# Precision X-ray energy and intensity measurements with XR-100CR Si-PIN Photodiode detector

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## Introduction

Model XR-100CR is a new high performance X-ray detector of AMPTEK Inc., U.S.A. with a preamplifier and cooler system. It uses a thermoelectrically cooled Si-PIN Photodiode as an X-ray detector. Also mounted on the cooler are the input FET and a novel feedback circuit. These components are kept at approximately -30ºC, and can be monitored by an internal temperature sensor. The hermetic TO-8 package of the detector has a light tight, vacuum tight 1 mil (25 µm) Beryllium window to enable soft X-ray detection. Power to the XR-100CR is provided by the PX2CR Power supply. The PX2CR is AC powered and includes a spectroscopy grade Shaping Amplifier. The XR-100CR/PX2CR system ensures stable operation in less than one minute from power turn-on.

## Experiment

In order to facilitate the electron/hole collection process, a 150 Volt bias is gradually applied across the silicon. This voltage is too high for operation at room temperature, as it will cause excessive leakage and eventually breakdown. Since the detector in XR-100CR is cooled, the leakage current is reduced considerably, thus permitting the high bias voltage. This higher voltage decreases the capacitance of the detector, which lowers the system noise. The Rise Time Discrimination circuit (RTD) prevents the false peaks from being counted by the MCA. The thermoelectric cooler cools both the silicon detector and the input FET. Cooling the FET reduces its leakage current and increases the transconductance, both of which reduce the electronic noise of the system.

Since optical reset is not practical when the detector is a photodiode, the XR-100CR incorporates a novel feedback method for the reset to the charge sensitive preamplifier. The reset transistor, which is typically used in most other systems, has been eliminated. Instead, the reset is done through the high voltage connection to the detector by injecting a precise charge pulse through the detector capacitance to the input FET. This method eliminates the noise contribution of the reset transistor and further improves the energy resolution of the system. A temperature monitor chip is mounted on the cooled substrate to provide a direct reading of the temperature of the internal components, which will vary with room temperature. Below 20ºC, the performance of the XR-100CR does not change with a temperature variation of a few degrees. Hence, the closed loop temperature control is not necessary when using the XR-100CR at room temperature.

The intrinsic full energy detection efficiency has been studied using $K_\alpha$ lines of selected elements. The resolution of the 5 $mm^2$ x 680 µm thick with 1 mil Be window detector for the 5.9 keV peak of $^{55}$Fe is found to be 186 eV with 20 µs shaping time.

The carrier free samples of radioisotope $^{177}$Lu produced by the irradiation of enriched $^{176}$Lu in the form of Lutetium Chloride solution were obtained from the Board of Radiation and Isotope Technology, Bhabha Atomic Research Centre, Trombay, Mumbai. The activity of the source was 10 mCi. Very thin uncovered sources with count rates of 500 to 1000 counts were prepared by drying the source solution on thin aluminized mylar backing supported on an aluminium ring of diameter 1.0 cm. Different sources of different source strengths were used in many number of runs. Experiments were performed using XR-100CR coupled to a PC based 8K MCA X-ray spectroscopy system for the X-ray spectra. The X-ray spectra were acquired at a source to detector distance of 10 cm for counting periods of 5.7 x $10^5$ seconds. GammaVision and FIT software were used for spectral analysis.

## Results and Discussion

The intense K and L- X-ray lines were acquired with the above described high performance, thermoelectrically cooled Si-PIN Photodiode X-ray detector and the partial spectra showing the prominent K and L X-rays from the experiment are shown in Fig. 1 and 2. Our X-ray intensities when normalized with respect to the $K_{\alpha 1}$ line (taken to be 2.79) agree very well with previous results with much smaller uncertainties. The values of energies and intensities of the 9 X-ray lines (5 L-shell and 4 K-shell) are presented in Tables I and II. The results of an earlier measurement by Schotzig et al [1] and the adopted values from Nuclear Data Sheets for A = 177 [2] are also shown, for comparison of the accuracy and precision of the present X-ray energy and intensity data. Thus, the XR-100CR Si-PIN detector is found to be better than any other $LN_2$ cooled Si(Li) or HPGe detector in the less than 100 keV energy range.

Table I

| X-ray energies in keV (Theory) | X-ray energies in keV | |
|---|---|---|
| | Schotzig et al [1] | Present work |
| 6.96 ($L_l$) | 7.0 | 7.06 1 |
| 7.96 ( $L_\alpha$, $L_\eta$) | 7.9 | 7.956 1 |
| 9.03 ($L_{\beta 1}$, $L_{\beta 3}$,$L_{\beta 4}$, $L_{\beta 6}$) | 9.0 | 9.033 1 |
| 9.34 ($L_{\beta 215}$) | 9.4 | 9.345 1 |
| 10.62 ($L_{\gamma 1}$, $L_{\gamma 6}$) | 10.5 | 10.462 2 |
| 10.86 ($L_{\gamma 2}$, $L_{\gamma 3}$) | 11.0 | 10.763 13 |
| 54.612 ($K_{\alpha 2}$) | 54.6 | 54.609 13 |
| 55.791 ($K_{\alpha 1}$) | 55.8 | 55.801 8 |
| 63.243 ($K_{\beta 1}$) | 63.2 | 63.187 2 |
| 64.942 ($K_{\beta 2}$) | 65.2 | 65.048 6 |

Table II

| X-ray energy keV | Relative Intensity | | |
|---|---|---|---|
| | Schotzig et al [1] | NDS 2003 [2] | Present |
| 6.96 | 0.0734 24 | 0.076 5 | 0.073 1 |
| 7.96 | 1.505 27 | 1.518 25 | 1.518 11 |
| 9.03 | 1.333 24 | 1.333 24 | 1.373 6 |
| 9.34 | 0273 6 | 0.273 6 | 0.294 6 |
| 10.62 | 0231 6 | 0231 6 | 0.238 4 |
| 10.86 | 0.0223 14 | 0.0223 14 | 0.030 5 |
| 54.612 | 1.551 25 | 1.60 5 | 1.60 4 |
| 55.791 | 2.72 5 | 2.79 5 | 2.79 4 |
| 63.243 | 0.883 12 | 0.896 17 | 0.895 4 |
| 64.942 | 0.238 4 | 0.245 7 | 0.205 4 |

Figure 1

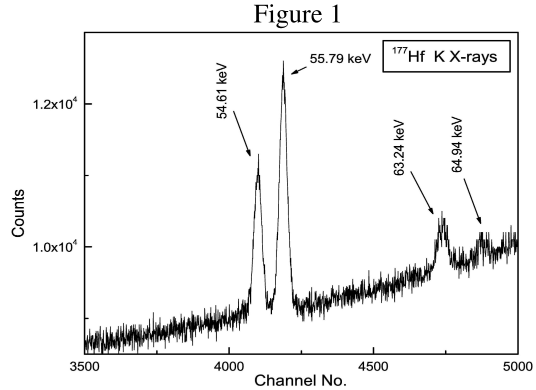
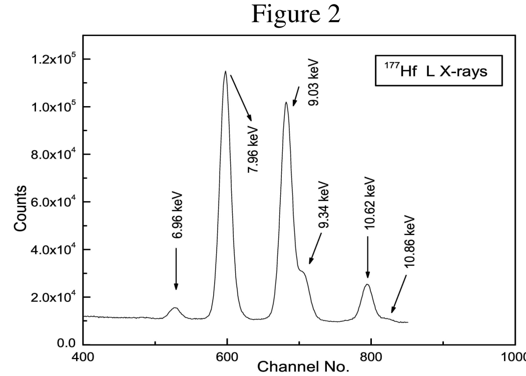



Figure 2




## References


[1] U. Schotzig, H. Schrader, E. Schonfeld, E. Gunther, R. Klein, Appl.Rad.Iso.55 (2001) 89

[2] F.G. Kondev, Nuclear Data Sheets for A =177, 98 (2003) 801.