μ is the coefficient of absorption

So,mass attenuation coefficient was obtained using Beer Lambert's law.It was found to be 17.94 cm^2/g. To obtain theoretical results NIST XCOM [26] software was used. After taking the relative concentration of components Pb, I, C, O & H between energy range 0.001 MeV to1,00,000 MeV and selection of graph for total attenuation with coherent scattering and photoelectric absorption,result was obtained which is represented in Fig.4& Fig.5.On the basis of results, it has been observed that, a straight line for a graph(from SciDAVis) between attenuation and concentration was obtained.

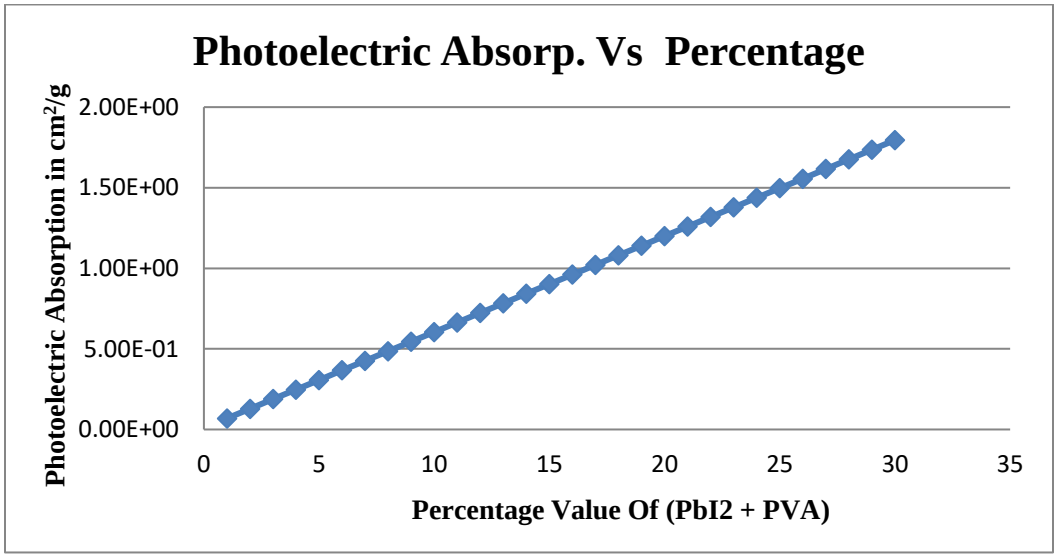

Fig.4: Photoelectric Absorption Vs Percentage

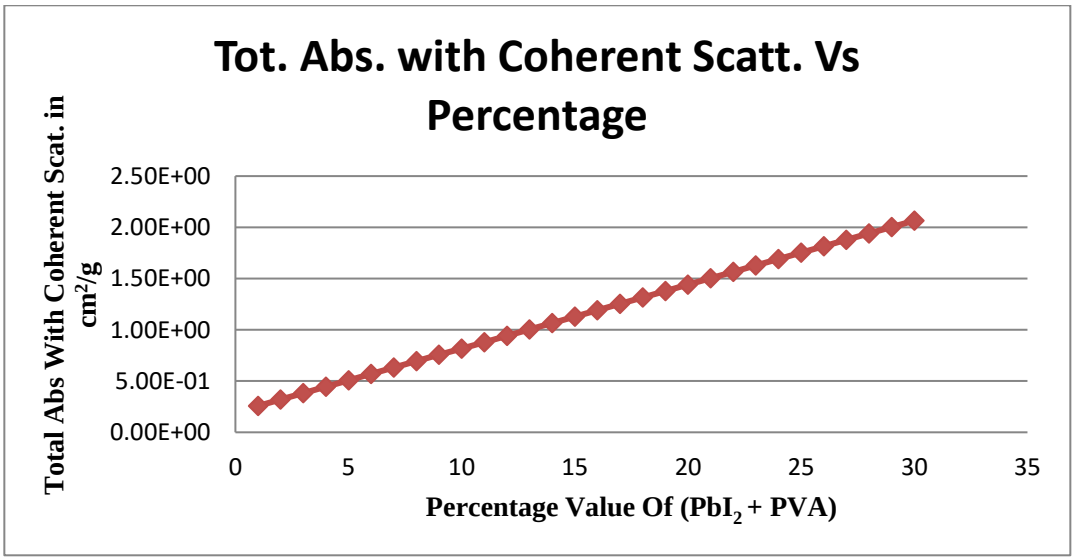

Fig.5 Total Absorption With Coherent Scattering Vs Percentage

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Conventional material like lead sheets is usually used as shielding materials. As mass attenuation coefficient of lead(Pb) is 5.46 cm^2/g and for Lead Iodide with PolyVinayl Alcohol is 17.94 cm^2/g. So, due to its high density and toxic behavior, present polymer composites with PVA as matrix material show 69.6% enhancement in mass attenuation coefficient. However, its density is 1.29 g/cc. This is much less than density of lead. For the radiation of energy range $1x\ 10^{-2}$ MeV these composites are better option.The drastic increase in mass attenuation coefficient is mainly attributed to iodine of lead iodide. Iodine alone has a very high mass attenuation coefficient (162.6 cm^2/g)[27]. But iodine cannot be used as shielding material due to its sublimation nature at room temperature. so the compounds of iodine like PbI_2 in present study brings the high mass attenuation coefficient at the same time providing stable composites. This is also important that one can mold such polymer composites to required shapes of protecting sheets.

III. CONCLUSION

The main aim of this study was to develop a light weight polymer sheet in protective garments [28] for x-rays shielding. In the present work, mass attenuation co-efficient was measured experimentally. Moreover, the result was also determined by using NIST XCOM [29]. According to the obtained data, experimental and theoretical result was found to be very close to each other. Moreover, sheets of PVA & PbI_2 provided good attenuation properties, which make it a good choice to be considered as an x-rays shield. These sheets found to provide the x-rays absorption upto 69.6 % higher than conventional shielding material like lead and are light in weight too.

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