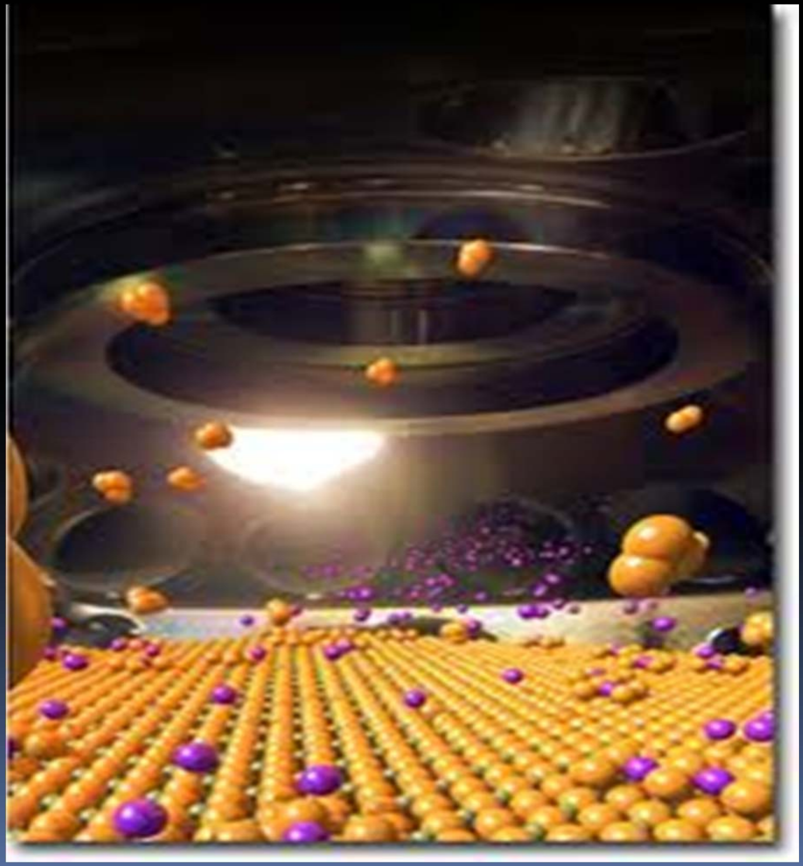
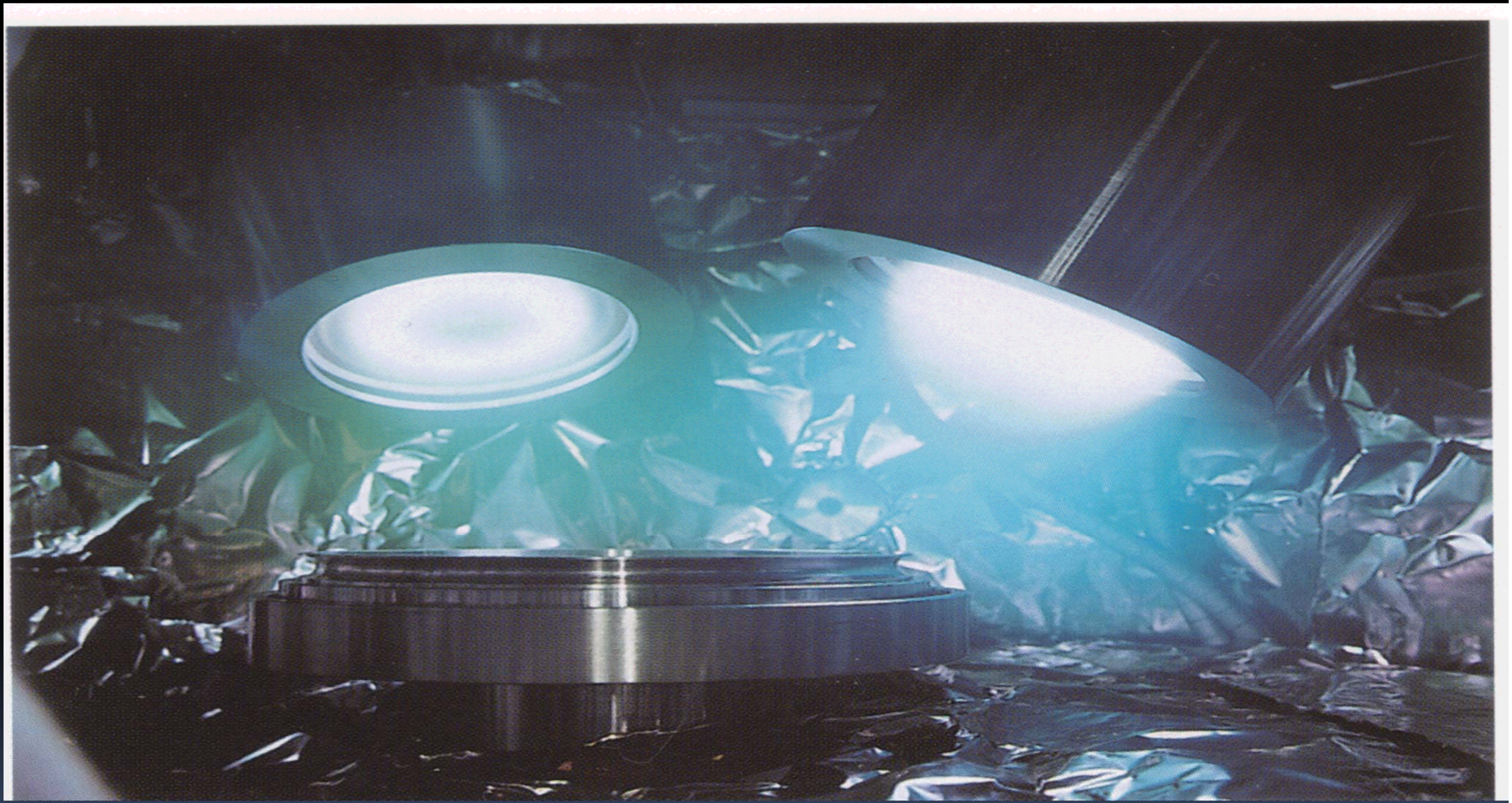
INVESTIGATING MAGNETRON SPUTTERED THIN FILMS USING ELLIPSOMETRY AND X-RAY FLUORESCENCE



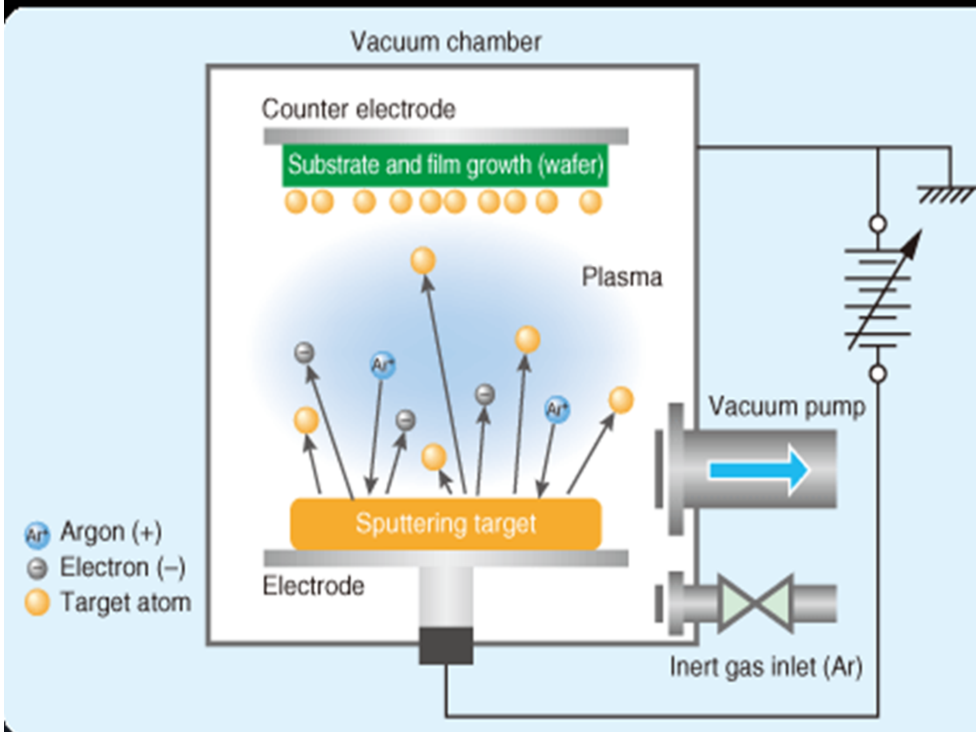
BY *IQRA NADEEM*

Magnetron Sputtering



Magnetron sputtering is a PVD (physical vapor deposition) technique that creates a nano-layer on a substrate. This involves use of magnetic fields to keep plasma in front of the target, hence, intensifying bombardment of ions and improving the efficacy and rate of the experiment.

The Underlying Physics



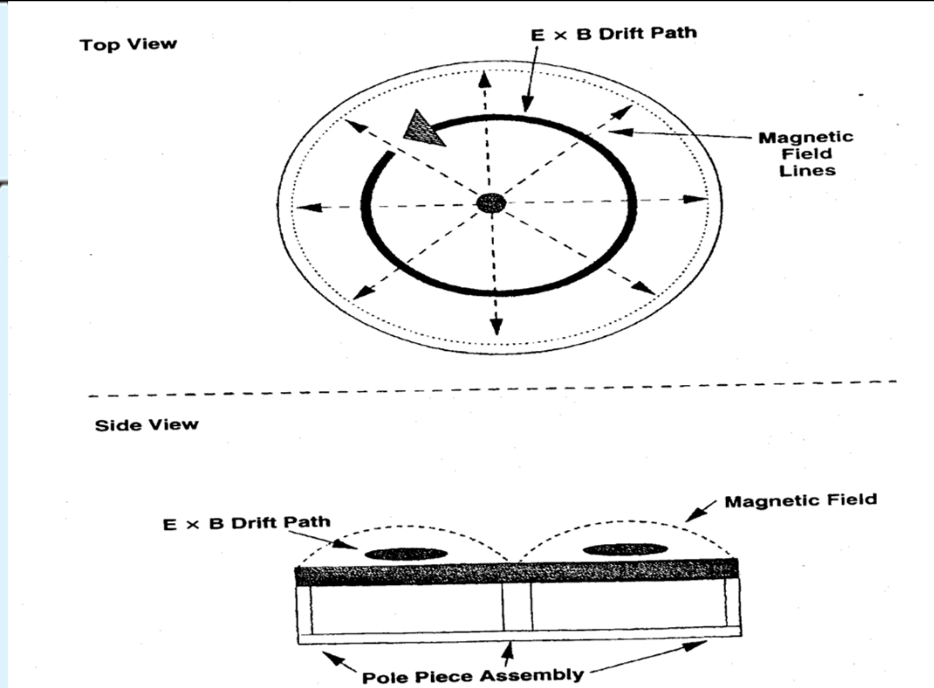


FIG. 3.13 Top and side view schematic of a circular planar magnetron cathode.

1) Argon gas filled in vacuum chamber.
2)A DC or RF supply creates a glow discharge(plasma).Ionized argon bombards a target anode.
3)This bombardment may lead to release of target atoms, secondary electrons or diffusion.
4)target atoms form a fine layer over the substrate.

The Experiment:

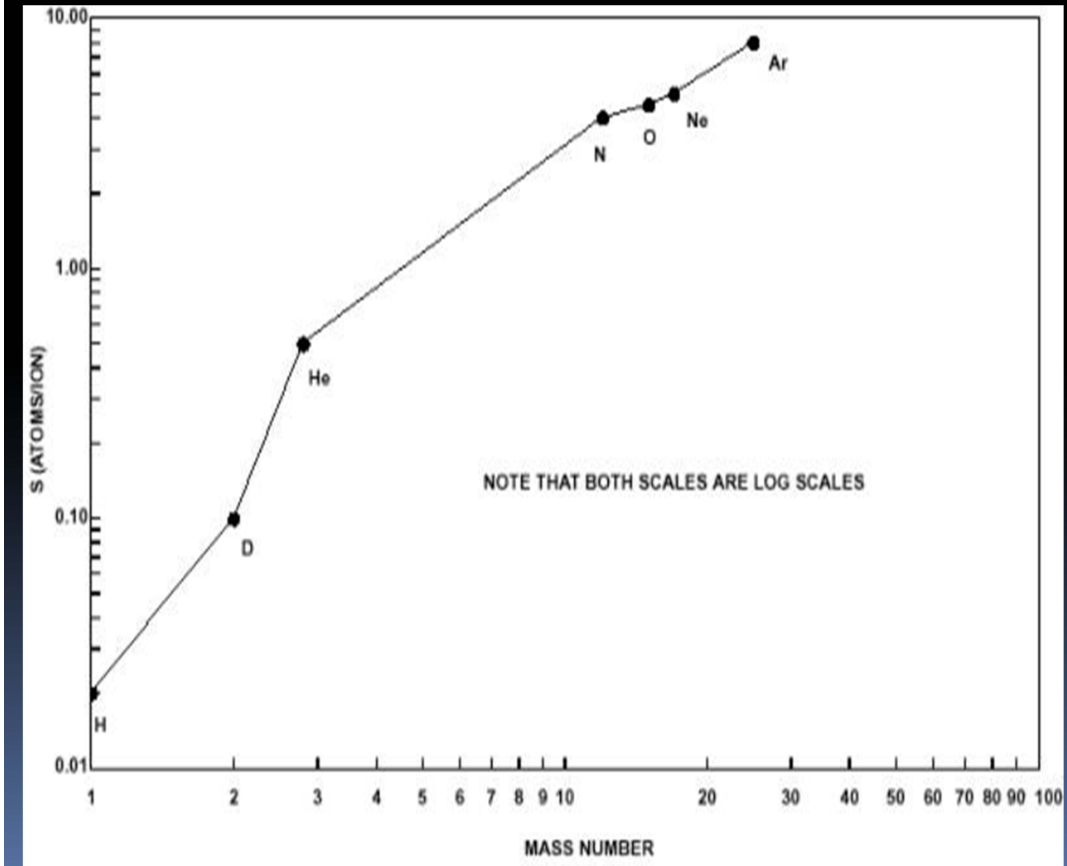
Voltage:300V
current:40mA
substrate: Glass
substrate temperature:100°C
working pressure:0.01 Torr
argon pressure: 100sccm
sputter time: 5 min

Sputtering yield

$$S = \frac{\text{number of sputtered atoms}}{\text{number of incident ions}}$$

S depends on:

- Ion energy
- Molecule Size
- Angle of Incidence(Billiard Ball Model)



VARIATION OF SPUTTERING YIELD S WITH MASS NUMBER FOR 5 keV IONS INCIDENT NORMALLY ON Ag

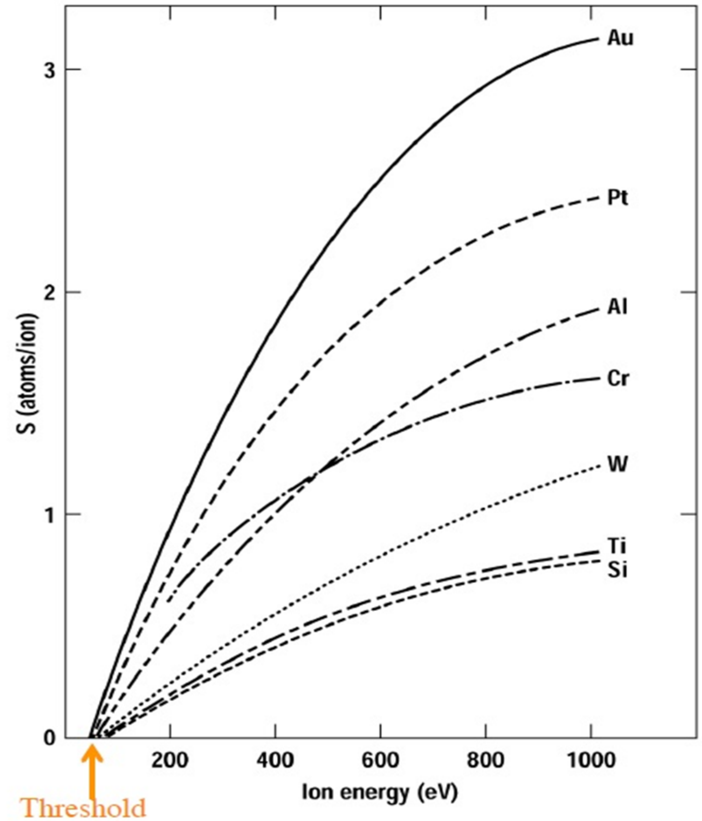


Figure 12.13 Sputter yield as a function of ion energy for normal incidence argon ions for a variety of materials (*after Anderson and Bay, reprinted by permission*).

The Billiard Ball Model

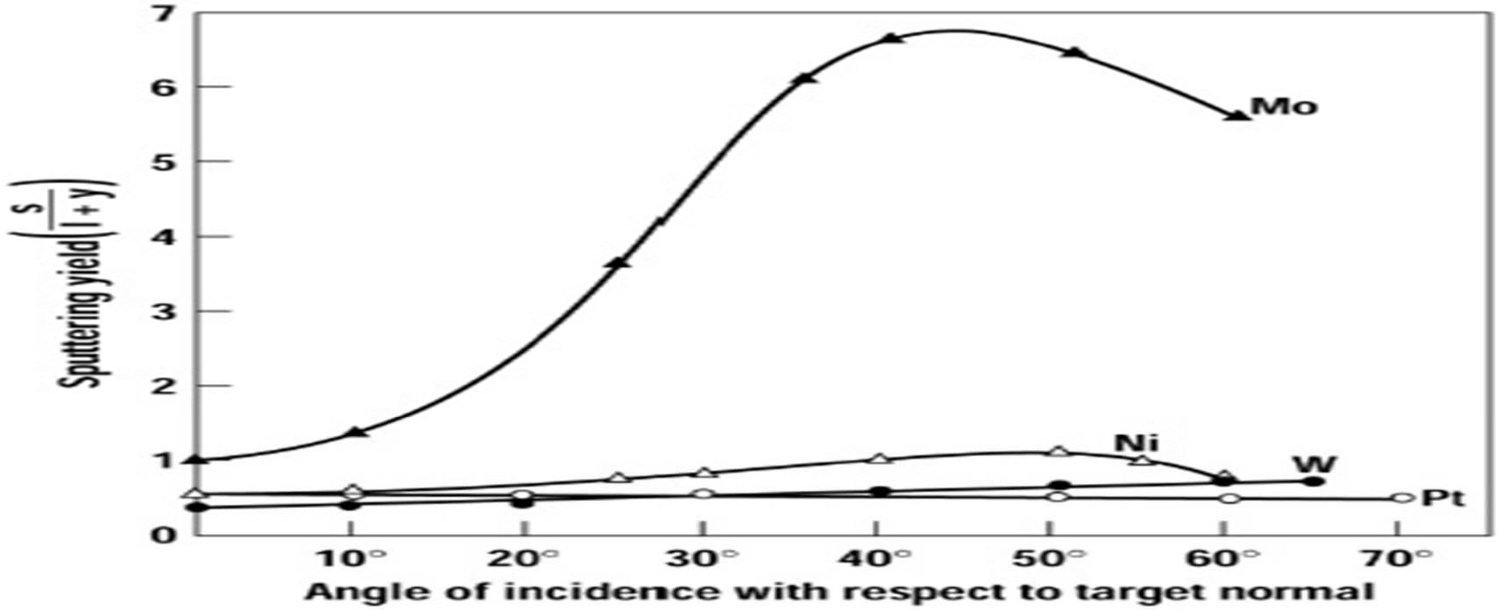
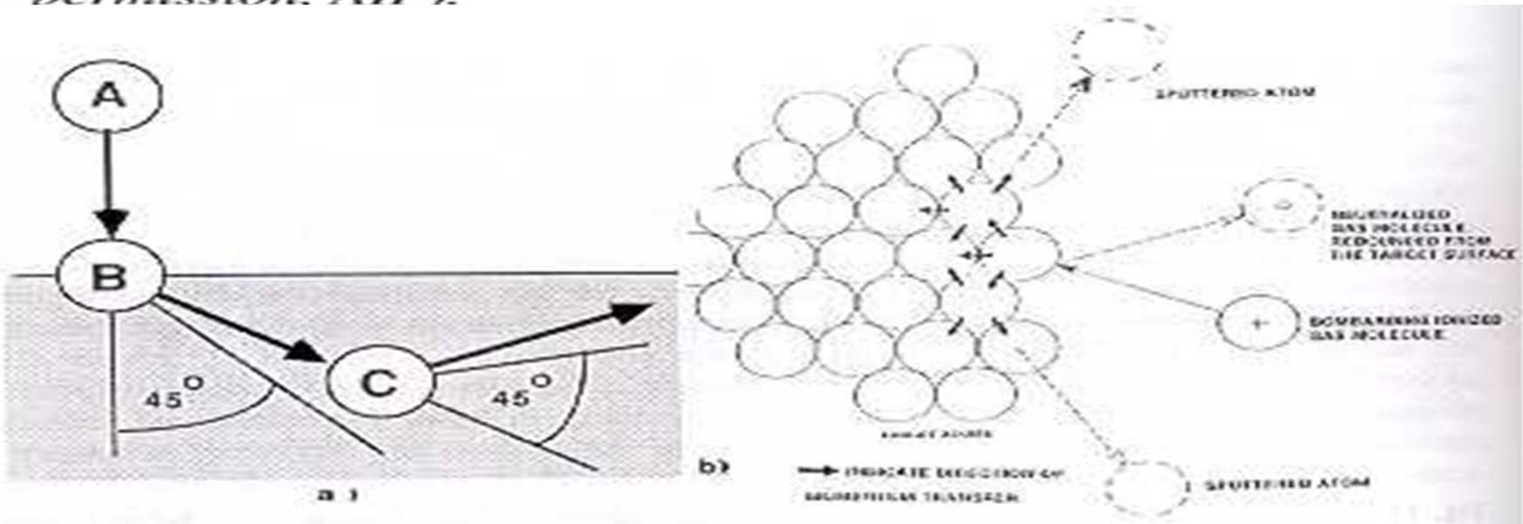


Figure 12.15 Typical angular dependence of the sputter yield for several different materials. The sputter profiles follow a cosine distribution *(after Wehner, reprinted by permission, AIP).*

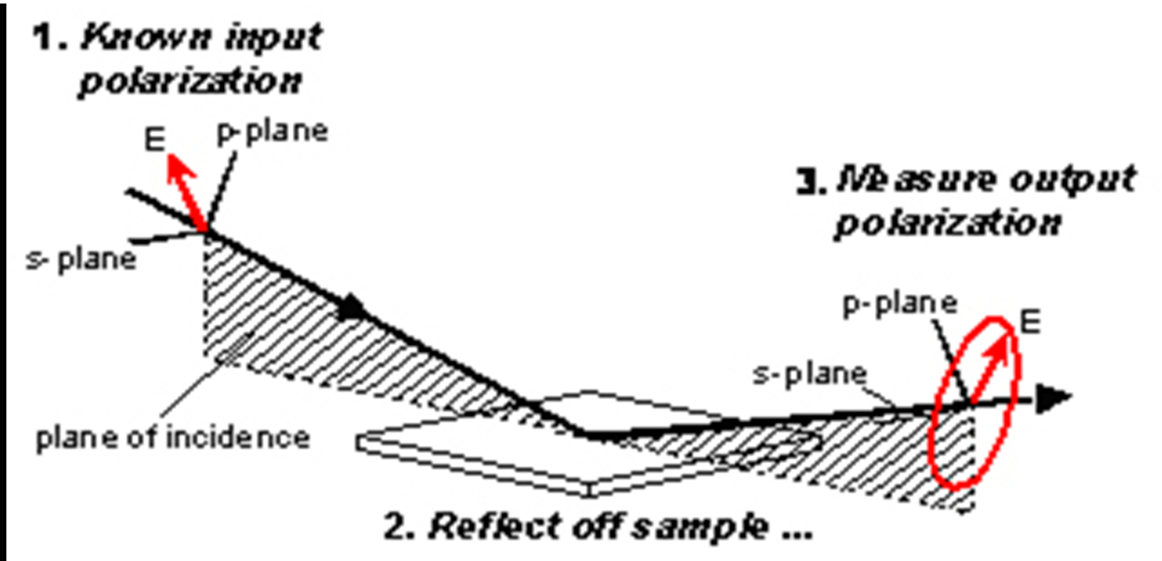


Types of sputtering

- Reactive sputtering
- Magnetron sputtering(DC and RF)
- Collimated sputtering
- Hot sputtering

Ellipsometry

Ellipsometry is an optical technique that is used to measure thickness and optical constants of thin films by means of change in polarization of incident light on the thin film.

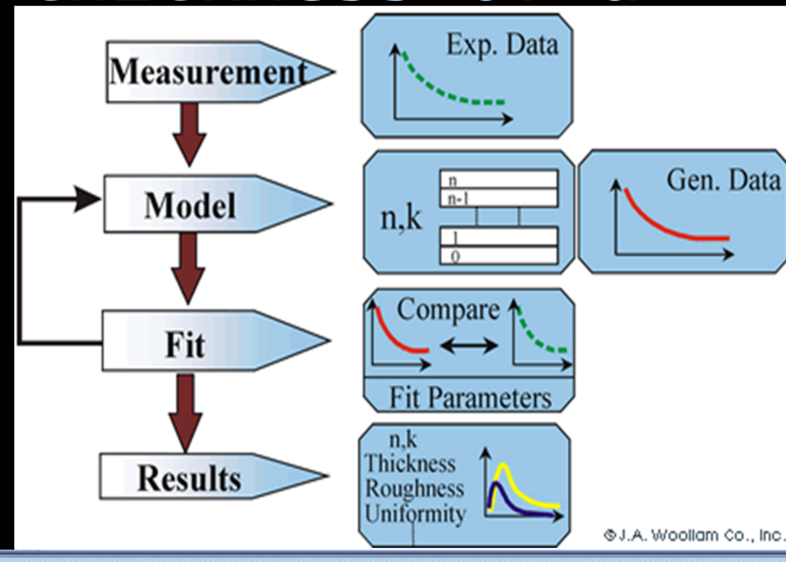


- After reflection on a sample surface, a linearly polarized light beam is generally elliptically polarized

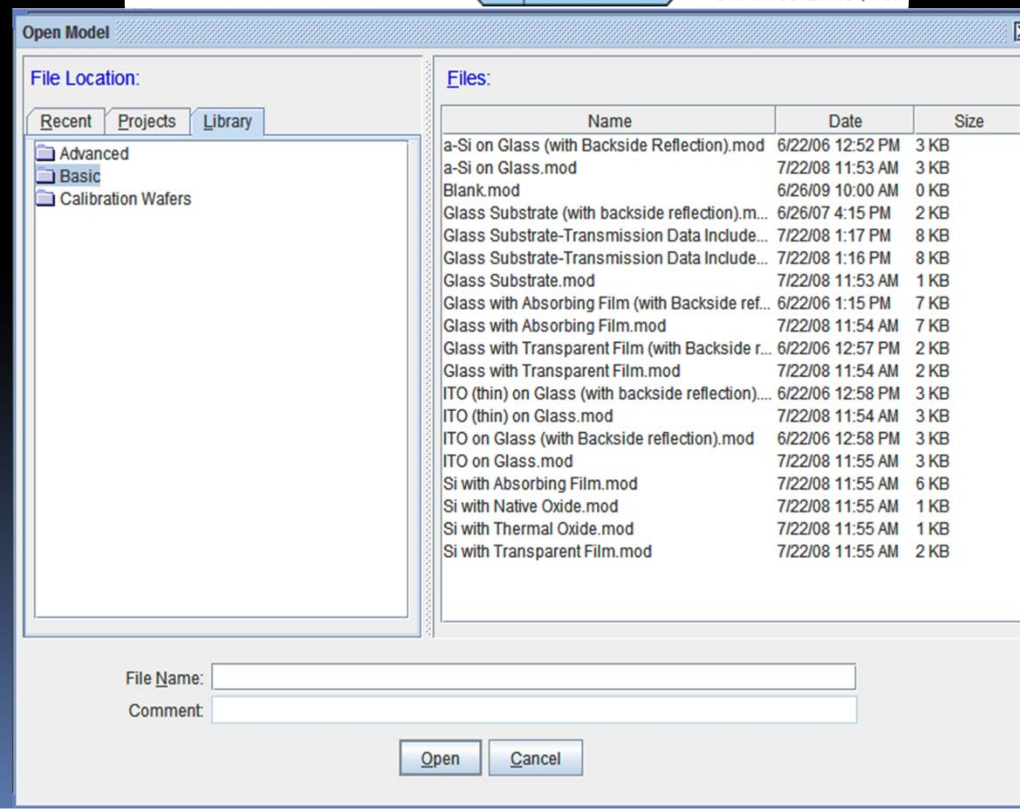
$$\rho = \frac{r_p}{r_s} = \tan\psi * \exp(i\Delta)$$

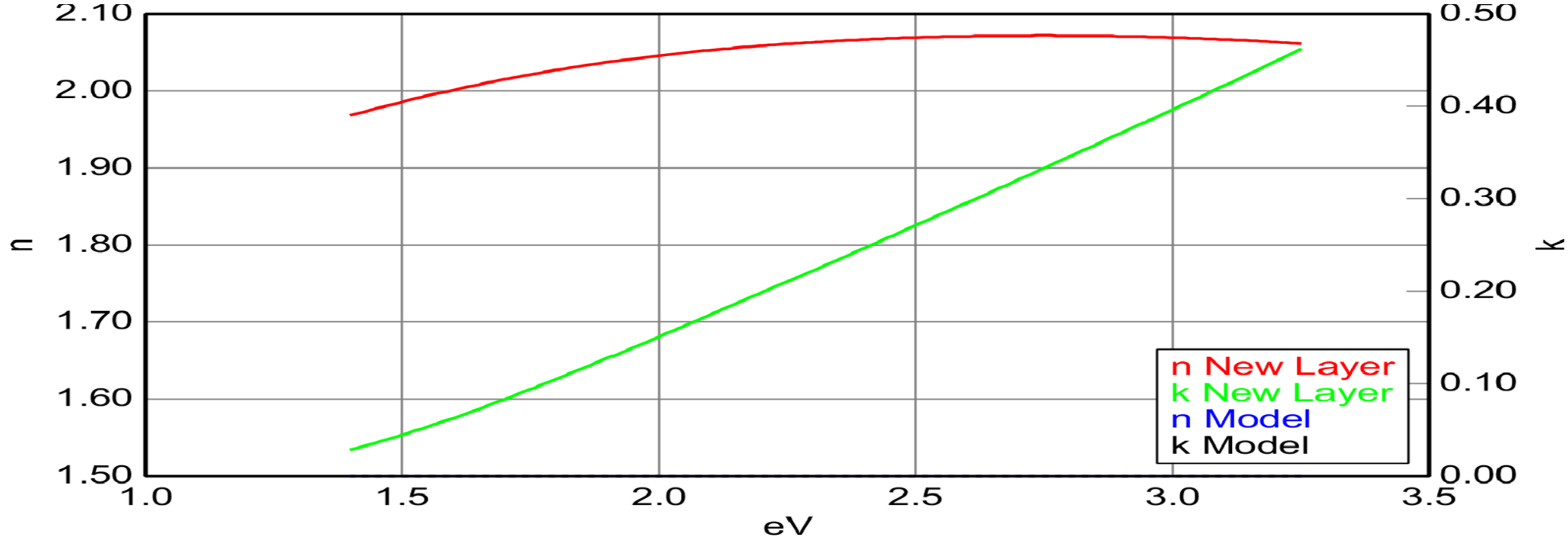
- where Ψ= amplitude ratio
- Δ =phase shift
- $n = N - iK$ of the surface.

Simple Steps to find thickness of a thin layer using Ellipsometry

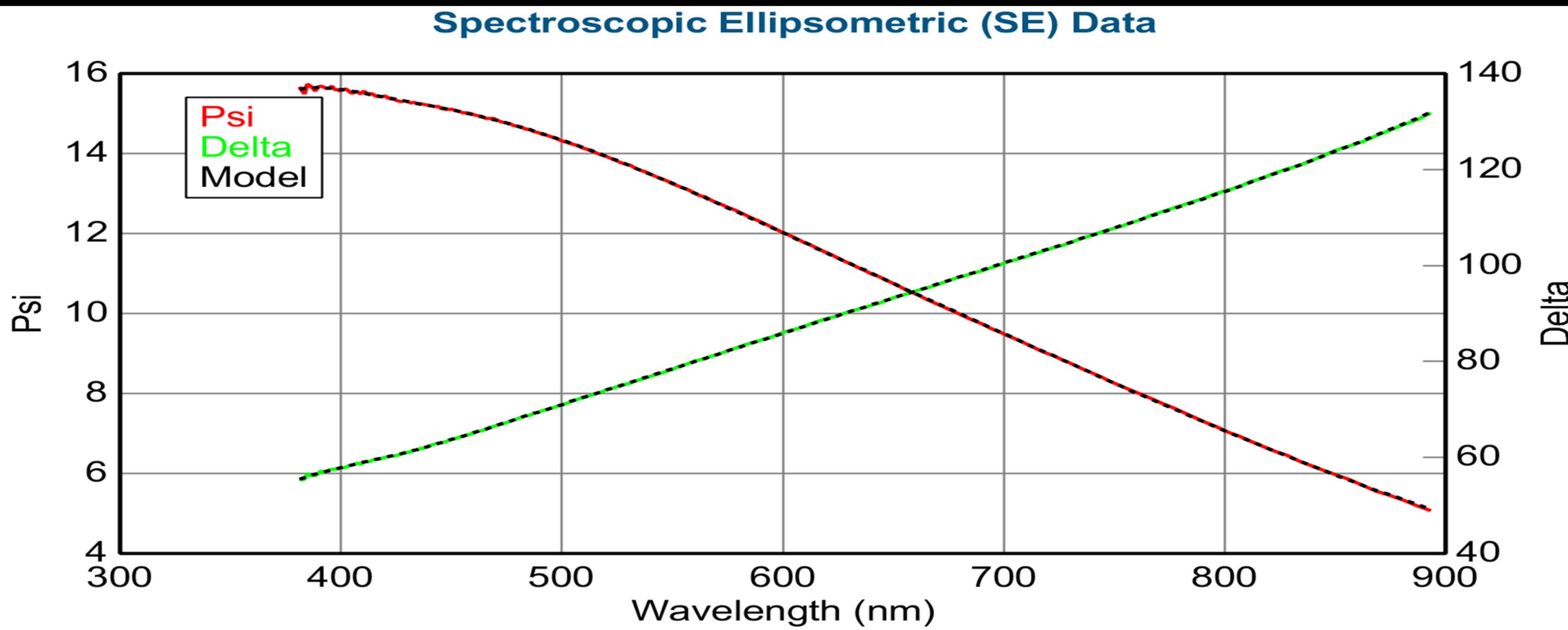


- Set the AOI to 70°
- Set the mode and sample alignment to standard
- Click Measure
- Go to analysis and open relevant model(dependant on substrate)
- Then fit the model.
- Acquire MSE and thickness value
- To acquire psi ,delta,rho right click on the graph type whereas to acquire n,k and real and imaginary parts of the extinction coefficients, right click on B-spline and chose parameterize layer.





n
k
eV
n New Layer
k New Layer
n Model
k Model

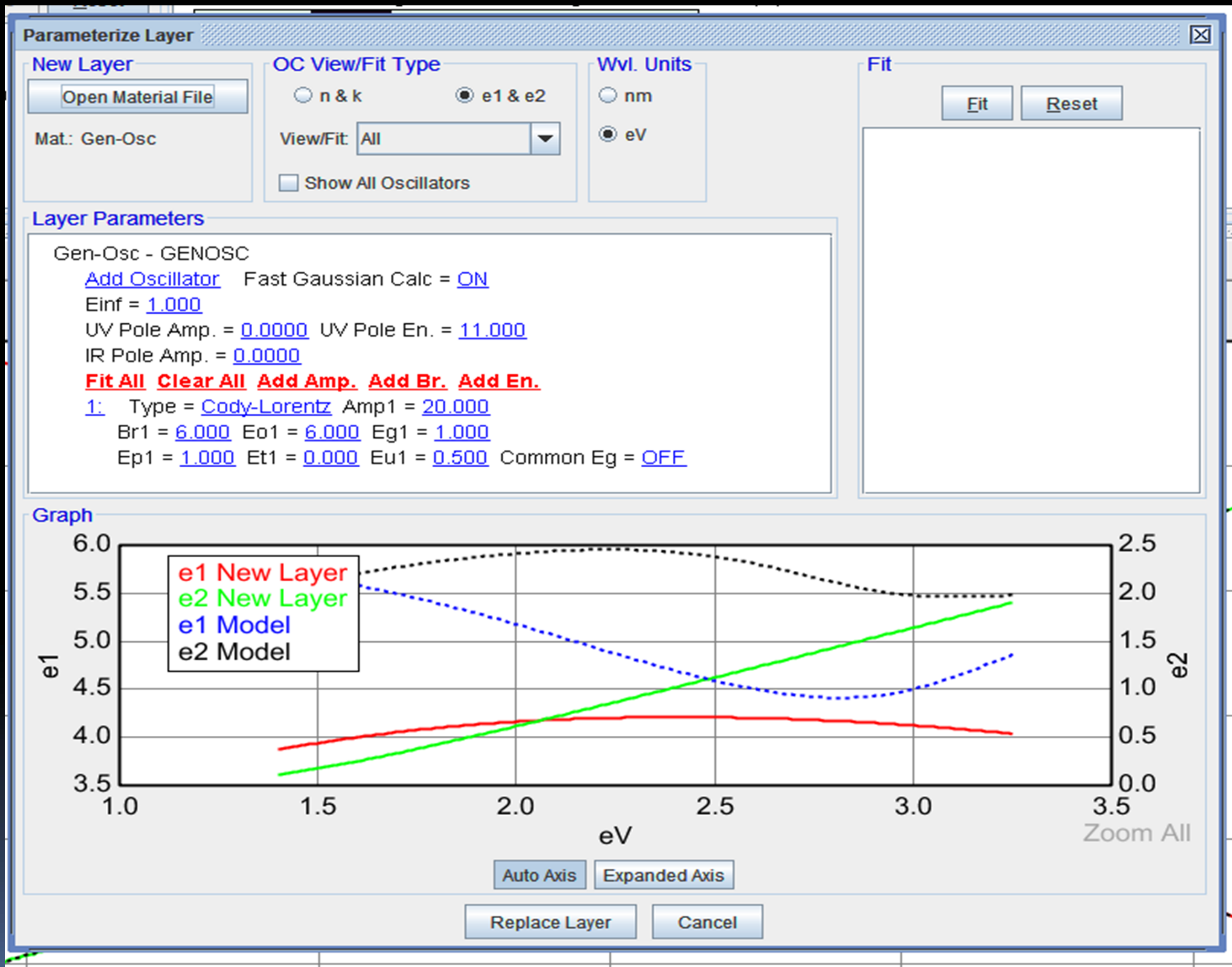


Spectroscopic Ellipsometric (SE) Data
Psi
Delta
Model
Wavelength (nm)

The Gen-Osc Functions

The Gen-osc layer is the general oscillatory material that allows summation of different oscillator line shapes and gives further parameters. For example depending on model:

optical band gap
optical resistivity
center energy
amplitude
intensity
broadening, etcetera.



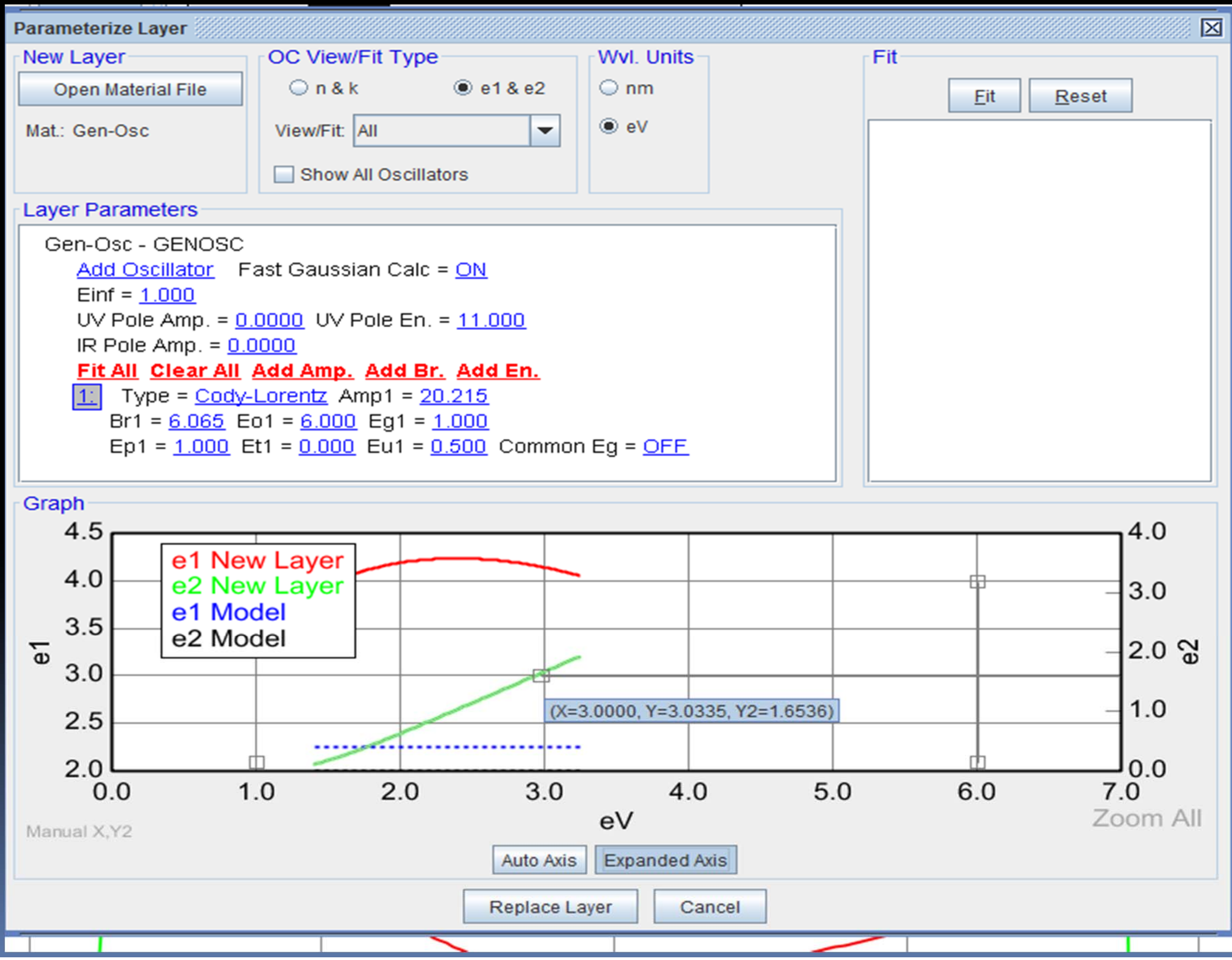
Parameterize Layer
New Layer
Open Material File
Mat.: Gen-Osc
OC View/Fit Type
n & k
e1 & e2
View/Fit: All
Show All Oscillators
Wvl. Units
nm
eV
Fit
Fit
Reset
Layer Parameters
Gen-Osc - GENOSC
Add Oscillator Fast Gaussian Calc = ON
Einf = 1.000
UV Pole Amp. = 0.0000 UV Pole En. = 11.000
IR Pole Amp. = 0.0000
Fit All Clear All Add Amp. Add Br. Add En.
1: Type = Cody-Lorentz Amp1 = 20.000
Br1 = 6.000 Eo1 = 6.000 Eg1 = 1.000
Ep1 = 1.000 Et1 = 0.000 Eu1 = 0.500 Common Eg = OFF
Graph
e1 New Layer
e2 New Layer
e1 Model
e2 Model
e1
e2
eV
Zoom All
Auto Axis
Expanded Axis
Replace Layer
Cancel

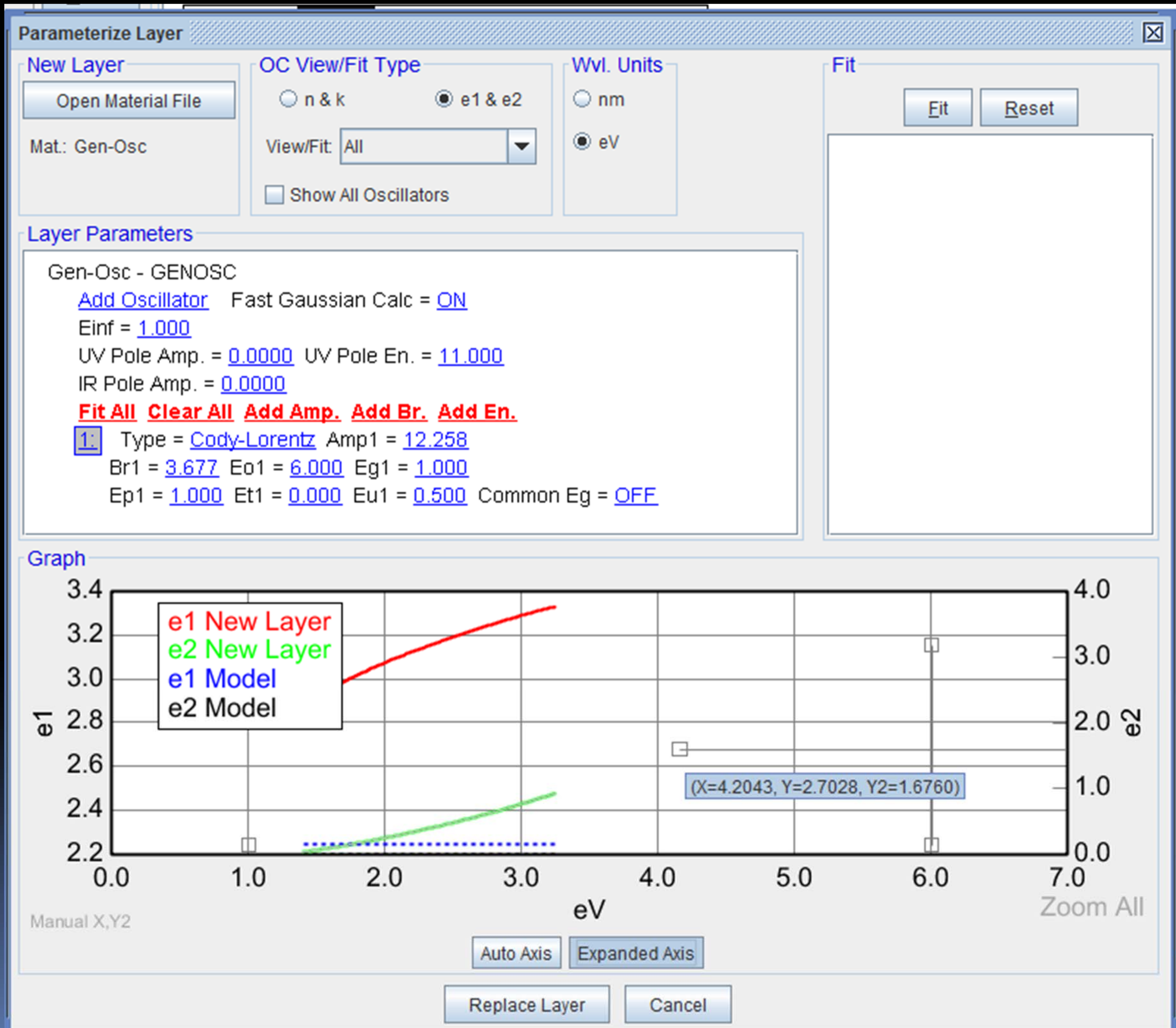
Types of Models

Fitting in Gen-Osc functions

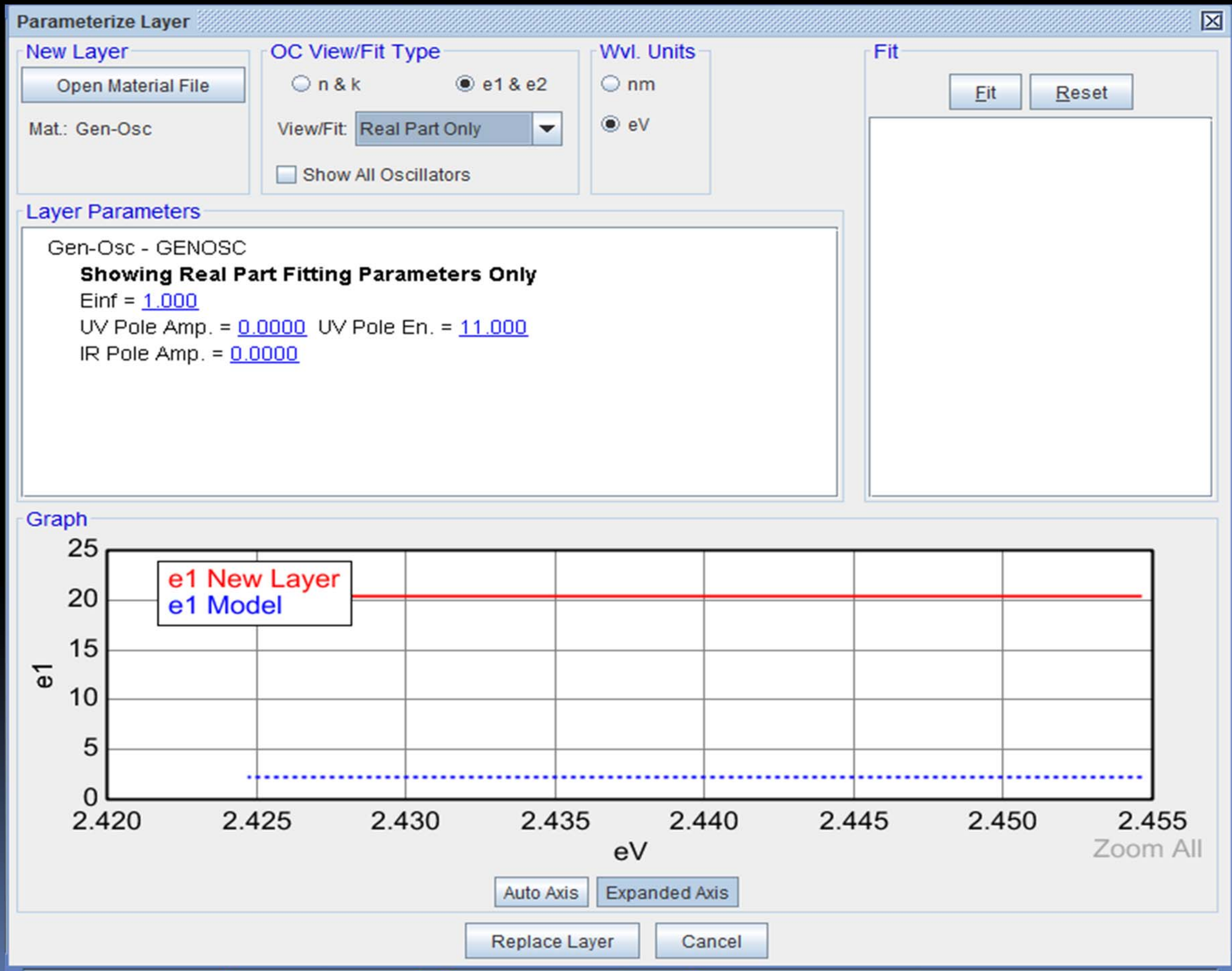
- Expanded axis
- Imaginary parts always matched first
- parameters changed by clicking at number left to oscillator and grey control boxes appear
- grabbing grey control points and moving them to bring about overlap
- View/fit→ imaginary and real parts
- Real parts are matchednext
- UV amp changed
- UV pole En changed
- Einf value changed
- FIT to get improved MSE value

Imaginary Part



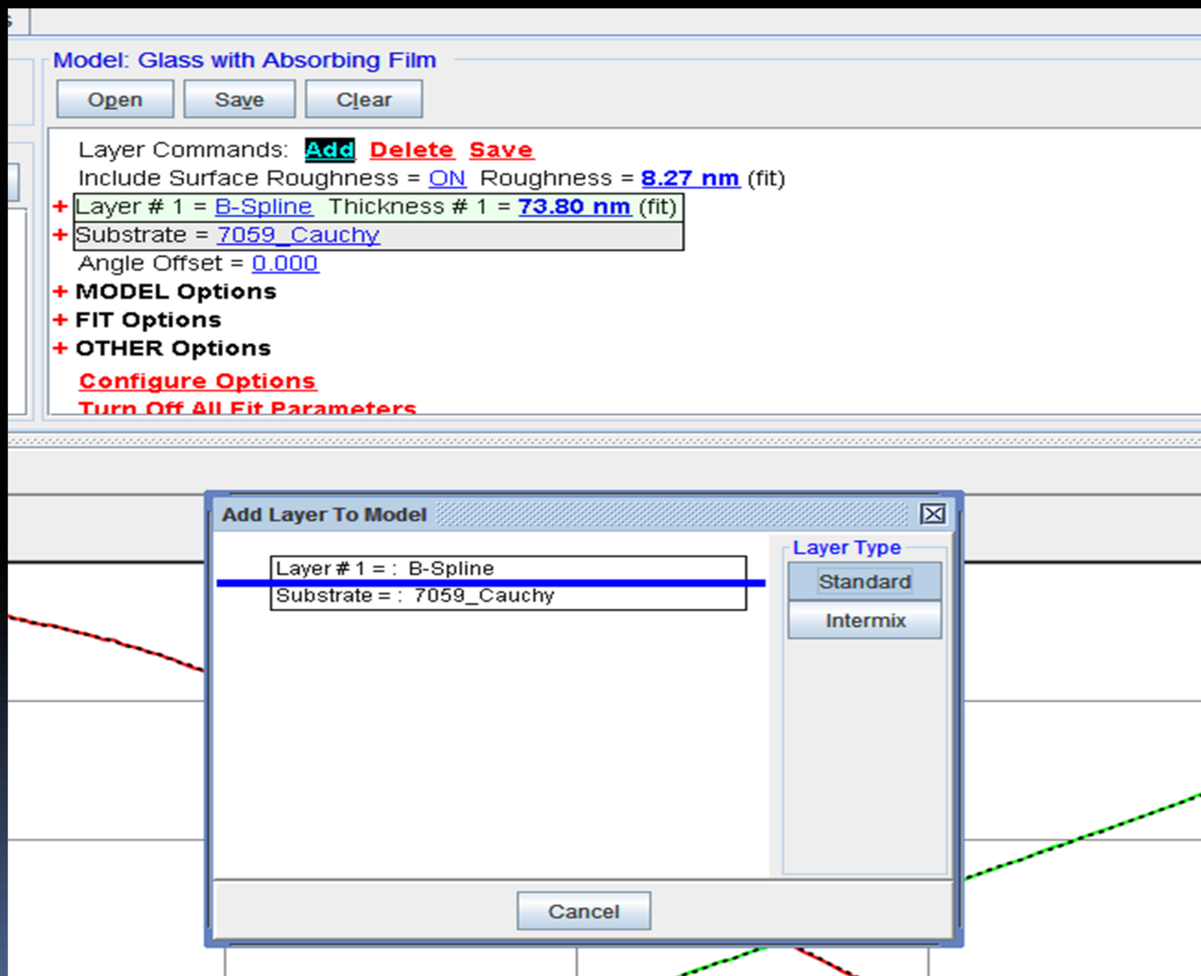

Parameterize Layer
New Layer
Open Material File
Mat.: Gen-Osc
OC View/Fit Type
n & k
e1 & e2
View/Fit: All
Show All Oscillators
Wvl. Units
nm
eV
Fit
Fit
Reset
Layer Parameters
Gen-Osc - GENOSC
Add Oscillator Fast Gaussian Calc = ON
Einf = 1.000
UV Pole Amp. = 0.0000 UV Pole En. = 11.000
IR Pole Amp. = 0.0000
Fit All Clear All Add Amp. Add Br. Add En.
1: Type = Cody-Lorentz Amp1 = 12.258
Br1 = 3.677 Eo1 = 6.000 Eg1 = 1.000
Ep1 = 1.000 Et1 = 0.000 Eu1 = 0.500 Common Eg = OFF
Graph
e1 New Layer
e2 New Layer
e1 Model
e2 Model
(X=4.2043, Y=2.7028, Y2=1.6760)
e1
e2
eV
Manual X,Y2
Zoom All
Auto Axis
Expanded Axis
Replace Layer
Cancel

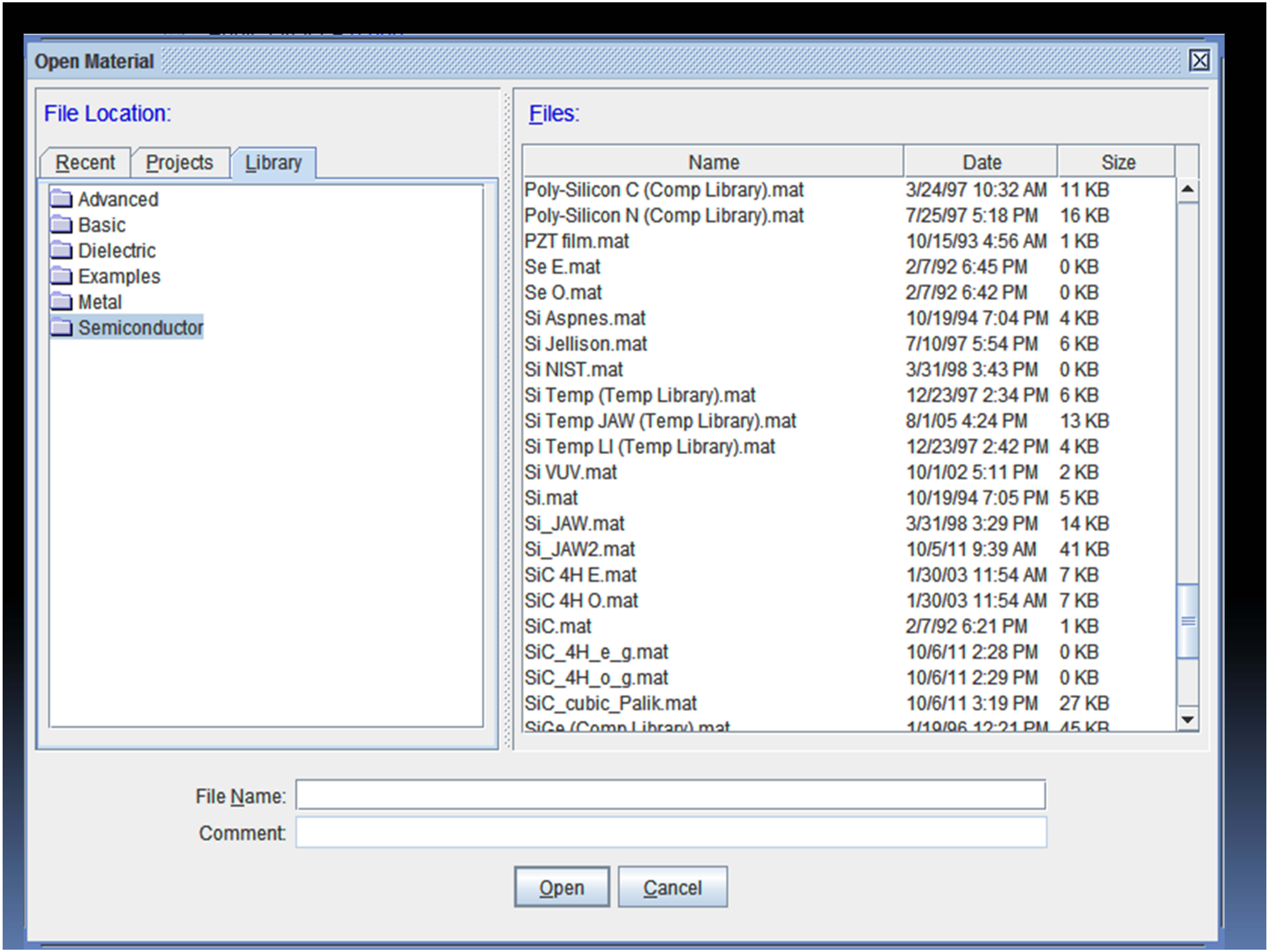
Real Part


Parameterize Layer
New Layer
Open Material File
Mat.: Gen-Osc
OC View/Fit Type
n & k
e1 & e2
View/Fit: Real Part Only
Show All Oscillators
Wvl. Units
nm
eV
Fit
Fit
Reset
Layer Parameters
Gen-Osc - GENOSC
Showing Real Part Fitting Parameters Only
Einf = 1.000
UV Pole Amp. = 0.0000 UV Pole En. = 11.000
IR Pole Amp. = 0.0000
Graph
e1 New Layer
e1 Model
e1
25
20
15
10
5
0
2.420
2.425
2.430
2.435
2.440
2.445
2.450
2.455
eV
Zoom All
Auto Axis
Expanded Axis
Replace Layer
Cancel

Multi-layered Thin films

Measurement?




Open Material
File Location:
Recent
Projects
Library
Advanced
Basic
Dielectric
Examples
Metal
Semiconductor
Files:
Name Date Size
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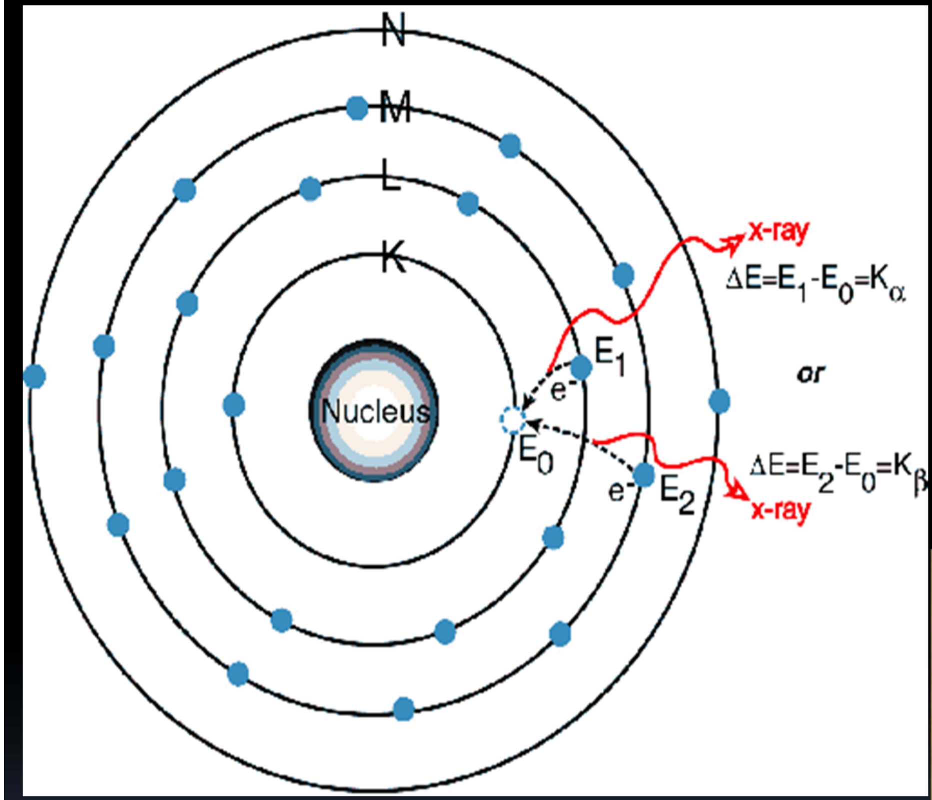
Poly-Silicon N (Comp Library).mat 7/25/97 5:18 PM 16 KB
PZT film.mat 10/15/93 4:56 AM 1 KB
Se E.mat 2/7/92 6:45 PM 0 KB
Se O.mat 2/7/92 6:42 PM 0 KB
Si Aspnes.mat 10/19/94 7:04 PM 4 KB
Si Jellison.mat 7/10/97 5:54 PM 6 KB
Si NIST.mat 3/31/98 3:43 PM 0 KB
Si Temp (Temp Library).mat 12/23/97 2:34 PM 6 KB
Si Temp JAW (Temp Library).mat 8/1/05 4:24 PM 13 KB
Si Temp LI (Temp Library).mat 12/23/97 2:42 PM 4 KB
Si VUV.mat 10/1/02 5:11 PM 2 KB
Si.mat 10/19/94 7:05 PM 5 KB
Si_JAW.mat 3/31/98 3:29 PM 14 KB
Si_JAW2.mat 10/5/11 9:39 AM 41 KB
SiC 4H E.mat 1/30/03 11:54 AM 7 KB
SiC 4H O.mat 1/30/03 11:54 AM 7 KB
SiC.mat 2/7/92 6:21 PM 1 KB
SiC_4H_e_g.mat 10/6/11 2:28 PM 0 KB
SiC_4H_o_g.mat 10/6/11 2:29 PM 0 KB
SiC_cubic_Palik.mat 10/6/11 3:19 PM 27 KB
File Name:
Comment:
Open
Cancel

So what about Optical Constants of individual layers?

Fit options→ Include Derived Parameters→ Layer#

X RAY FLUORESCENCE



- A source X-ray strikes an inner shell electron(k or l shell). If at high enough energy it is ejected from the atom.

- Higher energy electrons(l, m or n shell) cascade to fill vacancy, giving off characteristic fluorescent X-rays.
- Br

Types of XRF:

•EDXRF: dispersion accomplished by semi conductor detector. Energy is the factor of discrimination between elemental peaks.
-Gives peaks from Na-U.

•WDXRF: Wavelength is the factor of discrimination between elemental peaks.
-Gives peaks from Na-Be.

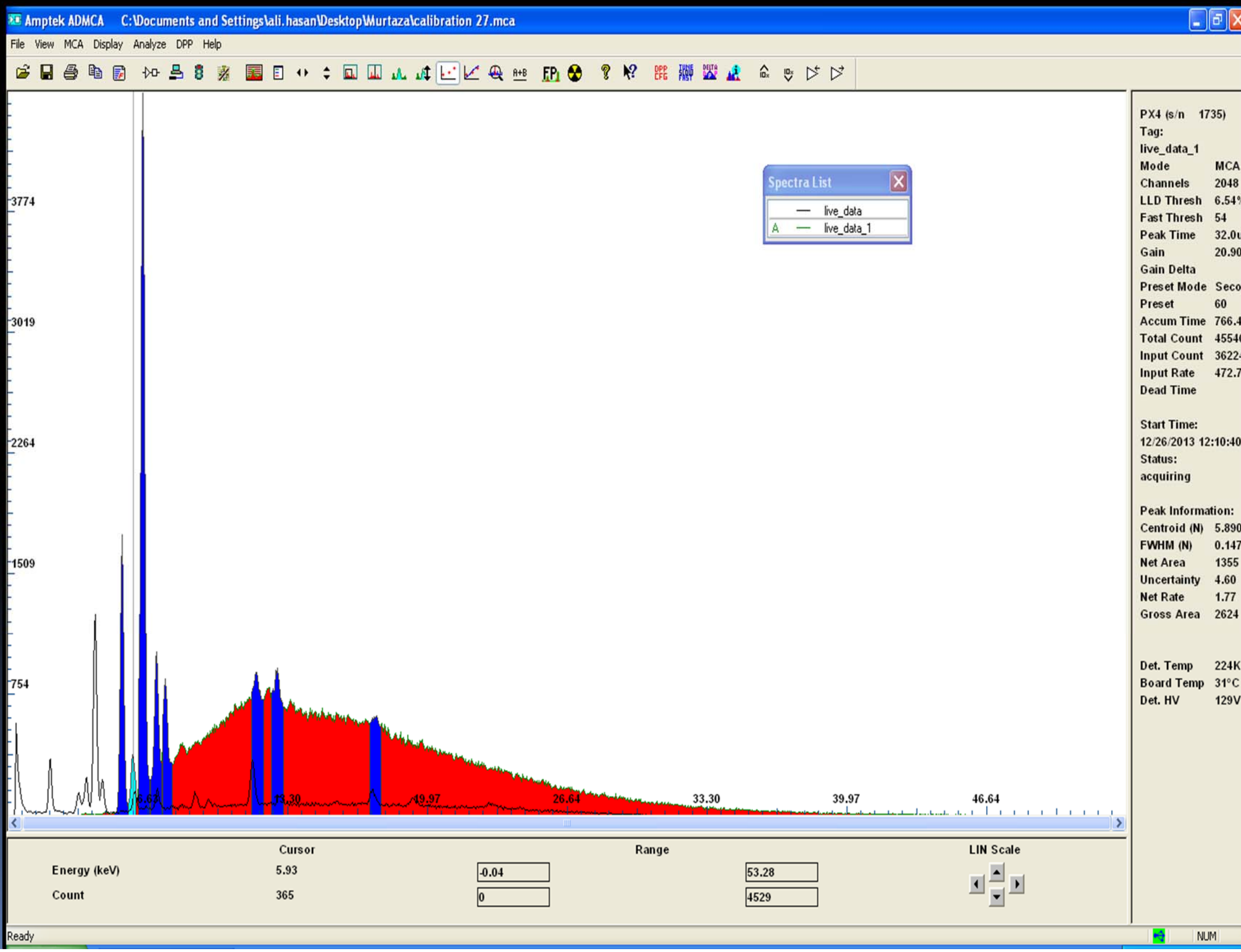
Limitations of XRF spectrometry

•Organic elements such as H,C,N,O do not show XRF peaks: Fluorescence photons from these elements are too low in energy to transmit through air and reach the detector

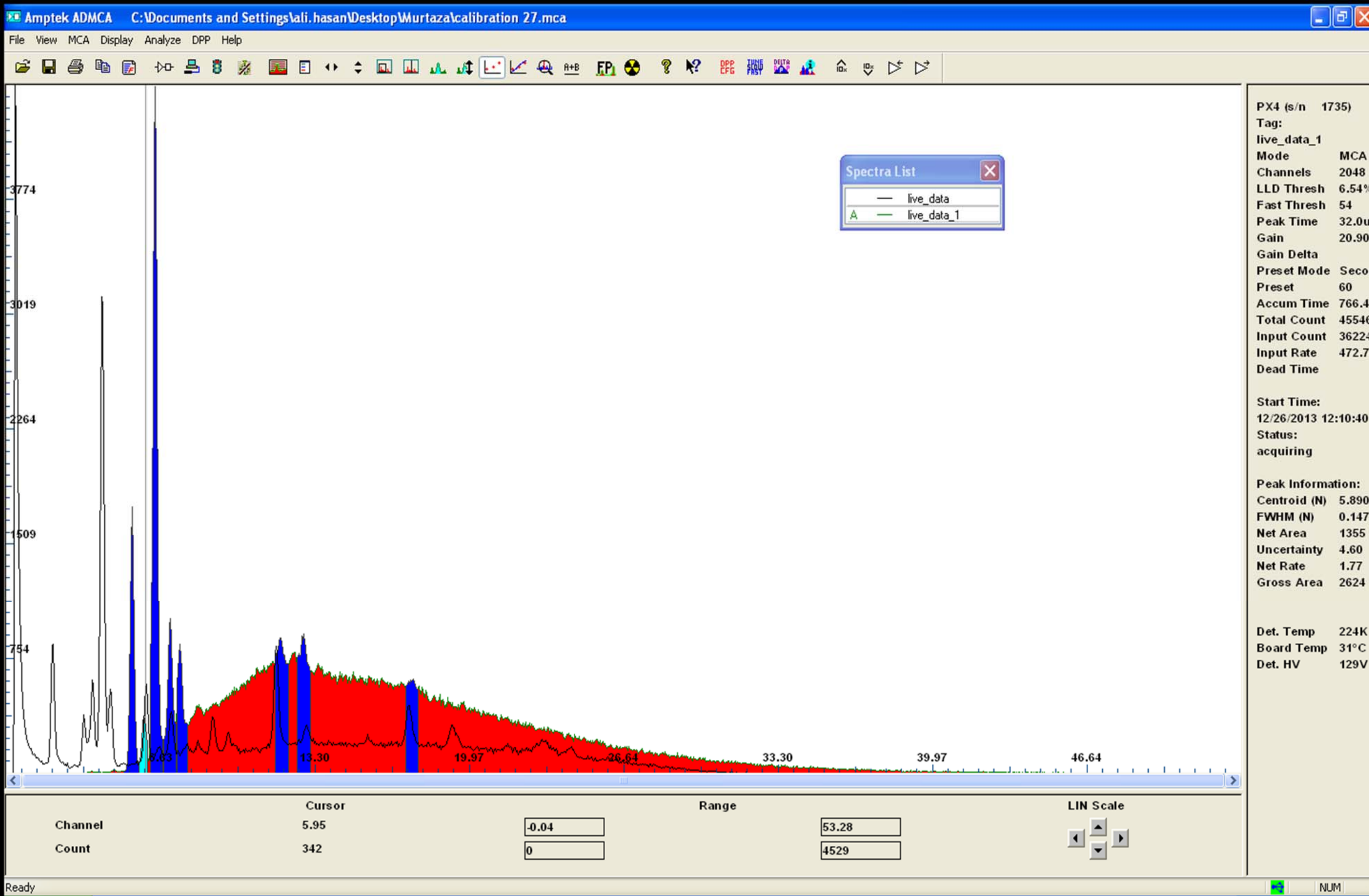
•Low Z elements such as Cl,Ar,K,Ca give only K peaks:Low energy photons

•High Z elements such as Ba,Pb,Hg,U give only L peaks: peaks from these elements have too high energy,electrons have high binding energies and cannot be removed with limited range of voltage supplies.

Elemental Analysis of Cr thin layer



Kb of Cr=5.95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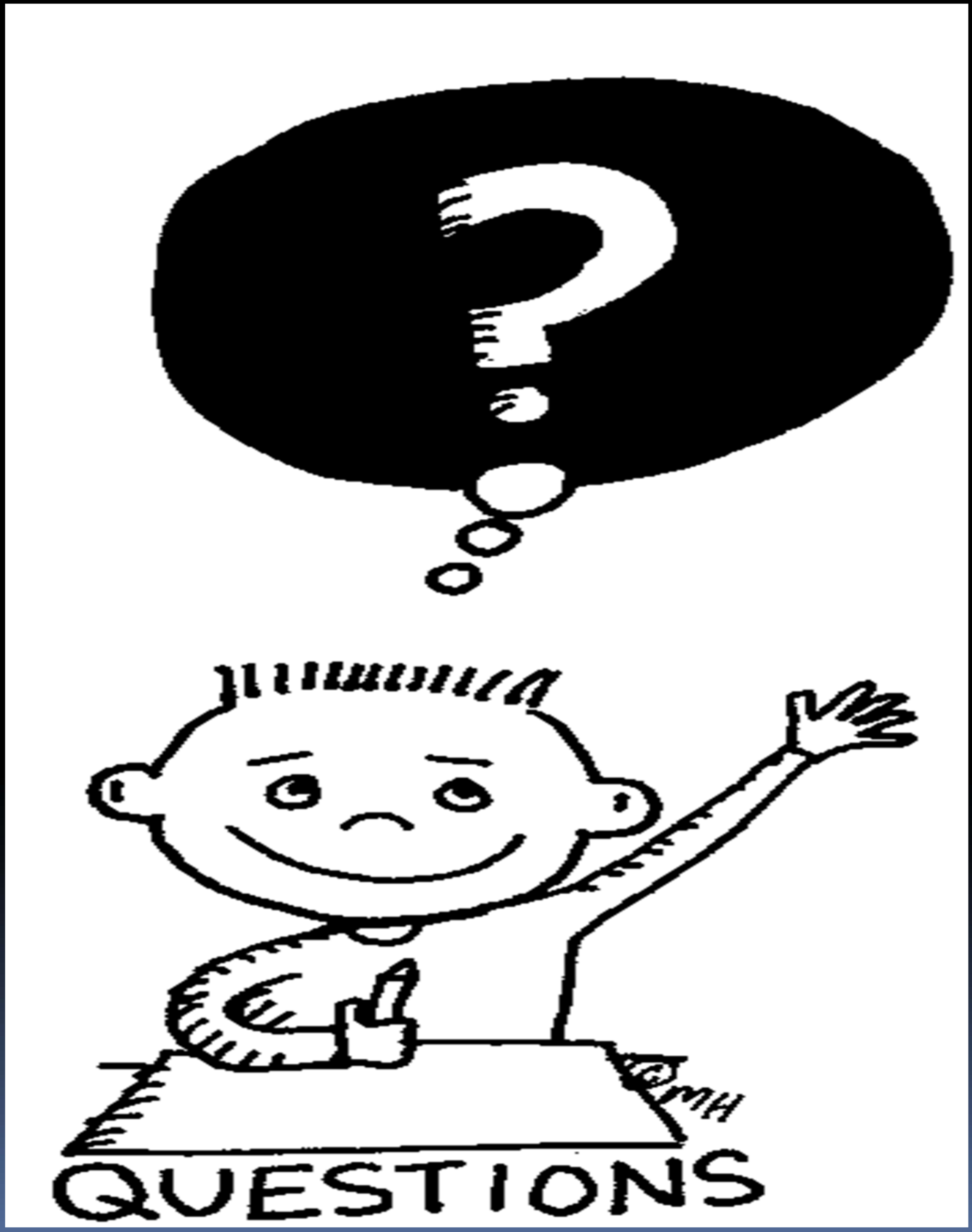
File View MCA Display Analyze DPP Help
Spectra List
live_data
live_data_1
PX4 (s/n 1735)
Tag:
live_data_1
Mode MCA
Channels 2048
LLD Thresh 6.54%
Fast Thresh 54
Gain 20.90
Gain Delta
Preset 60
Start Time:
12/26/2013 12:10:40
Status:
acquiring
Peak Information:
Centroid (N) 5.890
FWHM (N) 0.147
Net Area 1355
Uncertainty 4.60
Net Rate 1.77
Gross Area 2624
Det. Temp 224K
Board Temp 31°C
Det. HV 129V
Cursor
Range
LIN Scale
Channel 5.95
Count 342
-0.04
0
53.28
4529
Ready
NUM

Summary

- Thin layers formed by sputtering through plasma, thickness and uniformity depending on input parameters
- Thickness of layers and optical constants can be measured by means of ellipsometry
- XRF helps determine the elemental and percentage composition of the thin layer


QUESTIONS