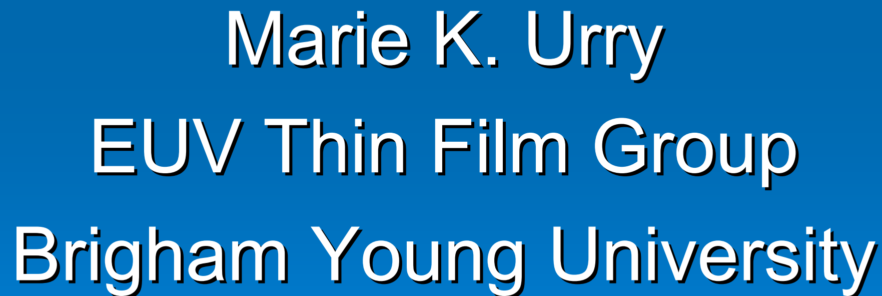
Optical Constants of Uranium Nitride Thin Films in the EUV (80-182 eV)

Marie K. Urry
EUV Thin Film Group
Brigham Young University



Acknowledgements

Thanks to:

Dr. David D. Allred

Dr. R. Steven Turley

Kristi R. Adamson

Luke J. Bissell

Jennie Guzman

Elke Jackson

Winston Larsen

Mindy Tonks

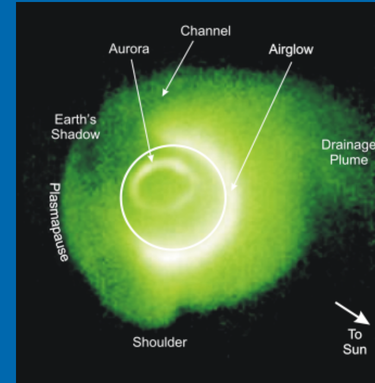
Department Funding

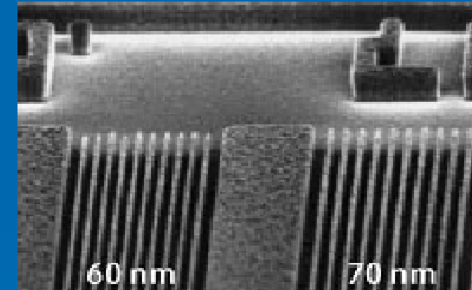
Outline

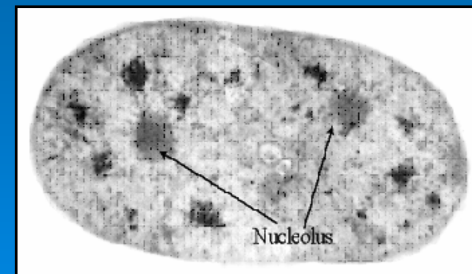
- Why We Do What We Do
- Making Thin Films
- Studying Thin Films
- Finding Optical Constants
  - Reflectometer

Why Extreme Ultraviolet (EUV)?

- Astronomy
  - Our IMAGE Satellite Mirror Project
- Lithography
  - Projection Imagining
  - Scheduled for 2009
- Medicine
  - High Resolution Imaging Microscopes







Images courtesy of http://euv.lpl.arizona.edu/euv/, www.schott.com/magazine/english/info99/ and www.schott.com/magazine/english/info99/.

Optical Constants

- Index of refraction:

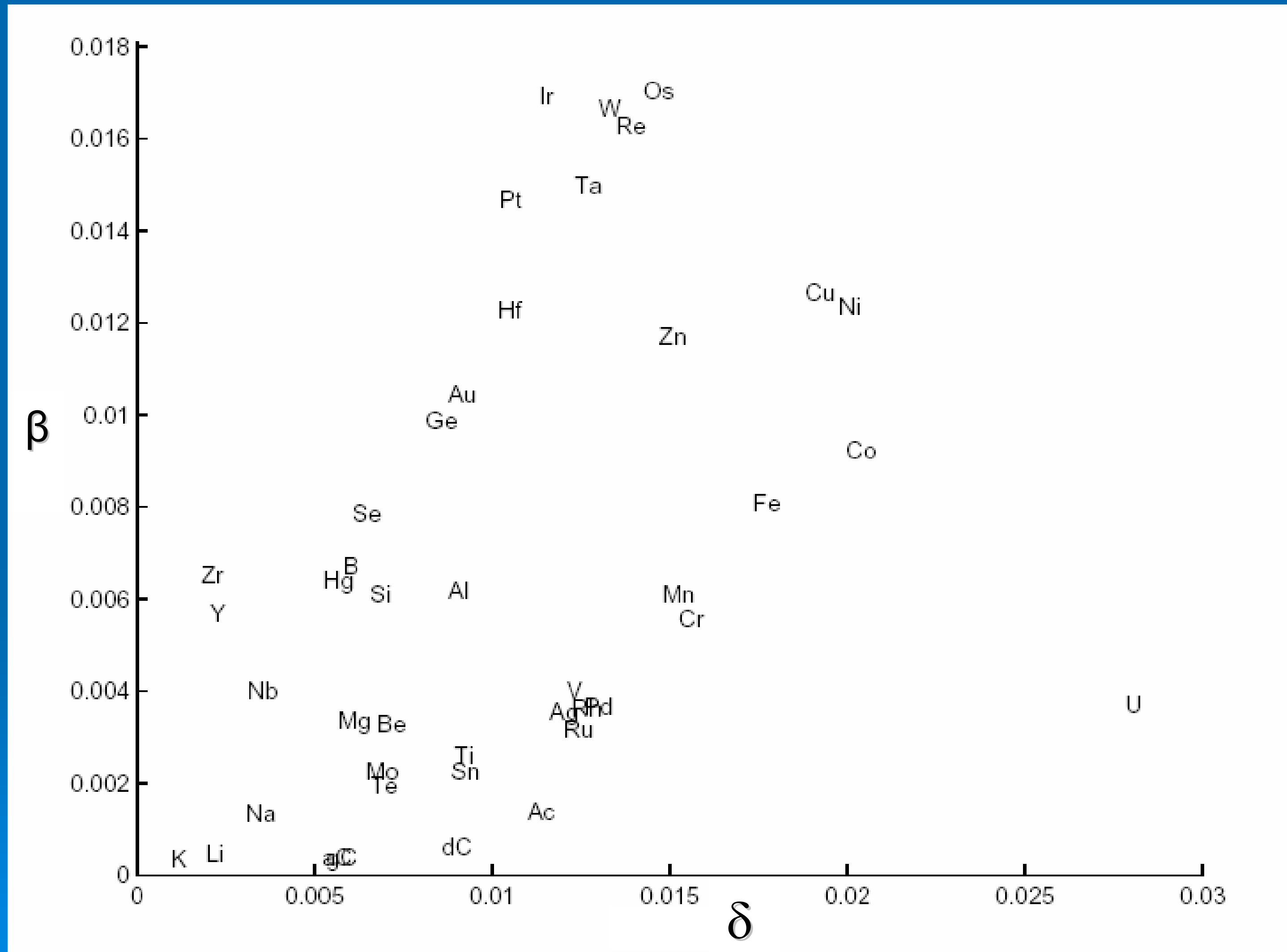
$$N = n + i\,k$$

- In EUV, $n \approx 1$ and k is huge.

$$\rightarrow \quad \begin{matrix} n = 1 - \delta \\ k = \beta \end{matrix}$$

- High δ and low β for maximum reflection for multilayers.

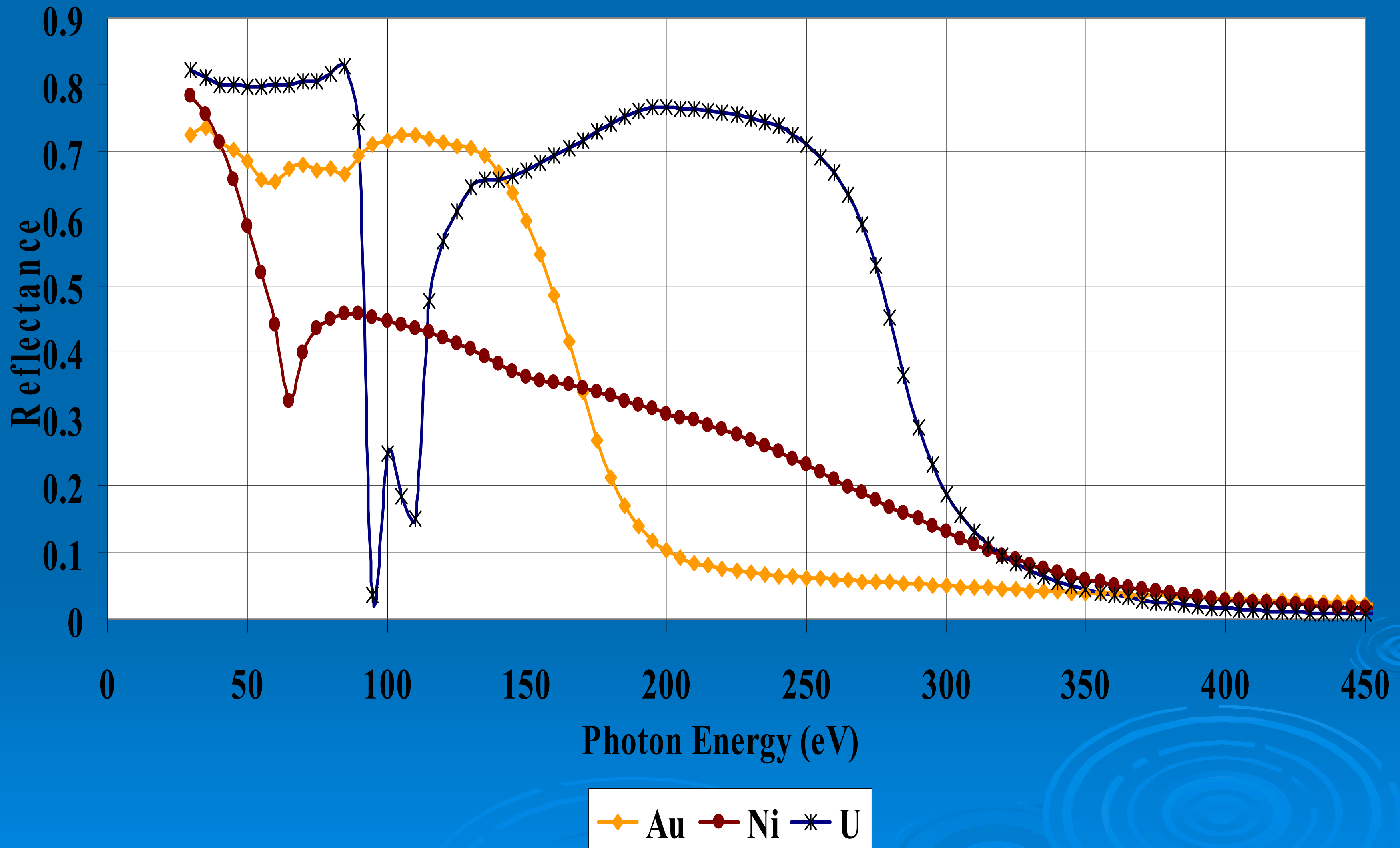
Delta-Beta Scatter Plot at 220 eV



Why Uranium Nitride?

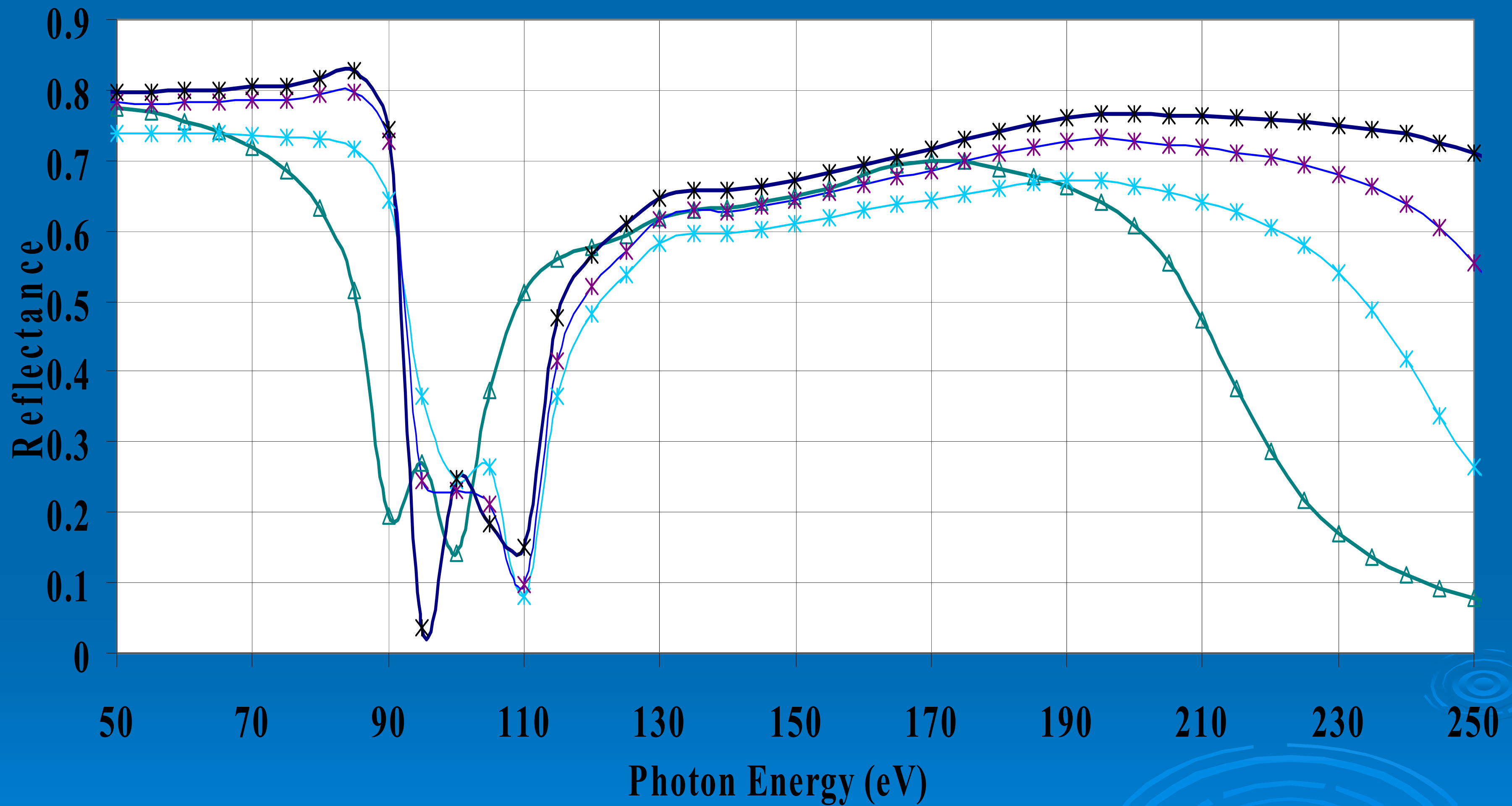
- Uranium
  - High theoretical reflectivity due to high δ
- Problem: Oxidation
- Nitride
  - Little effect on reflectivity
  - Prevents oxidation

Computed Reflectance at 10 degrees of various materials



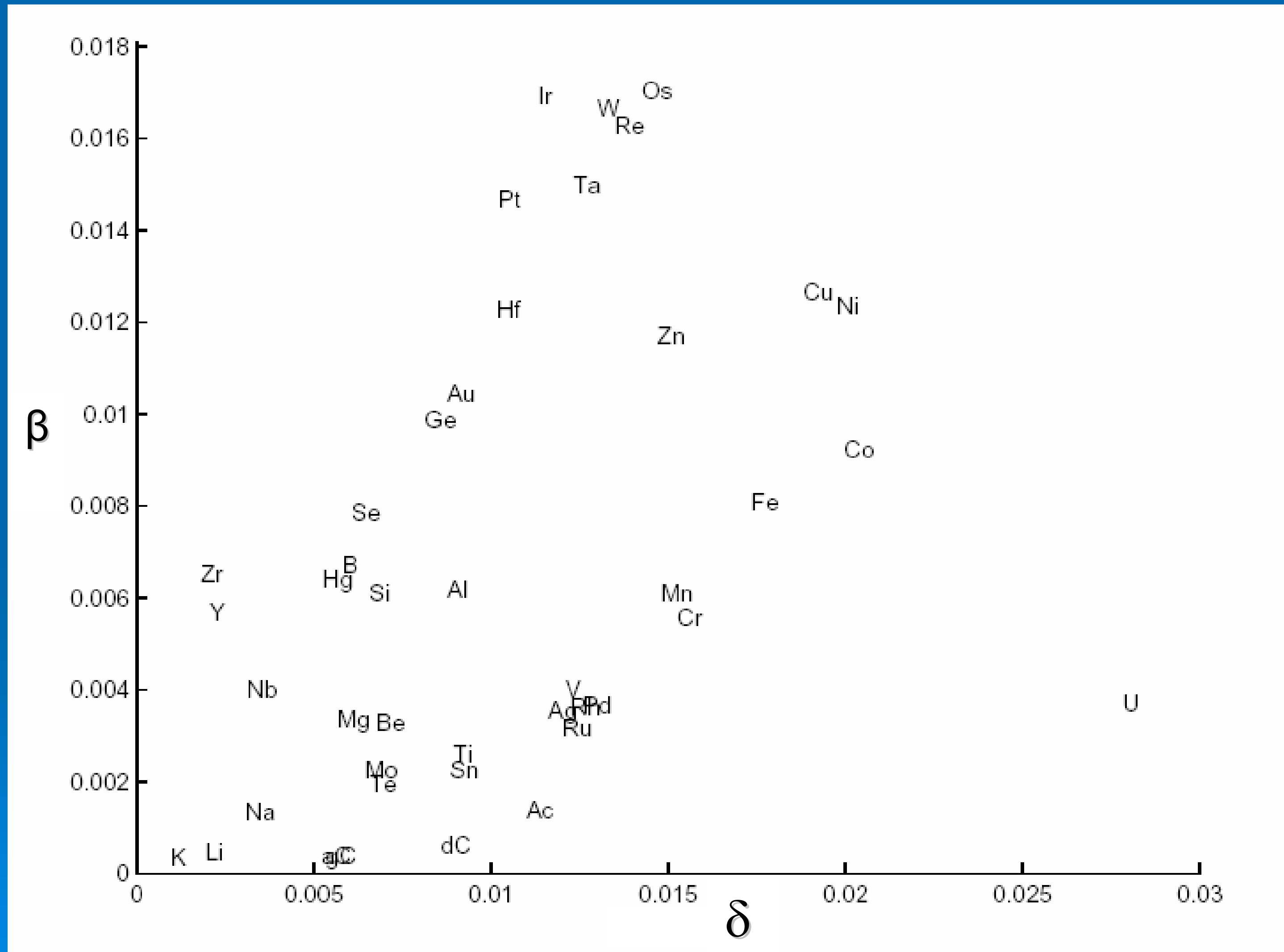
Reflectance computed using the CXRO Website: http://www-cxro.lbl.gov/optical_constants/mirror2.html

Computed Reflectance at 10 degrees of various materials



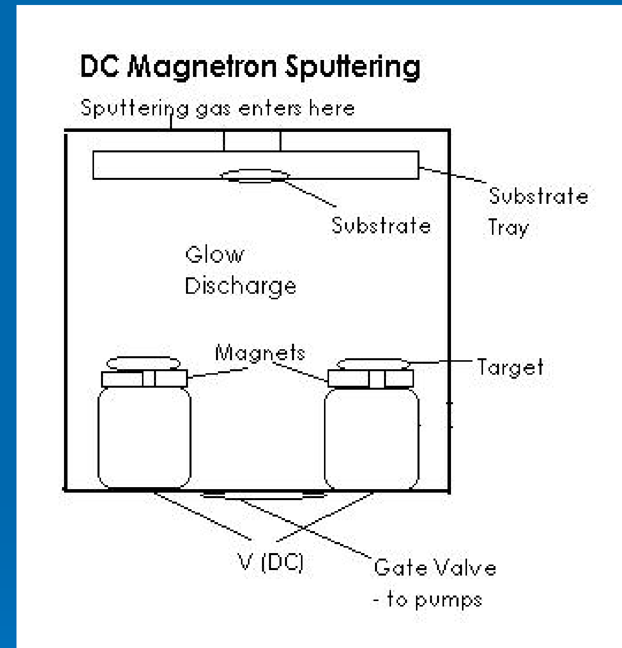
Reflectance computed using the CXRO Website: http://www-cxro.lbl.gov/optical_constants/mirror2.html

Delta-Beta Scatter Plot at 220 eV



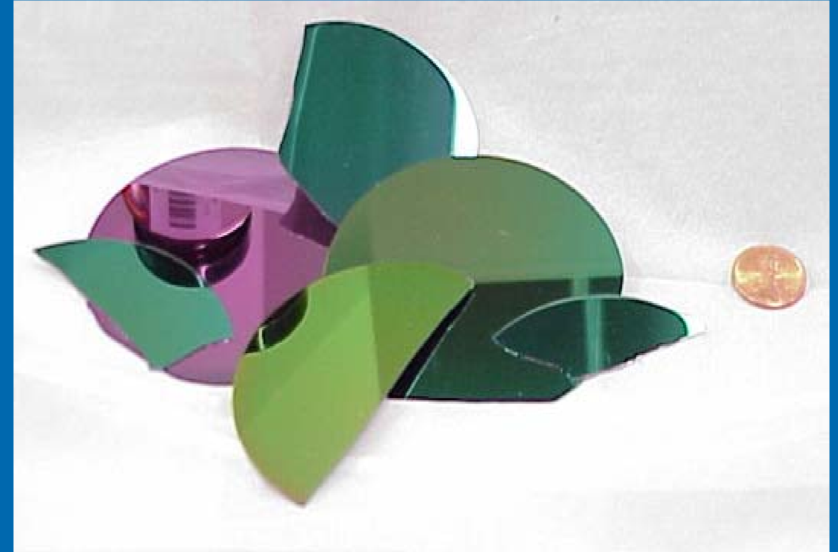
Making Thin Films

- Sputtering
  - Bombard target, uranium, with argon ions
  - Uranium atoms leave target due to collisions
  - Nitrogen partial pressure in plasma introduces N atoms
  - U and UN molecules deposit on our samples



Making Thin Films

- 10-30 nm thick



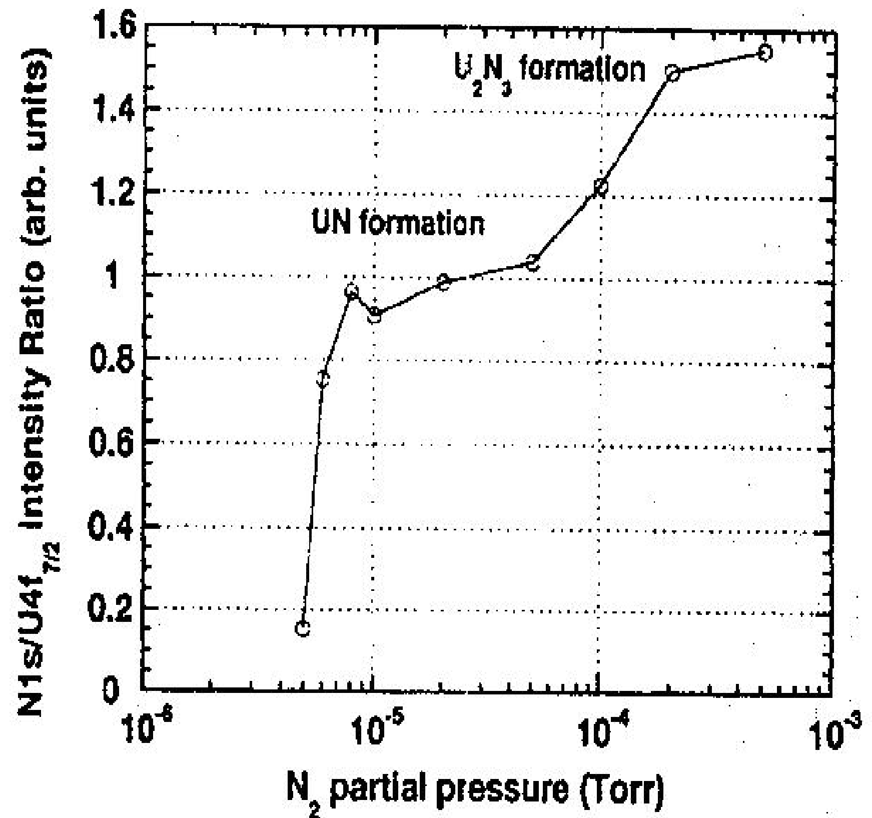
- Deposited on:
  - silicon wafers
  - quartz slides
  - polyimide films
  - SiN membranes
  - carbon coated TEM grids
- Low pressure sputtering
  - smooth, dense, low stress films

Side Note for Clarification

- Samples 002 – 005
  - 002 and 003 are U_2N_3
  - 004 and 005 are UN
    - 005 is new and unmeasured

Making Thin Films

- Partial pressure determines stoichiometry
- Our system couldn't control partial pressures in the critical range



N2 Partial Pressure vs N/U Ratio

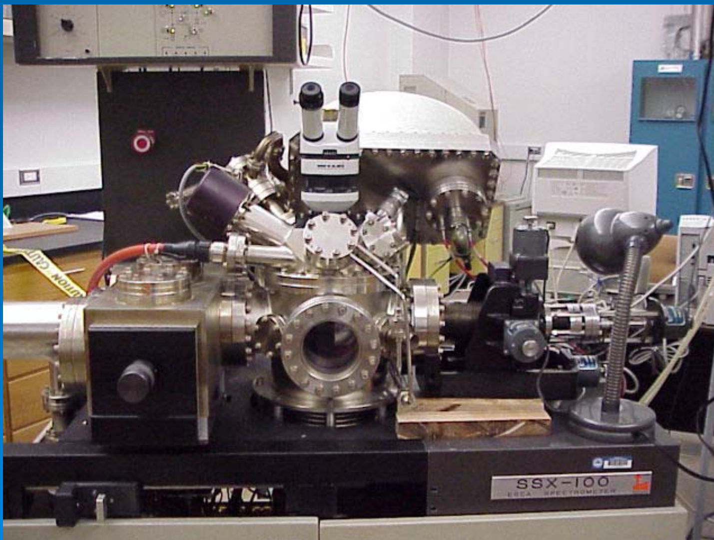
Image courtesy of L. Black, et al., Journal of Alloys and Compounds, **315** (2001) 36-41.

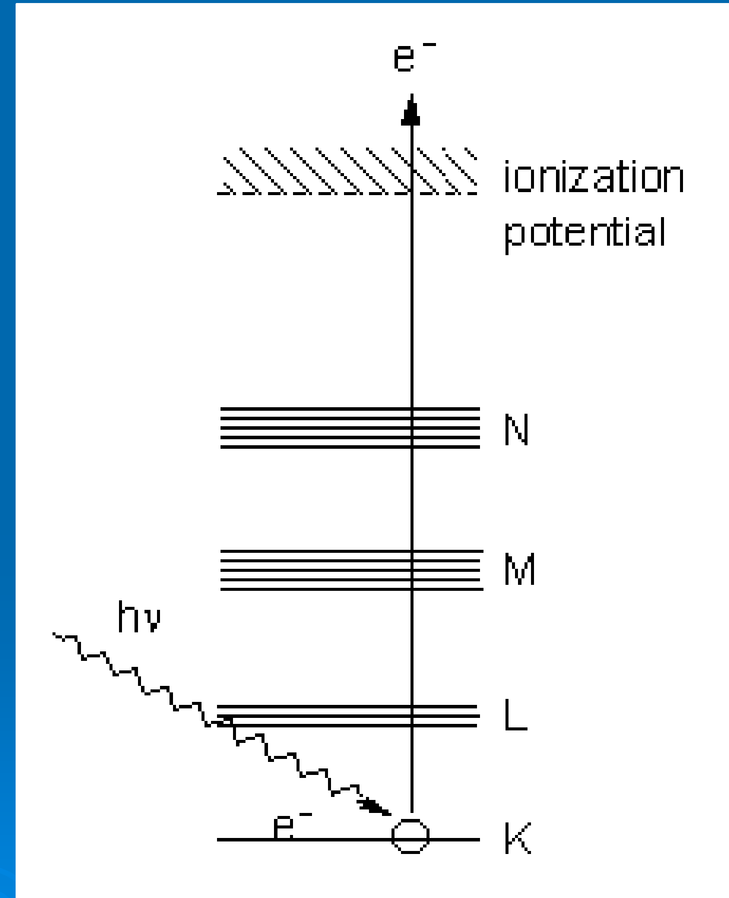
Learning About the Samples

- Composition
  - Depends on partial pressure in system
- Thickness
  - Crystal monitor is to the side of the film and gets less accurate with time
- Roughness
- Optical Constants

X-Ray Photoelectron Spectroscopy (XPS)

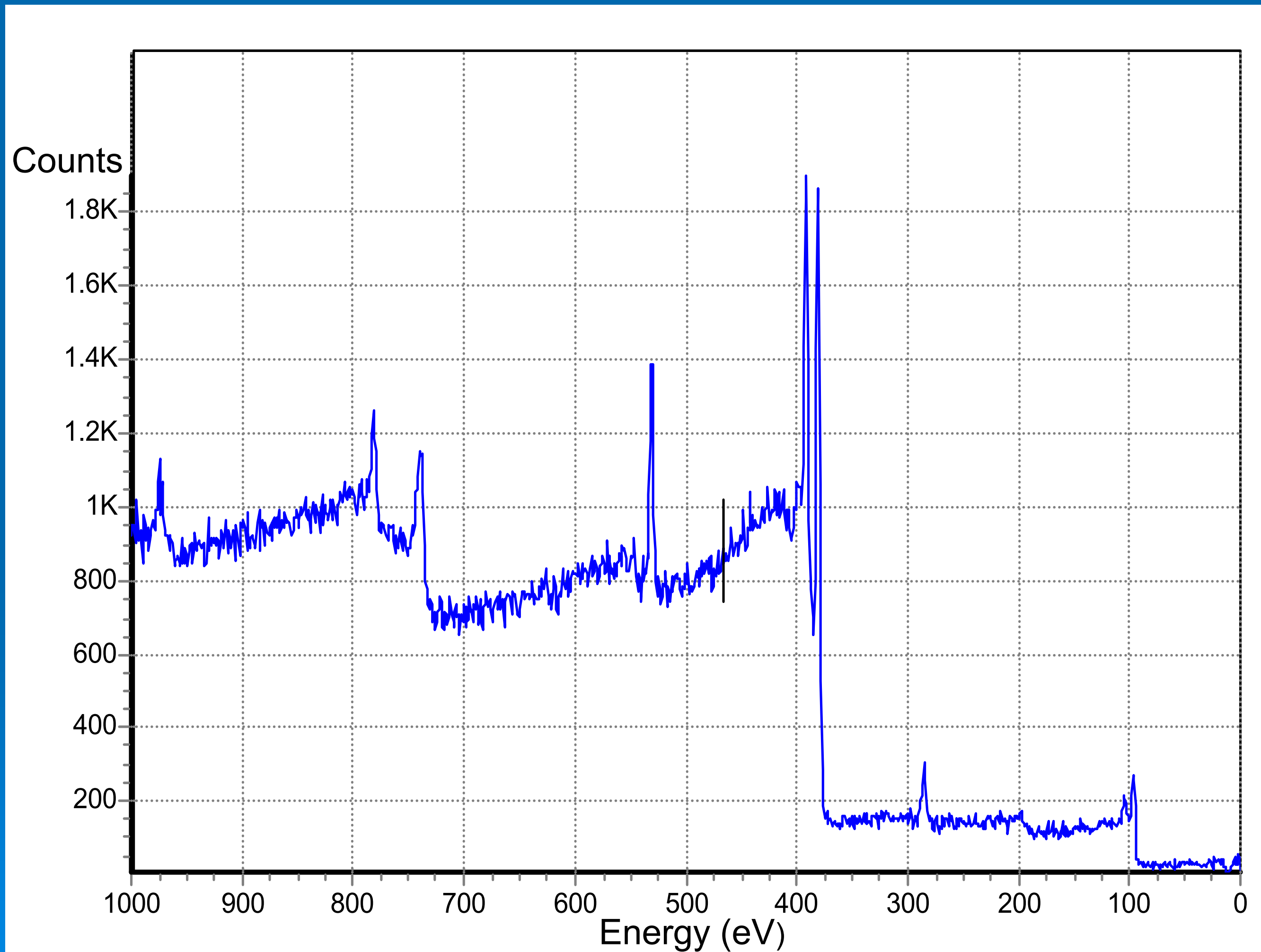
- Uses photoelectric effect to find composition





Images courtesy of http://volta.byu.edu/adamson03.pdf .

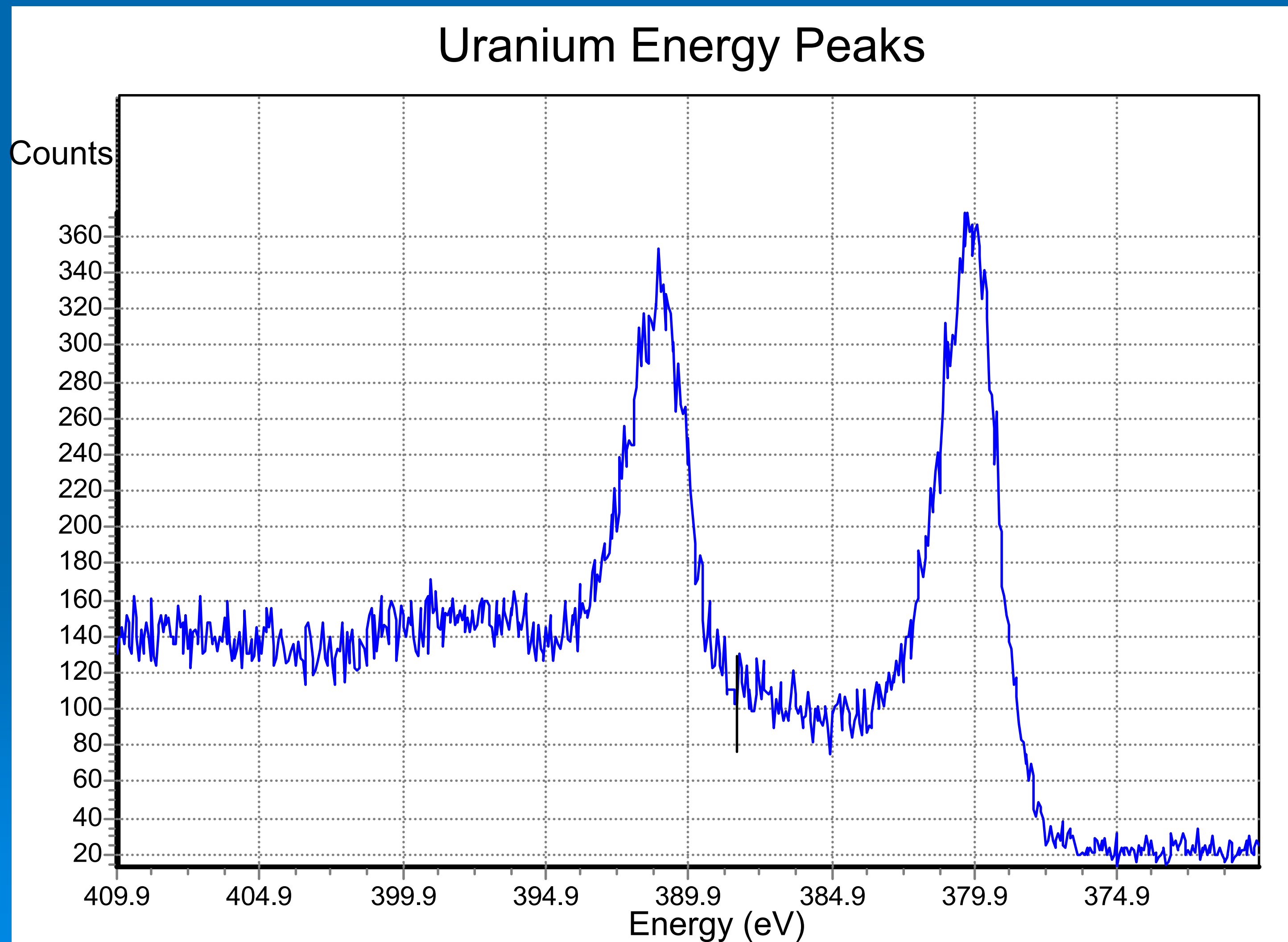
X-Ray Photoelectron Spectroscopy (XPS)



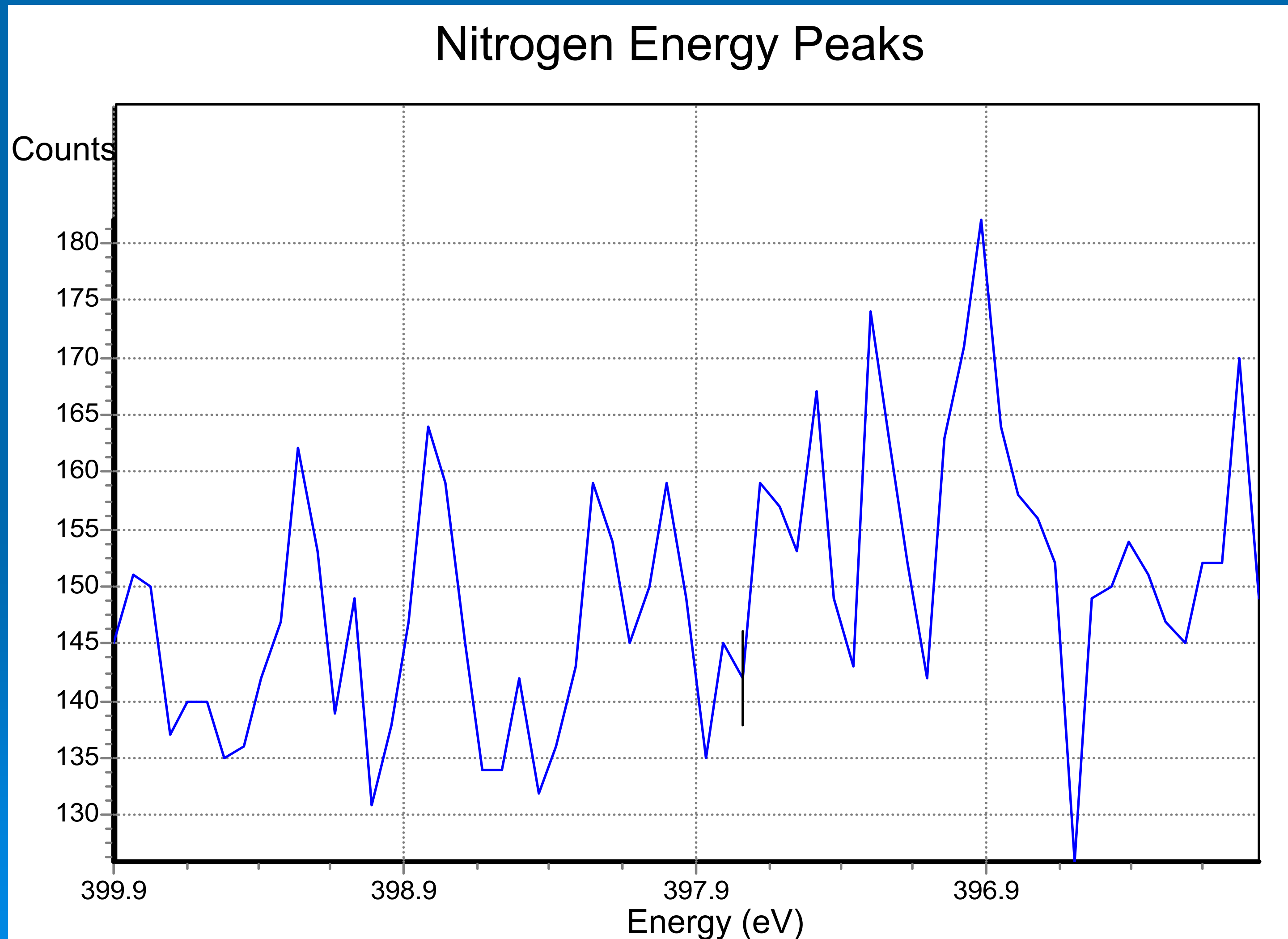
Survey Scan of Surface Identifying Peaks:

100eV – U 5d5/2
280eV – C1s
380eV – U4f7/2
390eV – U4f5/2
398eV – N1s
530eV – O1s
740eV – U4d5/2
780eV – U4d3/2
980eV – Auger O

X-Ray Photoelectron Spectroscopy (XPS)

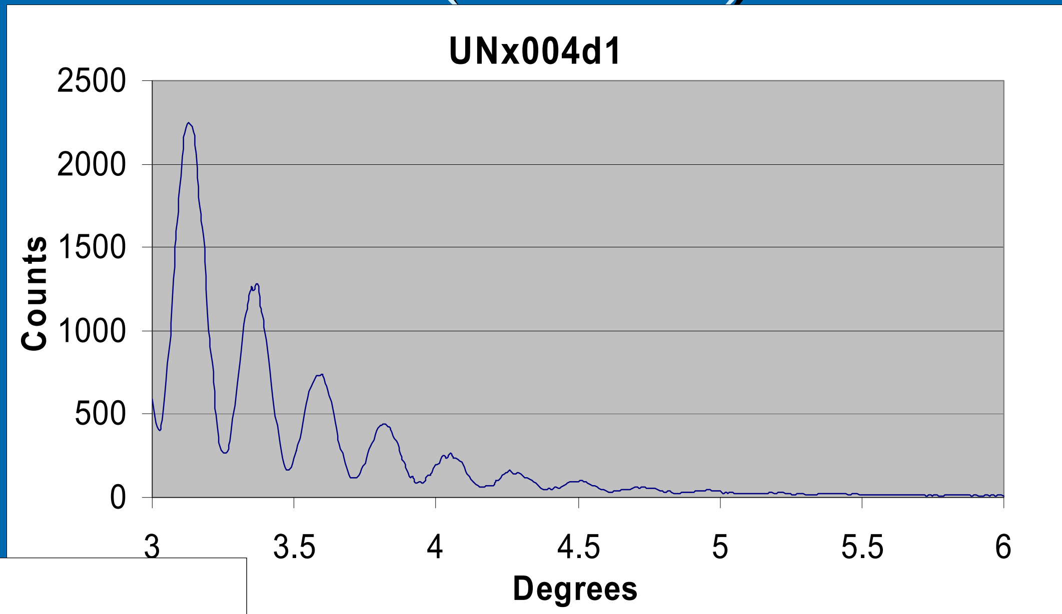


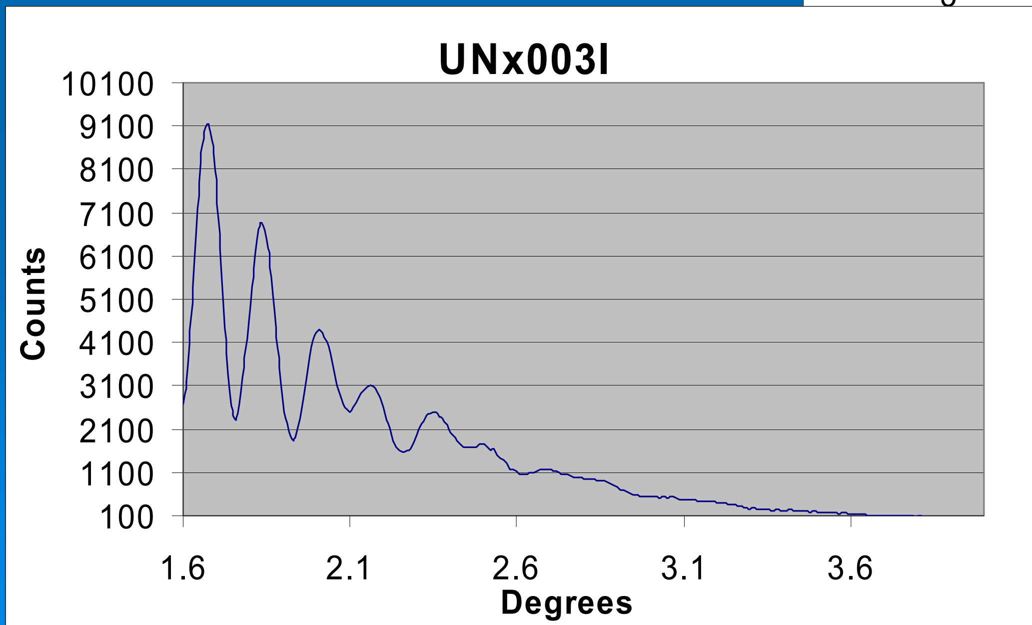
X-Ray Photoelectron Spectroscopy (XPS)

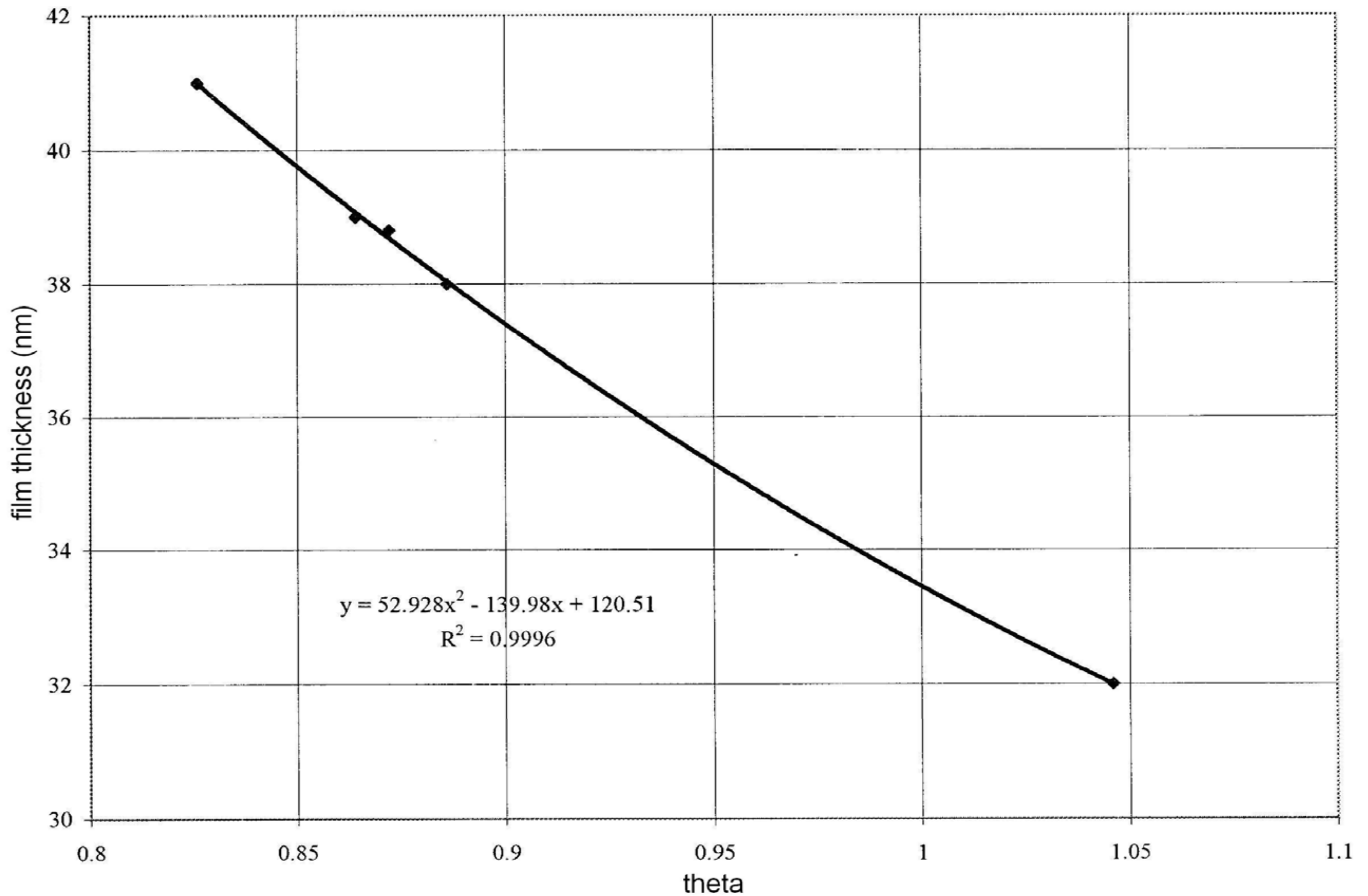


X-Ray Diffraction (XRD)

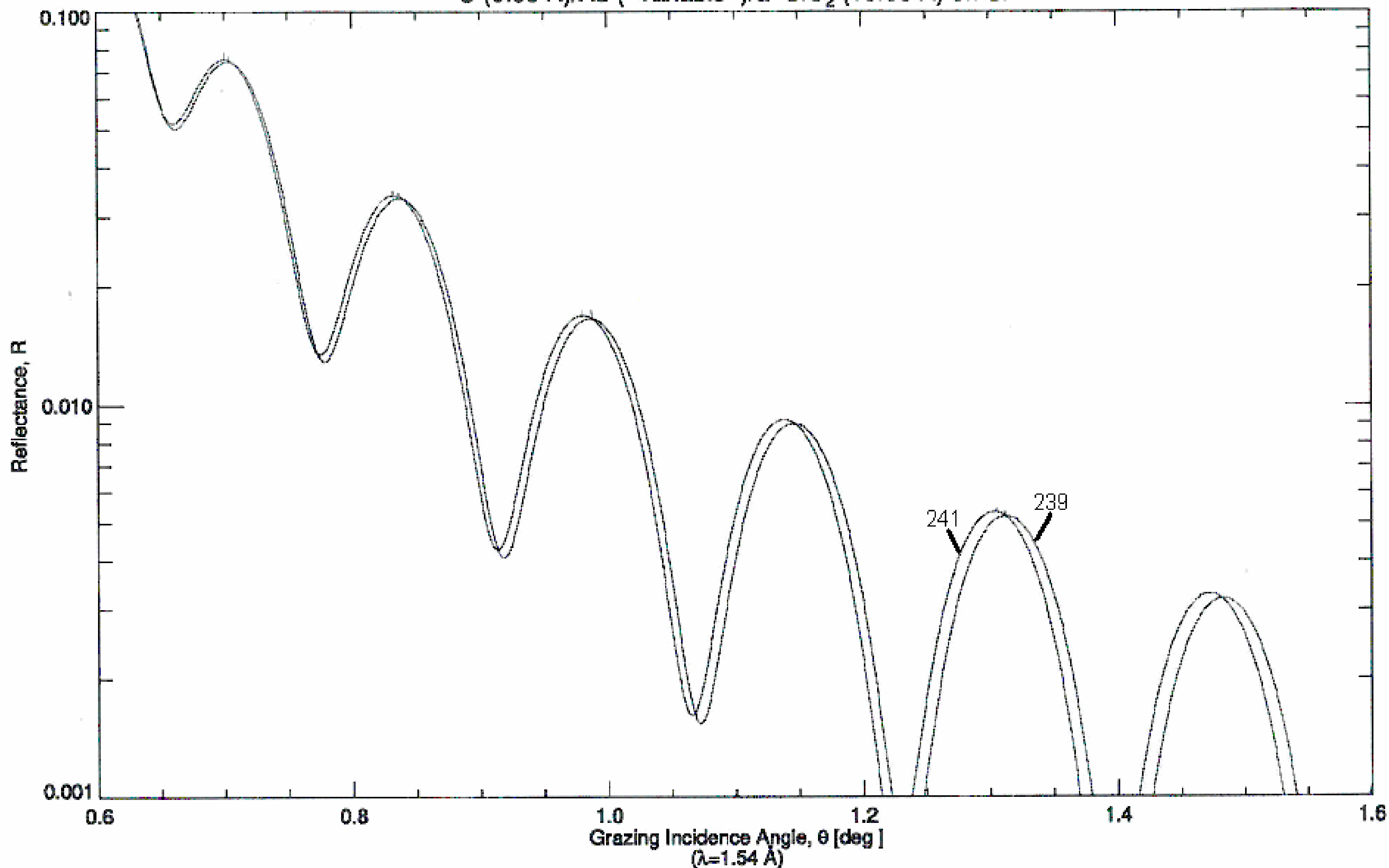
- To find thickness
- $m\,\lambda = 2d \sin\theta$





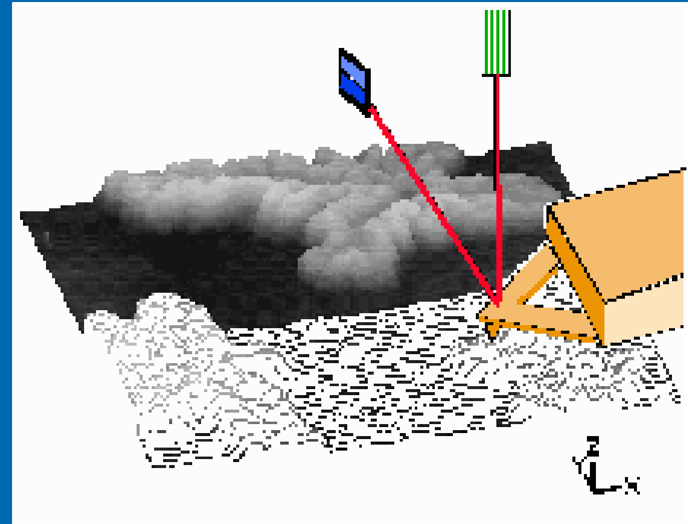


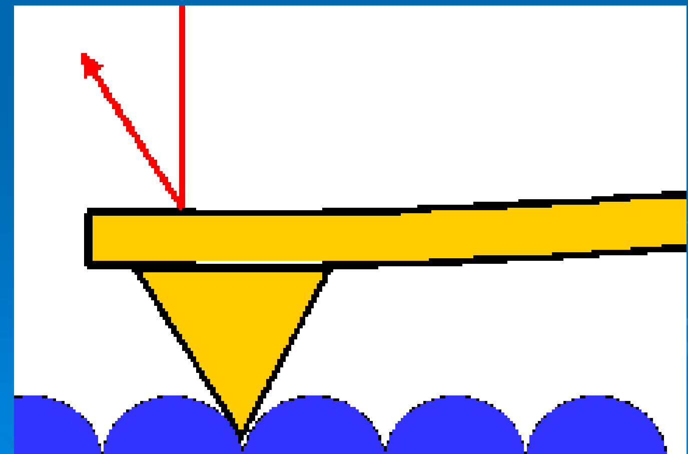
Change in theta between 8 peaks minima around theta=1.5 for UO_2


U (0.00 Å)/Au (–variable–)/a–SiO2 (18.00 Å) on Si
Reflectance, R
0.100
0.010
0.001
0.6
0.8
1.0
1.2
1.4
1.6
Grazing Incidence Angle, θ [deg]
(λ=1.54 Å)
241
239
U layer (1), z=0.00 Å
Au layer (2), z=–variable– Å
a–SiO2 layer (3), z=18.00 Å
Si substrate

Atomic Force Microscopy (AFM)

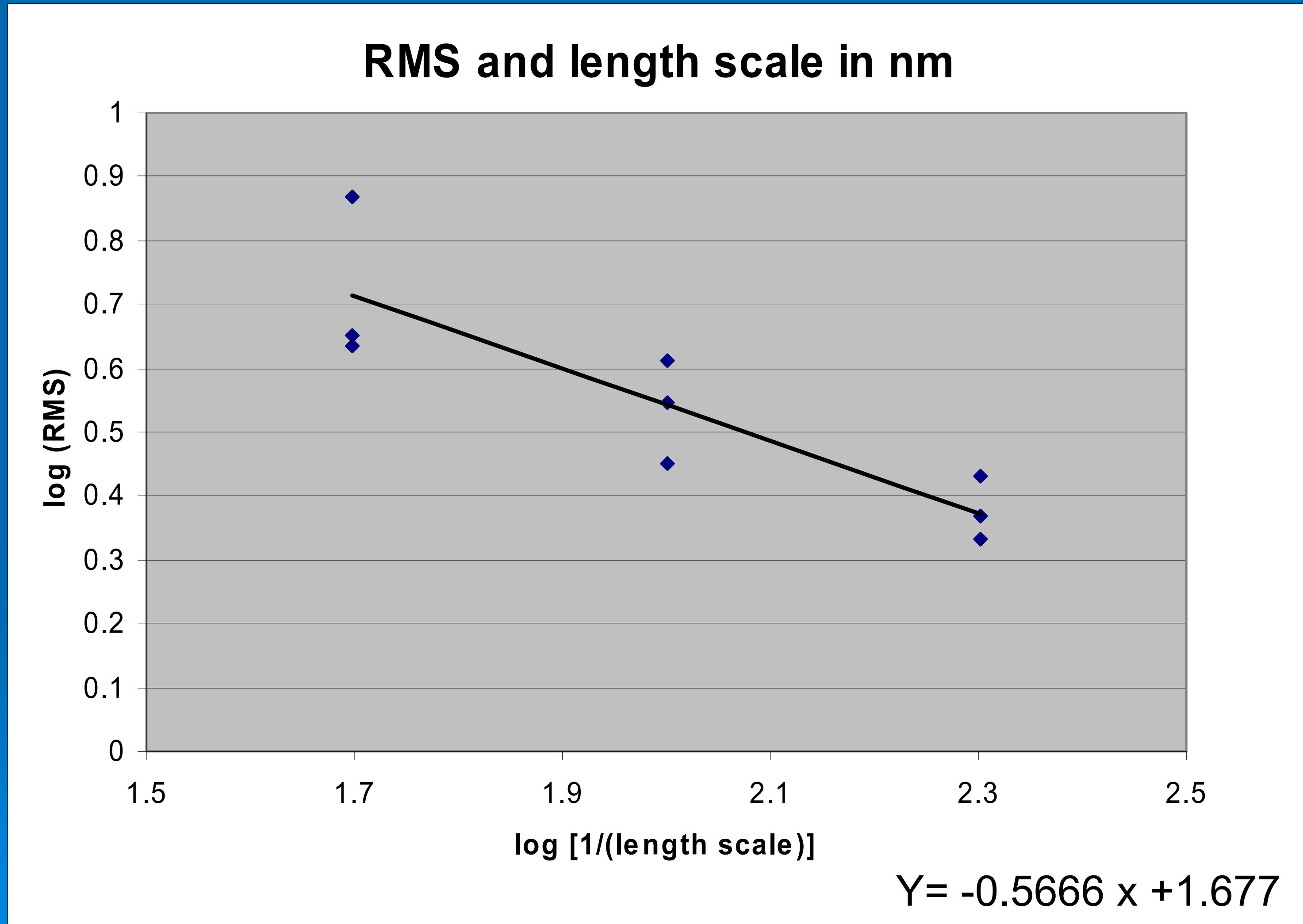
- To Measure Roughness
- Result: RMS roughness



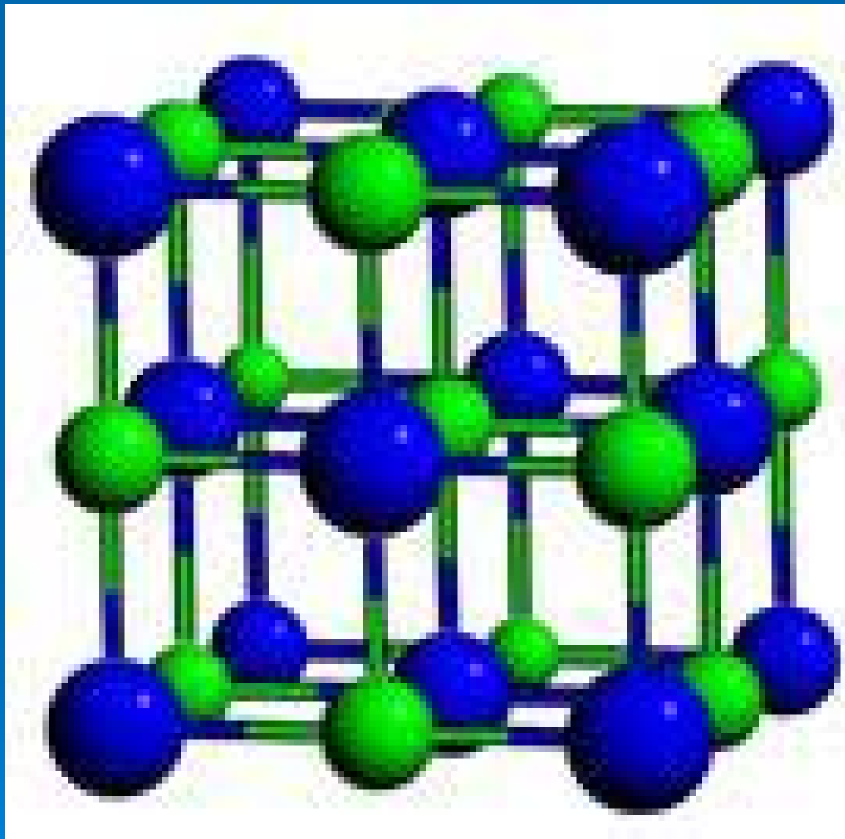


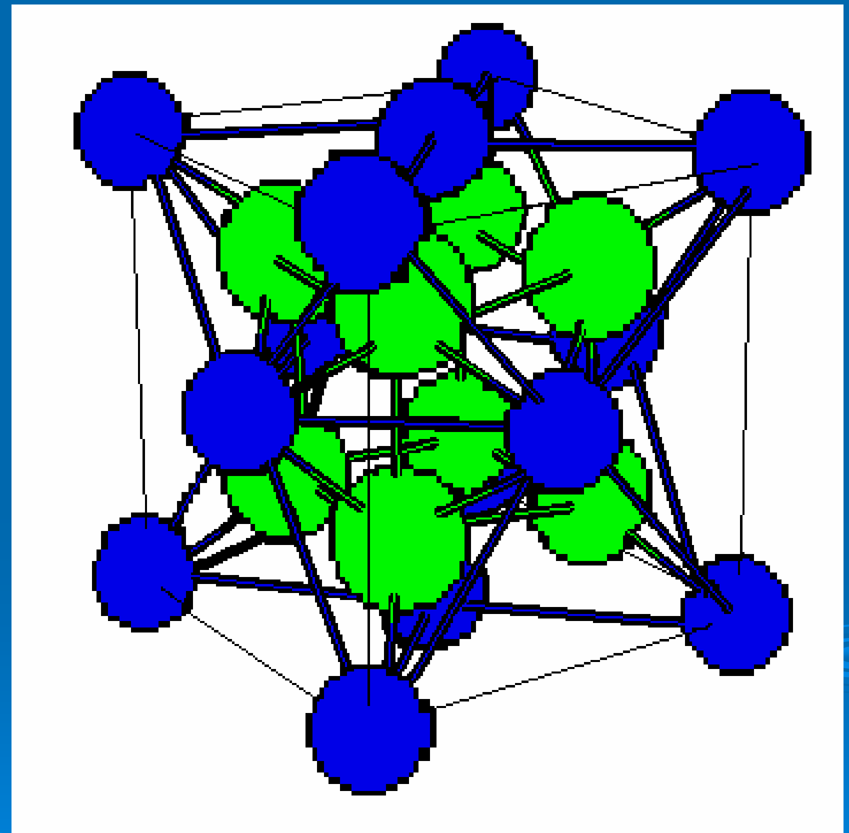
Images courtesy of http://www.weizmann.ac.il/surflab/peter/afmworks/.

Length Scale vs. RMS

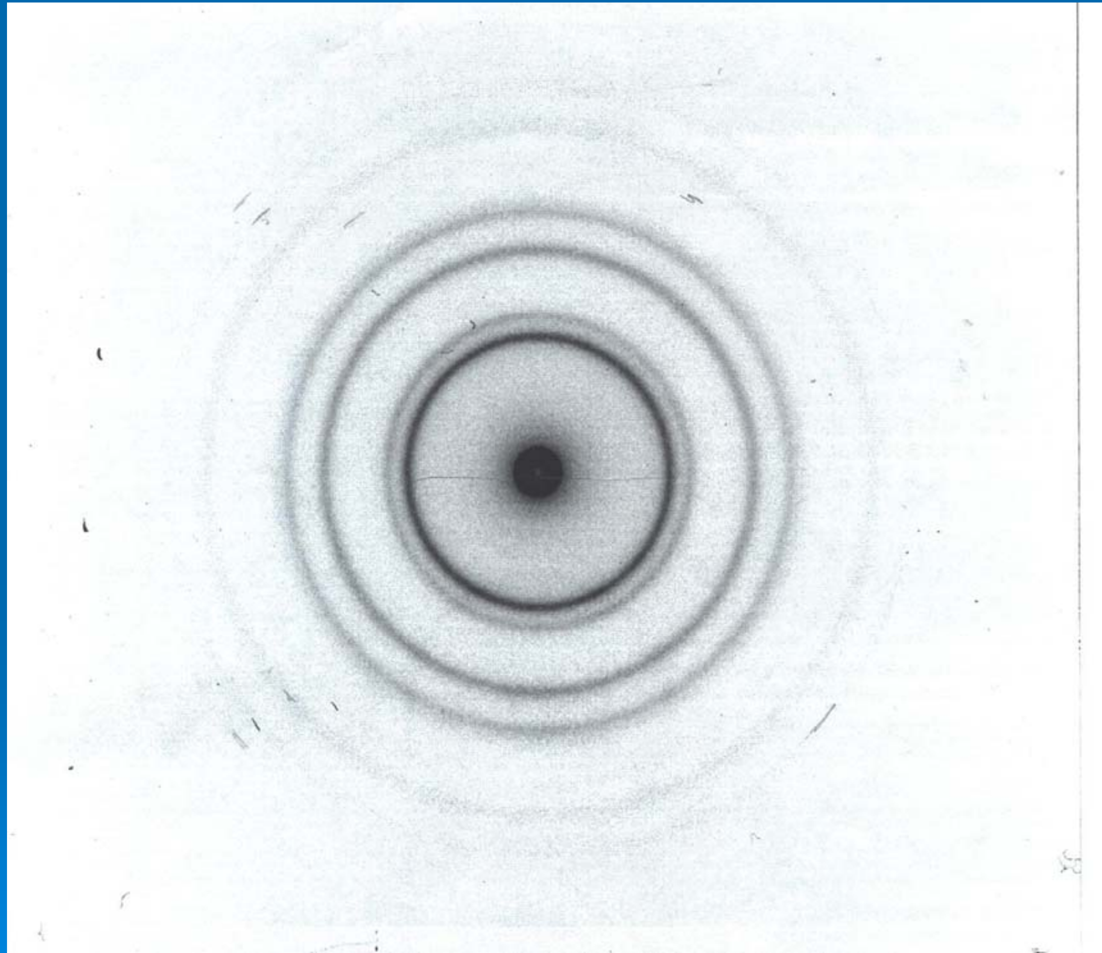


Transmission Electron Microscope (TEM)



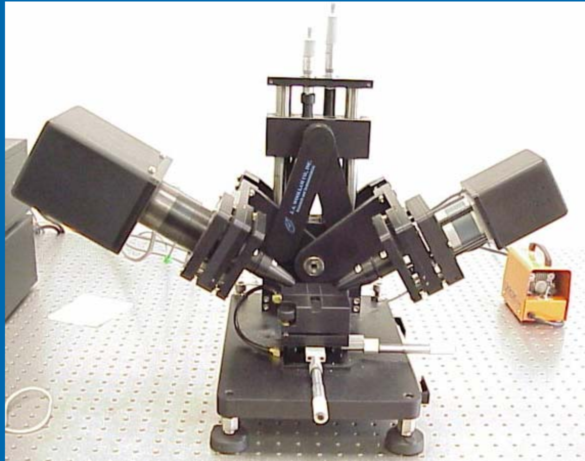


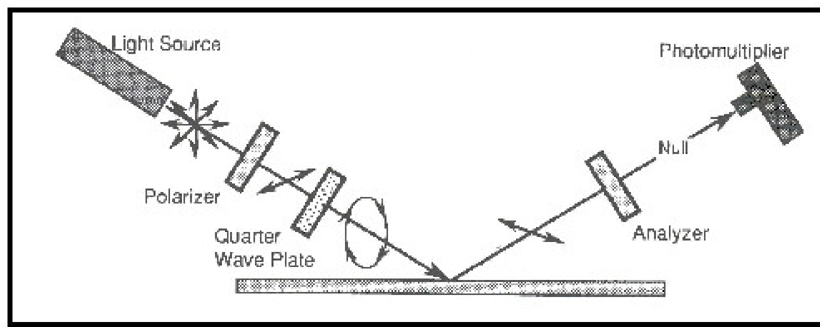
Transmission Electron Microscope (TEM)



SAMPLES	**UN002**	**UN003**	**UN004**
N_2 Pressure	>1e-4 torr	>1e-4 torr	~1e-5 torr
Suspected Phase	U_2N_3	U_2N_3	UN
Lattice Size			
Literature (Å)	5.34	5.34	4.89
XRD (Å)		5.0	4.0
TEM (Å)	5.46		4.98
Ratio (measured/lit)	1.022		1.018

Ellipsometry





- Optical constants are different for different polarizations of light
- If we know the substance and a model for the optical constants, we can find thickness and optical constants in UV

Images courtesy of http://www.swt.edu/~wg06/manuals/Gaertner117/ellipsometerHome.htm.

Finding Optical Constants

- Advanced Light Source at Berkeley
  - Light created by synchrotron
  - Measures reflectance at different angles and wavelengths

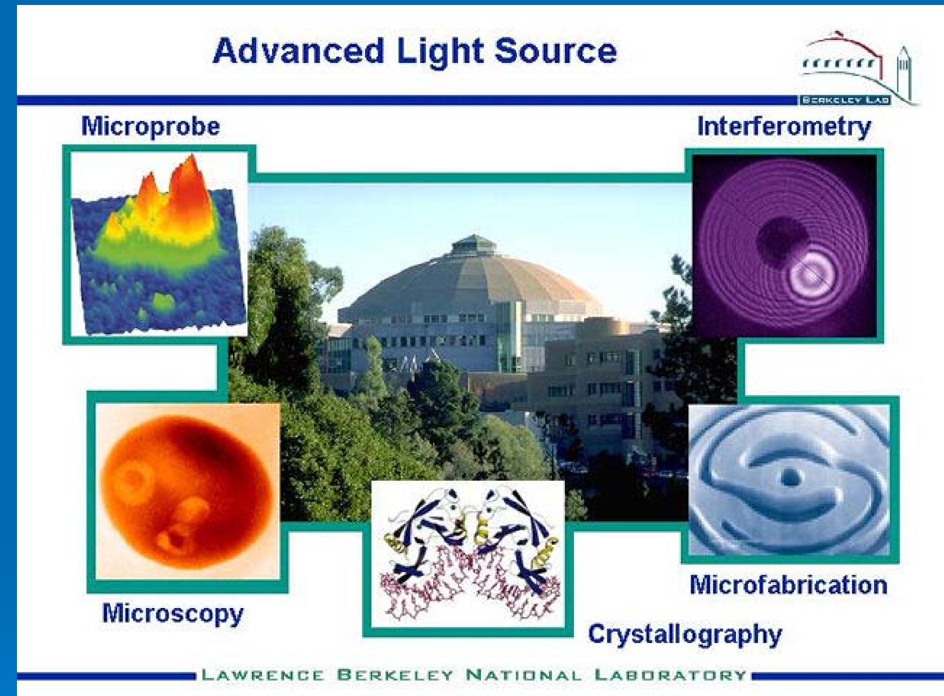
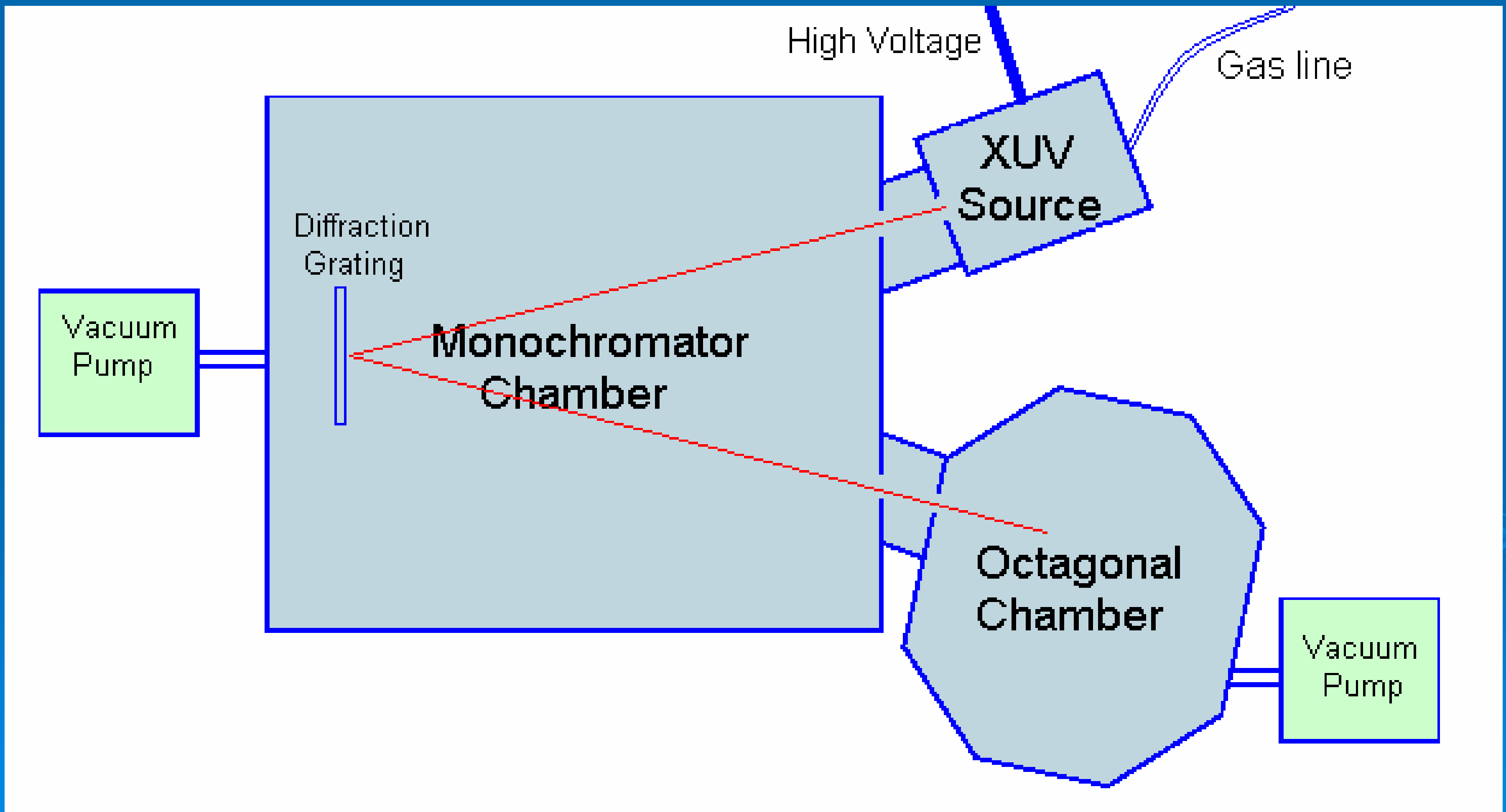


Image courtesy of http://www.lbl.gov/.

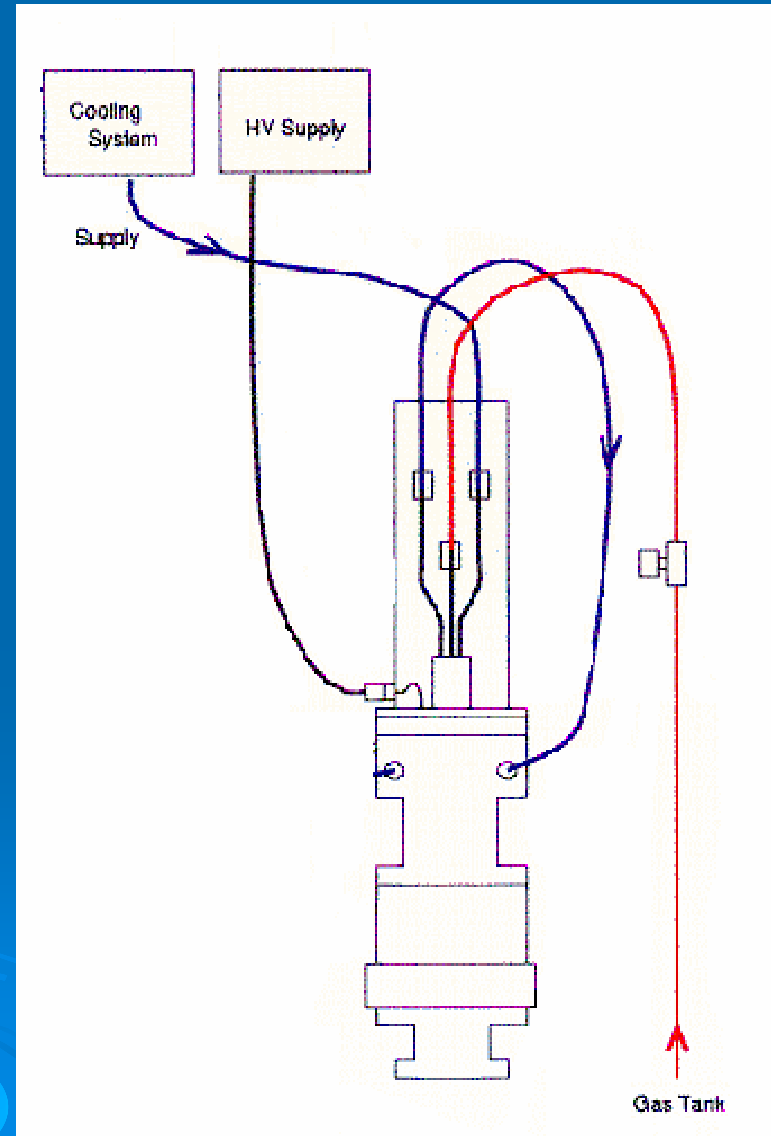
Reflectometer

- Reassembled and aligned



Hollow Cathode Light Source

- Plasma with H or He
- 700 V DC
- Spectral Lines from He
  - 304 Angstroms
    - 2p->1s
  - 584 Angstroms
    - $1s2p \rightarrow 1s^2$
- Found leaks
- Replace plexi-glass



Reflectometer

- Replaced CEM
- Purchased stages and stepper motors

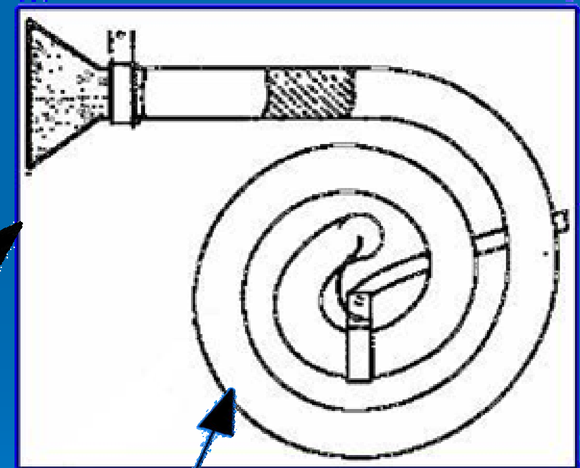
Stage

Pinhole

θ

2θ

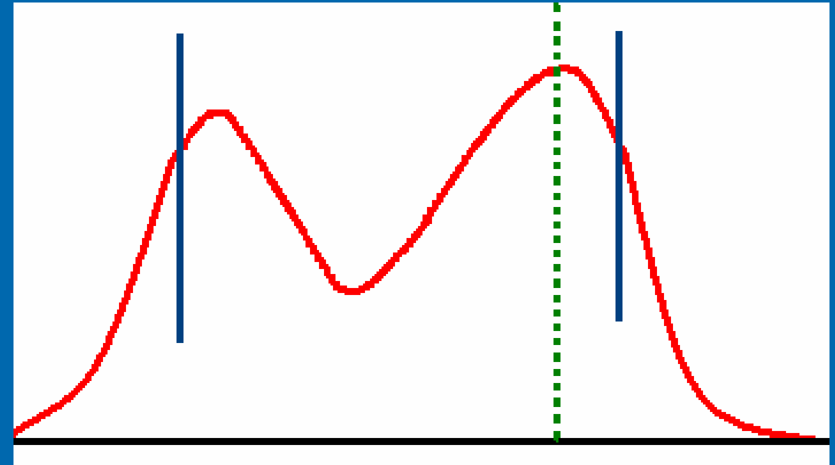
Channeltron
Photon
Detector

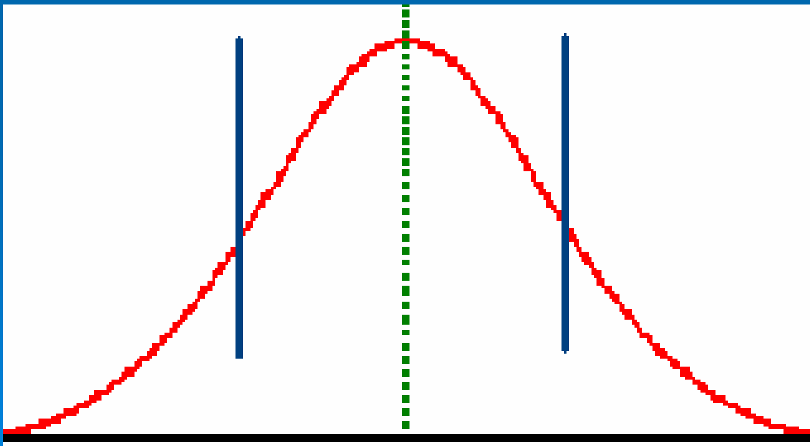


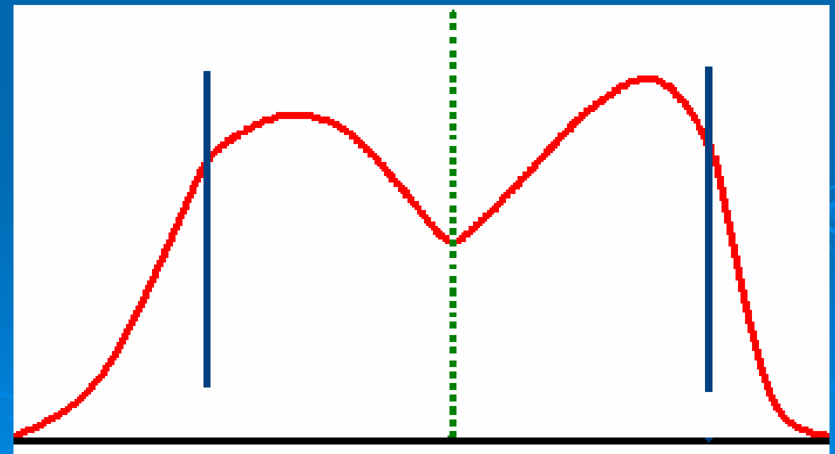
Electron
Multiplier
Tube

Reflectometer

- Lab VIEW Program for Centering Detector
  - Assumed a Gaussian
  - Theta/2*theta misalignment







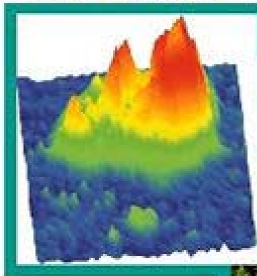
Reflectometer

- Other Improvements
  - Circuit diagrams
  - SOP's
- Still working
  - Fixing virus problems

On to Berkeley!

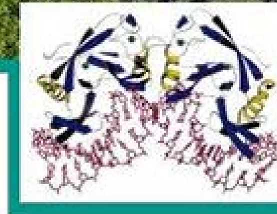
Advanced Light Source

Microprobe



Interferometry

Microscopy

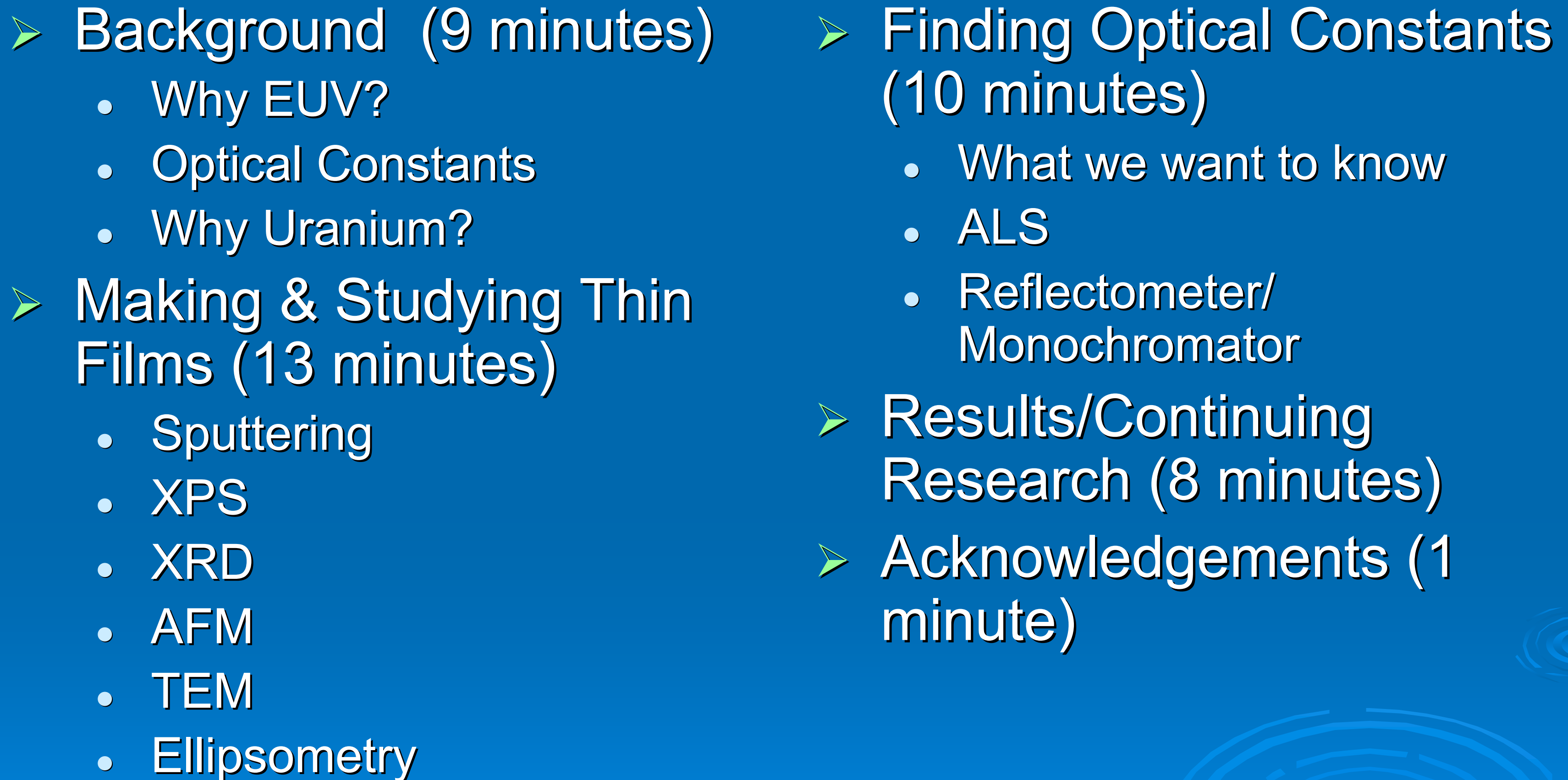


Crystallography

Microfabrication

LAWRENCE BERKELEY NATIONAL LABORATORY

Outline



To Do

- Learn about light source (internet)
- Ellipsometry stuff (Dr. Allred)
- Update “Problem!!” and data slides (Dr. Allred)

IMD

- Written by David Wendt
- Computes reflectivities of materials based on their optical constants
- We used UO model because of similar densities
- (Insert graph here)

Problem!!

- Our samples change with time.
  - The peaks seen in XRD move.
- Continuing research in this area.