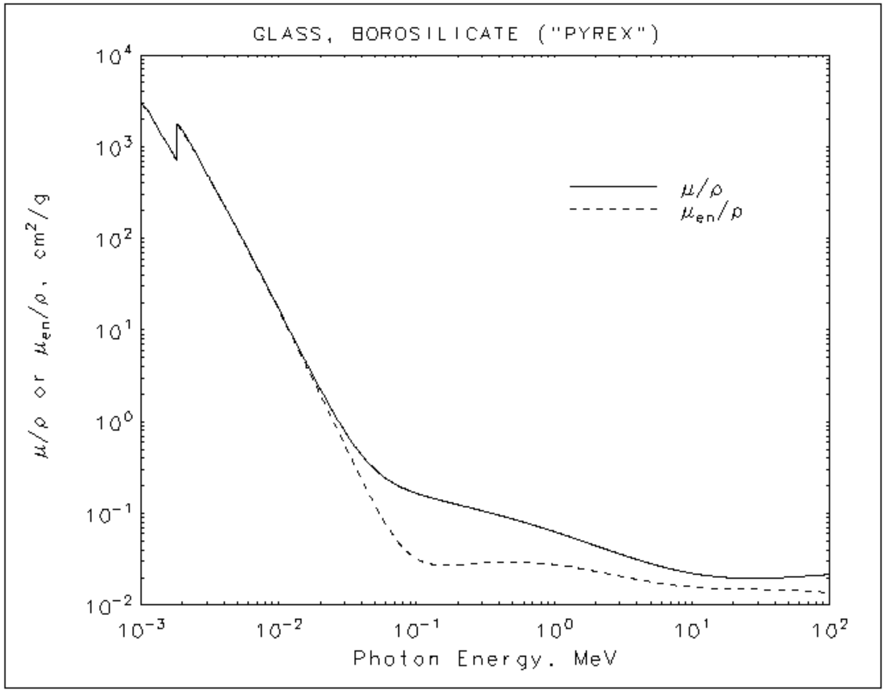
Calculation of the thickness a photon of a given energy can go through a given material



Dr. Buce J. Kaiser

Understanding that x ray attenuation is an exponential function of thickness and elemental mass

A narrow beam of mono energetic photons with an incident intensity I_o, penetrating a layer of material with mass thickness *x* and density emerges with intensity *I* given by the exponential attenuation law

$$I/I_o = \exp[-(\mu/\rho)x] \ .$$

Note that the mass thickness is defined as the mass per unit area, and is obtained by multiplying the thickness *t* by ρ the density i.e., *x* =

t = thickness of overlying material in cm

$$t = -Ln(I/I_0)/((\mu/\rho) \quad \rho * \quad) \text{ in centimeters}$$

http://physics.nist.gov/PhysRefData/XrayMassCoef/cover.html ***Gives the mass attenuation coefficients for each material type and each x ray energy***

(μ/ρ) = Mass attenuation coefficient read off the chart for a given material and a given x ray energy

ρ = density of the material that the x ray are going through

I = number of photons that one measures with the over lying coating

I_0 = number of photons that one measures without the over lying coating

Note we will use the number of Si photons that we count in 20 seconds as I and Io

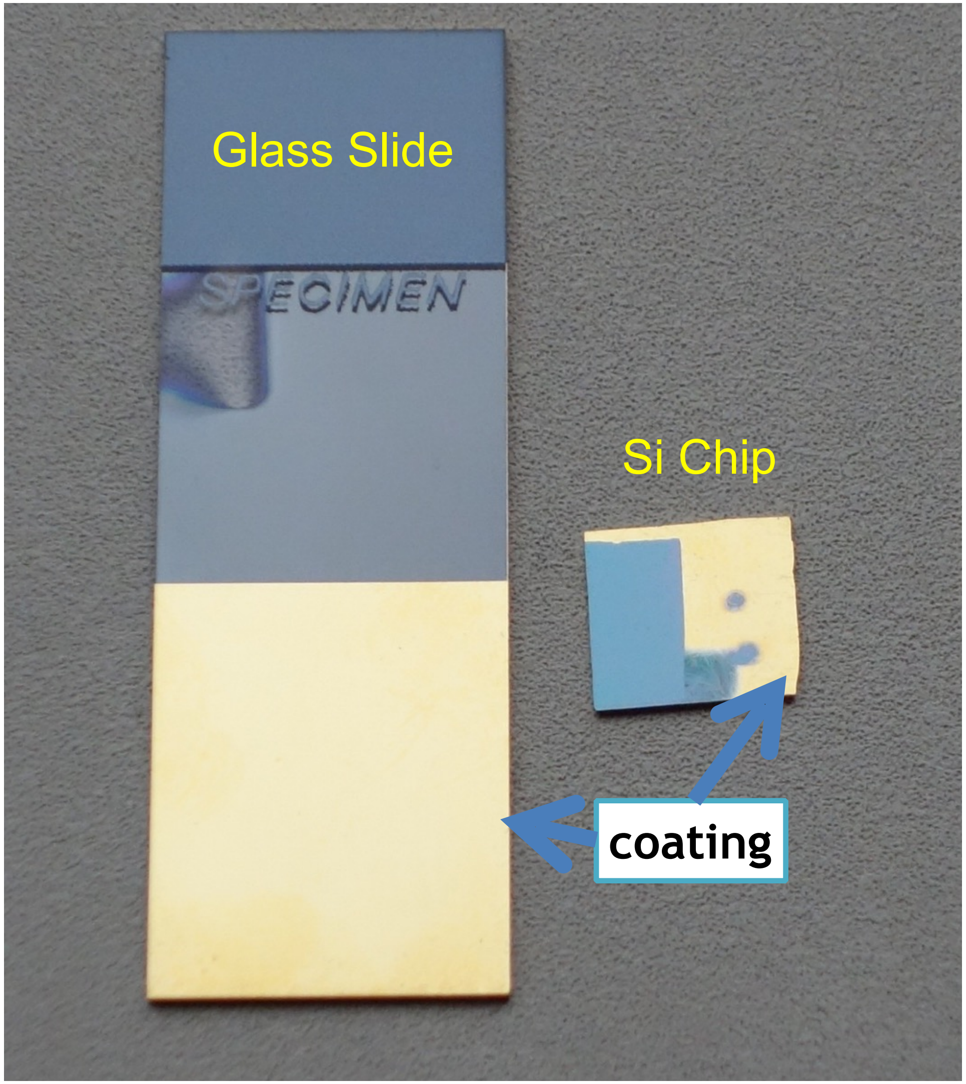
Typical Mass attenuation coefficients

material	Density	6 keV	7 keV	8 keV	9 keV	10 keV	15 keV	22 keV
aluminum	2.70E+00	1.15E+02	8.03E+01	5.03E+01	3.90E+01	2.62E+01	7.96E+00	2.98E+00
BSi glass	2.33E+00	7.5E+01	5.2E+01	3.27E+01	2.40E+01	17.1E+01	5.21E+01	1.98E+00
cobalt	8.90E+00	9.37E+01	7.00E+01	3.25E+02	2.72E+02	1.84E+02	6.20E+01	2.42E+01
iron	7.87E+00	8.48E+01	5.32E+01	3.06E+02	2.60E+02	1.71E+02	5.71E+01	2.22E+01
nickel	8.90E+00	1.09E+02	7.50E+01	4.95E+01	1.90E+02	2.09E+02	7.08E+01	2.78E+01
copper	8.90E+00	1.16E+02	7.50E+01	5.26E+01	2.78E+02	2.16E+02	7.41E+01	2.92E+01

All mass attenuation coefficients can be found on:

http://physics.nist.gov/PhysRefData/XrayMassCoef/cover.html

My mass does a lot of intimidating!


Glass Slide
SPECIMEN
Si Chip
coating

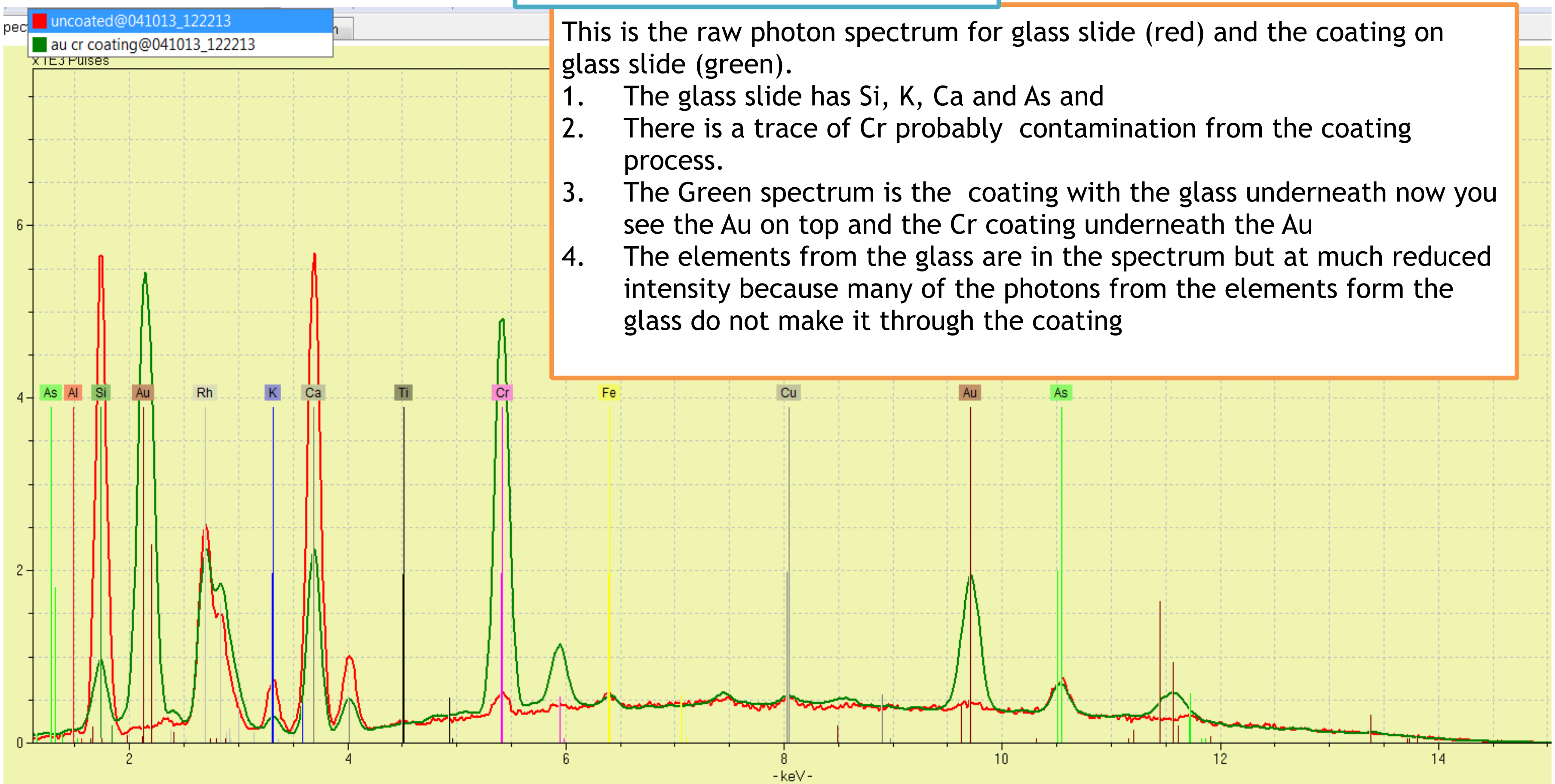
2 samples were measured to test the feasibility of using the k line emission from Si to measure the thickness of the Coating of Au and Cr on a Si wafer

1. The base material of each sample was measured
2. and then the coating was measured fro each base material

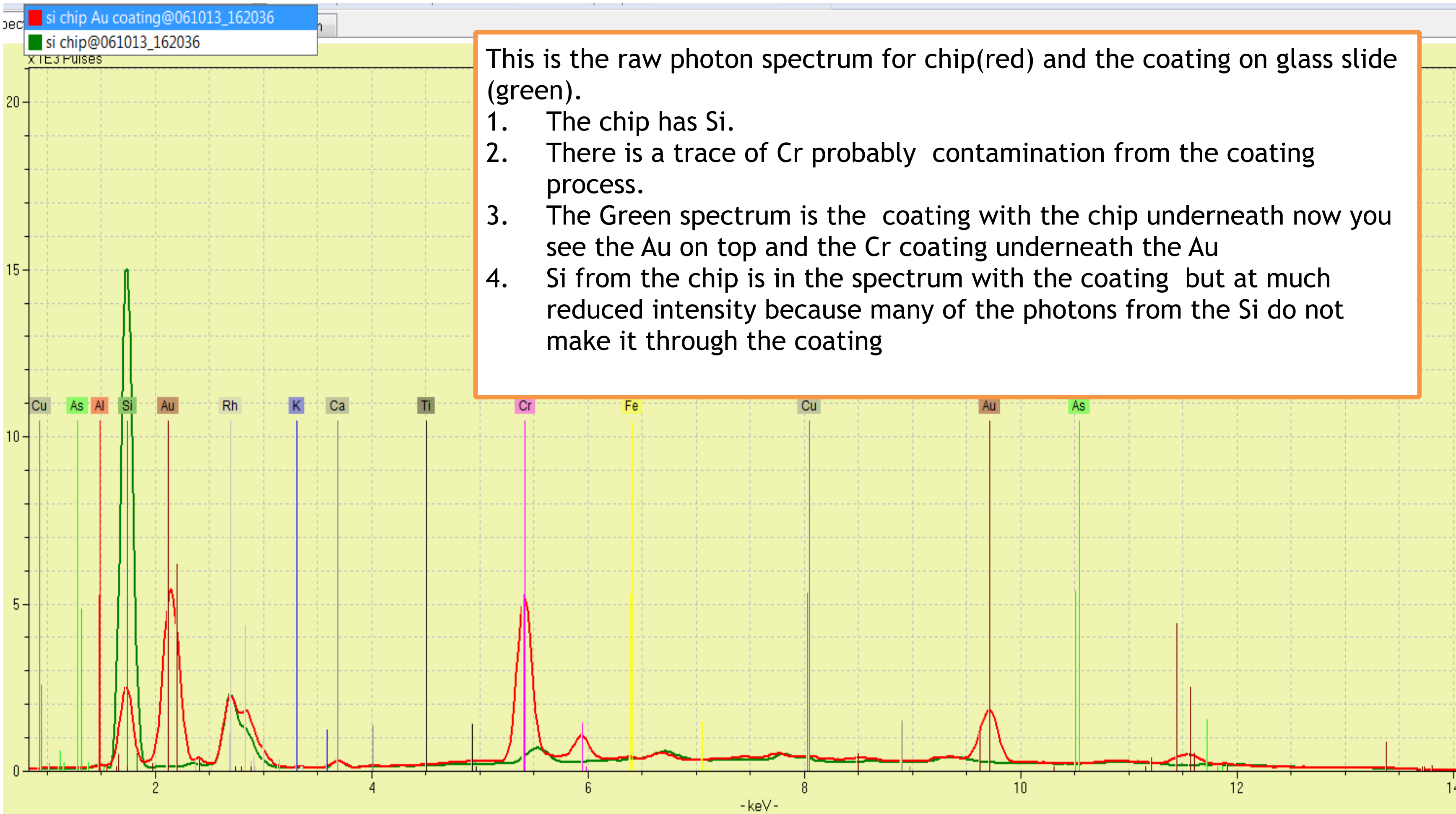
The Glass Slide Analysis

This is the raw photon spectrum for glass slide (red) and the coating on glass slide (green).

1. The glass slide has Si, K, Ca and As and
2. There is a trace of Cr probably contamination from the coating process.
3. The Green spectrum is the coating with the glass underneath now you see the Au on top and the Cr coating underneath the Au
4. The elements from the glass are in the spectrum but at much reduced intensity because many of the photons from the elements form the glass do not make it through the coating



The Chip Analysis



This is the raw photon spectrum for chip(red) and the coating on glass slide (green).

1. The chip has Si.
2. There is a trace of Cr probably contamination from the coating process.
3. The Green spectrum is the coating with the chip underneath now you see the Au on top and the Cr coating underneath the Au
4. Si from the chip is in the spectrum with the coating but at much reduced intensity because many of the photons from the Si do not make it through the coating

t = thickness of overlying material in cm

$$t = -\mathrm{Ln}(I/I_0)/((\mu/\rho) \quad \rho * \quad) \text{ in centimeters}$$

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Calculating the Thickness of the Coating

$$t = -Ln(I/I_0)/((\mu/\rho) \quad \rho * \quad) \text{ in centimeters}$$

	Au M1	Cr K12	Si K12
large uncoated glass	0	0	32338
au cr coating on glass	24934	36605	4525
	Au M1	Cr K12	Si K12
si chip	0	5238	95016
si chip Au coating	24952	40638	14457

So one more set of numbers are need to calculate the thickness of the Au coating. A sample with just Cr needs to be measured. Unfortunately that sample was not provided. But assuming the average density of the Coating of Au and Cr is 14 gm./cc and the attenuation coefficient of the combined coating for Cr and Au is about 2000, one can use the Si without coating as Io and the Si count with coating as I then the thickness of the combined coating can be calculated from the coating to be about 0. 7 microns

Conclusion

The change in intensity of the Si photon intensity from coated to uncoated as well as the change in intensity of Cr form coated to uncoated is well within the sensitivity of the instrument

Since these are exponential functions of thickness a very accurate analysis of thickness can be done using this proves that a very accurate measure of thickness can be done by this technique

Calculating the Thickness of the Coating can be done very accurately