Characteristics of Si-PIN diode X Ray Detector with DSP electronics

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Silicon PIN diode detectors are usually used for detection of X ray and low energy gamma rays. These detectors are rugged, cheap, light and portable with liquid Nitrogen free cooling and can handle high-count rate. The detector used in the present work is from Amptek, Inc. USA having an active area of 6mm^2, 500μm thick silicon crystal wafer and with a 0.5mil thick Beryllium window. The detector is thermoelectrically cooled to very low temperature of about –45^o Celsius internally. We have already characterised this detector with analog spectroscopy system. We found [1] that PIN diodes can be used as a detector complementary to a Low Energy Photon Spectrometer (LEPS: Planar HPGe) in nuclear gamma spectroscopy.

In the present work, we have extended our studies to investigate the features of this detector coupled with a digital processor. At low energies, backscattered Compton peaks are close in energy to photo peak of the gamma of interest. Thus the backscattered peaks pose a serious problem in the analysis of spectra of low energy gamma rays. We have initiated some measurements to quantitatively estimate the same as function of energy and Z of the scatterer. Recently [2] there has been application of backscattering in high-resolution gamma backscatter imaging for technical applications.

Improvement in detector performance with DSP electronics is evident from Fig.1. The resolution of the detector has improved substantially. Moreover occurrence of spurious peaks in the spectrum due to incomplete charge collection as discussed in Ref. [1] has reduced to a great extent.

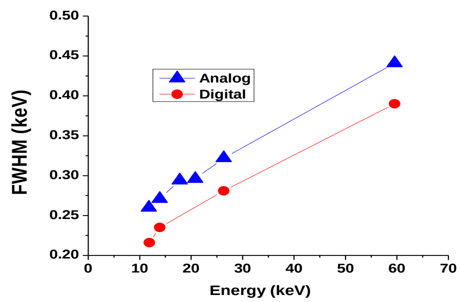

Fig.1 Comparison of variation in FWHM with photon energy for analogue and digital pulse processing**.**

Standard procedure has been followed to obtain detection efficiencies. The source used to draw the efficiency curve for the Pin diode was ^{241}Am. From the graph (Fig. 2), we find that with increasing values of energy the efficiency of the detector falls. We have plotted the efficiency curve in the range 11.8keV-59.5 keV. As per the specification of the detector quoted by the manufacturer, we know that the detector is more efficient for detecting energies lower than 11.8 keV. We thus need to find sources of energy <10 keV in order to complete the efficiency curve of the detector.

In the low energy region, the detection efficiency is usually estimated from the calculated transmission efficiency through a Be window, assuming its thickness as given by a manufacturer to be almost reliable. However, transmission of X rays through the Be window, gold contact layer, or silicon dead layer becomes sensitive to a slight difference in their thicknesses and the uncertainties of efficiency increases with decreasing X ray energies.

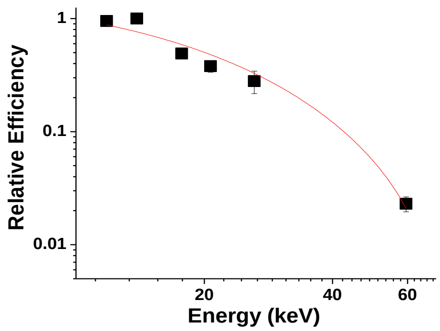

Fig. 2 Efficiency of Si-PIN detector

One such important model parameter is the accurate distance of the source-to-detector. From this we can locate the semiconductor surface position within the detector casing [2]. The source-to-Be window distance can be measured directly, but a suitable estimate of the Be window to-detector distance is necessary. For a point source, solid angle is inversely proportional to the square of the source-to-detector distance. This distance may be determined accurately by measurement of the count-rate of a low energy line at several source-to-Be window distances with subsequent application of a $1/r^2$ law.

The sources used in this measurement are ^{183}Re (emitting x-ray energies of 8.3 keV and 9.5keV) and ^{241}Am. The source was mounted perpendicular to the central axis of the detector and the source-to-housing distance was varied. Spectra were recorded for a fixed live time for a fixed distance of the source before the detector. For ^{183}Re the source was kept at distances up to 11cm from the detector. The intercept with the distance axis of a plot of (count-rate)$^{-1/2}$ vs. source-to-detector housing distance thus yields the position of the front face of the Si. Usually 90% of the~ 5keV photons are stopped within the first 0.07mm of the silicon. To investigate further a ^{241}Am source was used and the same procedure was followed to obtain the spectra. However this source was weaker as compared to the ^{183}Re, hence it was placed relatively closer to the detector than in the earlier case. Taking into account all the measurements at various energies, the mean Be window-to-crystal distance was found to be 5.07±0.31 mm.

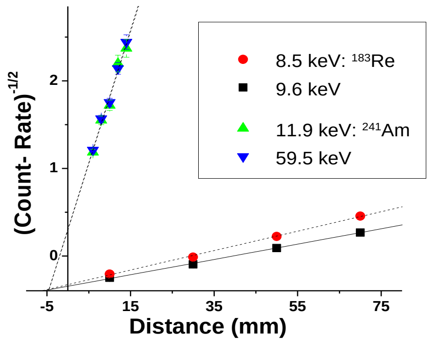

Fig. 3 Measurement of the position of the Si crystal.

The errors in this measurement may arise due to the following reasons. The source used was not a point source but had a finite dimension. Further there may be error in placing the source. As the energy of the incident photon increases the photon penetrates deeper and chances are there that this simple dependence is being violated. The attenuation factor due to air has been neglected.

Other parameters required for predicting the detection efficiency theoretically are obtained either from the suppliers of the detector or are being measured in our laboratory. The experimental data will be compared with the theoretical estimates to reveal anomalies in the detection efficiencies, if any.

Study on the effects on backscattering of gamma rays using different scattering materials has also been pursued to compare them with the theoretical estimates [4].

References

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