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Experimental Investigation of Effective Atomic Numbers for Some Pb-Sn Binary Alloys Using Gamma Rays Backscattering Technique

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***Abstract*—An attempt has been made to experimentally investigate the dependence of photon backscattering as a function of thickness and atomic number for some metals, which has been extended to determine the effective atomic numbers for some Pb-Sn binary alloys. Some metallic sheets ($_{13}$Al, $_{28}$Ni, $_{50}$Sn and $_{82}$Pb) as well as some binary alloy sheets (Pb-Sn in different compositions) were synthesized with the help of muffle furnace using melt quench technique. The intensity distribution of backscattered photons of Co^{57} radioactive isotope from different elements as well as synthesized alloys were recorded with the help of GAMMARAD5 (76 mm x 76 mm NaI(Tl) scintillator detector). The experimentally assigned effective atomic numbers were in good agreement with the theoretical ones (computed using atomic to electronic cross-section method with the help of mass attenuation coefficients database of WinXCom (L. Gerward et al. 2001)). It has been concluded that binary alloy; Pb80Sn20 can be used for shield designing at X-rays and lower gamma rays' facilities.**

***Index Terms*— Backscattering technique, Binary alloys, Effective atomic number**

I. INTRODUCTION

THE Backscattering of gamma rays photons is an important technique to find the effective atomic numbers of composite materials. The backscattered photons depend upon the thickness and the atomic number of the target used in the experiment. So the intensity distribution of backscattered photons was determined for calculating the effective atomic number of some Pb-Sn binary alloys. The effective atomic number cannot be represented uniquely over the wide nuclear energy domain and varies with incident photon energy. This number is also very valuable to visualize a number of properties of a material of technological, medical, nuclear industry, engineering, space research programs and agricultural interest. Hence, its measurement and computation with high accuracy is required. The backscattering of gamma rays is of prime significant in absorption, shielding, dosimetry of radiation and can be used for analyzing samples non-destructive manner. Non-destructive examination of samples using backscattering technique offers simple imaging and can be accessed the sample from the same side and also the depth information of the sample is possible. The backscattering of gamma photons, is effectively used as an experimental method for estimation of ''effective atomic number'' for Pb-Sn alloy of known composition. Gamma-ray backscattering method can be used for measuring corrosion in insulated pipe [3], non-destructive testing of material [1] and estimating the thickness of hot objects [2]. An alloy is a mixture of two or more elements of different characteristic properties so as to enhance the properties such as tensile strength, hardness, resistance towards corrosion etc. The binary alloys refer to alloys which are made up of two elements. High density materials are more suitable to block the intensity of radiation than low density materials. Due to the high atomic number (Z=82) of lead, it is mainly used for reducing the effect of gamma rays and X-rays. In the present work, some binary alloys of Pb-Sn in different compositions (as given in Table 1) were prepared and the effective atomic numbers for different compositions of Pb-Sn alloy were measured by gamma rays backscattering technique as well as computed using electronic to atomic cross-section ratio method.

II. EXPERIMENTAL DETAILS

The binary alloys of Pb-Sn, in different compositions (as given in Table 3.1) were prepared using the melt-quench technique with the help muffle furnace and cast iron mould. The high purity (> 99.5%) metallic granules of Sn (melting point: 231ºC) and Pb (melting point: 327 ºC) were procured from Nice chemicals (P) Ltd, India. To measure the effective atomic number for the synthesized binary alloys in terms of back scattered photons, an experimental setup is shown in Figure. 1. It comprises of ^{57}Co radioactive isotope, GAMMARAD5 (NaI(Tl) scintillator detector of dimensions 76 mm x 76 mm having energy resolution of 7% at 662 keV coupled with multichannel analyzer (MCA) procured from Amptek Co. USA and lead housing/collimators to minimize the noise (unwanted signal). The scintillator detector has been placed in front of gamma rays source at a distance of 9.5 cm as shown in Figure 1.

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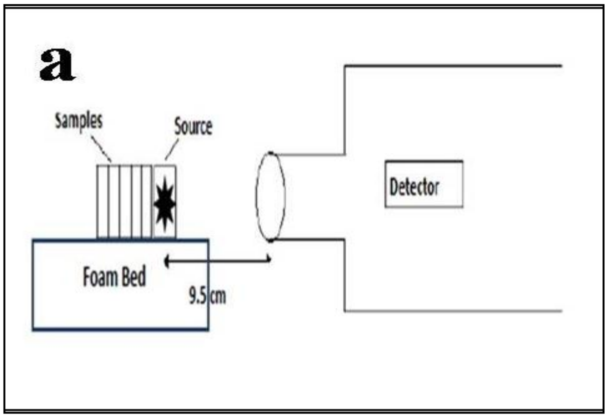

Fig 1. Experimental set-up (Not to scale)

Before initializing the investigation, the detector has been calibrated for energy scale. The pulse height spectra were recorded for different calibrating sources ^{57}Co (122 keV), ^{22}Na (511 keV), ^{133}Ba (81 keV, 302 keV and 356 keV), ^{137}Cs (662 keV), ^{60}Co (1173 keV and 1332keV). After calibration of the detector for energy scale (converting channel number into energy value along x-axis), the back scattered photon spectra of radioactive isotope (^{57}Co) from different thickness of some metals viz: $_{13}$Al, $_{28}$Ni, $_{50}$Sn, $_{82}$Pb; so as to cover wide atomic number range (13-82) were recorded. The metallic sheets of different elements having different thickness have been used.

One of the recorded spectra with and without aluminium sheets (thickness 20 mm) at scattering angle 180° has been shown in Figure 2. For fixed experimental geometry, the backscatter peak and photo peak appears at 82.5 keV and 122 keV respectively. The backscattering sample thickness was increased by placing the same metallic sheets one by one behind the previously placed known metals without disturbing the experimental geometry. The intensity of backscattered photons is evaluated by repeating this procedure for targets of different thicknesses and of different metals. The variation of backscattered counts with target thickness for different metals is shown in Figure 3. This procedure is repeated with samples of other metals. All the spectra were recorded for the time period of 600 sec, so as to have sufficient number of peaks under the backscattered peak and hence, the associated statistical error must be within the limits of ± 5%. The contribution of backscattered photons from a particular sample was obtained after subtracting area under the backscattered photon (with sample) from area under the backscattered photon (without sample). Finally, the backscattered photon spectra for the synthesized alloys were recorded for the same time duration.

TABLE 1: PHYSICAL PROPERTIES OF THE PREPARED ALLOYS

Sample No.	Selected alloys	Fractional weight	Thickness (cm)		Volume (cm^3)	Mass (g)	Density (g/cm^3)
1.	Pb-Sn	Pb80Sn20	Pb=0.80, Sn=0.20	0.75	2.94	27.19	9.25
2.		Pb60Sn40	Pb=0.60, Sn=0.40	0.82	3.46	27.87	8.08
3.		Pb40Sn60	Pb=0.40, Sn=0.60	0.877	3.22	27.07	8.41
4.		Pb20Sn80	Pb=0.20, Sn=0.80	0.87	3.50	24.76	7.08

III. RESULTS AND DISCUSSION

The backscattered photon spectra of ^{57}Co radioactive isotope from different metals and alloy samples were analyzed in order to find out the 'effective atomic number' of the alloy samples. It has been observed that the number of backscattered photons depends not only on the atomic number as well as on the thickness of the target material. The backscattered counts increases with increasing in the thickness of target material and saturates afterwards at particular thickness. The contribution of backscattered counts observed for the selected alloys (also mentioned in Table 1) are marked on the calibration line in Fig. 4. The corresponding atomic number values are interpolated along the X axis. These values are the effective atomic number of alloys under study. The theoretical values obtained using atomic to electronic cross-section method with the help of mass attenuation coefficients database of WinXCom (2001) agreed with the experimental measured values which has been tabulated in Table 2 and shown graphically in Figure 4. It has been concluded that binary alloy; Pb80Sn20 can be used for shield designing at X-rays and lower gamma rays' facilities.

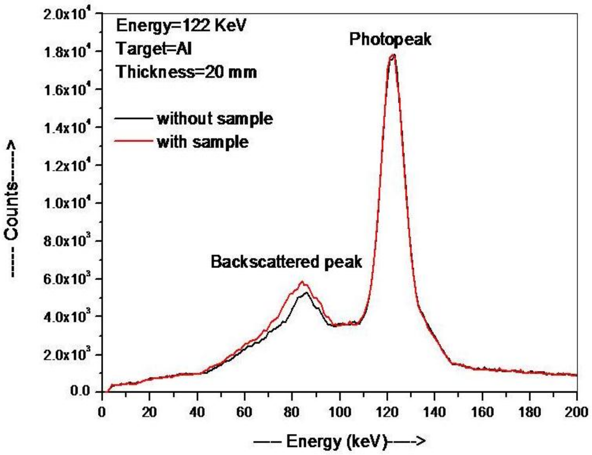

Fig.2: The backscattered peak (82.5 keV) and photo peak (122 keV) with Aluminum sample (thickness 20 mm) using ^{57}Co radioactive isotope

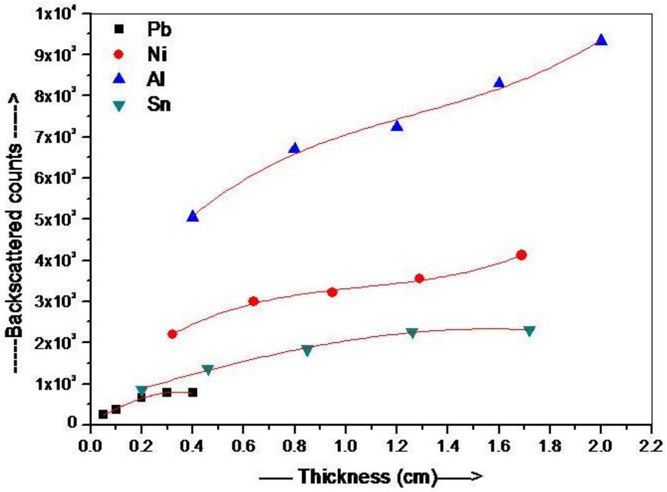

Fig. 3: Variation of backscattered counts for selected metals ($_{13}$Al, $_{28}$Ni, $_{50}$Sn and $_{82}$Pb) on the thickness of target at 122 keV gamma photons

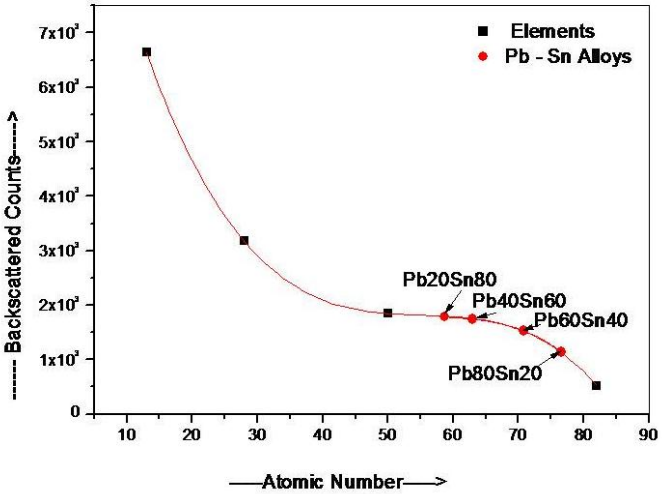

Fig. 4 : Variation of backscattered counts on the atomic number for Pb-Sn alloys of different compositions at 122 keV gamma photons

TABLE 2: EFFECTIVE ATOMIC NUMBER FOR SELECTED ALLOYS AT 122 KEV GAMMA PHOTONS

Sample No.	Selected Alloys		No. of backscattered counts	Z_{eff} (Theoretical)	Z_{eff} (Experimental)
1.	Pb-Sn	Pb80Sn20	1139	75.3	76.6
2.		Pb60Sn40	1529	68.7	70.8
3.		Pb40Sn60	1741	60.9	63
4.		Pb20Sn80	1781	55.8	58.7

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