Surface Analysis

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1-31-2011 Surface.ppt

OUTLINE

Introduction
Scanning Electron Microscopy (SEM)
Transmission Electron Microscopy (TEM)
Atomic Force Microscopy (AFM)
Energy Dispersive Analysis of x-rays (EDAX)
Auger Electron Spectroscopy
X-ray Fluorescence Spectroscopy (XPS)
Secondary Ion Mass Spectroscopy (SIMS)
Capacitance Voltage Measurements
Surface Charge Analyzer

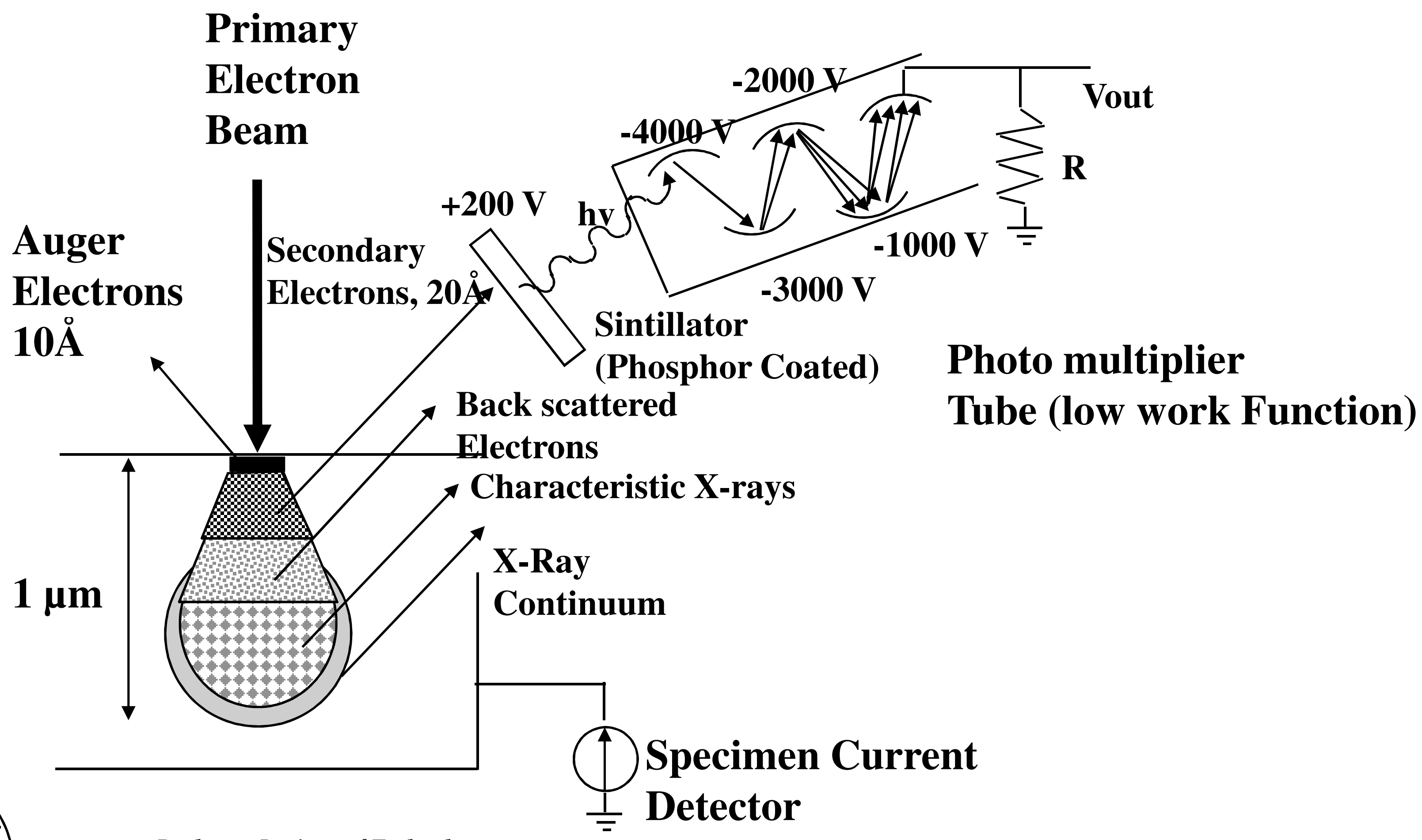
INTRODUCTION

Surface analysis refers to a collection of techniques to get information about the chemical or physical nature of a surface. (few µm)

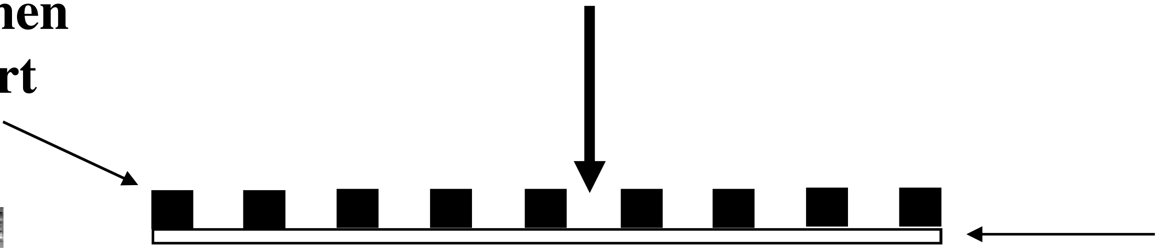
LEO EVO 50

AMRAY 1830 1 & 2

SCANNING ELECTRON MICROSCOPE (SEM)



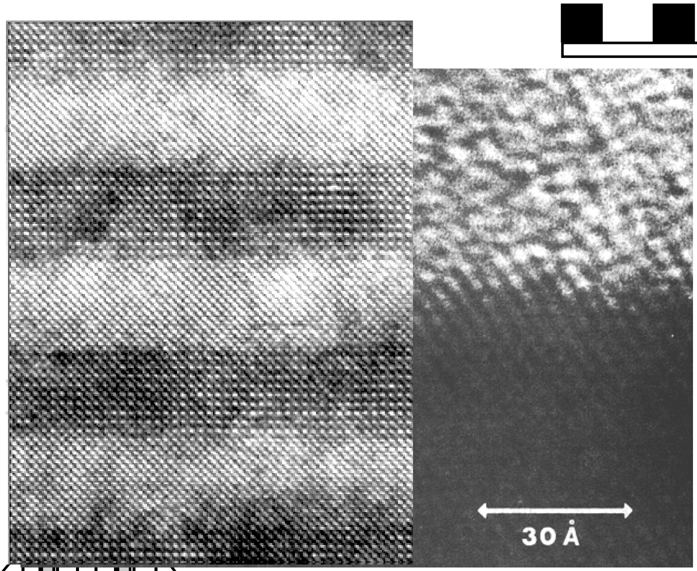
TRANSMISSION ELECTRON MICROSCOPE

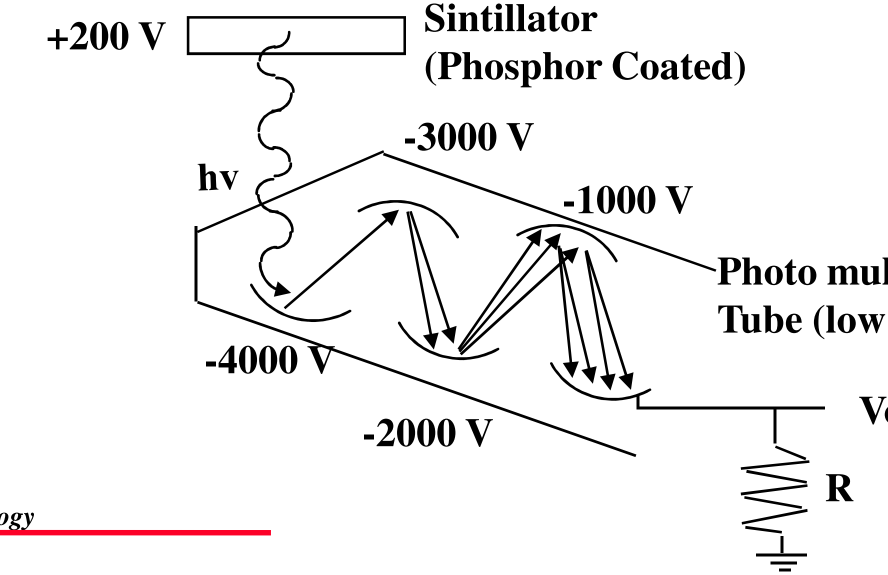


Primary Electron Beam

Specimen Support Grid

Very Thin Specimen < 1 µm





+200 V

Sintillator (Phosphor Coated)

hv

-3000 V

-1000 V

Photo multiplier Tube (low work Function)

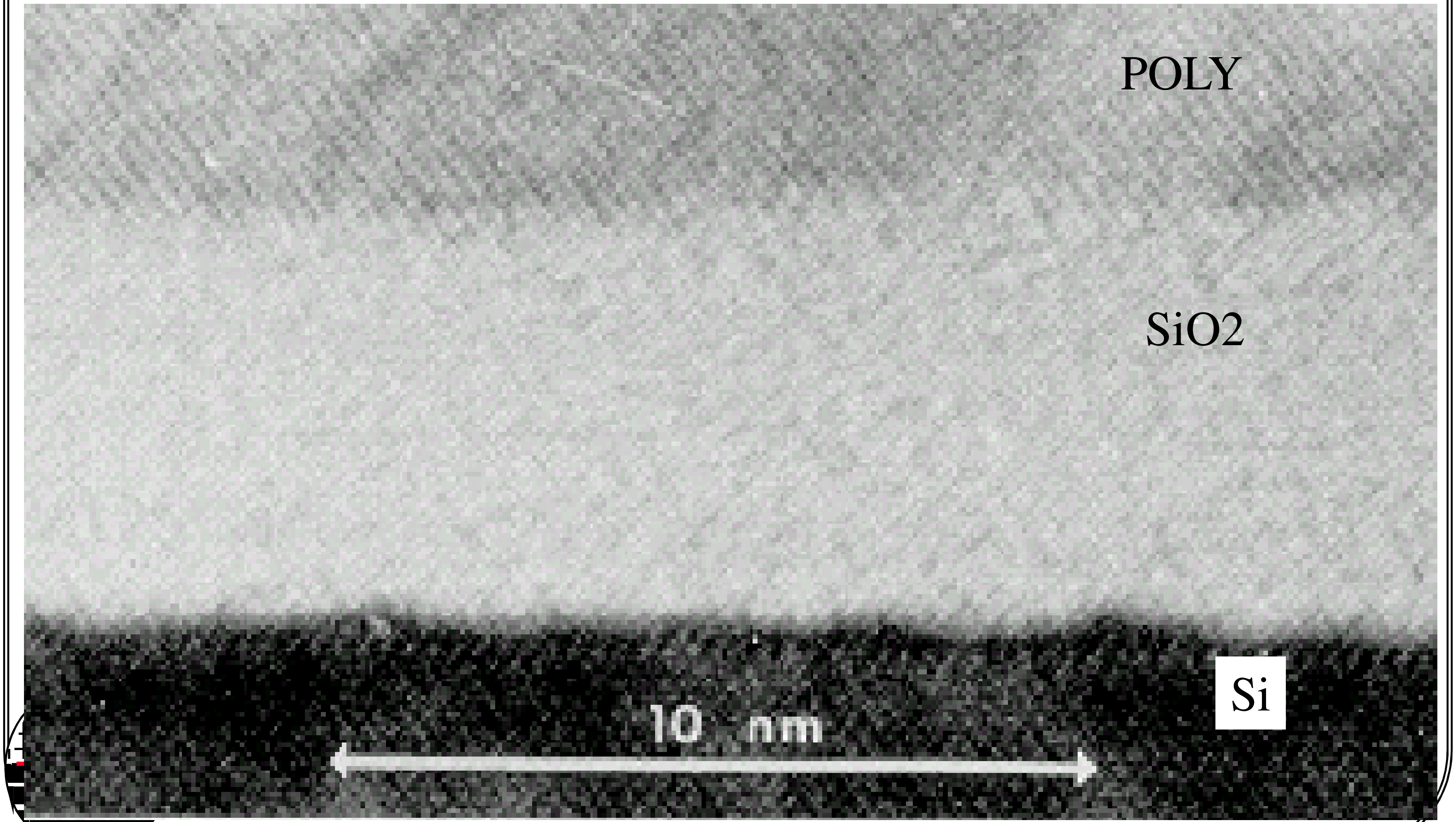
-4000 V

-2000 V

Vout

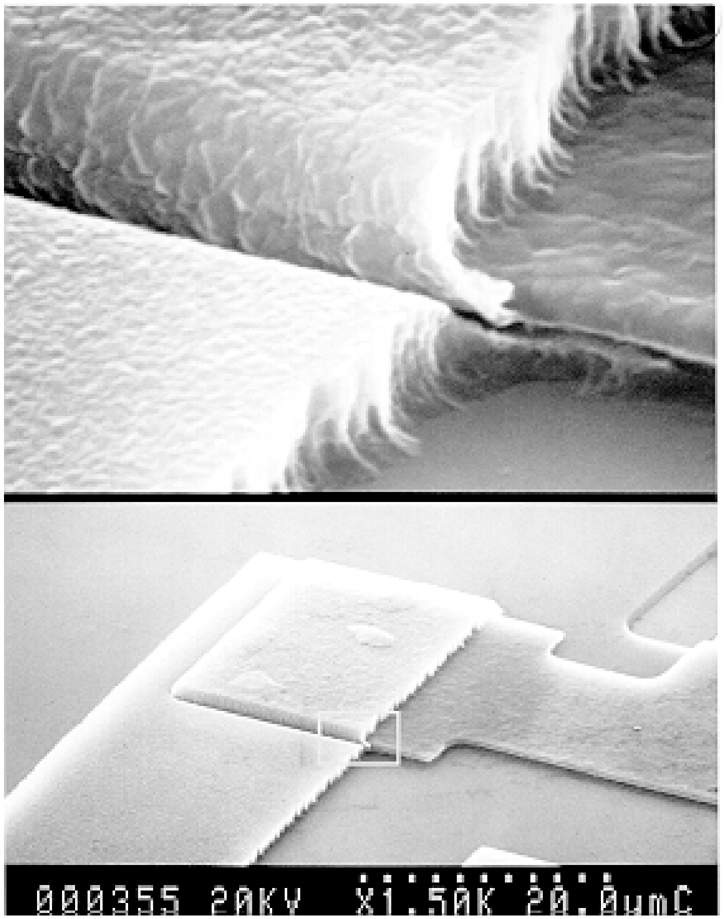
R

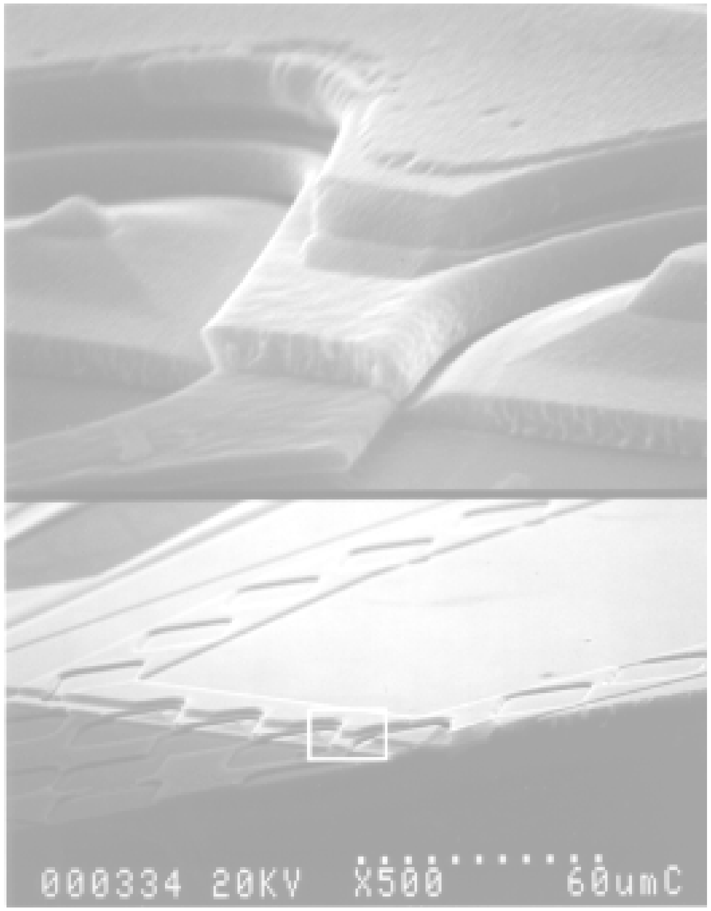
TEM OF MOS STRUCTURE



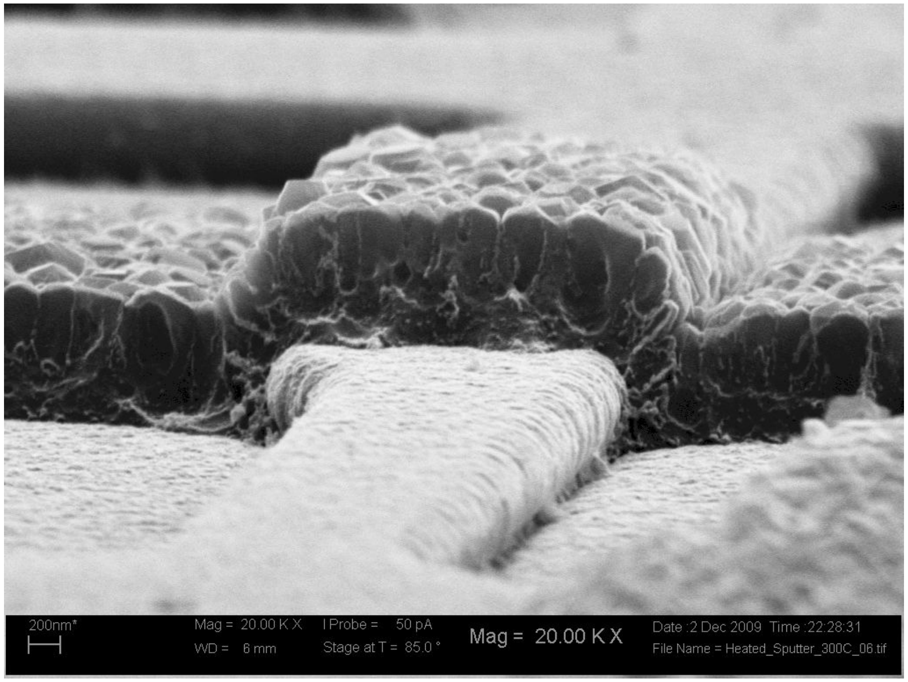
LEO EVO 50 SEM & EDAX

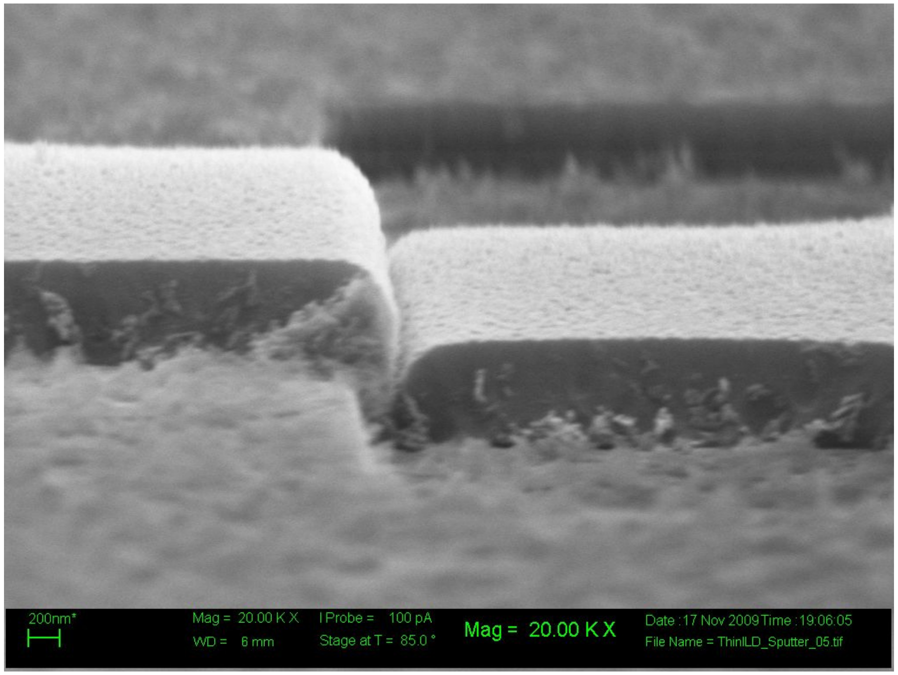
SEM EXAMPLES



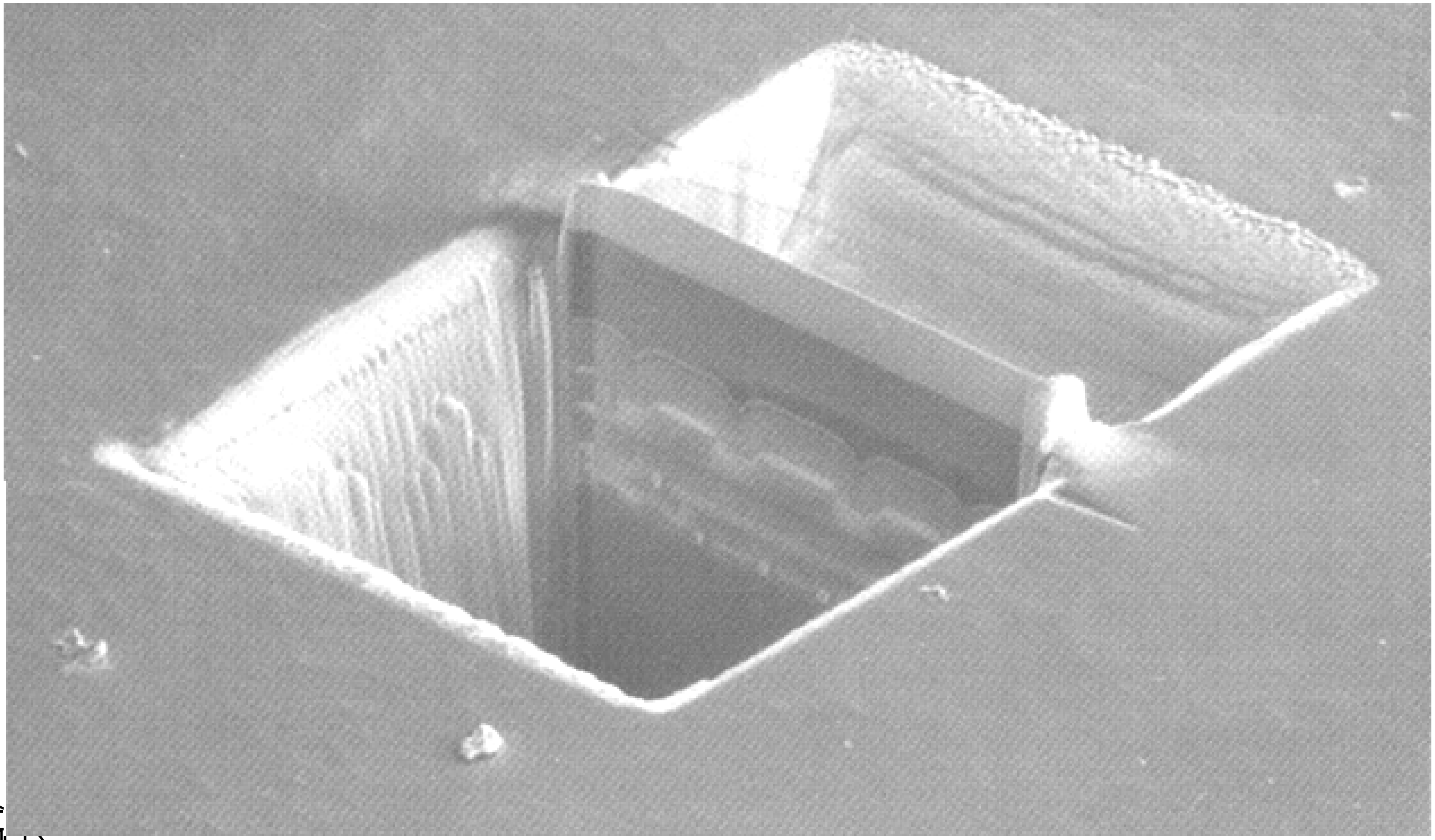


SEM EXAMPLES

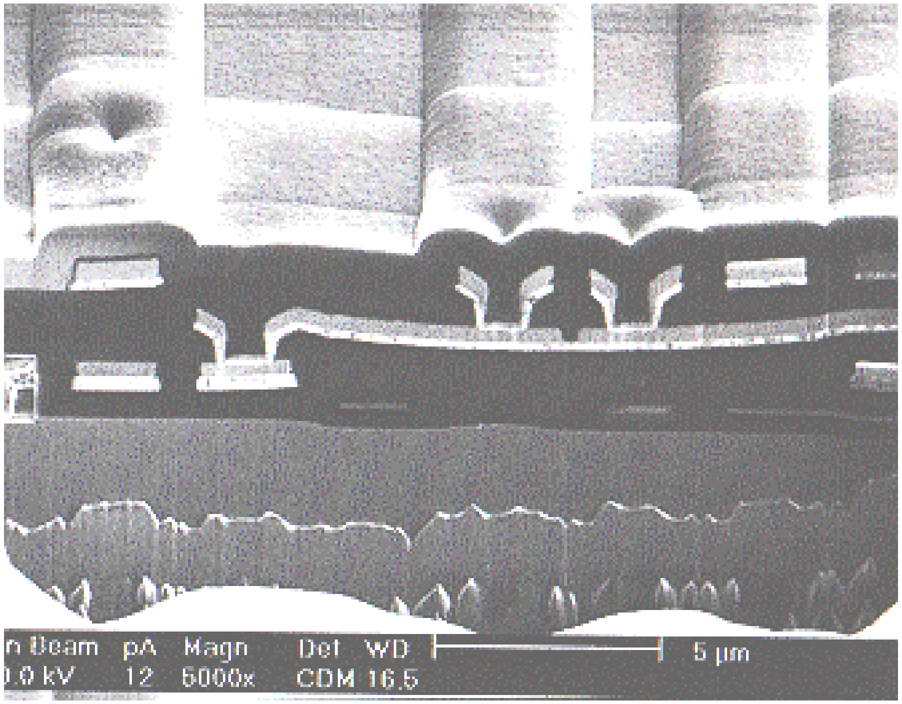


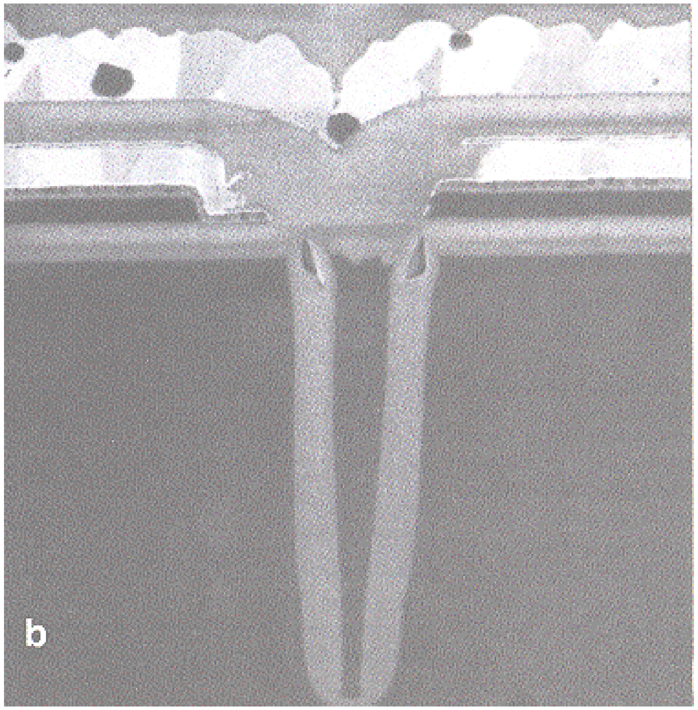


SEM WITH FOCUSED ION BEAM (FIB)



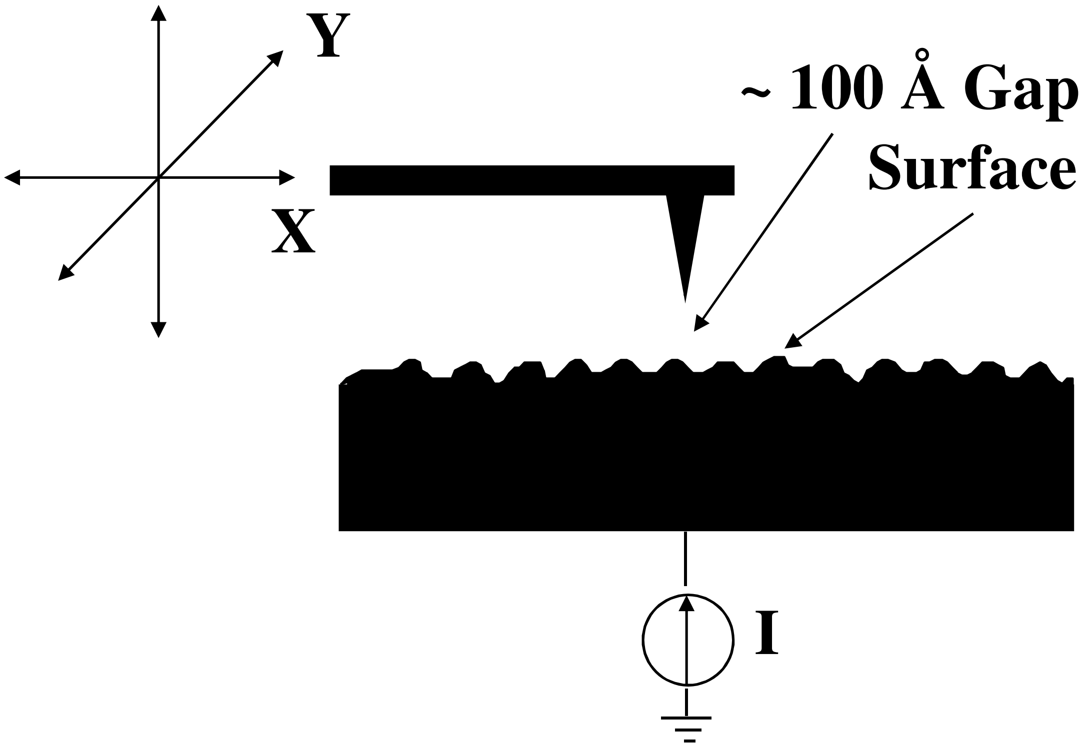
SEM WITH FOCUSED ION BEAM (FIB)

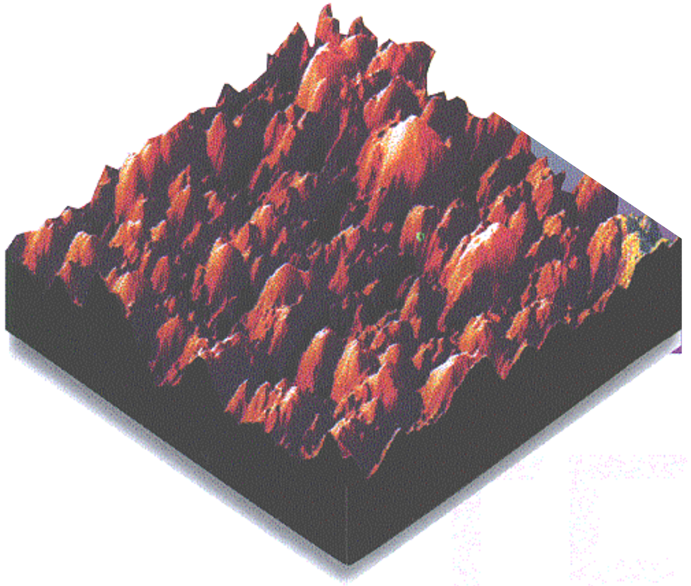




FIB allows crossection SEM images to be made at any point by cutting a trench with a focused beam of argon ions.

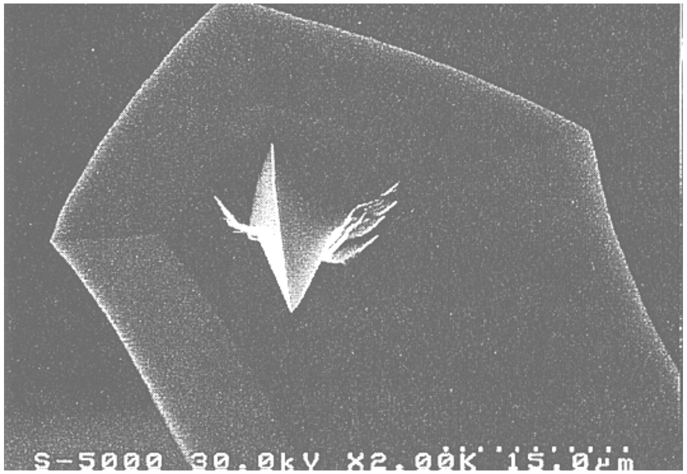
SCANNING TUNNELING MICROSCOPE (STM)

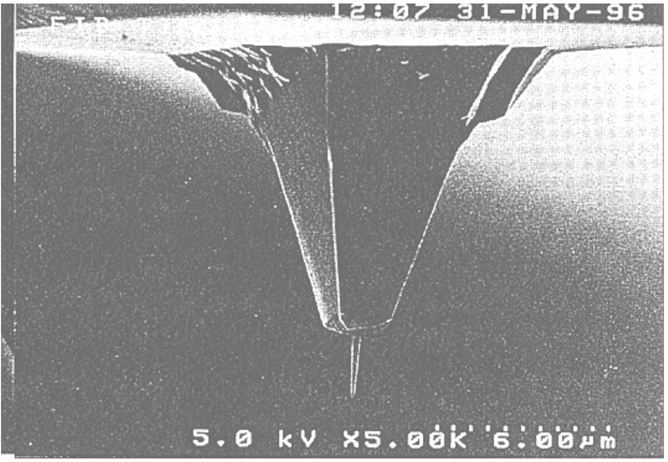


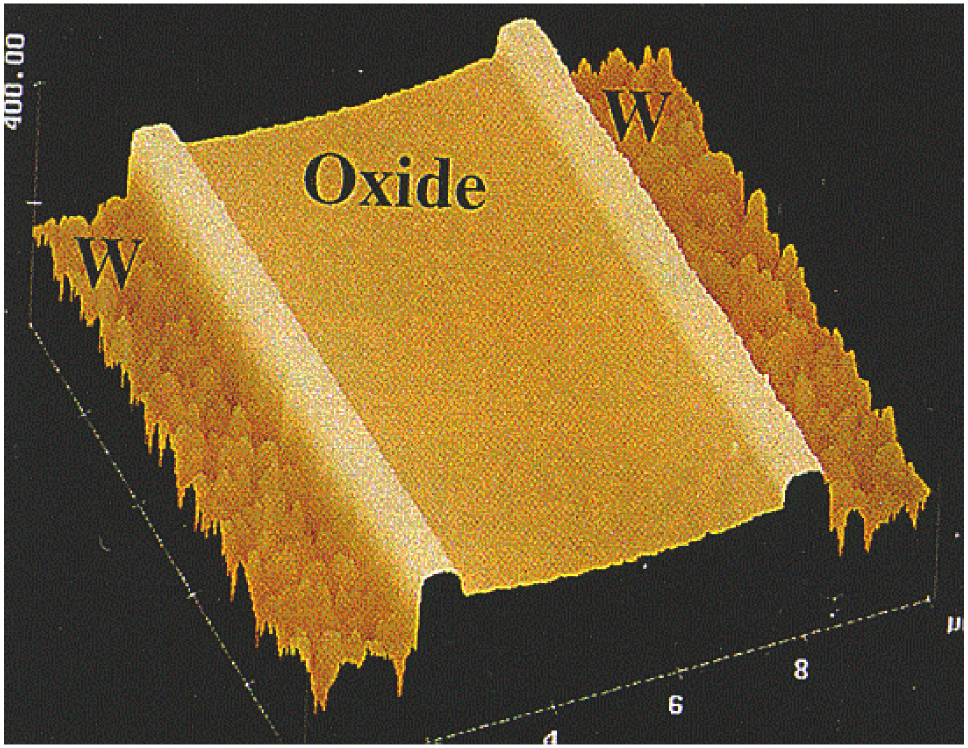


Piezoelectric Motors Scan Tip in X and Y, Electronics control Z such that the Tunneling Current I is Constant. The Control Voltage for Z is a Measure of Surface Topology

ATOMIC FORCE MICROSCOPE (AFM)

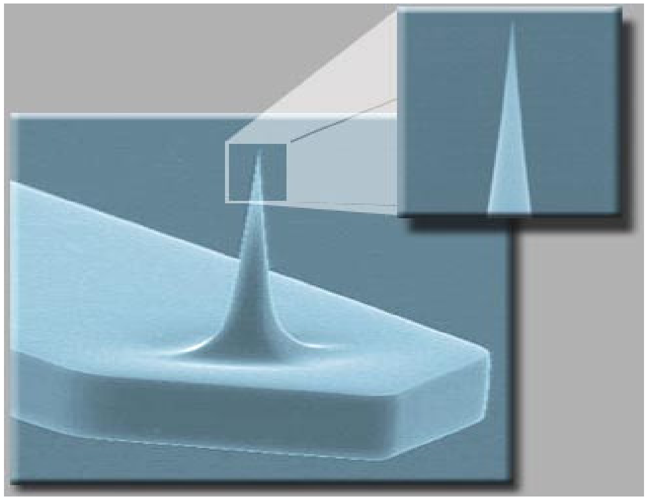


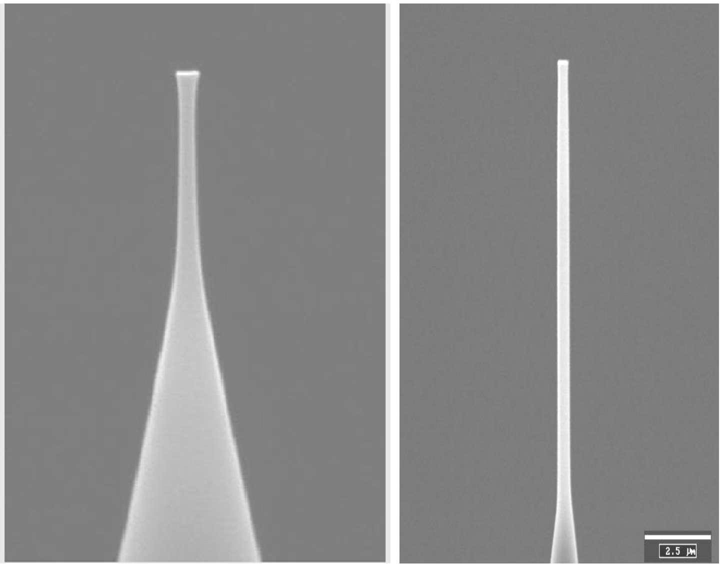




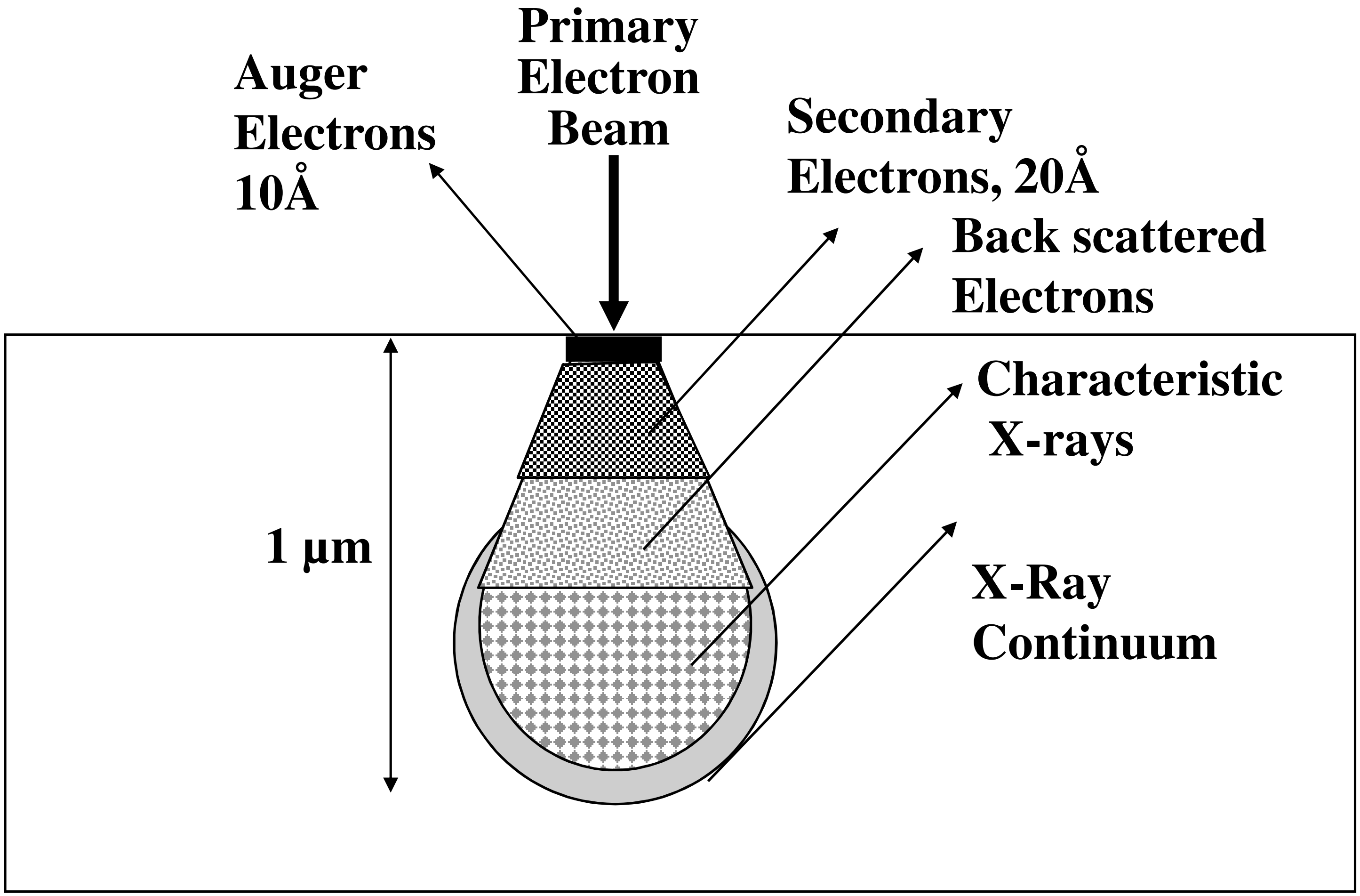
ATOMIC FORCE MICROSCOPE (AFM)

- **Standard**
  - Sharp Apex
  - Slender
  - Long
  - Used in Contact mode
- **CD Mode (Conical and Flared)**
  - Flared tip able to measure undercut sidewalls
  - Used in non-contact mode

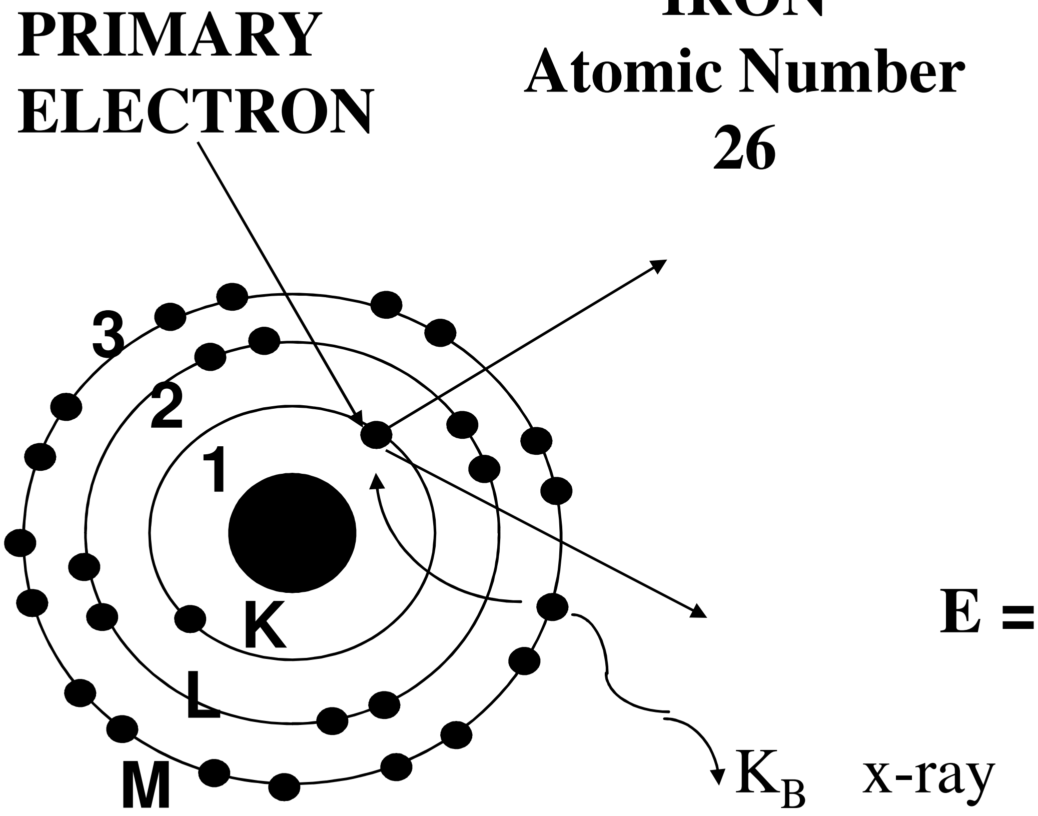




ENERGY DISPERSIVE ANALYSIS OF XRAYS (EDAX)



ENERGY DISPERSIVE ANALYSIS OF XRAYS (EDAX)



$E_n = -13.6\ Z^2/n^2$

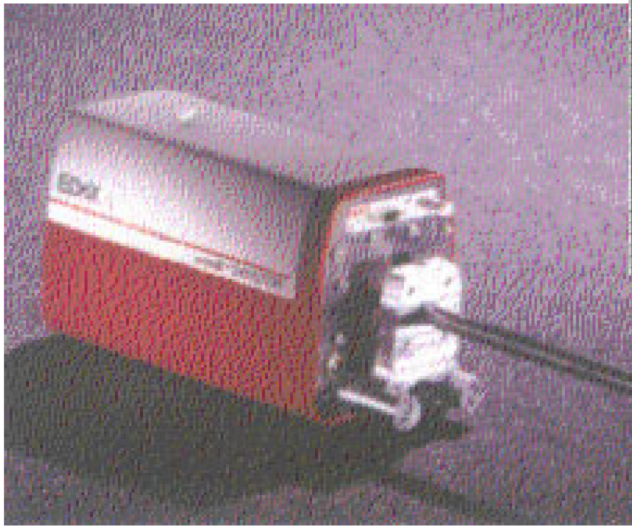
E1 = -9194 eV
E2 = -2298 eV
E3 = -1022 eV

$E = h\nu$ or $\lambda = hc/E$

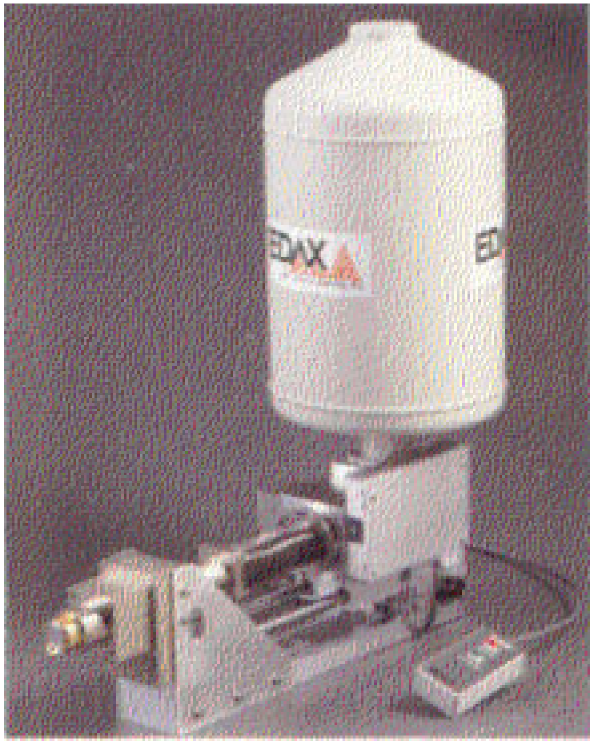
Notation: K x-rays are associated with transitions to 1st shell, L x-rays to the 2nd shell. α x-rays are between adjacent shells, B x-rays are two shells apart, etc.

EDAX

Crystal Detector

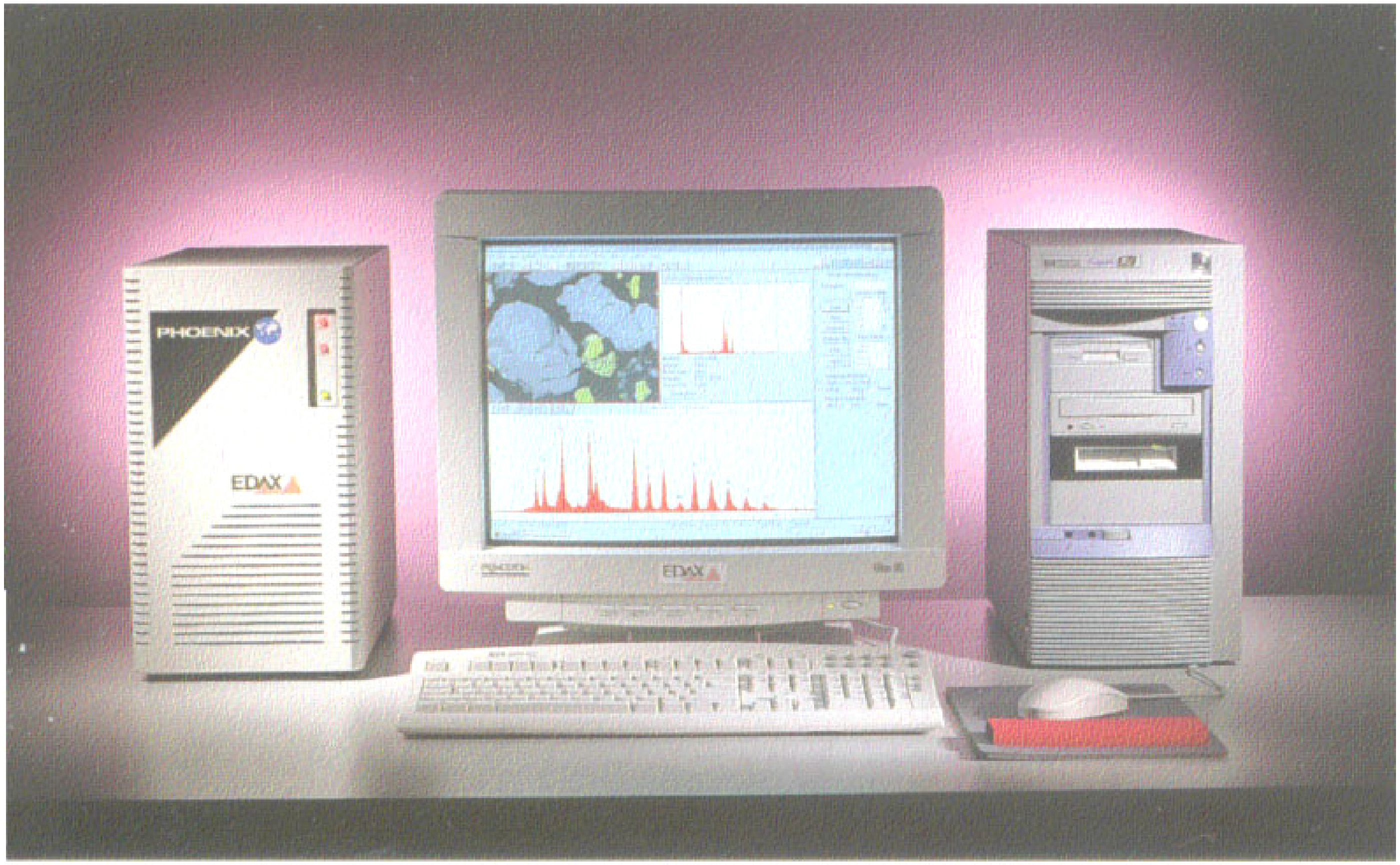


Cryogenic Semiconductor Detector



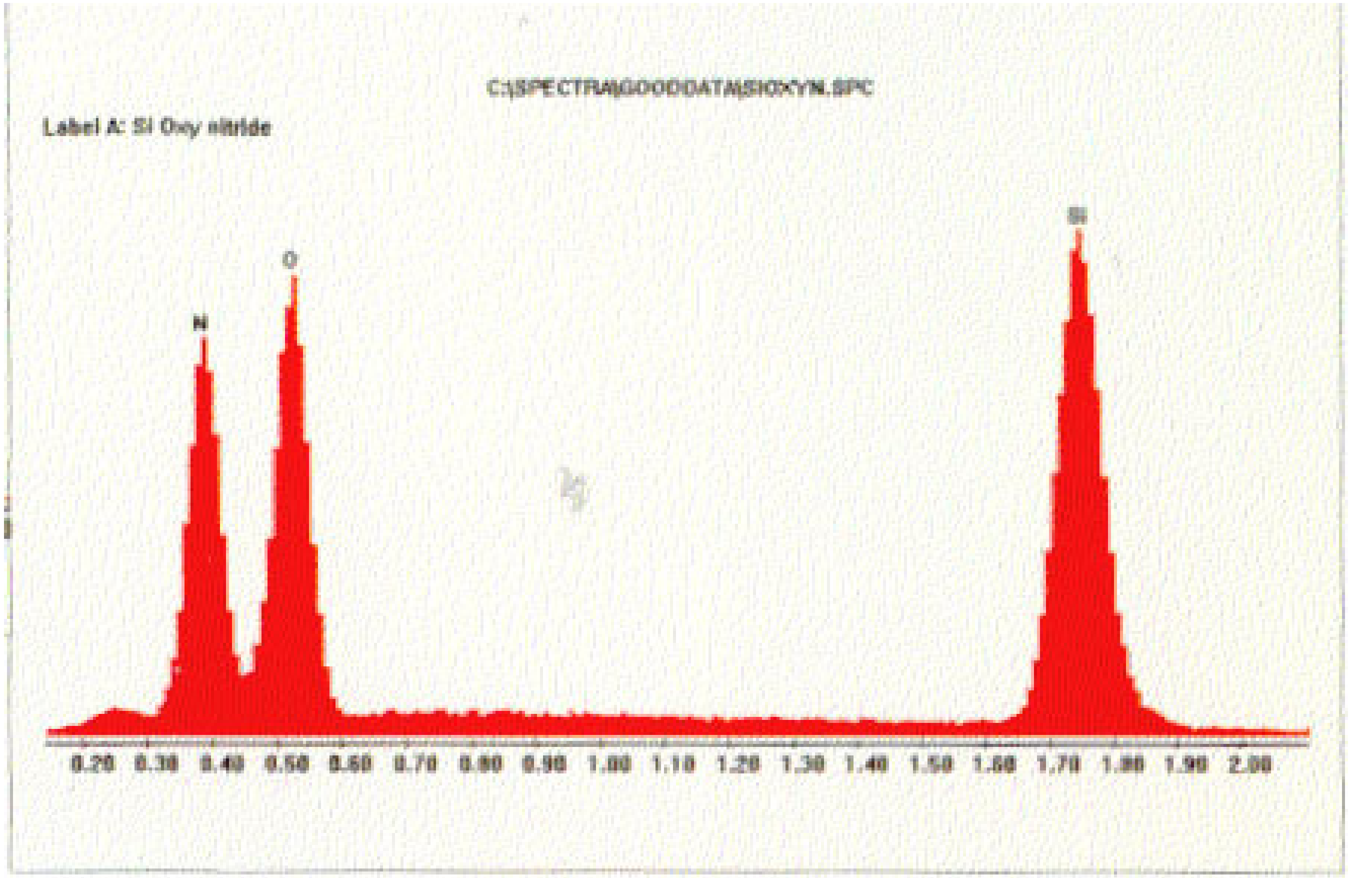
Liquid Nitrogen Cooled
Semiconductor Detecto

EDAX



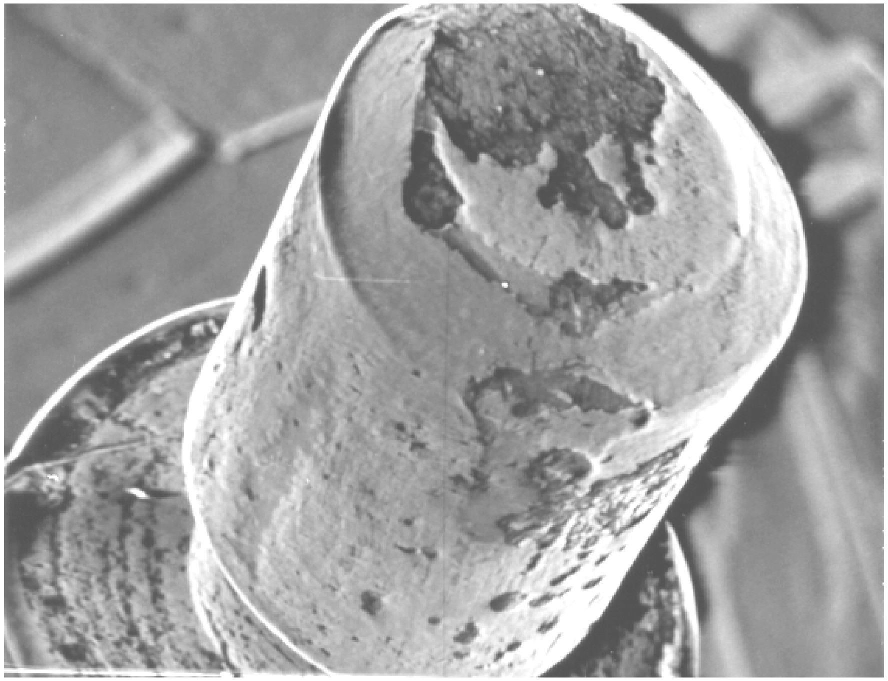
Phoenix microanalyzer including EDAM III acquisition electronics and PC.

EDAX

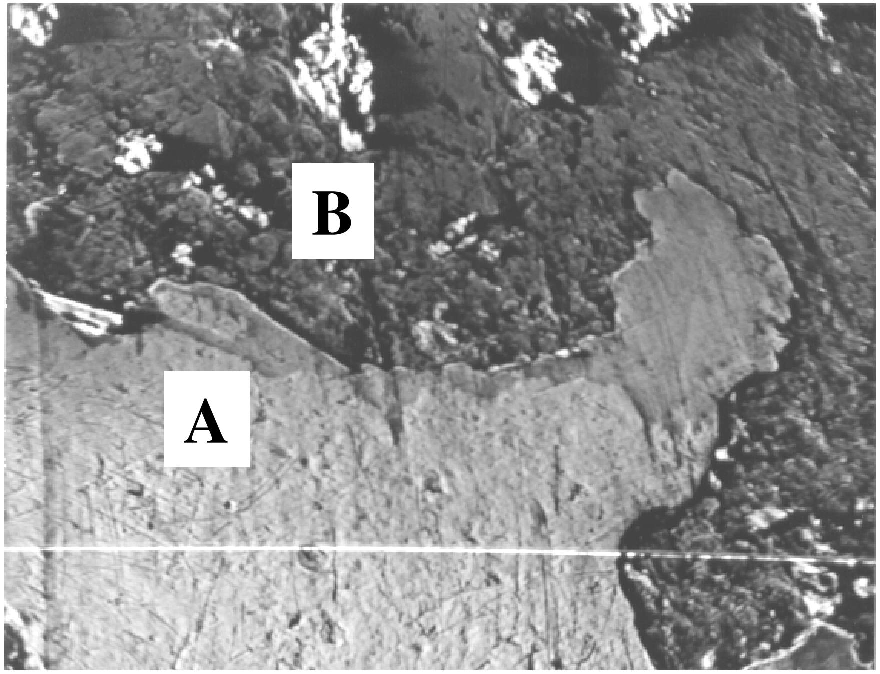


Spectrum of silicon oxynitride acquired at 5 kV.

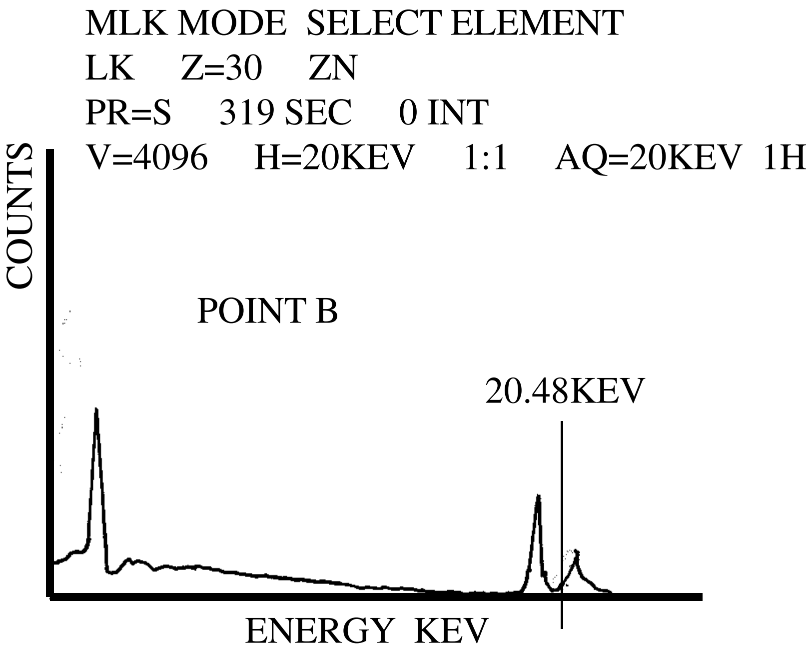
EDAX ANALYSIS OF FAILED RF PIN

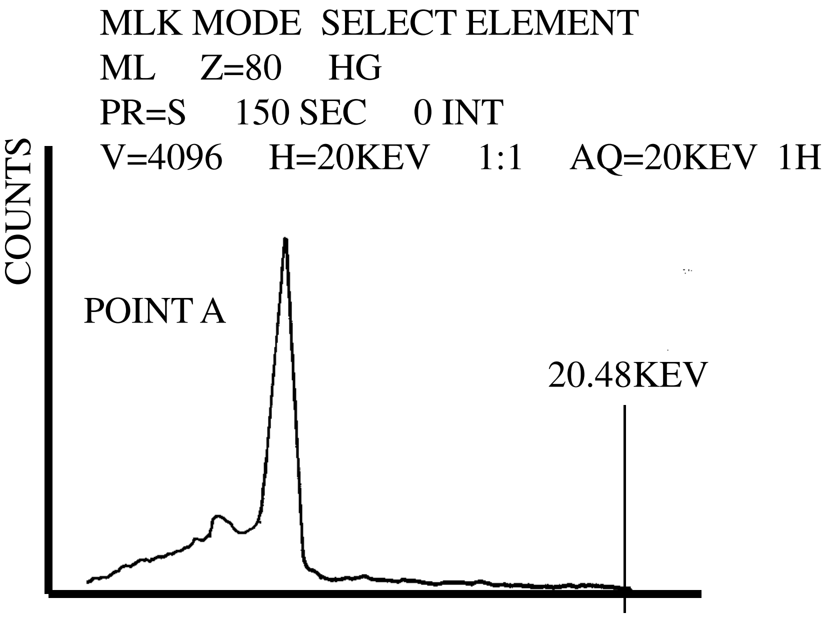


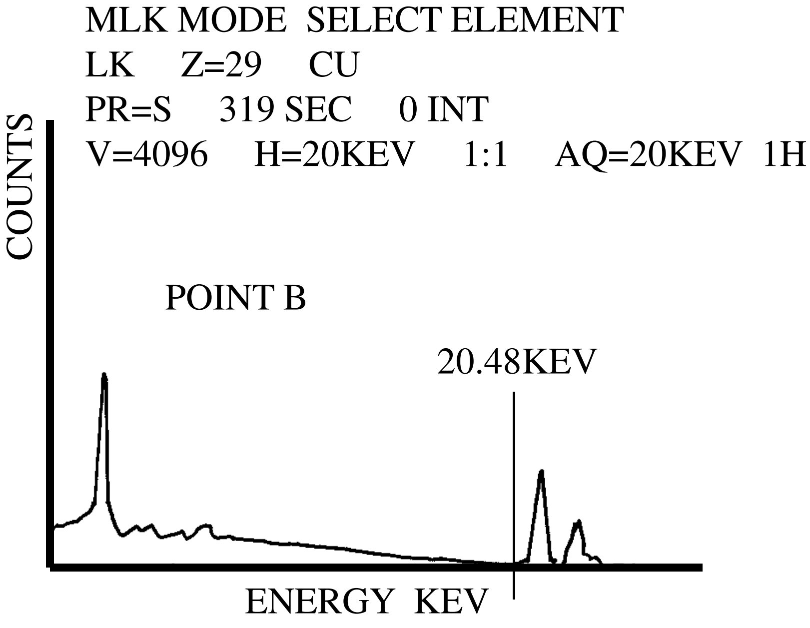
Failed RF Pin: 40X

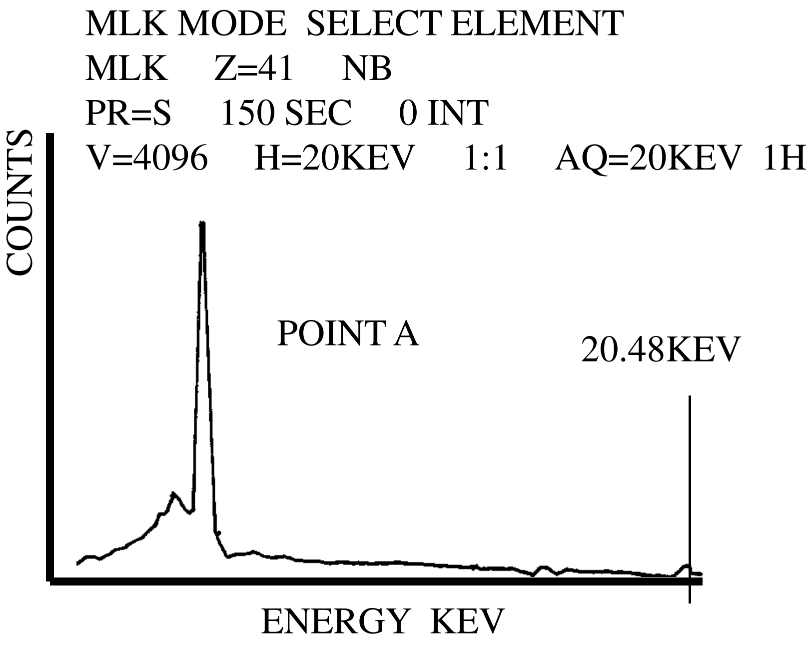


Failed RF Pin: 320X
Point A & B Analyzed using EDAX

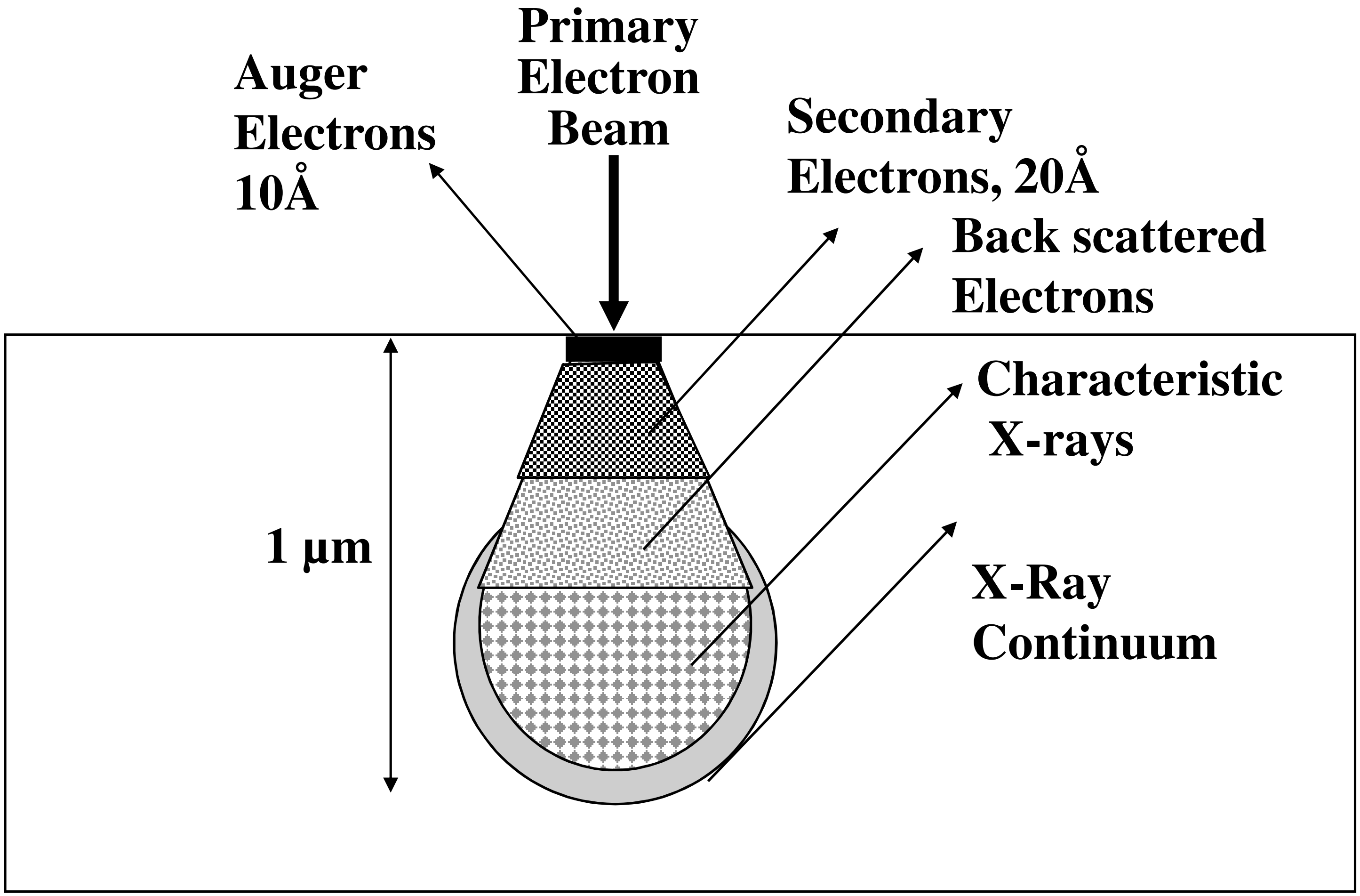

MLK MODE SELECT ELEMENT
LK Z=30 ZN
PR=S 319 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H
COUNTS
POINT B
20.48KEV
ENERGY KEV


MLK MODE SELECT ELEMENT
ML Z=80 HG
PR=S 150 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H
COUNTS
POINT A
20.48KEV
ENERGY KEV

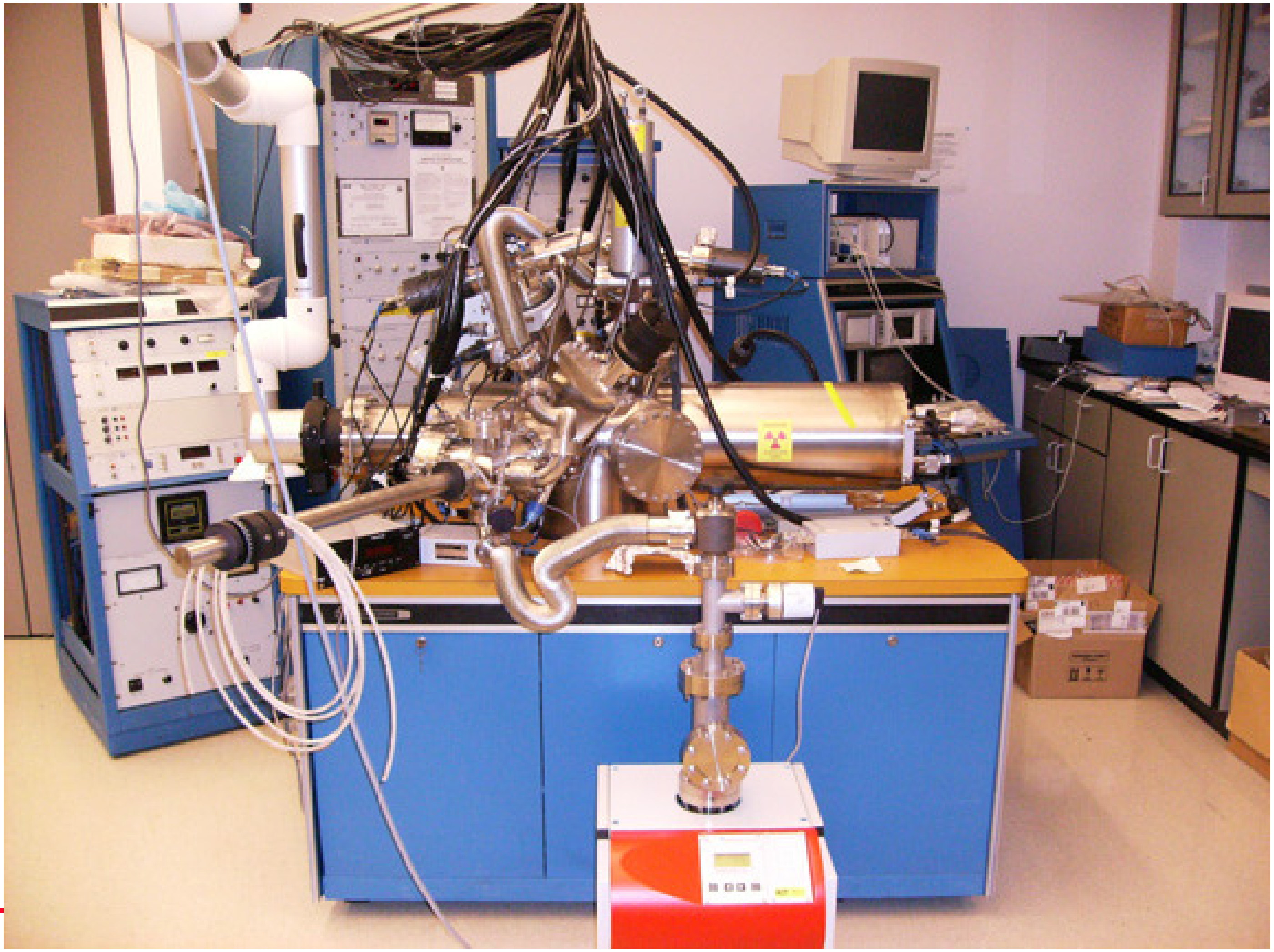

MLK MODE SELECT ELEMENT
LK Z=29 CU
PR=S 319 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H
COUNTS
POINT B
20.48KEV
ENERGY KEV


MLK MODE SELECT ELEMENT
MLK Z=41 NB
PR=S 150 SEC 0 INT
V=4096 H=20KEV 1:1 AQ=20KEV 1H
COUNTS
POINT A
20.48KEV
ENERGY KEV

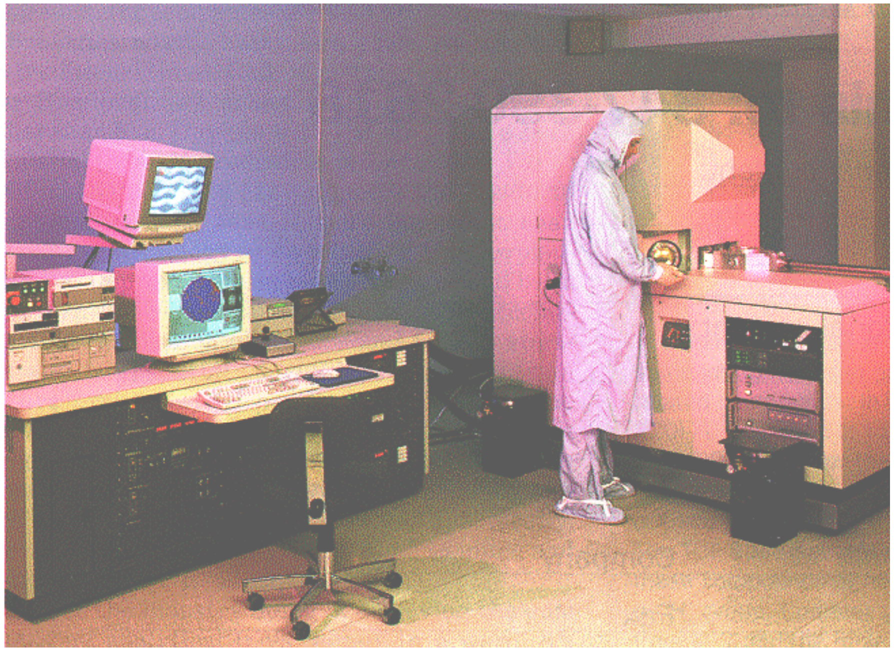
AUGER ELECTRON SPECTROSCOPY

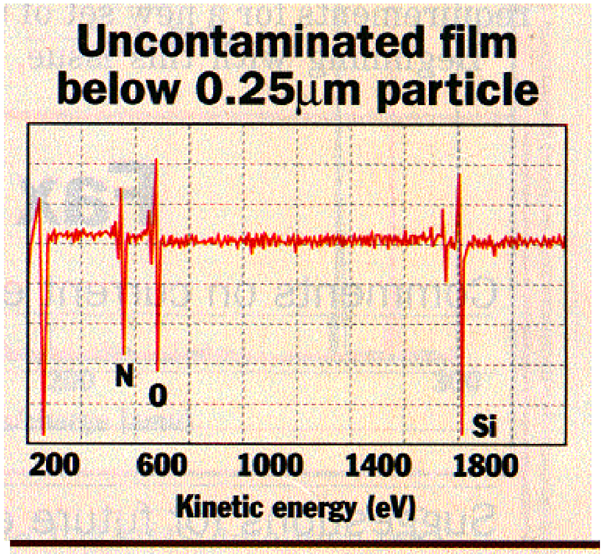


AUGER

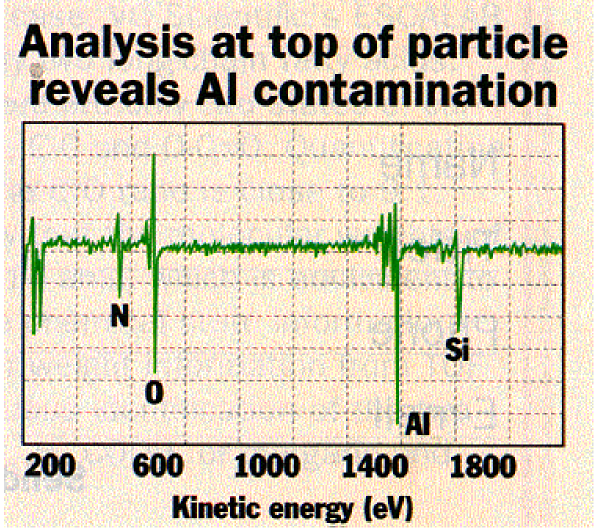


AUGER





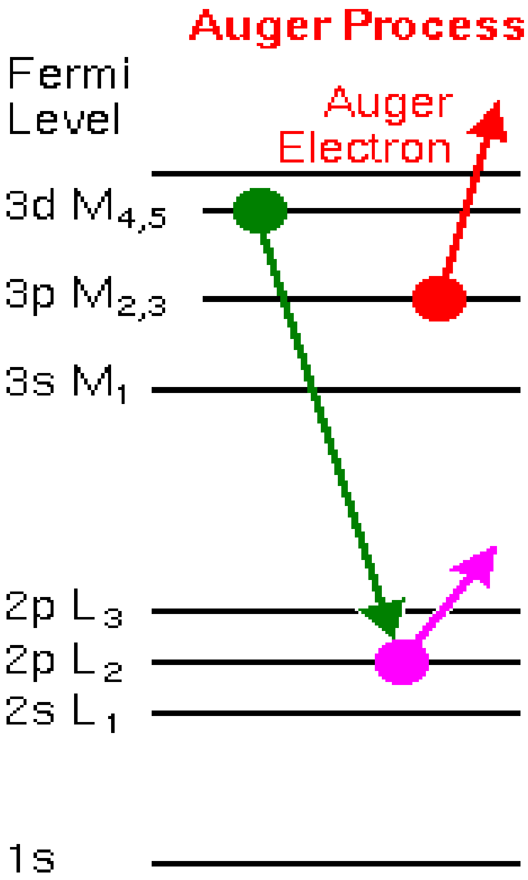
Uncontaminated film below 0.25µm particle



Analysis at top of particle reveals Al contamination

Auger analysis showed an aluminum particle contaminated the wafer.

AUGER

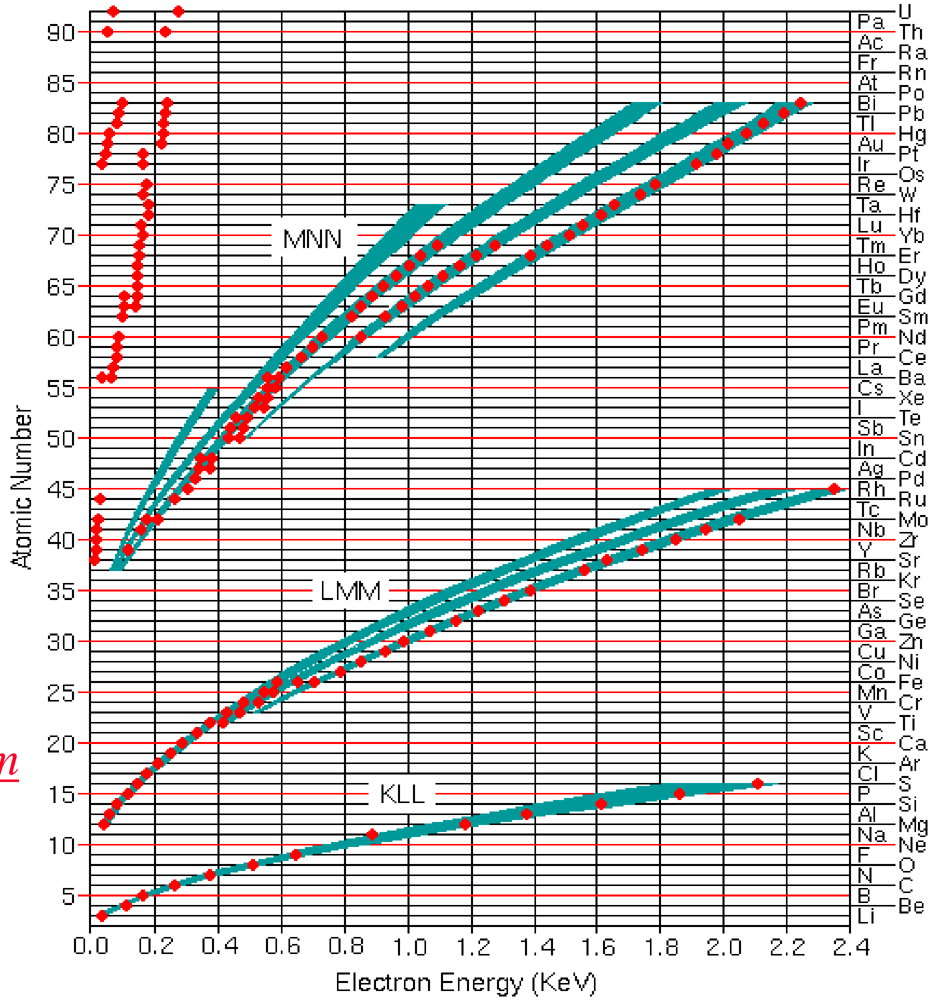


- **Simultaneous Process**
- **Ionization of Core Electron**
- **Upper level electron falls into lower energy state**
- **Energy release from second electron allows Auger electron to escape**
- **The illustrated LMM Auger electron energy is ~423 eV (EAuger = EL2 - EM4 - EM3)**

http://www.cea.com/cai/augtheo/process.htm

AUGER

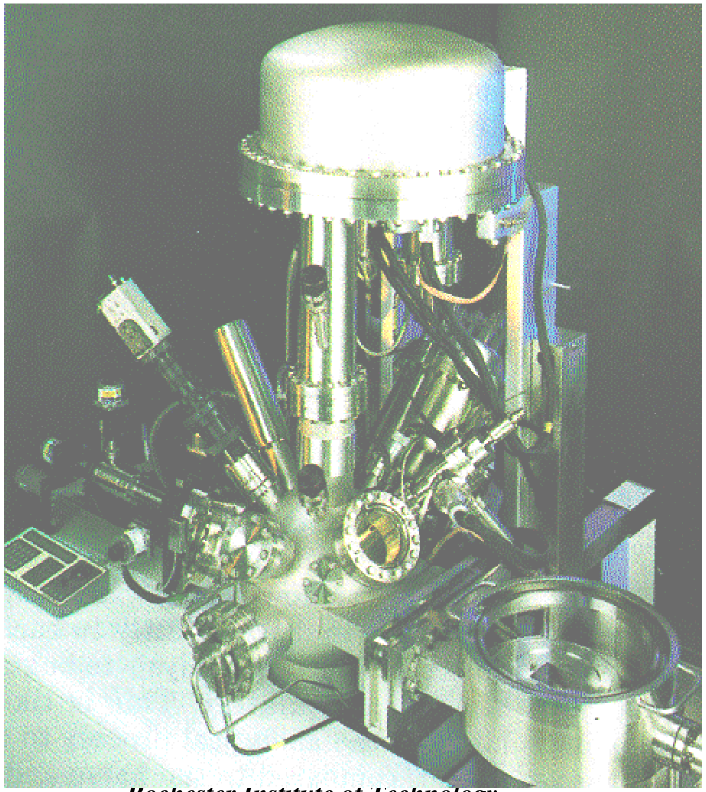
- **Chart of principal Auger electron energies**
- **Dots indicate electron energies for principal Auger peaks for each element**

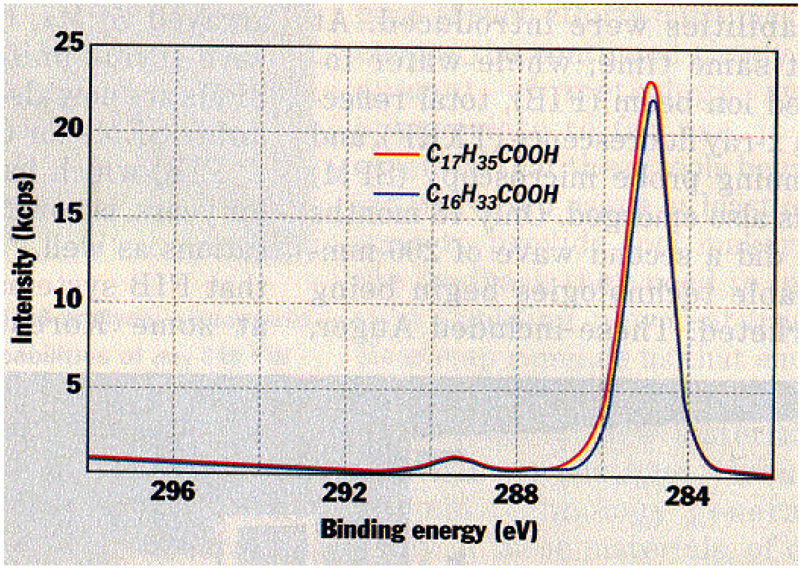


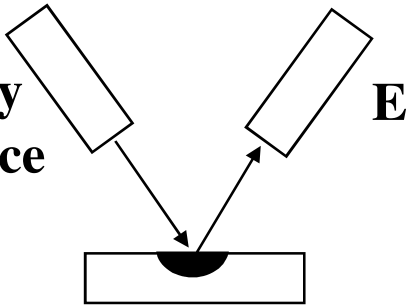
http://www.cea.com/cai/augtheo/energies.htm

ESCA or XPS

Electron Spectroscopy for Chemical Analysis (ESCA) or X-ray Photo Electron Spectroscopy (XPS)





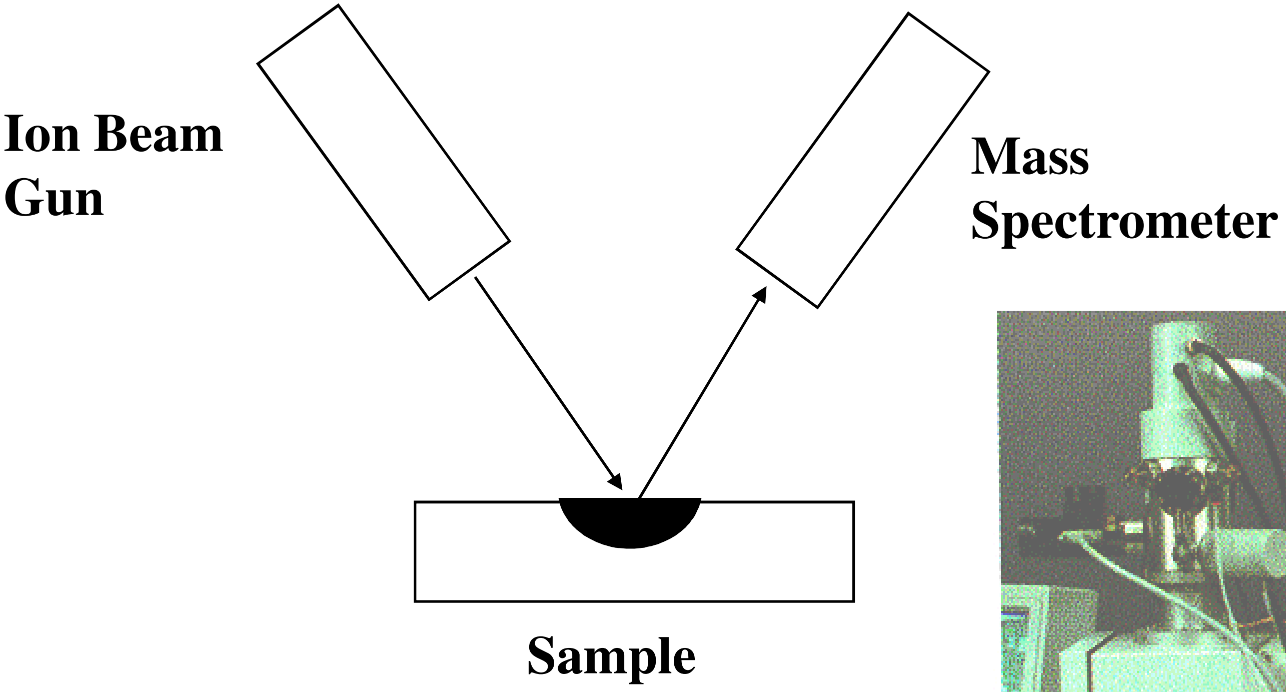


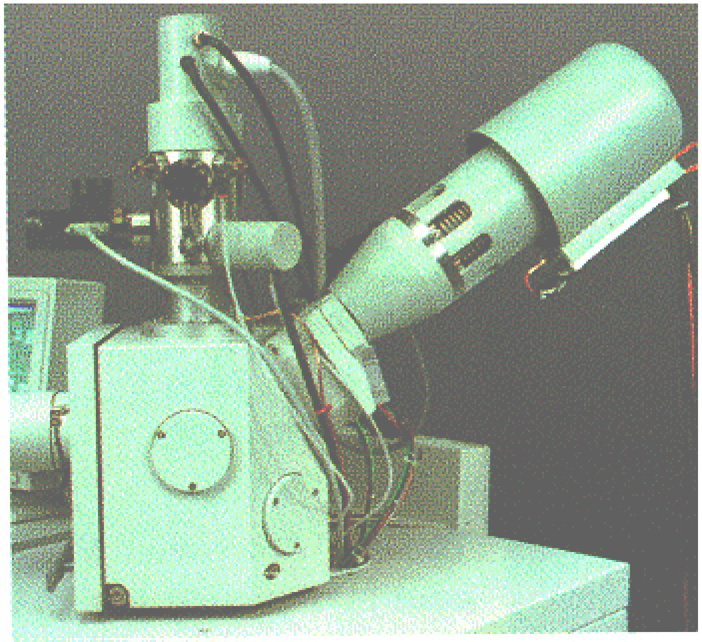
X-ray Source

Electrons

Sample

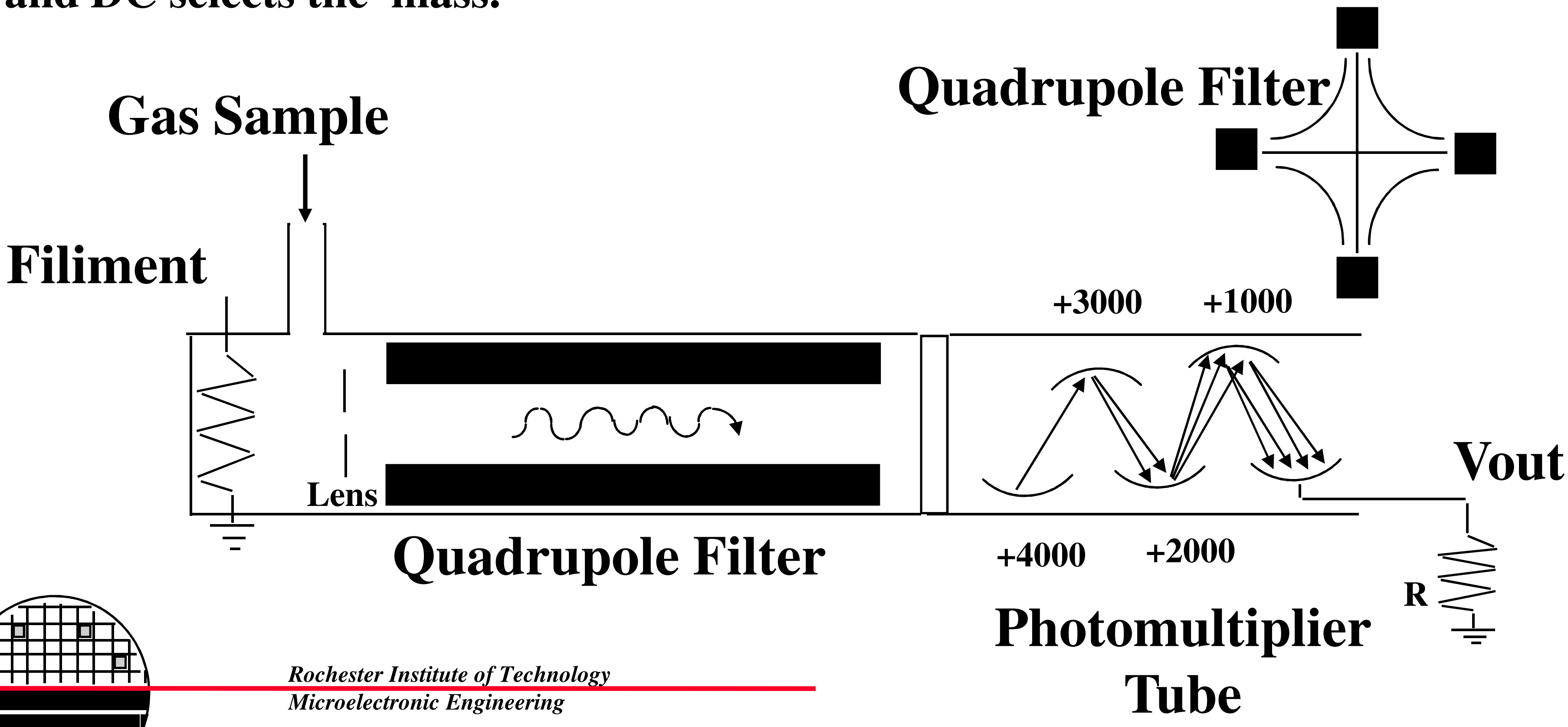
SECONDARY ION MASS SPECTROSCOPY (SIMS)



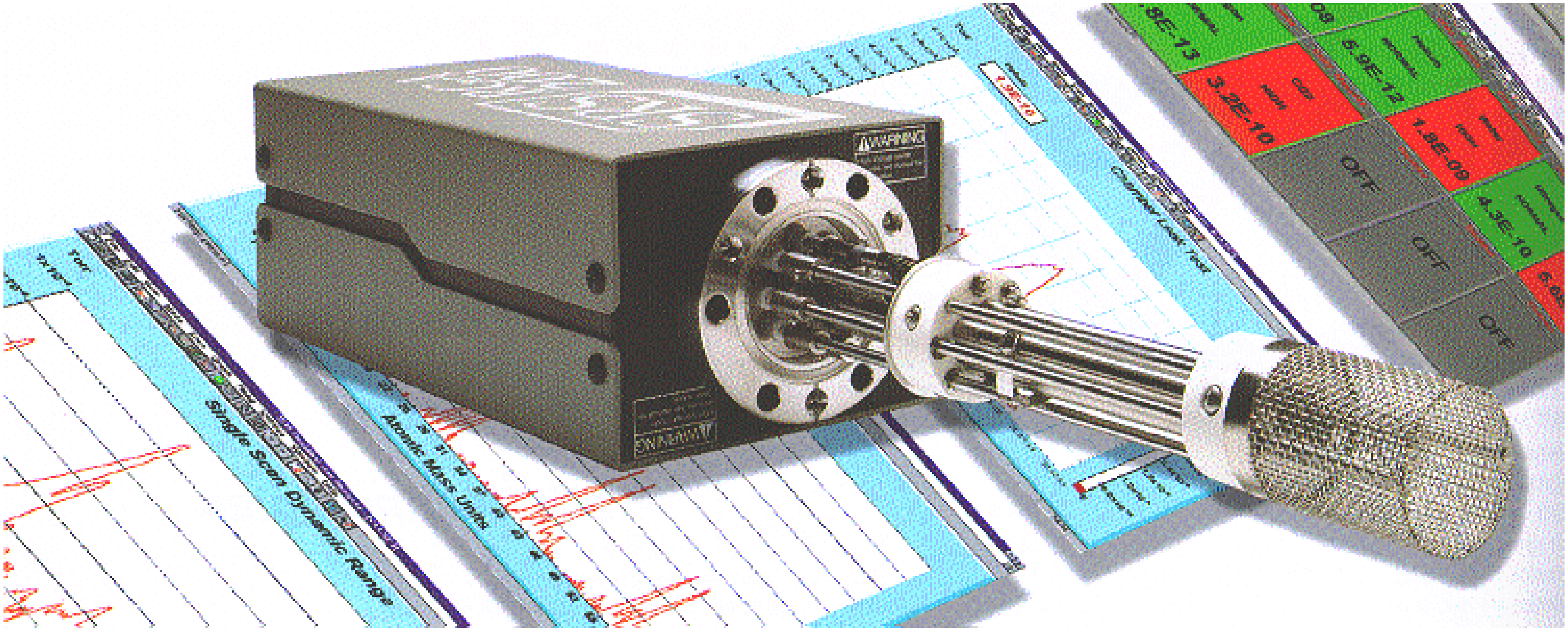


RESIDUAL GAS ANALYZER (RGA)

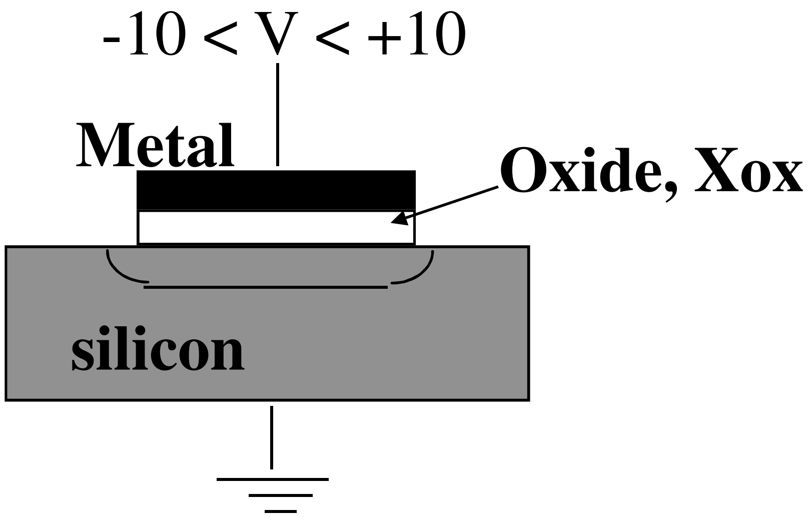
The Quadrupole Filter has voltages such that down the center there is a zero potential equipotential surface. Only ions of a certain mass make it all the way to the photomultiplier tube. The voltage applied to the filter at radio frequency and DC selects the mass.



RGA


WARNING
Single Scan Dynamic Range
Atomic Mass Units
Chamber Leak Test
3.2E-10
6.9E-12
1.8E-09
4.3E-10
OFF
OFF
OFF

CAPACITANCE VOLTAGE MEASUREMENTS

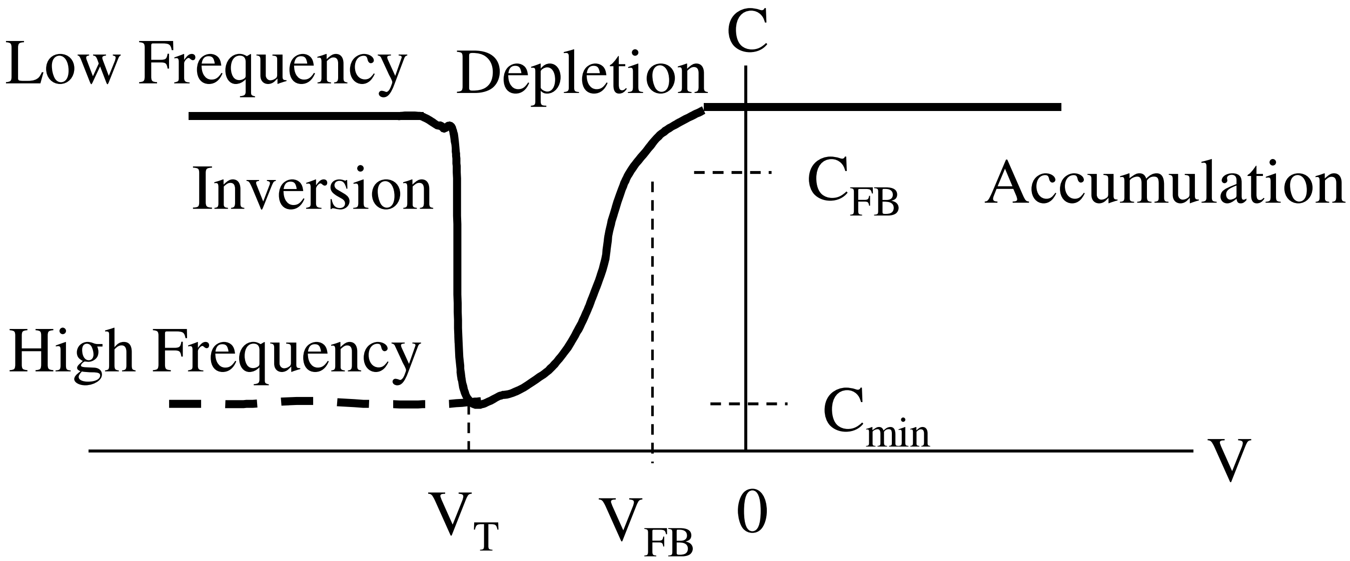


Cox= Ɛo Ɛr Area/Xox

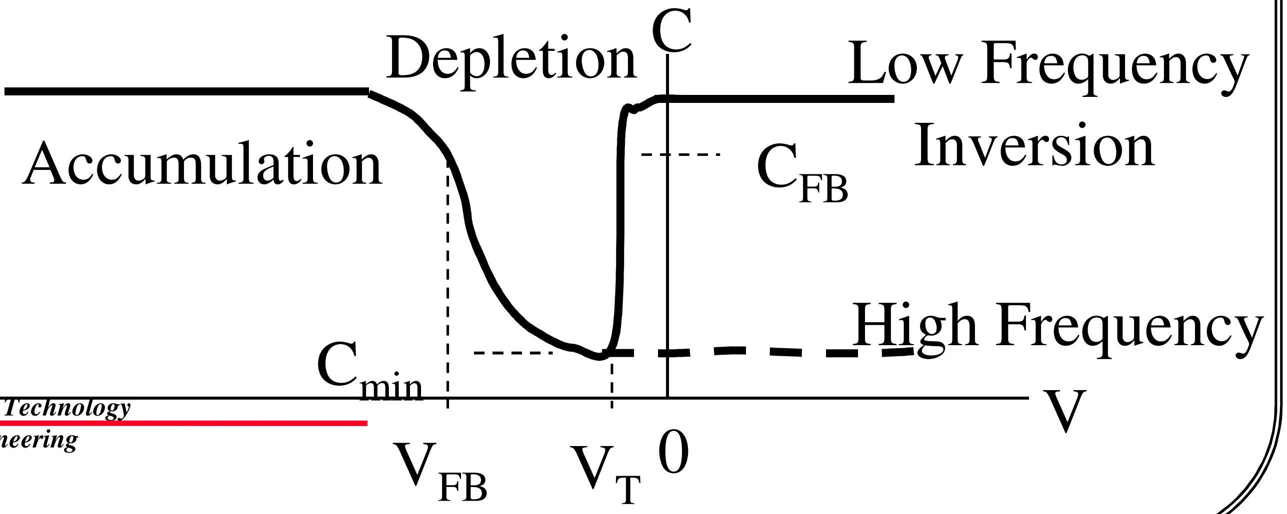
Apply a DC voltage (V) to the capacitor and measure the capacitance. High frequency and low frequency capacitance measurement techniques are available.

CV MEASUREMENTS

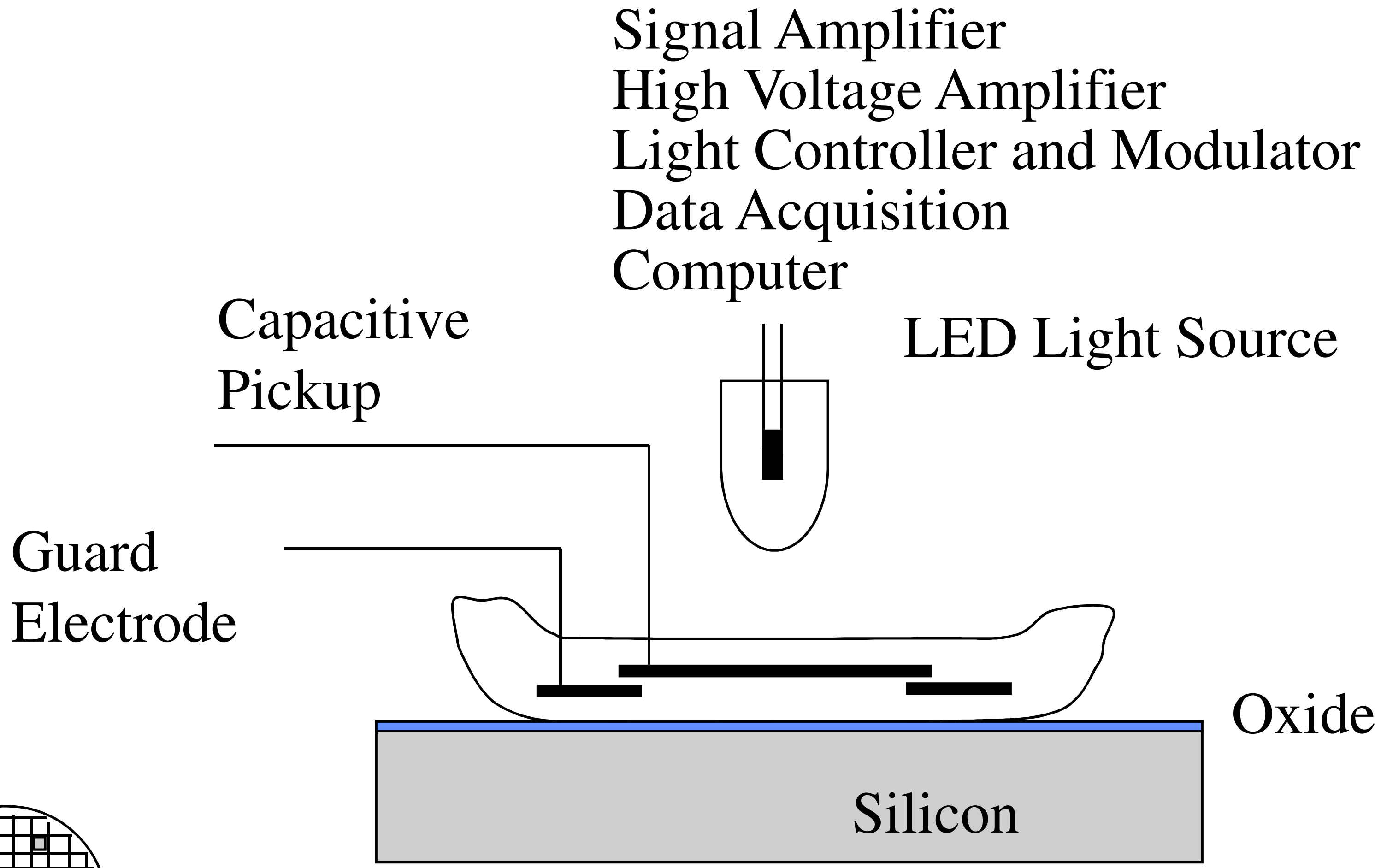
N-Type Silicon



P-Type Silicon

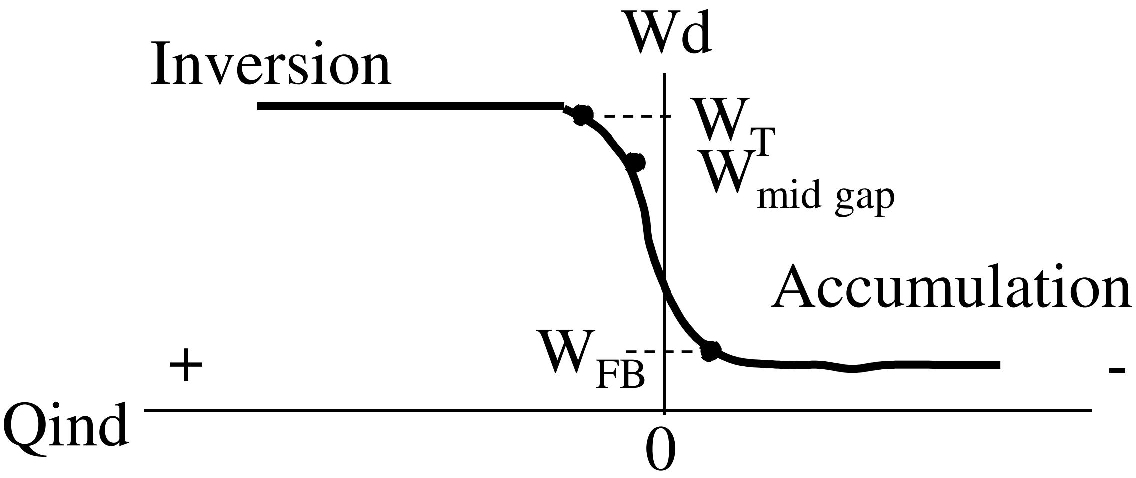


SCA

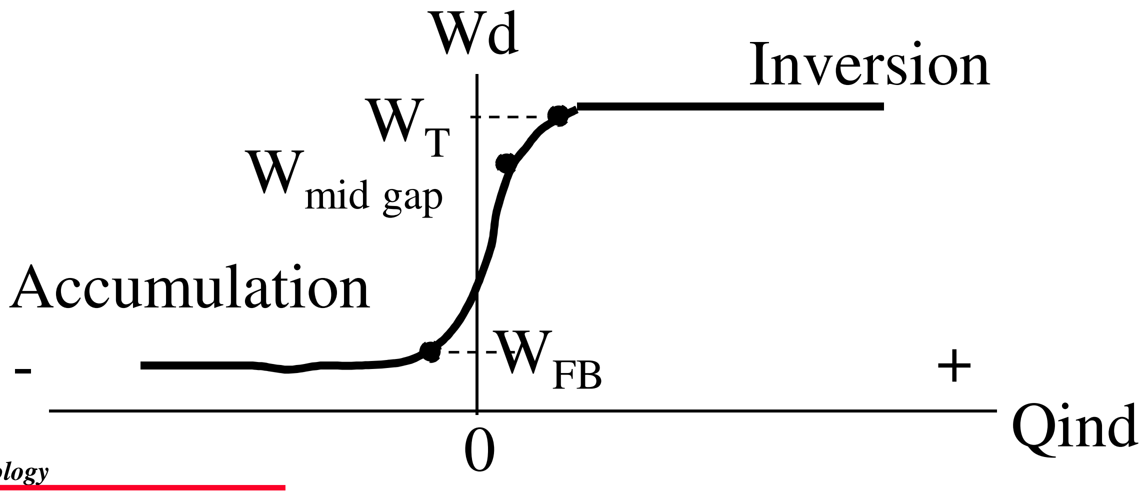

Signal Amplifier
High Voltage Amplifier
Light Controller and Modulator
Data Acquisition
Computer
Capacitive Pickup
LED Light Source
Guard Electrode
Oxide
Silicon

SCA

P-type Wafer



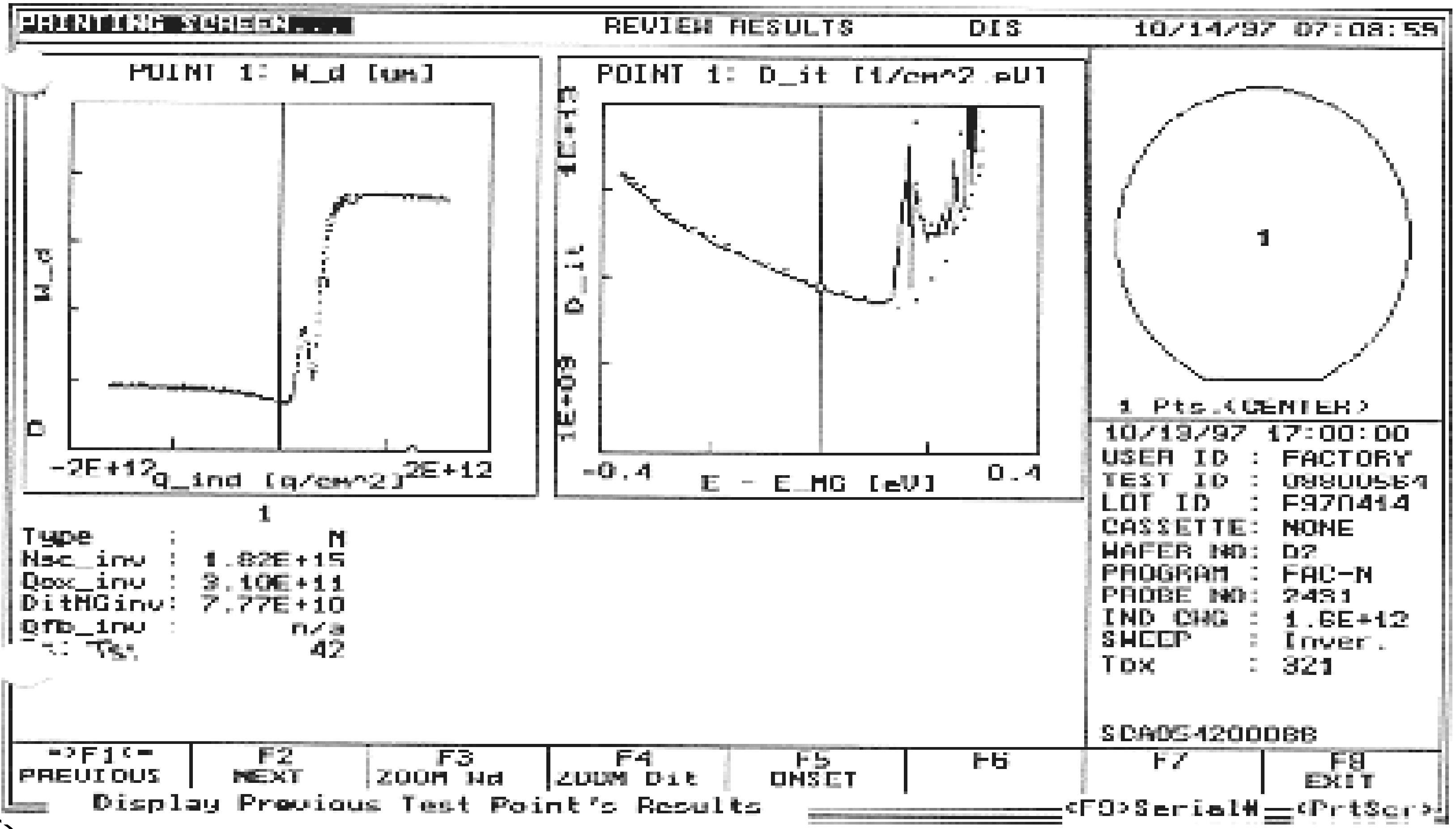
N-type Wafer



SCA-2500 SETUP

Login: FACTORY
Password: OPER
<F1> Operate
<F1> Test Place the blank spot in middle of wafer on center of the stage
Select (use arrow keys, space bar, page up, etc)
 PROGRAM = FAC-P or FAC-N
 LOT ID = F990909
 WAFER NO. = D1
 TOX = 463 (from nanospec)
<F12> start test and wait for measurement
<Print Screen> print results
<F8> exit and log off
<ESC> can be used anytime, but wait for
 current test to be completed

EXAMPLE OF SCA OUTPUT MEASURED AT RIT



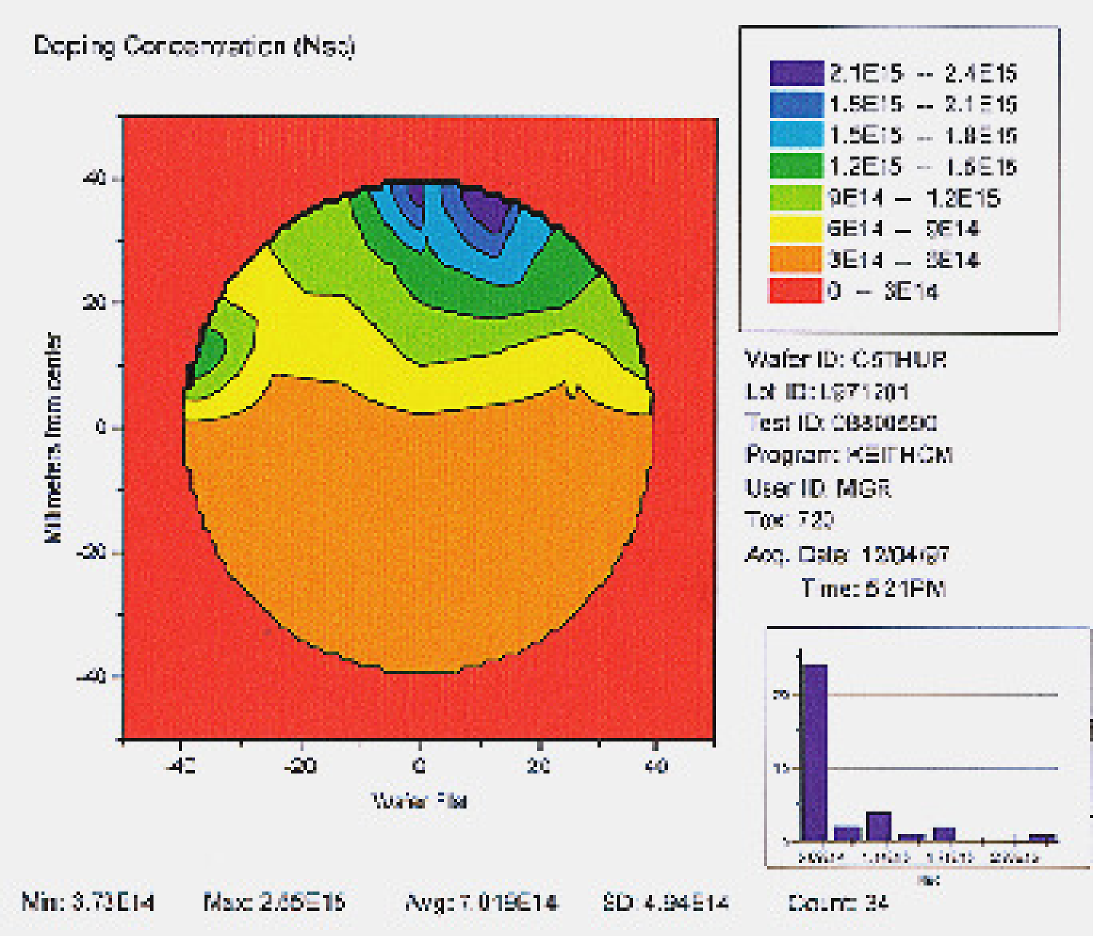
```
                  1
Type     :        N
Nsc_inv  : 1.82E+15
Qox_inv  : 3.10E+11
DitMGinv : 7.77E+10
Qfb_inv  :      n/a
[illegible]       42
```

```
10/13/97 17:00:00
USER ID  : FACTORY
TEST ID  : 09800564
LOT ID   : F970414
CASSETTE : NONE
WAFER NO : 07
PROGRAM  : FAC-N
PROBE NO : 2431
IND CHG  : 1.6E+12
SWEEP    : Inver.
Tox      : 321

SDADS42000088
```

```
Display Previous Test Point's Results
```

EXAMPLE OF SCA OUTPUT MEASURED AT RIT



Wafer ID: C5THUR
Lot ID: L971201
Test ID: CB80059O
Program: KEITHCM
User ID: MGR
Tox: 720
Acq. Date: 12/04/97
Time: 6:21PM

Min: 3.73E14 Max: 2.65E15 Avg: 7.019E14 SD: 4.94E14 Count: 34

REFERENCES

1. Scanning Electron Microscopy, Michael T. Postek, et, al., Ladd Research Industries, Inc., 1980.

2. Micro-X7000 Operating Manual, Kevex Corporation, 1101 Chess Drive, Foster City, CA 94404, 1982.

3. EDAX Inc., 91 McKee Drive, Mahwah, NJ 07430-9978, Tel (201) 529-3156

4. AFM see, **http://spm.phy.bris.ac.uk/techniques/AFM/, and http://www.fys.kuleuven.ac.be/vsm/spm/images/introduction/afm.html**

HOMEWORK: SURFACE

1. Calculate the wavelength of the K_α and L_B x-ray for copper.]
2. Explain how SIMS gives doping profiles.
3. Why can't Auger and a ESCA give doping profiles.