

Thickness Determination of Metallic Thin Film for X-ray Yield Measurement using Alpha Particle Spectroscopy

P.K.Prajapati

Ph.D. Student, Institute of Science, Department of Physics, Banaras Hindu University, Varanasi, India

ABSTRACT: Several techniques (PIXE, RBS, XRF, XRD) has been developed for thickness measurement, but one very important technique is Alpha Particle Spectroscopy. In this method energy loss of alpha particle from radioactive source, was measured and then we able to estimate thickness of thin foil with help of known stopping power. Stopping power was calculated from SRIM. Different metallic thin foils (Al, Fe, Cu, Se, Ag, Sn, Pb and Bi) with Mylar backing and self supported film has been used for thickness determination by Alpha Particle Spectroscopy and SRIM Program. Mylar thickness (10 μm) also determined which is act like standard in our measurement. These metallic thin films were used for X-ray yield measurement by low energy proton, which is very important for PIXE application.

KEYWORDS: Radioactive Source, PIXE, RBS, XRF, SRIM.

I. INTRODUCTION

Thickness Measurements of metallic thin foils using alpha particles from radioactive source is a well known and non destructive technique. Thickness of a foil can be determined by measuring energy loss through film if the stopping power of the thin foil material is well known. The use of low energy alpha particle from radioactive sources or accelerators provides favourable, non destructive method of measuring thickness of metallic thin targets. Alpha particle thickness gauge is suitable to determine surface density upto 12 mg/cm^2 [1-2, 5]. Fabrication and characterization (thickness and Purity) of target for accelerator based research is play very important role. Characterization means purity of the material and can be investigated from PIXE or XRF technique. Thin metallic target with backing are required in several experimental and theoretical study like Nuclear reaction and measurement of X-ray Production cross-section for PIXE (Proton Induced X-ray Emission) application [8]. Since our targets were used for X-ray yield measurement hence one very essential requirement was the proper choice of target thickness and its fabrication, because target thickness for X-ray cross-section measurement by proton or photon is very important. In this present work thickness of metallic thin film with Mylar backing and self supported foil has been determined by measuring the energy of alpha particle from radioactive source (^{241}Am) and after transmission through the film. More details are given in ref.[9].

II. EXPERIMENTAL SET-UP AND PROCEDURE

The experiment was carried out for several metallic film with standard Mylar film at Nuclear Physics Section in the Department of Physics, Banaras Hindu University, Varanasi (India).To performed this measurement, a radioactive source of strength μCi , Pre-amplifier and Surface barrier detectors were used [2]. Energy loss of alpha particle was measured by using surface barrier detector of active area 50 mm^2 .The energy calibration were carried out using three standard radioactive sources ^{241}Am , ^{244}Cm and ^{238}Pu .The radioactive source, detector and target were put between source and detector, inside a small vacuum chamber. Different thin metallic targets with Mylar backing were prepared using diffusion pump based coating unit (high vacuum evaporator) in the Department of Physics, Banaras Hindu University [7]. The transmitted alpha particle energy through the targets was measured by surface barrier detector. With the help of TRIM simulation mean transmission energy approximately equals measured exit energy, this energy

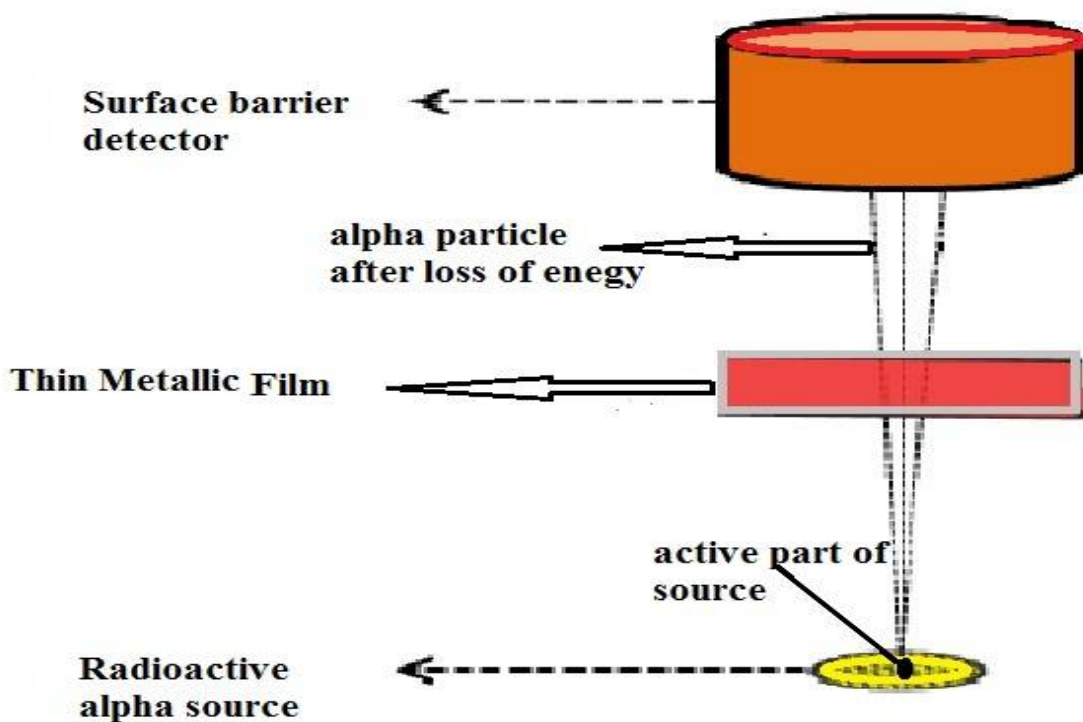
International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

corresponds to the determined thickness of film. For Al thin film, energy peaks of alpha particle from ^{241}Am source and peaks after transmission through the film measured simultaneously by putting the film on a frame. When a charged particle pass through the semiconductor detector then detector responded approximately linearly. Hence there is linear relationship between energy of the alpha particle and channel number.



Schematic diagram for experimental set-up of alpha particle transmission spectroscopy.

III. CALCULATIONS

In order to thickness estimation of thin film, energy loss measurement of the alpha particle is important. thickness has been determined by using energy loss and stopping power in thin absorber that is penetrated by alpha particle. The relationship between energy loss and stopping power within the film is defined by $\Delta E = (-dE/dx)_{\text{avg}} * t$ ref.[5]. where t is the absorber thickness (target or metallic thin film) and $(-dE/dx)_{\text{avg}}$ is the linear stopping power averaged over the energy of the particle while alpha particle was being within the absorber. Stopping power of different material was calculate by SRIM program. Stopping power was calculated in energy range between entering into the material and emerging from the material. To find out value of energy loss through material, centroid of the each peak has been taken. Experimentally measured energy loss was verified by TRIM. Energy of alpha particle from ^{241}Am ^{244}Cm and ^{238}Pu sources was 5.486, 5.805, 5.593 MeV respectively. Calibration of sources was done and shown in the fig.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

IV. RESULTS AND CONCLUSION

Thickness of different thin film has been determined using alpha particle spectroscopy. Thickness of Standard Mylar film has been determined approximately its standard value (10µm) and found 9.56 micron which is nearly its standard value with uncertainty approximately upto 4%. Different metallic targets were deposited on Mylar film hence during calculation correction of Mylar film has been included. In thickness determination, uncertainty was estimated 4-10 %. Thickness of Al ,Fe ,Cu , Se, Sn , Ag , Pb, and Bi has been determined and result is shown in table 2. Determined thickness from two different radioactive sources ²⁴¹Am and ²⁴⁴Cm is approximately similar.

| Source | Energy (MeV) | Channel No. |
|-------------------|--------------|-------------|
| ²⁴¹ Am | 5.486 | 2040 |
| ²³⁸ Pu | 5.499 | 2046 |
| ²⁴⁴ Cm | 5.808 | 2150 |

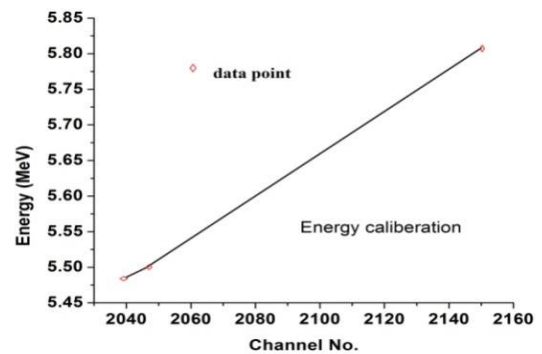


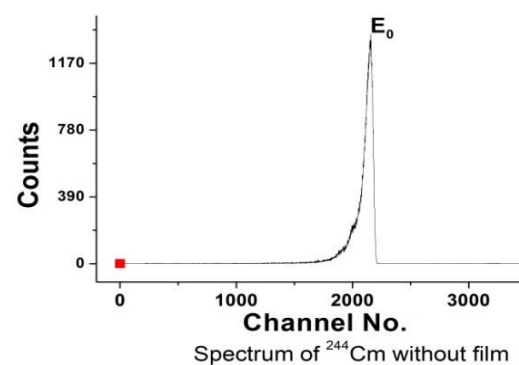
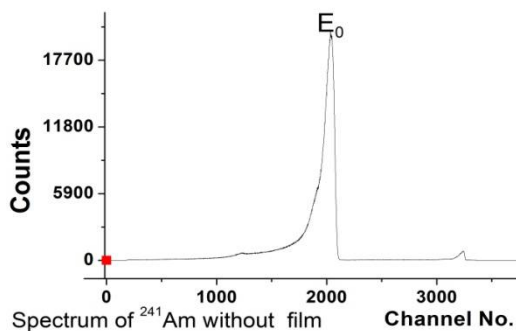
Fig. shows calibration curve

Energy at any channel has been calculated by fitting linear equation

$$\text{Energy} = 0.00295 * \text{Channel No.} - 0.5276 \quad (\text{for without Mylar backing})$$

$$\text{Energy} = 0.00295 * \text{Channel No.} - 0.5276 - 1.0653 \quad (\text{for with Mylar backing})$$

Energy loss of alpha particle in Mylar film is 1.0653



International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

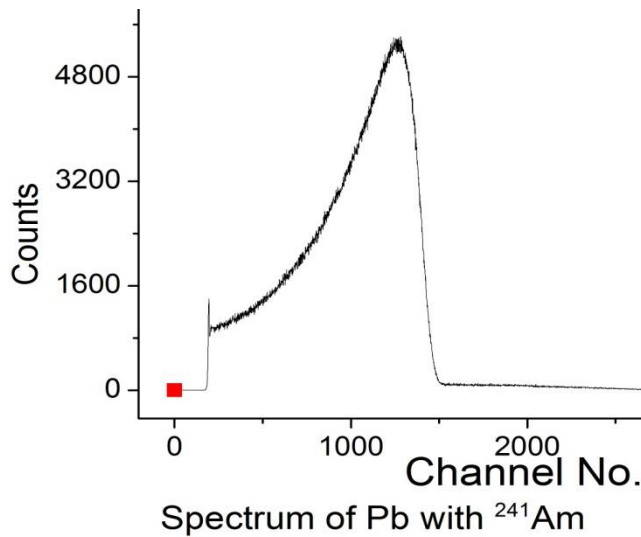


Fig.(a) shows spectrum of Pb with ²⁴¹Am radioactive source

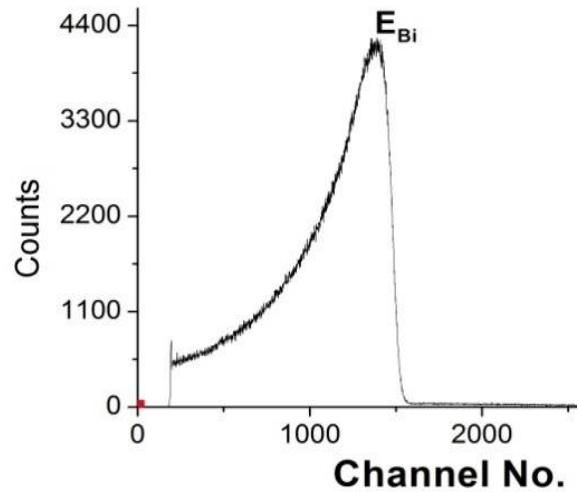


Fig.(b) shows spectrum of Bi film with ²⁴¹Am radioactive source

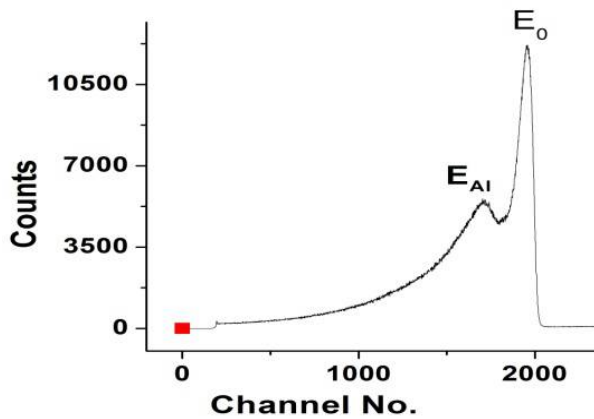


Fig.(c) shows peaks with Al and without Al film ²⁴¹Am radioactive source

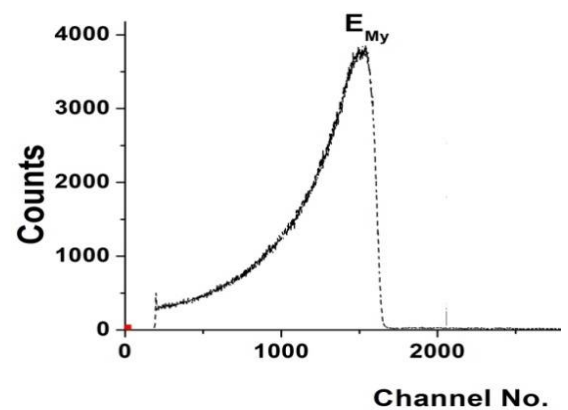


Fig.(d) shows spectrum of Mylar film with ²⁴¹Am radioactive source

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Table for thickness determination from ^{241}Am radioactive source:

| Thin foil | Channel No. | Energy Loss (MeV) | Stopping Power MeV/ mg/cm ² | Thickness (mg/cm ²) | Thickness (μm) |
|-------------------------|-------------|-------------------|---|---------------------------------|----------------|
| Mylar | 540 | 1.0653 | 0.8512 | 1.2515 | 9.6497 |
| Al (without Backing) | 322 | 0.4222 | 0.6082 | 0.6942 | 2.5712 |
| Fe (with Mylar Backing) | 629 | 0.2625 | 0.5070 | 0.5178 | 0.6583 |
| Cu (without Backing) | 627 | 1.3219 | 0.4208 | 3.1413 | 3.5295 |
| Cu (with Mylar Backing) | 588 | 0.1416 | 0.4208 | 0.3364 | 0.3780 |
| Se (with Mylar Backing) | 635 | 0.2802 | 0.3934 | 0.7123 | 1.4810 |
| Ag (with Mylar Backing) | 583 | 0.128 | 0.3634 | 0.3490 | 0.3333 |
| Sn (without Backing) | 567 | 1.1449 | 0.3474 | 3.2958 | 4.5263 |
| Pb (with Mylar Backing) | 760 | 0.6490 | 0.2592 | 2.5038 | 2.2079 |
| Bi (with Mylar Backing) | 632 | 0.2714 | 0.2590 | 1.0478 | 1.0692 |

V. DISCUSSIONS

Transmission alpha particle spectroscopy is very useful technique for the calculation of thicknesses. The main uncertainties of the thickness determination depend on the uncertainty of the energy loss measurement and the uncertainty of the stopping power values which is calculated from SRIM. For more precise thickness determination energy loss correction in source itself and detector dead layer must be included. Energy calibration of the alpha particle detector is play very important role for the energy loss determination and broadening of the peaks can lead to the uncertainty in thickness determination.

VI. ACKNOWLEDGEMENT

The author is highly thankful to Nuclear Physics Section In-charge (BHU) Prof B. K. Singh for providing experimental facility and also thankful to Banaras Hindu University to provide research fellowship under Ph.D. registration No. (PHY/RES/RET Qualified-2013/2013-2014/923dated 20.11.2013). Thanks to Mr.R.S.Mishra and Mr. Rajesh Singh for technical support.

REFERENCES

- [1] An Alpha particle thickness Gauge.V E Lewis NIM 64(1968) 293-296.
- [2] Herbert L. Anderson NIM1291961) 111-114
- [3] K. Ramavataram NIM 4(1959) 239-242
- [4] The Stopping and Range of Ions in Matter calculated from SRIM site. www.srim.org
- [5] D C Santry et.al NIM B 159(1979) 523-527
- [6] C. Yalcin NUBA Nuclear Physics and Astrophysics **590** (2015) 012050
- [7] Anna Stolarz J Radioanal Nucl Chem (2014) 299:913-931
- [8] S.A.E. Johanson, J.L. Campbell PIXE, A Novel Technique for Elemental Analysis, John Wiley & Sons, 1988.
- [9] *Radiation Transmissions-based Thickness Measurement System –Theory and Applications to the Flat Rolled Strip Products* by Mark E. Zipf

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

BIOGRAPHY



Pradeep Kumar Prajapati is pursuing his PhD in Experimental Applied Nuclear Physics, from Department of Physics, Banaras Hindu University, Varanasi 221005, INDIA.