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X-ray Spectrometry In The Fast Lane: An Introduction To High Speed Digital Processing Techniques And Their Application To Emerging EDS Technologies

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Silicon drift detectors (SDDs), a new class of energy dispersive detector that operates at near-room temperature, have just started to become commercially available from companies such as Photon Imaging (PI) [1] and Röntec [2]. Using a design that employs applied electric fields to laterally drift charge deposited in the detector from absorbed x-rays to a tiny, small capacitance anode, SDDs achieve energy resolutions comparable to the best Si(Li) detectors but at much shorter peaking times. Recent studies by X-ray Instrumentation Associates' (XIA) personnel have shown that rather remarkable results can be obtained using these detectors: 215 eV FWHM at Mn Kα using a peaking time of 300 ns, and output counting rates (OCRs) exceeding 500 kcps using a 150 ns peaking time, using the Röntec XFlash SDD. In addition, with the PI SDD, the detection of C Kα x-rays (at 277 eV) has been demonstrated using peaking times as short as 2 µs [3].

The exceptional performance of these detectors at short peaking times allows running at count rates that are unheard of in conventional EDS systems based upon Si(Li) detectors. The sub-microsecond peaking times can handle input count rates (ICRs) approaching 1 Mcps with reasonable deadtimes, with the ability to resolve elements as light as Silicon (1.74 keV) or possibly even lighter. For light element work, a peaking time of 2 µs allows OCRs in excess of 75 kcps with the ability to work with Oxygen or even Carbon; for clean Carbon spectrometry, a peaking time of 4 µs achieves OCRs in excess of 35 kcps, well beyond the capabilities of current Si(Li) systems. These count rates present a significant challenge to the processing electronics in terms of raw processing speed. A greater challenge is to maintain spectral quality under those conditions.

XIA has already demonstrated preliminary SDD measurements achieving output counting rates exceeding 500,000 cps using one of our DXPs (digital x-ray processors), so the raw processing power to handle the SDD rates exists. The DXP achieves the exceptional throughput using a patented approach where the digital filtering (including triggering and pileup inspection) is done in real time in fast programmable logic, and the event by event processing is handled by a digital signal processor, which adds no deadtime beyond the pileup inspection interval. With this approach, the DXP achieves optimal throughput for a given peaking time. Furthermore, since the DXP has the processing power to run at very short peaking times (100 ns minimum), the throughput can be very high. However, the quality of the spectrum does degrade with rate, especially using the ultra-short peaking times, primarily due to pileup effects and baseline tracking problems. Figure 1 shows results from early work with the PI SDD at the Stanford Synchrotron Radiation Laboratory, demonstrating the spectral distortions at high rates [4].

Pileup effects are the most noticeable problem with extreme rate spectrometry. The typical pulse-pair resolution for the fast trigger signal in a spectrometer is 200 ns; at an ICR of 1 Mcps, nearly 20% of all pulses occur within 200 ns of another pulse. To the spectrometer, these pulses are indistinguishable, and they form pileup. The pileup issues are slightly different when using longer peaking times (2 –4 µs) for light element work, at ICR's ranging from 50 kcps to 200 kcps. Under these conditions, the pileup rate is not large as long as the fast filter can detect the energy pulse; however, the noise associated with the short trigger filter is too large for light element detection, and pileup inspection must be based upon longer filters.

Baseline tracking becomes a problem when running at high rates, due to the fact that the energy filter rarely gets down to baseline. In a digital spectrometer, discrete samples are averaged to determine the signal baseline level; under high deadtime conditions, the number of samples available to track the baseline is small, and the baseline average is not well correlated with the current baseline value, leading to peak broadening effects. Furthermore, high rates increase the chances of erroneous baseline sampling, where some energy pulses go undetected and are included in the baseline average. This effect biases the baseline average, leading to peak shifts in the spectrum.

Work is progressing towards improving the quality of EDS spectra taken at extreme count rates. After a brief introduction to the general principles of high speed spectrometry, several new approaches will be presented, along with the most recent results of work with SDDs. [5]

References

[1] J.S. Iwanczyk et al., *IEEE Trans. Nucl. Sci.* 46 (1999) 284-288.
[2] L. Strüder et al., *Microsc. Microanal.* 4 (1998) 622-631.
[3] Based on testing at SEAL Laboratories in Los Angeles, CA and at NIST in Gaithersburg, MD.
[4] SSRL beamline 9-1, 1999. The aid of the SSRL beamline support staff is appreciated.
[5] An SBIR grant has been submitted to NIST (solicitation 7.17.02) to support new development work.

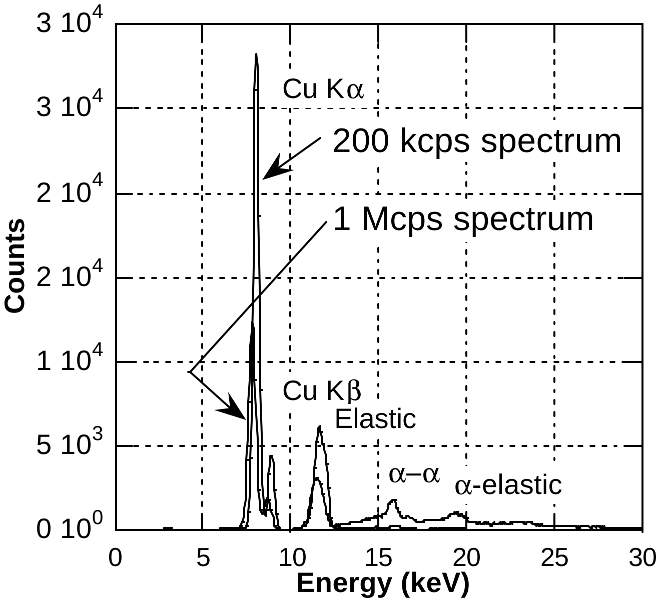

FIG. 1. Normalized spectra taken using PI SDD detector and XIA DXP-X10P using a 20 MHz ADC, 40 MHz DSP. The ICRs are 200 and 1,100 kcps. OCRs are consistent with a 900 ns deadtime. Note the spectral distortions caused by pileup, which increase at the higher rates.