Introduction

The question being addressed is: “What is the best detector to use for non-aluminum metal and alloy identification, an SDD or a PIN detector?” This paper shows that both a PIN and a SDD detector are equally adequate for identifying many common non-aluminum metals and alloys. The results section will focus the explanation on stainless steel 316 as an example material. Therefore, for this application a PIN detector will work perfectly well and will be preferable to an SDD given the price difference.

Comparing Detectors

The two main types of energy dispersive detectors are PINs and SDDs. The table below outlines a brief comparison between the two:

<table>
<thead>
<tr>
<th></th>
<th>Detection Area</th>
<th>Fe$^{55}$ Resolution</th>
<th>Detector Inner Temp.</th>
<th>Upper Input Count Rate (ICR) Limit</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical SDD</td>
<td>10 - 50mm$^2$</td>
<td>120 - 160eV</td>
<td>-20 to -40°C</td>
<td>~500kcps</td>
<td>More expensive</td>
</tr>
<tr>
<td>Typical PIN</td>
<td>5 - 15mm$^2$</td>
<td>150 - 220eV</td>
<td>-20 to -40°C</td>
<td>~100kcps</td>
<td>Less expensive</td>
</tr>
</tbody>
</table>

Table 1: A brief comparison between typical SDD and PIN detectors.

A typical SDD has better performance over a PIN; they have a better ultimate energy resolution, and they are able to count more x-rays in a given time. The resolution is important in resolving x-ray events from different elements, and the counting is important for getting better statistics in a shorter time frame. A typical PIN detector has the major advantage of being less expensive, and is often used in XRF systems that are price sensitive.

PIN detectors are a good fit for many XRF applications, such as metal and alloy identification, which do not need the performance advantages that the SDD provide.

Experimental Conditions

This testing has a standard XRF set-up, shown in Figure 1. Moxtek’s 50kV, 4 Watt Ultra-Lite x-ray source with a tungsten anode were used for this test. The source was set at 50kV with an emission current between 15 and 20µA. The source-to-sample distance is 25mm, and there is a 70µm copper filter in front of the source. Each detector has a sample-to-detector distance of 25mm. The signal from the detector was processed by Moxtek’s MXDPP-50. The x-ray source and the detectors tested have an aluminum sleeved brass collimator on them. The collimator is 11mm long with a diameter of 3.8mm. The aluminum sleeve is necessary to eliminate the stray XRF signal from the brass, insuring the XRF signal is coming exclusively from the sample.

Figure 1. On the left is a sketch of the XRF setup, outlining the most critical parts. On the right is an image of the set up where all the components including collimators can be seen.
The Cu filter eliminates most of the x-rays from the source below ~15keV, giving a better signal-to-noise ratio in this region, but the Cu filter does let one tungsten L$_\alpha$ line through at ~8.3keV. The tungsten L$_\alpha$ line does improve the excitation from Nickel and the lower Z elements, but also leads to a non-XRF peak which may confuse the untrained operator or an XRF algorithm. Figure 2 shows the XRF spectra from a clean plastic sample, comprising the Compton scattered tungsten L$_\alpha$ line and Compton scattered bremsstrahlung from the source.

An SDD, XPIN6 and XPIN13 detector where compared for their XRF performance in identifying non-aluminum alloys and metals. Table 2 outlines the critical technical merits of each detector in this experiment.

For a quazi-normalized XRF performance comparison, each detector was set to run at about a 30% dead time by adjusting the tube emission current. The SDD, as expected, has higher technical performance than the PIN detectors. The SDD has a lower Fe$^{55}$ FWHM resolution at a faster peaking time and more detecting area. This results in the SDD having roughly a 3X higher counting rate than the PIN detectors.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Area</th>
<th>Thickness</th>
<th>Fe$^{55}$ FWHM</th>
<th>SS316 Spectra</th>
<th>Dead time</th>
<th>DPP Peaking</th>
<th>Tube current</th>
<th>Detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDD</td>
<td>20mm$^2$</td>
<td>500µm</td>
<td>150eV</td>
<td>360k</td>
<td>27%</td>
<td>8µsec</td>
<td>20µA</td>
<td>-45 °C</td>
</tr>
<tr>
<td>XPIN6</td>
<td>6mm$^2$</td>
<td>625µm</td>
<td>165eV</td>
<td>125k</td>
<td>24%</td>
<td>20µsec</td>
<td>20µA</td>
<td>-35 °C</td>
</tr>
<tr>
<td>XPIN13</td>
<td>13mm$^2$</td>
<td>625µm</td>
<td>200eV</td>
<td>139k</td>
<td>27%</td>
<td>20µsec</td>
<td>15µA</td>
<td>-35 °C</td>
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Table 2. A functional comparison between an SDD, XPIN6 and XPIN13 detector. Each detector was tested in a XRF setup (Figure 1) for non-aluminum metal alloy detection.
XRF Results

Stainless steel 316 is comprised of <0.03% C, <1% Si, <0.045% P, <0.03% S, 16-18.5% Cr, 10-14% Ni, 2-3% Mo and the balance in Fe. This XRF setup is not adequate for detecting elements below calcium on the periodic table, therefore only the elements of chromium and above will be detected in the SS316.

Each detector recorded an XRF spectrum from a 316 stainless steel source for 30 seconds. Figure 3 shows the full spectrum from the SDD, XPIN6, and XPIN13, showing all the major elements. Figure 4 shows the same spectral data focused on the region from 5 to 9keV. One key point is all the element’s Kα lines are separated well enough for clear identification.

The collected spectra from the stainless steel 316 sample were run through an XRF fundamental parameters (FP) routine to turn the spectra into elemental concentrations. FP uses first principles; one inputs the tube settings, the detector characteristics and the spectrum; the algorithm then outputs elemental concentrations. Table 3 below outlines the physical parameters in the XRF set-up, which are needed as inputs into the FP routine.

Each detector, when properly set up in the FP program, gives nearly the same results. Table 4 below outlines the resulting concentrations from each detector. 30 second and 10 second XRF scans were taken on each detector. For comparison to the industry, scans of about 10 seconds or less is usual for handheld XRF instruments for metal identification. Comparing the 30 to 10 second scans show that the identification can easily be achieved for all the detectors in 10 seconds. The higher count rates of the SDD are not explicitly needed for sub-percent level element identification in short time frames of about 10 seconds for alloy and metal identification.

Using the FP routine, each detector gave an elemental concentration within 1% or less for each of the elements compared to each other detector. This level of accuracy is adequate for identifying stainless steel 316.
**Conclusion**

Both PIN and a SDD detectors are equally adequate for identifying many common non-aluminum metals and alloys, such as stainless steel 316. Therefore a PIN detector will work perfectly well and will be preferable to an SDD given the price difference.