Characterization of a PIN diode detector and Quality assurance capable Digital signal processor system for FP analytical work

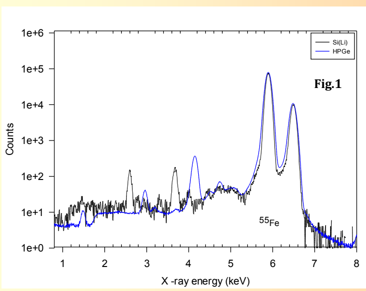
Introduction

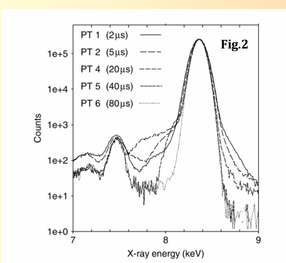
In x-ray based analytical technique the knowledge of the true input rate, and the true detection efficiency is unavoidable. We have developed a method for this aim and present the application for a Si PIN diode detector. We have characterized the Si PIN diode detector with a digital signal processor, which unique capability, beside the high throughput rate, excellent resolution and line shape is the QA (quality assurance capability). We also compare some aspects of the performance with Si(Li), HPGe, and SDD detectors.

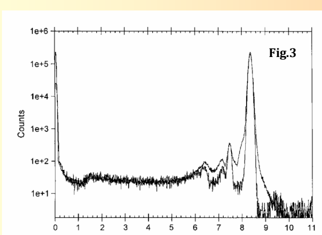
It is difficult to assess the reliability of the basic physics parameters, on which the fundamental parameter methods analytical techniques are based [1]. Some of the measurements reports striking observations, like strong deviation from Feynman's Golden rule [2], or strong chemical effects, which explanation is yet to be given [3]. Beyond that the detector performance and detector models have large variations [4,5]. Therefore it is important to have as much detailed information about the detection system and equipment parameters, as possible. It is customary to characterize the detector response function and parameterize it in terms of a phenomenological model, using the hypermet function and exponential tailings [6], or the double exponential plateaus derived from the electron energy loss processes [5].

The digital signal processor retaining all events, and sort them into several spectra. By that way all the events can be analysed. It also allows the determination of the energy and noise dependent electronic efficiency curve as well. The simpler mode it creates two spectra, one for the good quality spectra and one for the rejected events, which do not meet the criteria established by the discriminators. We have characterized a PIN diode x-ray detector response function, and established the functional forms for the analysis of the rejected spectrum. The absolute counting capability and the rejection ratio are also characterized, which have never been presented before.

The best quality analog signal chain systems, can give excellent line shape for Si(Li) and HPGe detectors (figure 1.) The lineshape with a given setup is usually stable, and it is customary to characterise the detector response function, and compare it with Monte-Carlo simulations, generally reaching excellent agreements, despite of that the Monte –Carlo methods ignore the single most significant process the plasmon creation. So what is going on? Turning one of the setup dial on the signal processor, very different line shape is resulted (figure 2-3).
The constant line shape of the detector response function under varying noise conditions imply that the noisier events are rejected and it's rejection ratio varies with noise

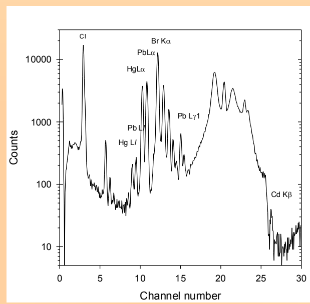


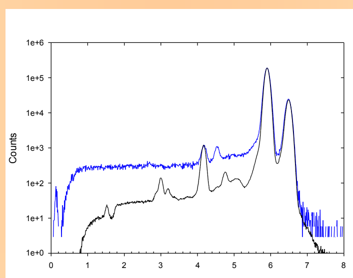




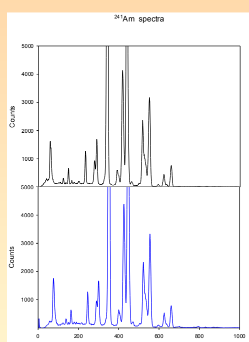
The response function of a high-quality HPGe detector at 8.46 keV x-ray energy. The spectra were measured at 10 (upper curve) and 80 (lower curve) microseconds processing times with the same signal processor, otherwise under identical conditions. The peak-like structures between 6 and 8 keV are identified as Ge L-shell x-ray escape peaks, and Auger and photoelectron peaks of detector and front contact materials.

Application of SDD and SIPIN detectors with digital signal processors on commercial XRF equipment is typical, and some features of them are presented in fig 4-6.



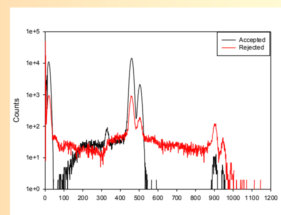


Spectra of 55 Fe sources measured with silicon drift detectors and two different signal processors. The tailing cannot be attributed to a dead layer in this case. The spectrum with black line presents several expected features.

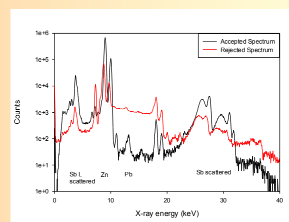


The response function of SiPIN detectors is not reported in the literature and cannot be compared its performance with the other detectors. We have studied it and two commercially available detectors' spectra are presented for the 241 Am source.

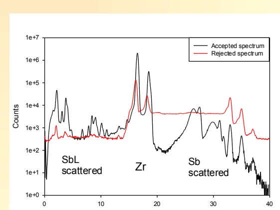
For the determination of the true input rate it is necessary to establish a separate input rate for the
i) true accepted events
ii) true but rejected noisy event
iii) noise triggered events (non x-ray events)
iv) all pile up combinations of it.
We have achieved it by recording all events and sorting them to several spectra. Analysing all the spectra, the true input rate for each x-ray line can be determined. Important issues are the energy dependent noise components and detection efficiency.



The two spectra, accepted and rejected, for an ^{55}Fe source. The line shape of the x-ray lines are reasonably good. It has merit for application.



An x-ray spectrum of a Zn secondary target, excited by a Sb primary target x-rays, in the 45-45 degrees off geometry. Cambridge scientific CSX3 digital signal processor was used with a Pin diode detector. The two spectra are the accepted and the rejected spectra. The selected pulse shaping method was cusp shaping, which is expected to give the best resolution. Although the resolution was indeed good, the rejected spectrum has an additional peak feature, to the previously described components [7]. The peak at the rejected spectrum at a displaced lower energy has an unexpected good resolution. Such a "ghost" peak is not uncommon, but here we have the advantage that it is in the rejected spectrum. Further unusual feature is the sloping pile up plateau, which we have not observed with other detectors.



Measurement with a trapezoidal noise filter was selected as a compromise, sacrificing some energy resolution, but having a simpler rejected spectrum. Here the continuous pile up plateau is flat, and the ghost peak is in the rejected tail spectrum.

Conclusions

The selected SiPIN diode has some nice features for application in high volume industrial XRF equipments.
The line shape is constant in the accepted spectrum, and reasonable good compared with other type detectors. Therefore it worth and can be characterised. The low energy side exponential tail is reduced compared to other detectors, which is very desirable. It can be discriminated against and placed into the rejected spectrum. The spectral features in the rejected spectra can be described with the already built in tail functions in the XRF programs, like CSXRF.
Therefore complete analysis is possible, obtaining the true input rate for each x-ray line.

References

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