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Factors Affecting WDS Performance Superiority over EDS

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WDS has traditionally been credited with superior analytic performance compared to EDS. WDS's spectral resolution is far better than EDS, but uses a reduced energy window. WDS's better detection ability was always promoted claiming that the better signal and peak-to-background (P/B) would always provide superior sensitivity. But WDS only gains that superiority when using high to extreme beam currents. The energy filtering of the spectrometer ignores 99% of the x-ray signal ensuring that the WDS electronics are not overwhelmed. The EDS has no energy filtering and must process all of the x-rays. Traditional SiLi EDS detectors and electronics could not process high input count rates and would become overwhelmed even at medium beam currents. However, modern high-throughput SDD and matched electronics do not have this same limitation and can provide very good spectroscopic performance, in fact rivaling WDS capabilities [1-2]. If EDS capabilities have progressed in general, it is very important to understand under what analysis conditions or energy range(s) WDS retains its dominance.

A study is performed to measure spectroscopic performance of a modern SDD EDS system and a WDS system. The data are collected simultaneously on a JEOL JSM-7000 FESEM thus leading to identical operating conditions. EDS spectra were collected for 10 sec livetime and WDS spectra were collected at 1 sec per 1 eV step. Performance metrics that were measured directly from spectra include peak intensity (counts per second per nanoamp, cps/nA), FWHM spectral resolution (eV), and P/B measurements. Spectral resolutions were coarsely measured by counting spectral channels of 10 eV in EDS and 1 eV in WDS. Background counts are a linear interpolation to the peak energy. Beam current was measured using a Faraday cup into a picoammeter.

A series of spectra from metals, compounds, and mineral standards were collected that had characteristic x-rays in the operating range of the WDS spectrometer (250 eV – 12 keV). The acquisitions were collected using an SEM beam voltage of 20 kV, beam current of 5 nA, an EDAX Octane 30mm^2 EDS detector at full insertion, and a EDAX TEXS WDS spectrometer. The important spectral values were measured from these spectra. Ratio measurements of these values as a function of energy were plotted to compare one spectroscopy to the other. The advantage of using ratios is that the effects of some experimental conditions (for instance beam voltage and x-ray over-voltage) are removed and only spectroscopic measures are compared.

One spectroscopic value not removed by using a ratio method is the solid-angle of the EDS detector. The EDS intensity values scale directly with solid angle, which is a function of both detector active area and insertion distance. This outcome can have a significant effect on the determination of the superior spectroscopy. As all WDS spectrometers are focusing, they have a fixed insertion geometry, but the solid angle varies within the spectrometer with other energy dependent terms. This means that in practice, the user has no direct ability to change the solid angle between experiments.

Some spectroscopic ratio results are shown in Figures 1-2. Figure 1 shows the EDS/WDS FWHM spectral resolution ratio plotted as a function of energy. The EDS values vary

monotonically with energy but the WDS values vary with angle for each diffractor. The WDS values are constant for SEM operating conditions, but the EDS values depend heavily on the electronics settings which affect the ultimate output count rate; these data were collected using an electronics shaping time which produces a Mn resolution of 130 eV. The ratios are above 1.0 for the whole energy range which shows the spectral resolution superiority of WDS for peak separation, as expected. Figure 2 shows the ratio of the WDS/EDS spectral peak intensity as a function of energy. The individual measurements depend on at least the x-ray over voltage, detector solid angle, and WDS diffractor efficiency at the Bragg angle. The x-ray over-voltage is the same for both techniques and is removed using the ratio of values. The diffractor efficiency produces a very complicated energy functionality. More importantly, ratio values above the threshold of 1.0 show the superior performance of the WDS spectrometer compared to the current EDS detector. Using the current EDS detector geometry, the WDS has superior intensity values only in the energy region below 2 keV while the current EDS detector has superior performance above. It should be noted that an EDS detector of 1/3 the solid angle would use a threshold of 0.3 in this plot for technique comparison. Using this small EDS detector, the superiority of WDS covers a much larger energy range up to 8 keV except for the small energy range of ~2000-3800 eV where EDS is superior.

A benefit of the resultant plots is that a WDS spectrum can be modeled or simulated from a simple EDS spectrum. With ratio plots of resolution, intensity and P/B, transformation of an EDS spectrum to a representative WDS spectrum is possible. With this information, a user could determine over which energy ranges EDS or WDS would provide superior analytic capabilities.

WDS has maintained its superiority over SDD EDS for spectral resolution. However, the energy dependence of WDS intensity values and the availability of various size SDDs has eroded the sensitivity advantage of WDS.

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[1] N. W.M. Ritchie, J. M. Davis and D. E. Newbury, Microsc Microanal **17** (2011), pp. 556-7.
[2] N. W.M. Ritchie, D. E. Newbury and J. M. Davis, Microsc Microanal, **18**, (2012), pp. 892-904.

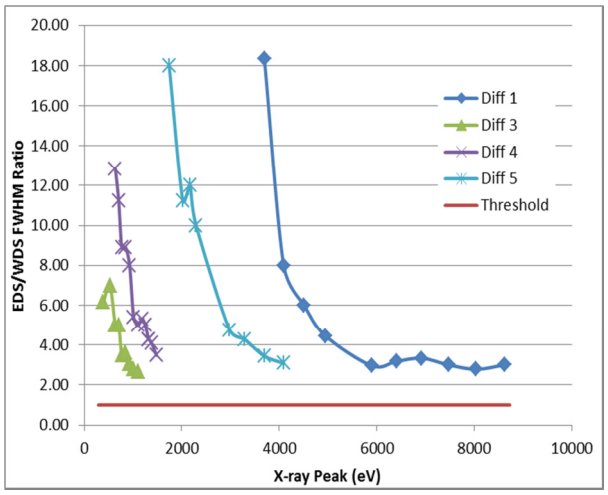

Figure 1: A plot of EDS/WDS spectral resolution ratio as a function of peak energy.

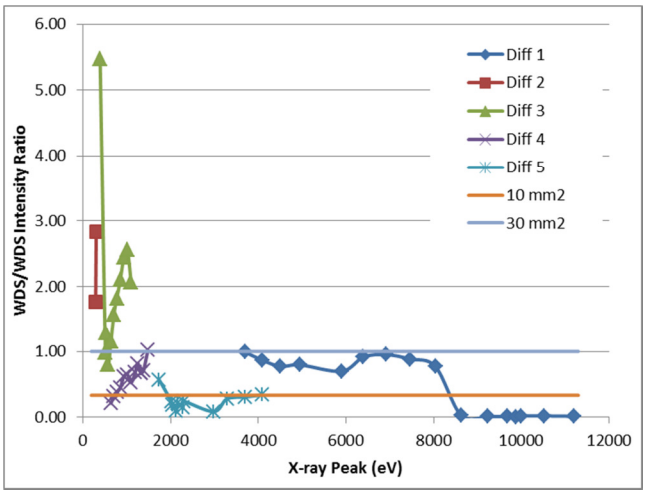

Figure 2: A plot of WDS/EDS peak intensity ratio as a function of peak energy.

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