

Analysis Depths for Micro-XRF

When measuring thin-film coated samples with Micro X-ray Fluorescence (Micro-XRF), one of the most common questions asked is “how thick can the coating be?” Also referred to as critical depth, or infinite thickness, this indicates the maximum sampling depth from which an analyte photon can be detected. It is important for thin-film applications because it defines the measurable thickness range for a given layer. However, because analysis depth is matrix-dependent, knowing the order of the layers and their composition is important in determining this value.

It is imperative to first understand the fundamental difference between “thin” and “bulk” thicknesses for Micro-XRF. Bulk thickness is approximated when 99% or more of the incoming X-ray signal undergoes photoelectric absorption or scattering, and less than 1% of the original signal is detected in the direction of the measuring system. In this case, the bulk sample has reached saturation of the intensity, where increasing the thickness will no longer increase the fluorescence signal. However, if more than 1% of the X-ray is detected (or less than 99% loss) it can be treated as a thin sample. Unlike bulk samples, the measured intensity of a thin sample is a direct function of its thickness.

Figure 1 below illustrates the incident and emergent beam, and their respective paths. The incoming X-ray reaches a critical depth d , and the emitted fluorescence signal emerges towards the measuring system over path length x . If 99% or more of the initial X-ray signal is absorbed over path length x , it is considered a bulk sample.

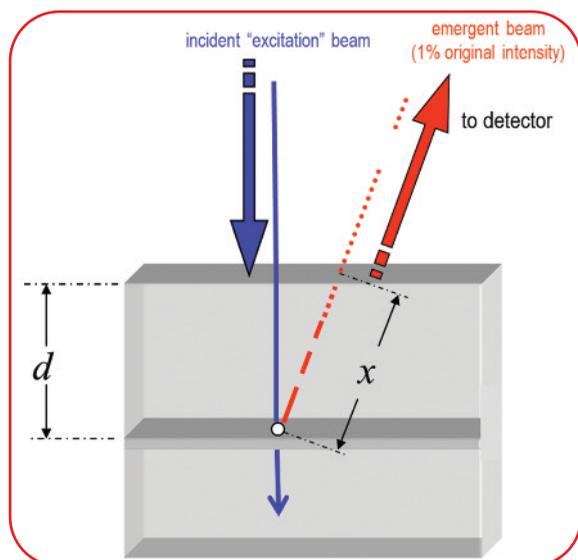


Figure 1. Illustration of incoming and outgoing X-ray paths, with x defined as the critical analysis depth.

Analysis depth x can be derived from the Beer-Lambert formula, shown below. This also factors in the density (ρ) and mass attenuation coefficient (μ) of the sample. I_x represents the measured intensity through x , and I_0 is the initial incoming X-ray intensity.

$$I_x = I_0 \exp(-\mu \rho x)$$

Since the criteria for bulk samples is at least 99% attenuation of the initial signal, the ratio of I_x/I_0 can be set to 1%, or 1/100. Now analysis depth x can be solved by simplifying the equation to:

$$x = 4.605 / (\mu \rho)$$

Using this formula, analysis depth can be calculated for any sample with known density and mass attenuation coefficients. The table below shows examples of nominal measured analysis depths for various pure elements.

| Pure Element Analysis Depths (um) For Micro-XRF | | | |
|---|-----|-----|------|
| Element | K | L | M |
| Ti | 20 | | |
| Ni | 25 | | |
| Zn | 35 | | |
| Mo | 60 | 1.5 | |
| Pd | 70 | 2.5 | |
| Ag | 75 | 2.5 | |
| Sn | 100 | 3 | |
| Pt | | 6.5 | 0.3 |
| Au | | 8 | 0.5 |
| Pb | | 10 | 0.75 |

Table 1. Nominal pure element analysis depths in microns, for K, L, and M series.

Because the mass attenuation coefficient decreases with increasing energy, the general trend in Table 1 shows increasing analysis depths as the atomic number increases. This is expected because as the atomic number increases, the energy of the emitted photon increases as well, allowing it to “escape” the sample from greater depths. When switching to lower-energy transition series, for example from K-series lines to L-series lines, then the analysis depth is significantly decreased.