

## Amptek Mini-X X-Ray Tube Application Note Filters on an X-Ray Tube

### Why would one filter the X-ray tube?

The primary reason is to improve the peak to background ratio for elements of interest. A secondary reason to use a filter is to reduce the characteristic X-ray intensity from the anode and materials located near the anode.

X-rays from any element are most efficiently produced by incident X-rays just above the absorption edge. An X-ray tube produces a bremsstrahlung continuum extending to low energy, which scatters from the sample. X-rays below the absorption edges do not excite the elements of interest and instead form a background which degrades precision and increases the detection limit.

If a filter is placed between the tube and the sample, then X-rays below the K-edge of the filter will be absorbed, improving the signal to background ratio and hence improving precision and detection limit. The filter reduces the beam intensity by eliminating X-rays which are not producing a useful signal.

Properly selecting the kV setting of the tube and the filter, its material and thickness, are critically important for reducing background and thus improving detection limits for a given set of elements. However, a particular kV setting and filter will only help over a limited energy range; the precision and detection limit will be degraded above and below this range. To measure elements over a wide energy range, most instruments use several different excitation conditions, each with the best kV and filter for a given energy range.

### Reference

A very nice discussion was written by Andy Ellis in the *Handbook of X-ray Spectrometry*:

*A primary beam filter acts as an X-ray absorber and it is placed between the X-ray tube and the sample to modify the X-ray tube output spectrum to which the sample is exposed. In general, the kV is selected first to ensure high excitation sensitivity and then an appropriate filter is chosen. The filter acts to reduce scattered background in the region of interest and to reduce the excited intensity of lower energy peaks. The characteristics of the filter are defined by its X-ray absorption curve, which is controlled by selecting the material and its thickness. Filter are typically thin, pure metal foils in the range of 10 to 500  $\mu\text{m}$ ...*

*The combination of kV and an absorption filter provides an energy region in which the P/B ratio is optimal. On the low energy side of this region, the excitation is suppressed, which allows more of the system's counting capability to be used in the region itself. On the high energy side of the region, the excitation from the tube is tuned to provide a high integrated intensity above the energy of the absorption edges of the element lines of interest...*

*Most modern EDXRF systems provide the ability to use more than one set of conditions per analysis. Depending on the analytical needs, the kV and filter are chosen to optimize the important part of*

*the spectrum and the data from spectra at each of these conditions are consolidated to provide the best P/B values.*

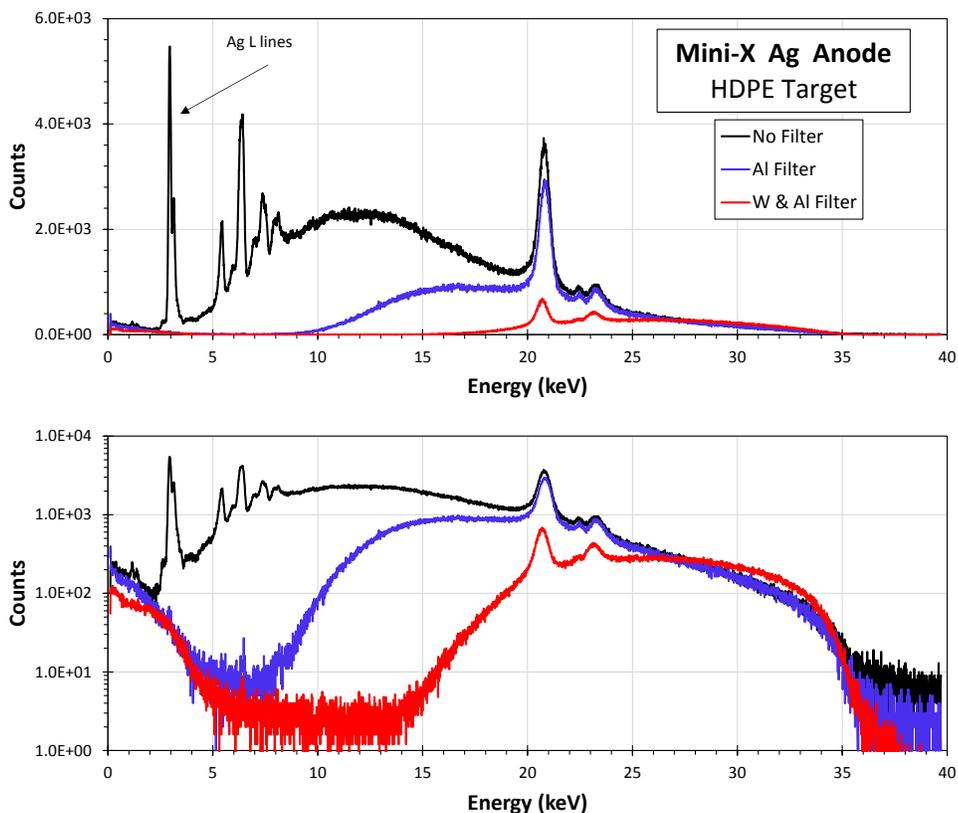
A. Ellis, *Energy dispersive X-ray fluorescence analysis using X-ray tube excitation*, Chap 3 of the *Handbook of X-ray Spectrometry*, 2<sup>nd</sup> edition, Ed. R. van Grieken, A. Markowicz, Marcel Dekker, Inc, pp 204-207, 2002

### Example 1

The plots below shows the spectrum measured in Amptek's Experimenter's Kit with an X123-FastSDD and an Ag anode Mini-X X-ray tube. The sample is a block of high density polythelyne (HDPE), a nearly pure polymer which therefore should produce no characteristic X-rays and which efficiently backscatters the X-rays.

The black trace shows a spectrum with no filter at all. Notice that the continuum extends to low energies (the lowest energies are being filtered by the air in the enclosure). Notice the clear presence of the Ag L lines, which we expect from the anode, but also the presence of Ni, Cu, and other lines. These are produced by materials used in the tube construction. They will cause spectral interference: if one were to measure a sample with trace amounts of Cu, accuracy would be limited.

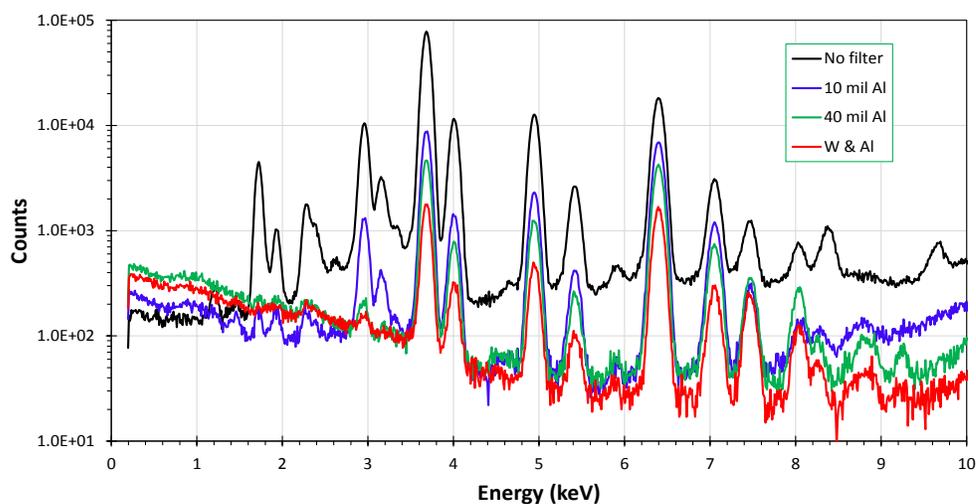
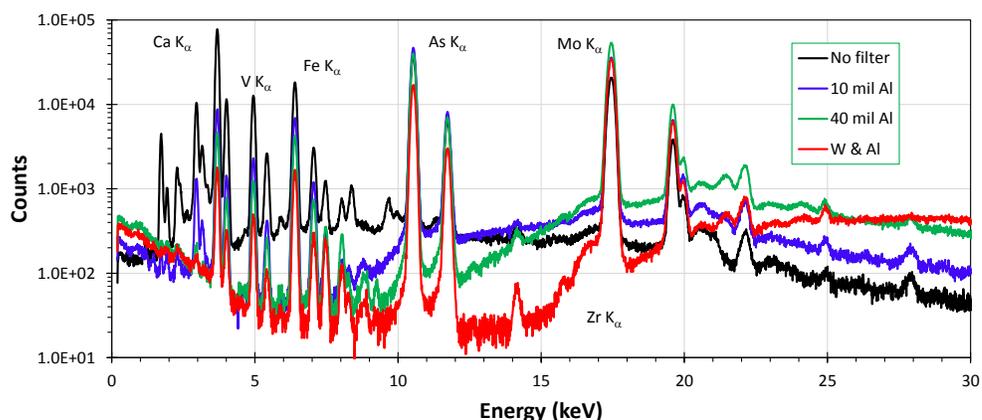
The blue and red traces show spectra measured with a 40 mil Al filter and a sandwich of 1 mil W and 40 mil Al, respectively. Note that the spectral interference is cleared up. Note also that the background is significantly reduce below 15 and 20 keV, respectively. These filter should give more precise measurements for characteristic lines of 5-10 and 10-15 keV, respectively. The total intensity is obviously much lower for the red trace but the tube is operated nowhere near full power; by increasing beam current, the system is producing more X-rays that are actually exciting elements of interest.



## Example 2

The plots below show spectra measured with different filters using an XRF drift monitor, Fluxana SP1. The sample contains 28% CaO and approximately 3% each  $V_2O_5$ ,  $Fe_2O_3$ ,  $As_2O_3$ , and  $MoO_3$ . All the spectra were measured at 40 kV excitation. Data were taken with no filter (black), a 10 mil Al filter (blue), a 40 mil Al filter (green), and a two layer filter with 1 mil W and 40 mil Al (red). The beam current was adjusted to keep 10% dead time in all cases.

The As  $K_{\alpha}$  line illustrates the issues. In going from no filter to a 10 mil filter, at fixed dead time, the photopeak intensity increases by about 25% while the background intensity decreases by a factor of two. The 40 mil Al filter has about the same photopeak intensity with the background decreased by a further factor of three. The thickest filter reduces background but also photopeak intensity. The 40 mil Al filter provides the optimum peak to background for As, in this sample.



For Ca and V, the situation is quite different. Although the background intensity is reduced with the filter, so is the photopeak intensity. Even 10 mil of Al is too much filtering for these elements. For Mo, the heaviest filter is the best. There is a small Zr peak visible in the spectrum, presumably a contaminant in the glass; it is clearly visible with the heaviest filter but not seen in the unfiltered spectrum.

**What should I do if I need good measurements over a broad energy range?**

The recommended approach is to take multiple spectra, each under a different excitation condition (i.e. a different kV and filter). You can measure the lightest elements with a low kVp and a light filter, the medium-Z elements with a higher kVp and a moderate filter, and then measure the heaviest elements using the highest possible kVp and a thick, high-Z filter. Most turn-key XRF analyzers include a filter wheel with 5, 8, or even 10 different filters which can be rotated into place.

One can take the intensities measured under these different conditions and combine the results to obtain a quantitative analysis for all these elements. Amptek's XRS-FP software permits this.