PHI 5000 Versaprobe-II
Focus X-ray Photo-electron Spectroscopy

The very basic theory of XPS

XPS theroy

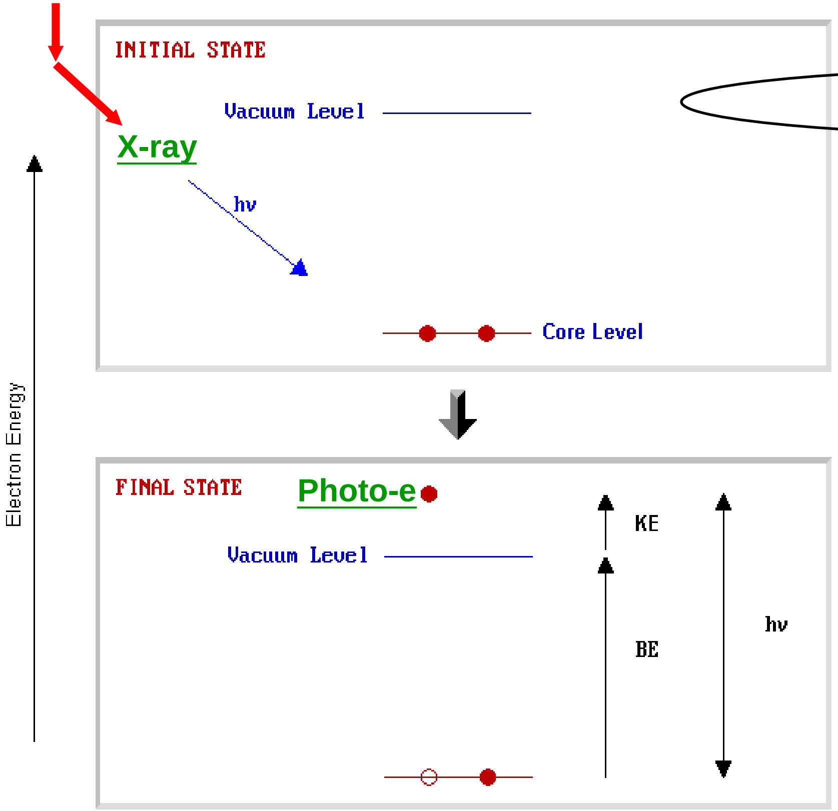
Surface Analysis

Ultra High Vacuum (UHV)

XPS Theory

- **XPS = X-ray Photo-electron Spectroscopy**

X-ray and Photo Electron



Concept of Binding Energy

The XPS equation

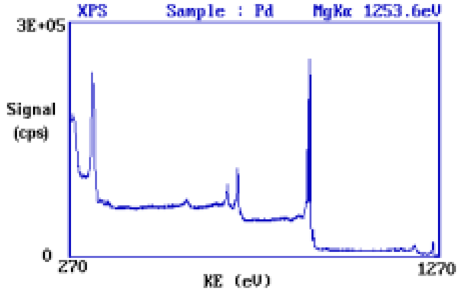
$$hv = KE + BE$$

hv = X-ray energy

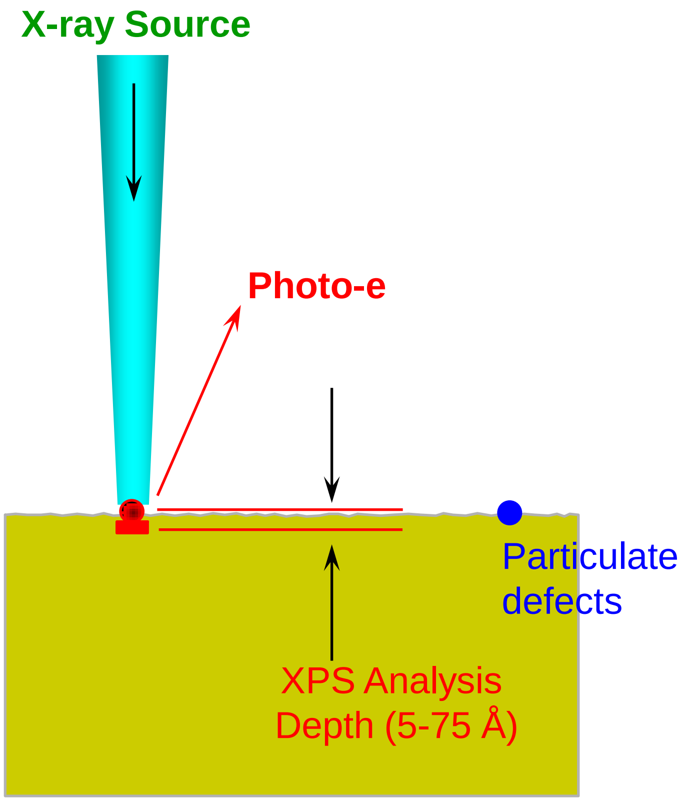
KE = Kinetic energy of photo-e

BE = Binding energy

$$\rightarrow BE = hv - KE$$



XPS as a Surface Analysis technique



1. Only the generated photo-e from the top surface about 5 to 75A can have enough energy to pop out of the sample surface.

2. Minimum X-ray probe size from the Versaprobe-II system is ~10um and it makes small area analysis possible.

3. No special sample preparation is required for XPS analysis

Why Ultra High Vacuum

- **The generated Photo-electrons are coming from the very top surface of the sample (0.5-7.5nm)**
- **Therefore it is very surface sensitive.**
- **Surface Analysis = surface sensitive**
- **So its important to first have the UHV environment to avoid surface contamination**

PHI 5000 Versaprobe-II system hardware overview

System component
X-ray Generation
Analyzer Input lens
Hemispherical Spherical Analyzer (HSA)
Multi-Channel Detector (MCD)
Ion gun with floating
Electron Neutralizer

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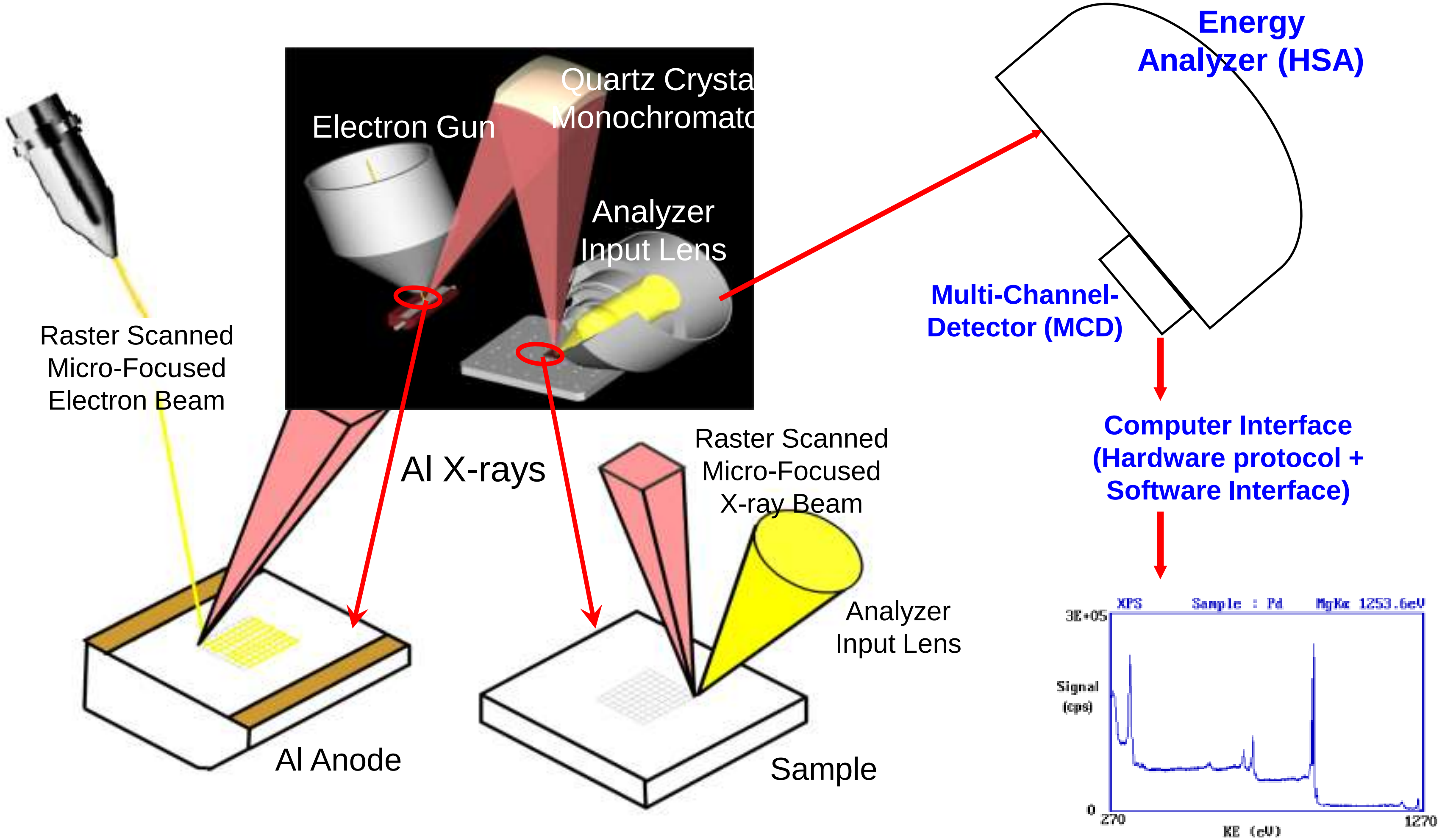
System component overview



Electron Gun

Quartz Crysta
Monochromat

Analyzer
Input Lens

Energy
Analyzer (HSA)

Multi-Channel-
Detector (MCD)

Raster Scanned
Micro-Focused
Electron Beam

Al X-rays

Raster Scanned
Micro-Focused
X-ray Beam

Analyzer
Input Lens

Al Anode

Sample

Computer Interface
(Hardware protocol +
Software Interface)

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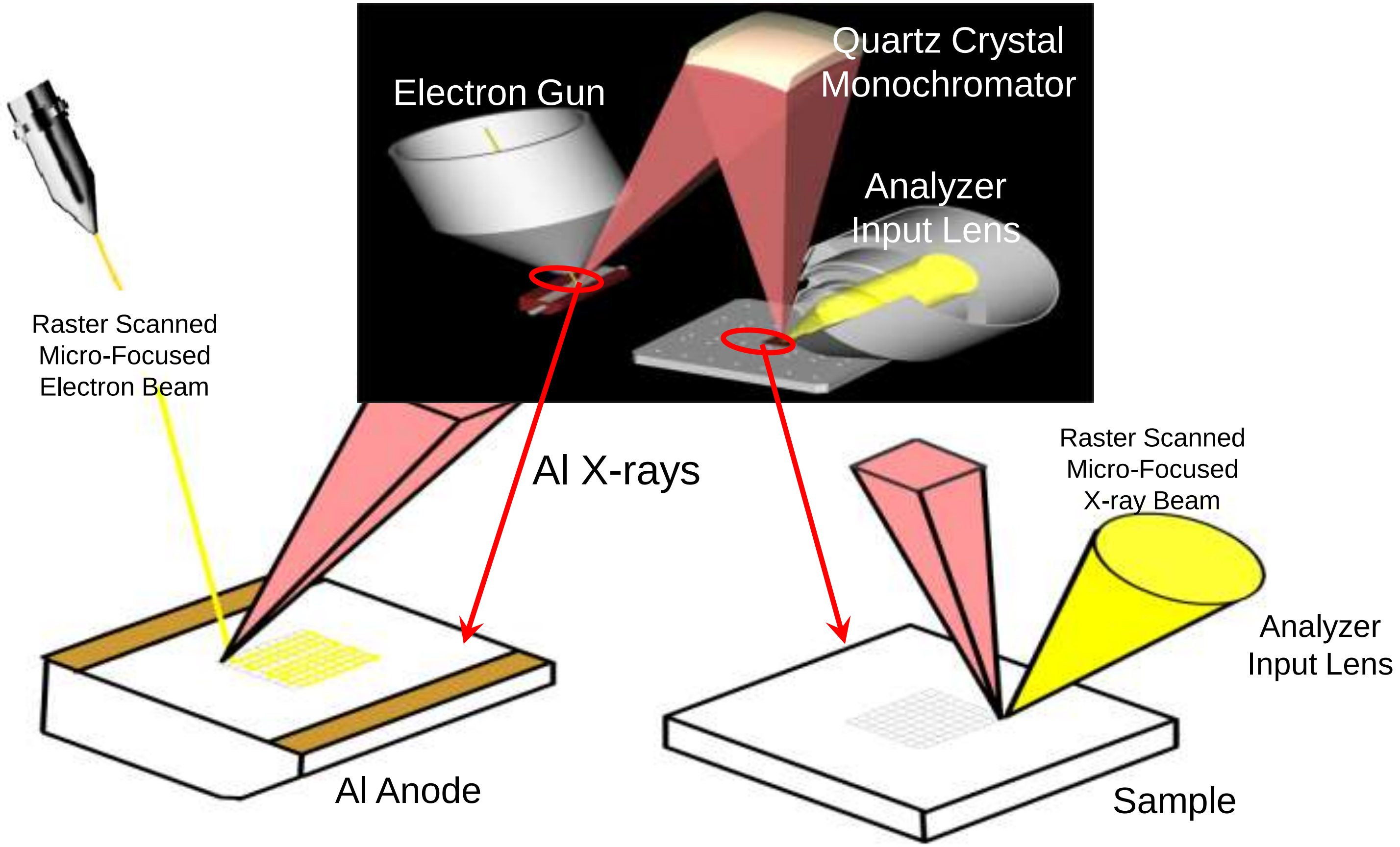
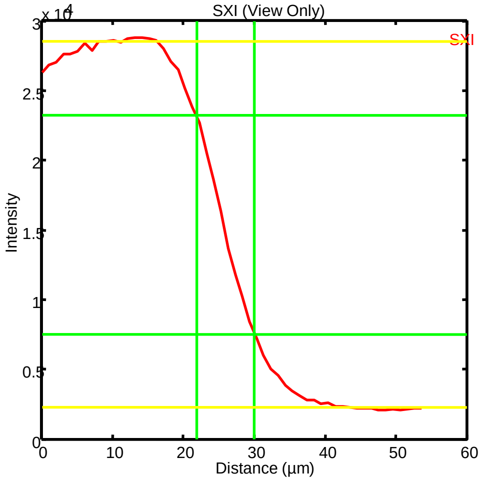
X-ray Generation (1), Concept of focus X-ray



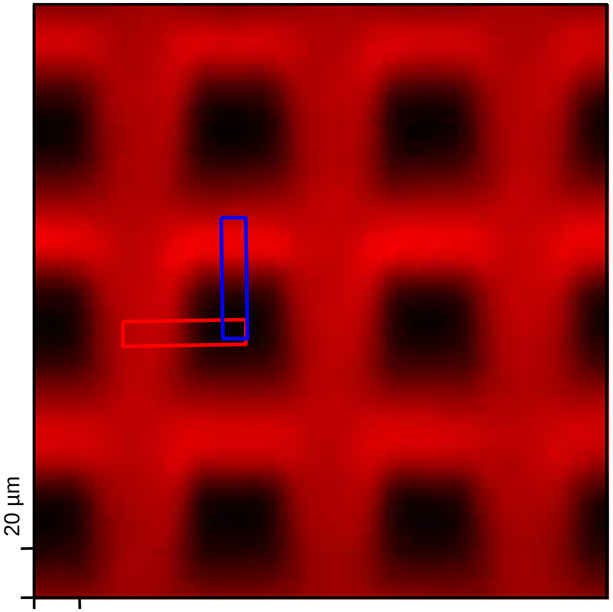
- **The source Electron Beam is generated by a LaB6 filament. The emitted E-beam is then focus by Electrostatic lens and be able to scan onto the Aluminum Anode by varying the voltages on the scanning plates.**
- **On the Al Anode, a scanning X-ray is generated by the scanning E-beam. Then with the reflection takes place at the Monochromator, the scanning X-ray could be reflected and uses as the source beam onto the sample.**

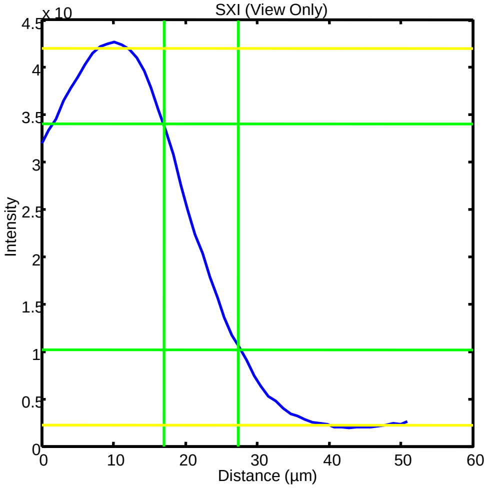
X-ray Generation (2), Concept of focus X-ray

Scanning X-ray Beam Induced
Secondary Electron Image



X: 9.4 µm





Y: 9.3 µm

Versaprobe-II Specification < 10 µm

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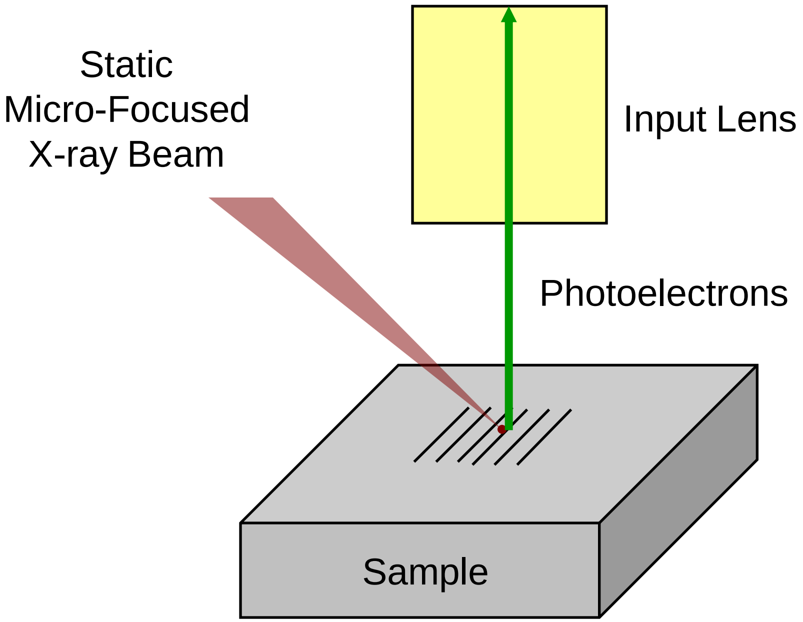
Analyzer Input lens

- **Purpose of Input lens – The analyzer is making an angle to the sample surface (usually 45-degree)**
- **When photo-e(s) are generated by the X-ray and pop-out of the surface, they tends to fly all over in the provided vacuum environment.**
- **So to enhance the number of photo-e that can go into the Analyzer, we will need the Input lens to attract and focus the maximum number of photo-e into the Energy Analyzer**



- **There are 3 lens in this input lens, as function in attracting and focusing the photo-e into the optics path, then direct into the Energy Analyzer.**
- **The Input lens is also scanning and it is synchronize to the X-ray scanning.**
- **The 3 lens are named as:**
  - Gauze lens
    - Scanning lens
  - Lens 2
  - Lens 3

PHI 5000 Versaprobe-II system hardware overview

System component

X-ray Generation

Analyzer Input lens

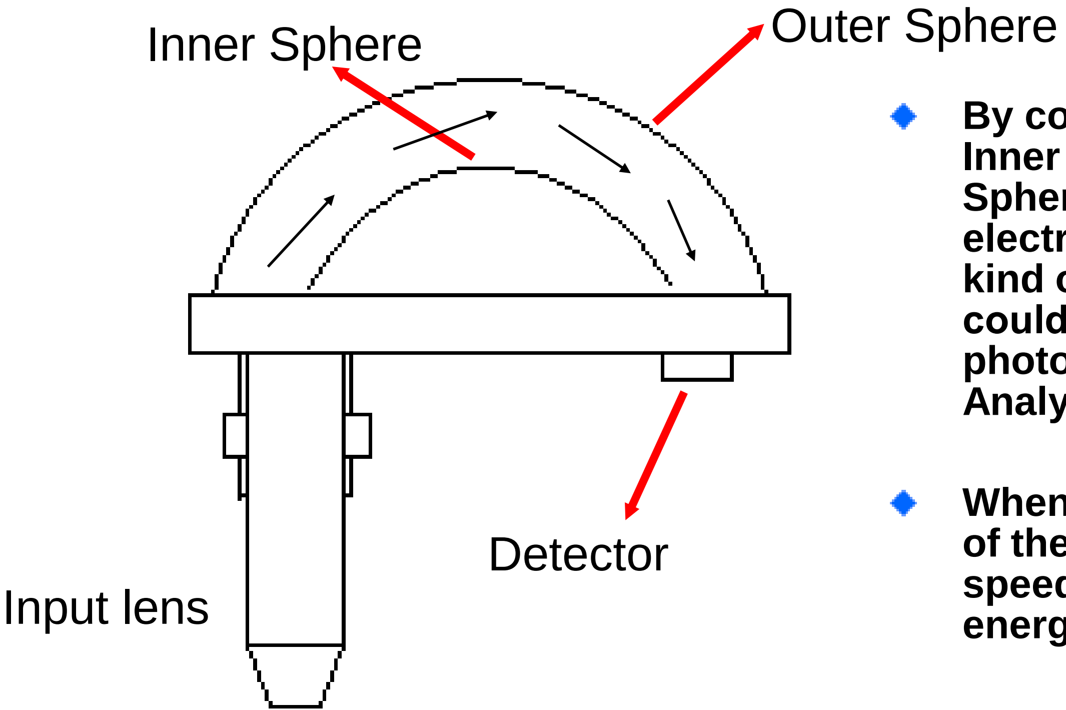
Hemispherical Spherical Analyzer (HSA)

Multi-Channel Detector (MCD)

Ion gun with floating

Electron Neutralizer

Hemispherical Spherical Analyzer (HSA)



- **By controlling the voltages on Inner Sphere (IS) and Outer Sphere (OS), we could generate a electrostatic field which act as kind of a band-pass filter. So we could set as what energies' photo-e can go travel along the Analyzer path.**
- **When saying different energies of the photo-e, we means the speed of the photo-e (i.e. Kinetic energies)**
- **The selected range of photo-e energies range will finally arrive to the detector.**
- **The difference in voltage between the inner & outer sphere is the Pass Energy**

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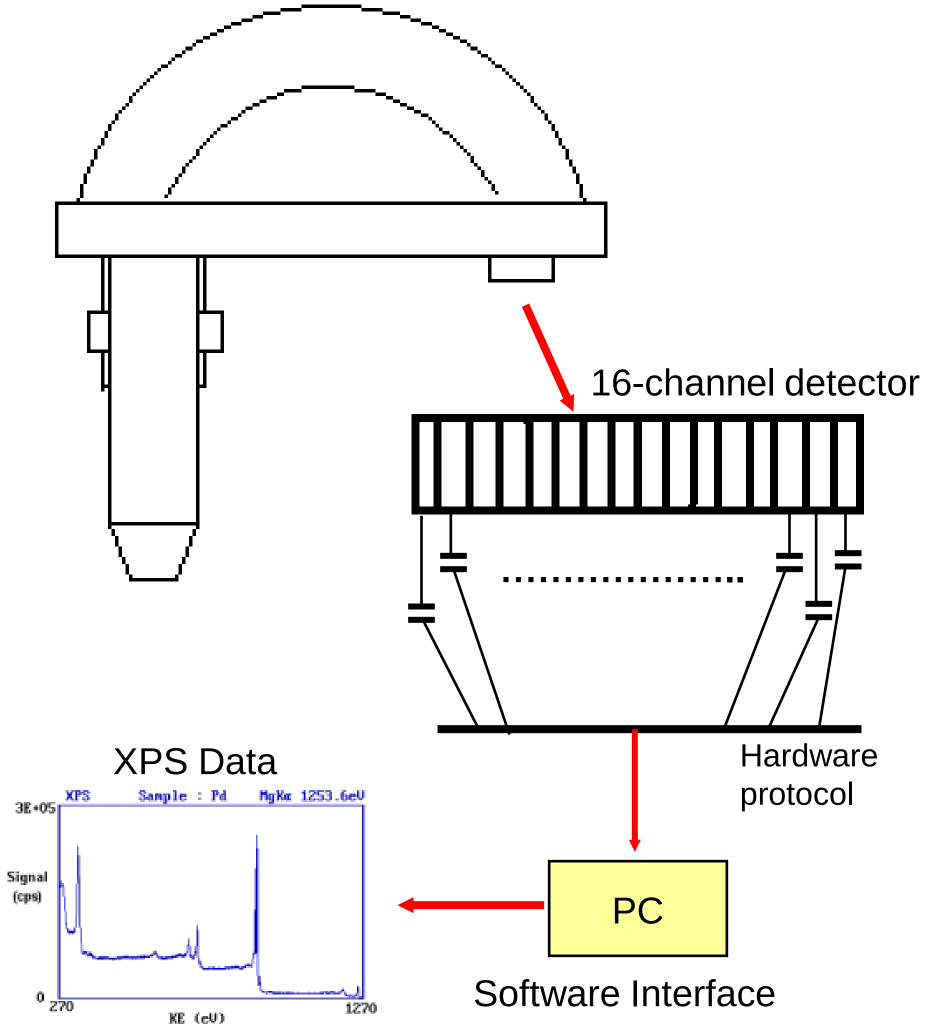
Multi-Channel Detector



16-channel detector

Hardware protocol

PC

Software Interface

XPS Data

- **The PHI-5000 Versaprobe-II system equip with a 16-channel Multi-Channel Detector (MCD).**
- **The Multi-Channel Detector allows the system to achieve a higher sensitivity XPS spectrum.**
- **The 16 channels data are stored into a capacitor matrix and then convert to XPS data by appropriate Hardware protocol and Software interface.**
- **Now we got the whole XPS phenomena took-place and spectra is generated.**

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Electron Neutralizer

The FIG-5 Ion gun (with floating)

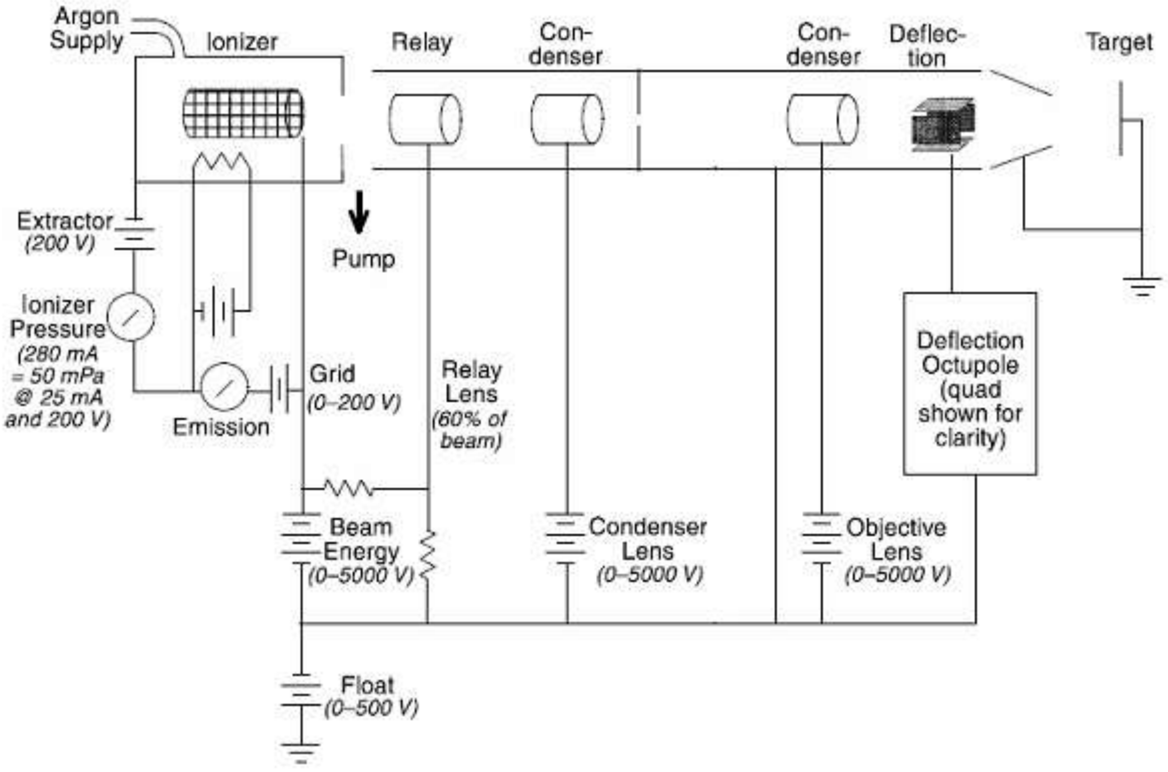

Illustration of the Ion Gun.

-The ion gun in the Versaprobe-II system has 3 main purposes

Cleaning (surface contamination)

Sputtering (Depth-profiling)

Charge Neutralization

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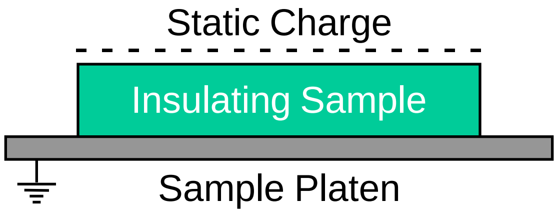
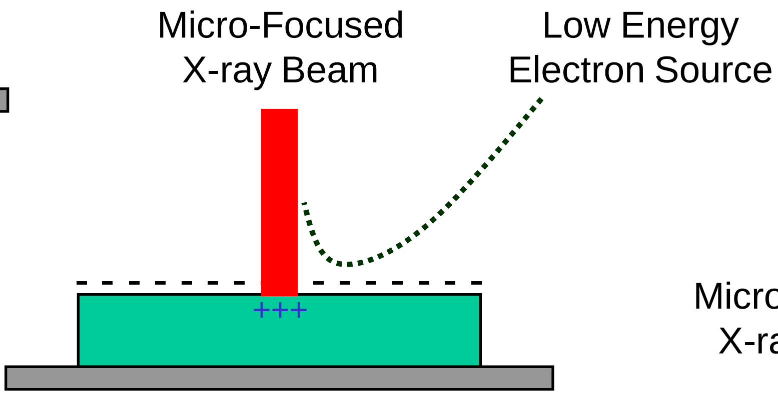
Electron Neutralizer

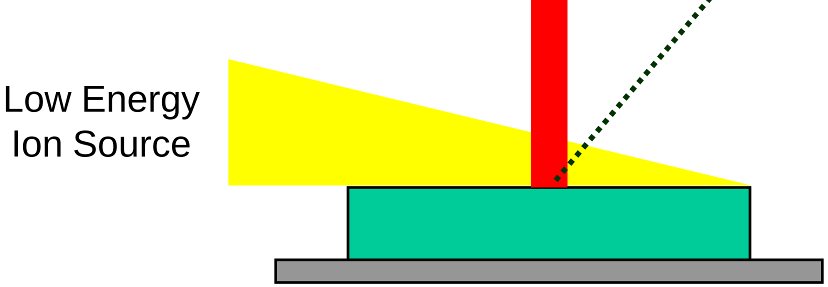
Electron Neutralizer
(Together with Ion Neutralization)



Traditional electron flood gun charge neutralization is not effective in neutralizing the localized positive charge created by the x-ray beam because the samples static charge interferes with the low energy electron beam.

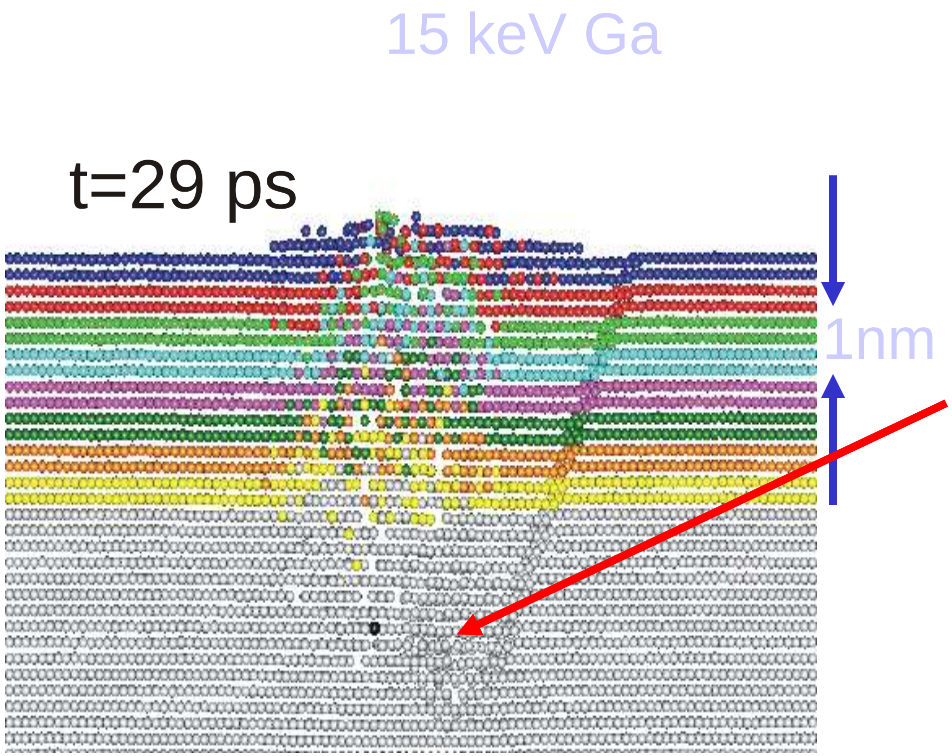


PHI's patented* dual beam charge neutralization method uses a low energy ion beam to eliminate the samples static charge allowing the low energy electron beam to reach the sample and neutralize the localized positive charge created by the x-ray beam.



- **PHI typical electron source energy ~ 1 eV**
- **PHI typical ion source energy ~ 5 to 10 eV**

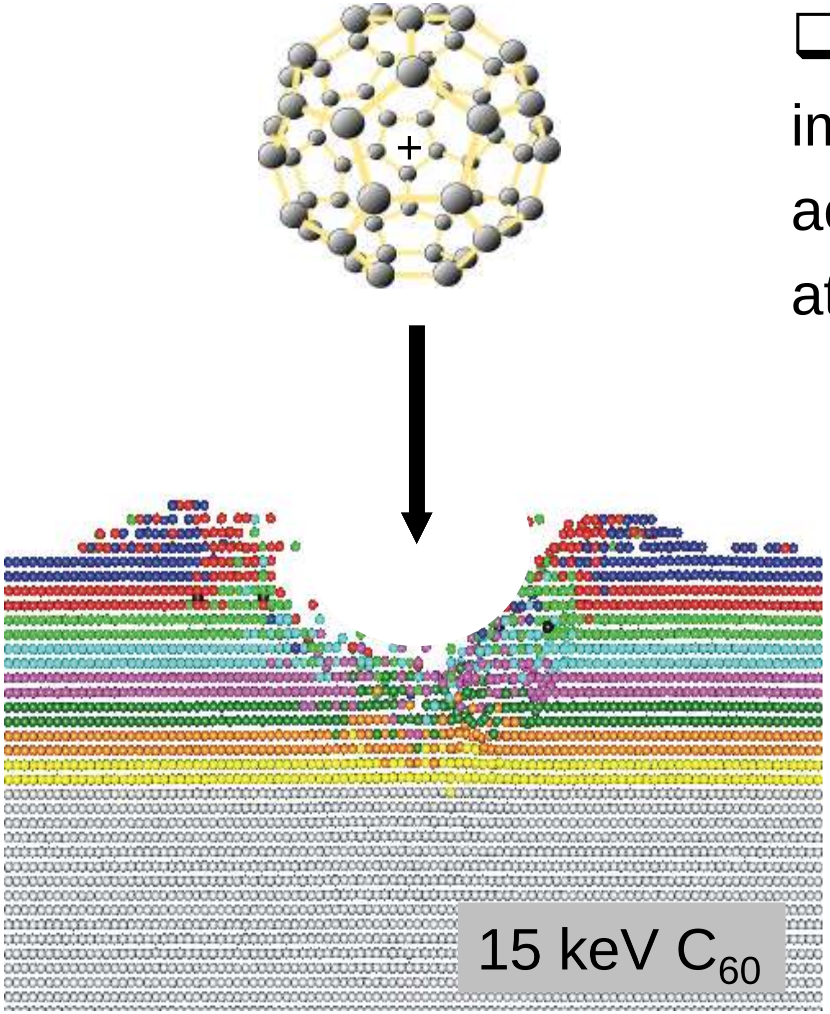
Chemical Damage with Traditional Sputtering



- Molecular Dynamics provide insights
- Energy cascade produced deep into the sample
- Energy cascade promotes chemical damage
- Sputtering only from the surface
- Chemical damage remains

C_{60} bombardment calculations, Zbigniew Postawa; Enhancement of Sputtering Yields due to C_{60} vs. Ga Bombardment of Ag{111} as Explored by Molecular Dynamics Simulations, Z. Postawa, B. Czerwinski, M. Szewczyk, E. J. Smiley, N. Winograd and B. J. Garrison, Anal. Chem.y, 75, 4402-4407 (2003); Microscopic insights into the sputtering of Ag{111} induced by C_{60} and Ga Bombardment, *ibid*., J. Phys. Chem. B108, 7831 (2004).

Sputtering with C_{60} Ions



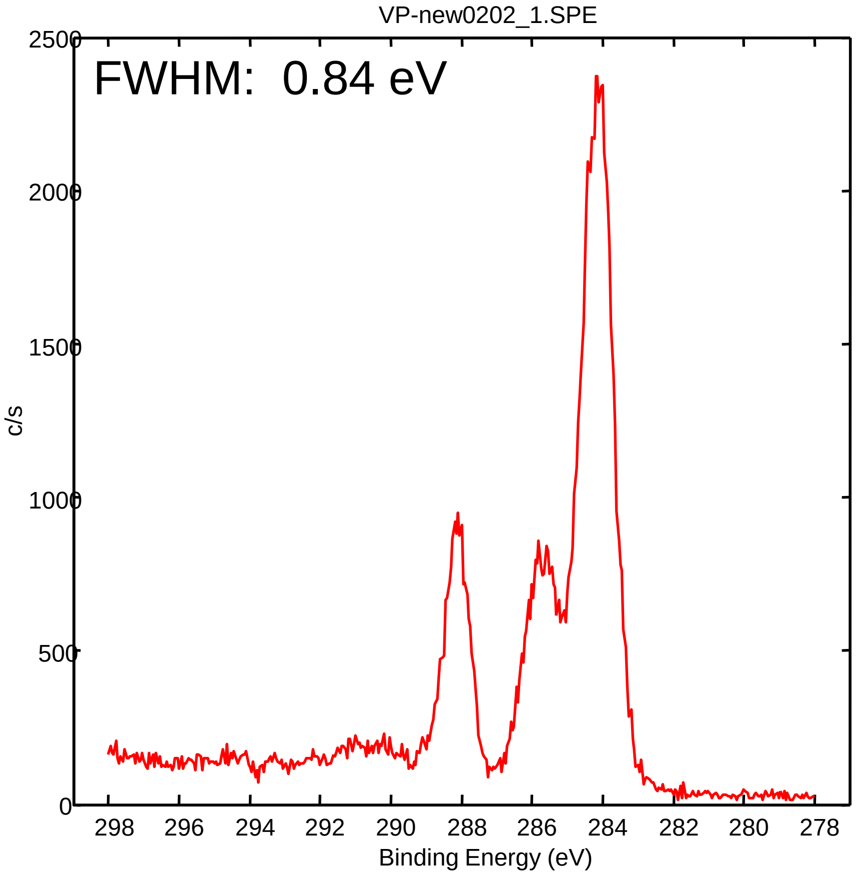
- C_{60} molecule collapses on impact distributing its initial acceleration energy over 60 C atoms:
  - Shallow penetration depth
  - Efficient removal of material
  - Thin damage layer
  - Practical cleaning and depth profiling of organic/polymer materials

So what can the PHI 5000 Versaprobe-II system do?

Real-life examples…

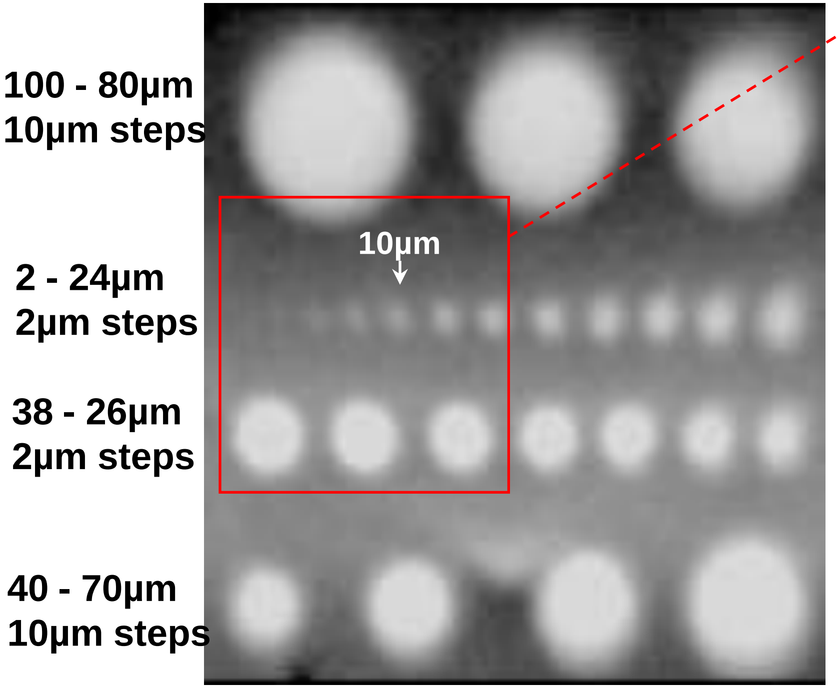
Example for PET analysis
(Showing Charge Neutralization)

VP-new0202_1.SPE: PET (100 micron spot): Company Name
2007 May 11 Al mono 26.7 W 100.0 µ 45.0° 11.75 eV 2.3740e+003 max 2.67 min
C1s/Area1/1



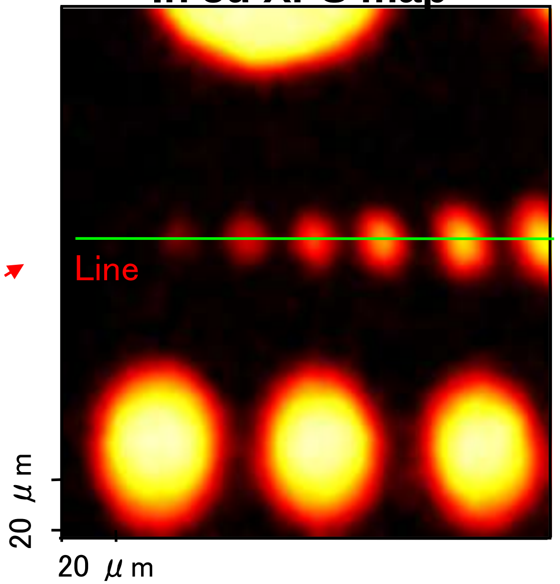
Meets Specification
< 0.85 eV FWHM

Indium Map and Line acquisition
(Small area analysis)

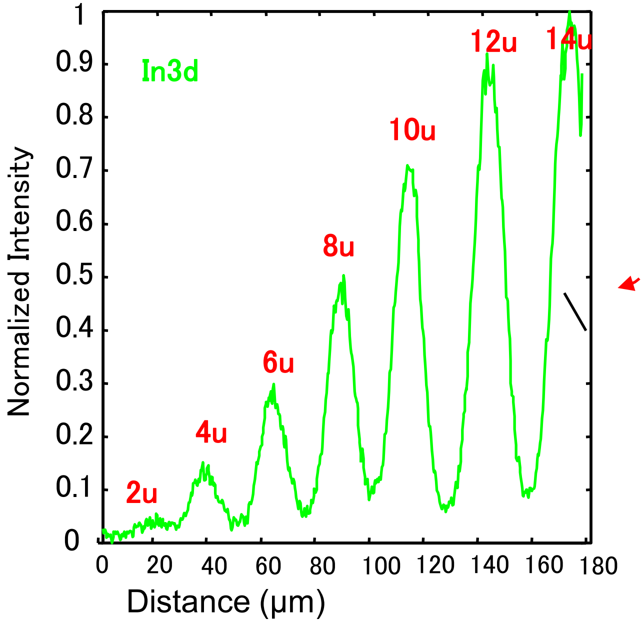


X-ray Beam Induced Secondary Electron Image

In 3d XPS map



In 3d XPS line scan

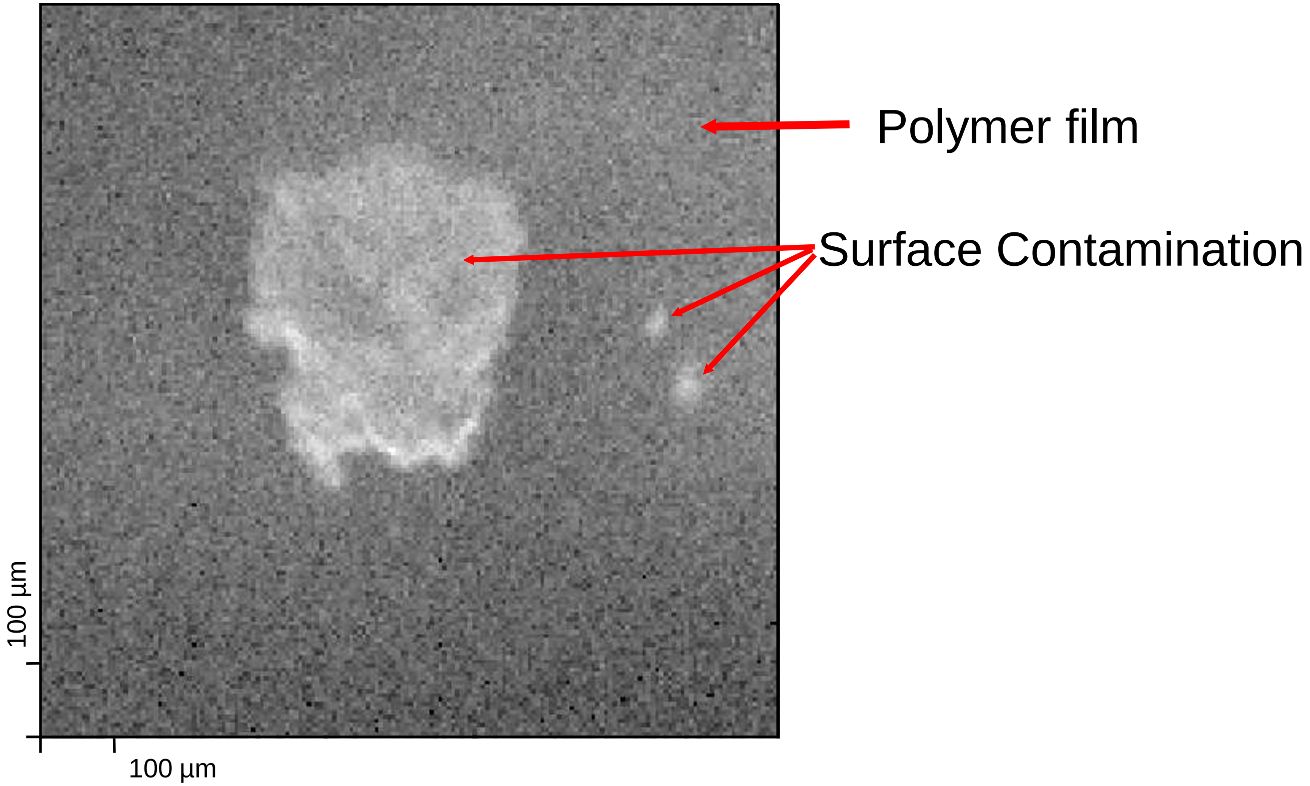


Scanning X-ray Beam for Secondary Electron Images of all Conducting and Insulating Samples

Secondary electron image quickly locates contamination

and features for XPS analysis

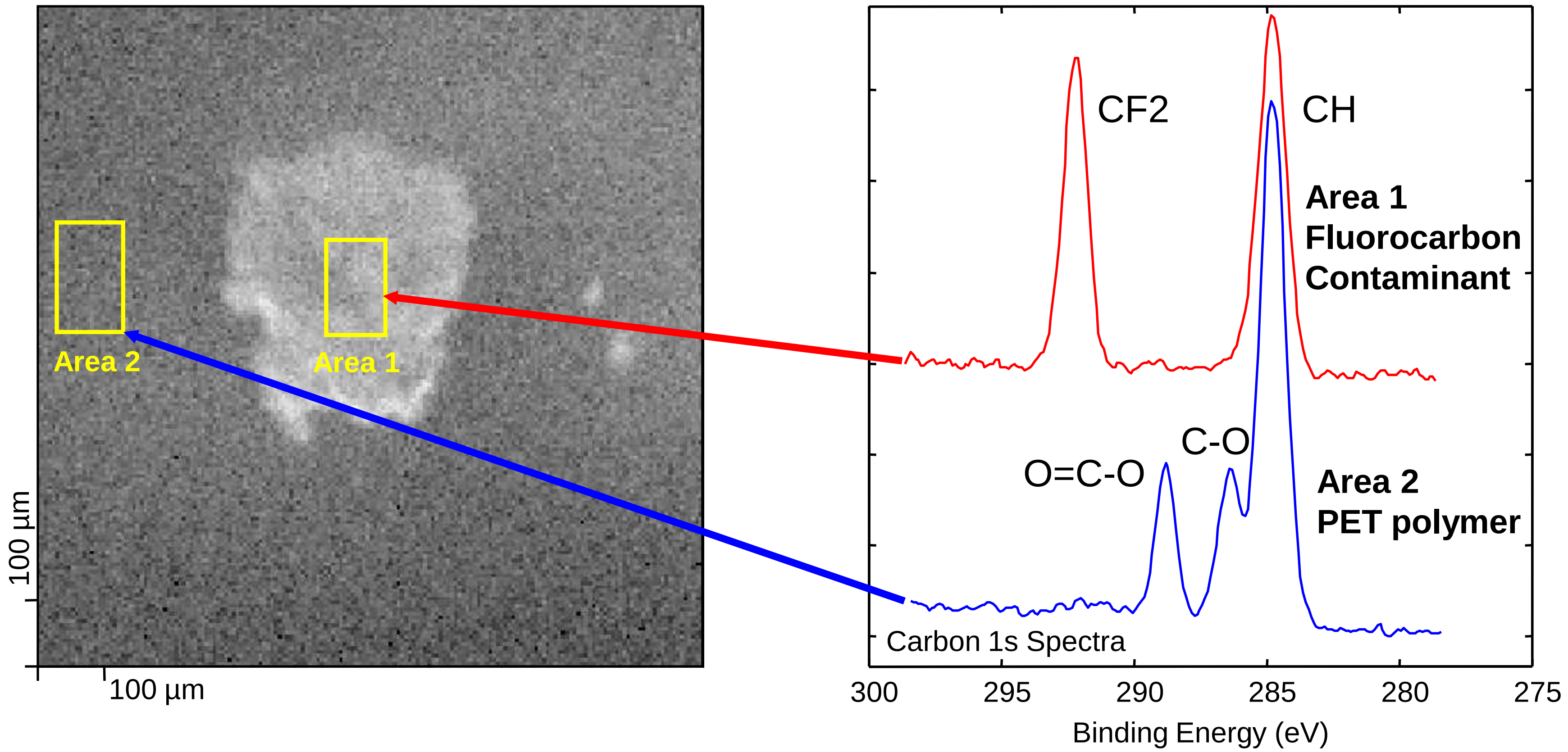
Accurate location of 10 micron features



Secondary Electron Image

User selects Analysis areas for Scanning X-ray Beam using Secondary Electron Images

Chemical identification of clean polymer and contaminant with XPS analysis



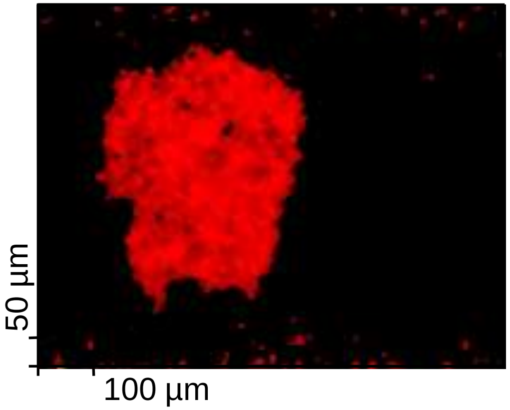
Secondary Electron Image

User defined areas scanned with 20 µm diameter x-ray beam in less than 10 minutes

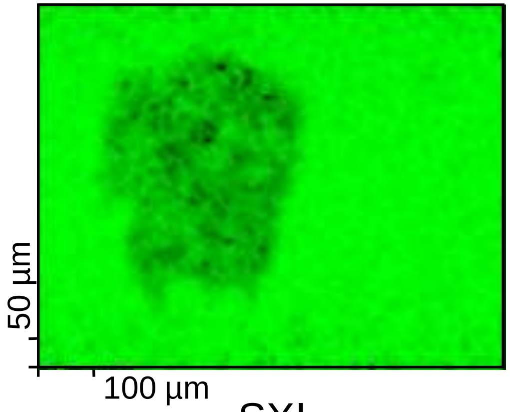
Scanning X-ray Beam Produces User Defined Areas for XPS Elemental and Chemical State Maps

XPS maps provided spatial distribution information and identified areas for additional micro-area spectroscopy

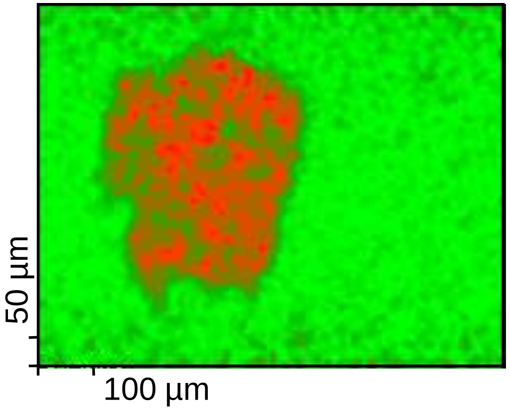
F 1s Map



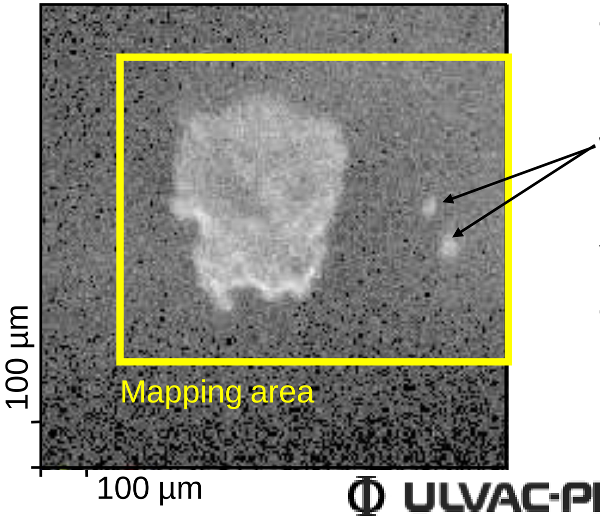
C 1s Map



F (red) + C (Green)



SXI

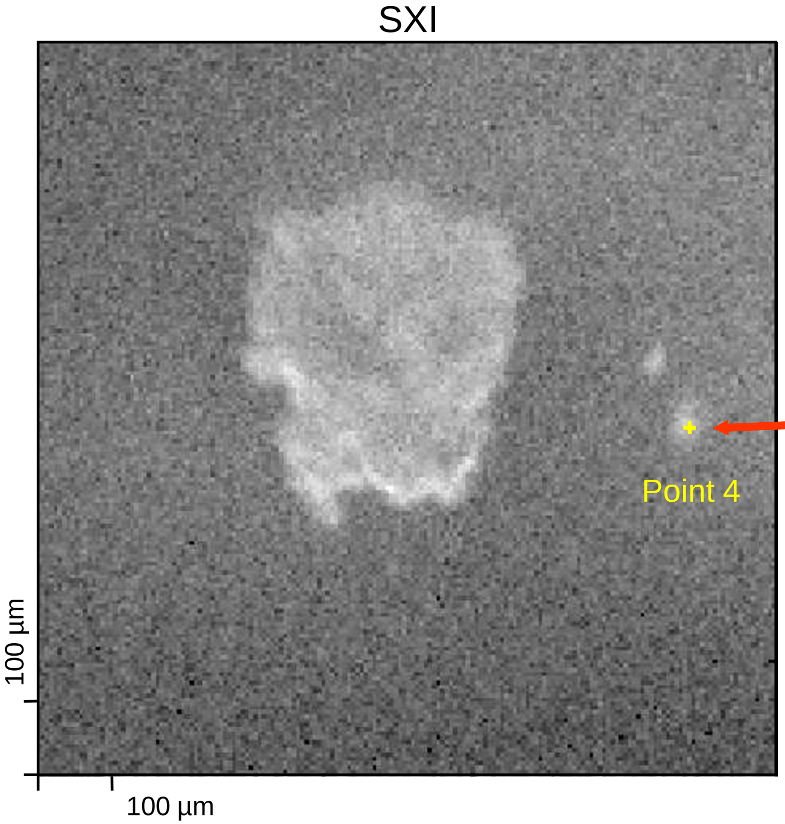


Sample features not associated with fluorine.

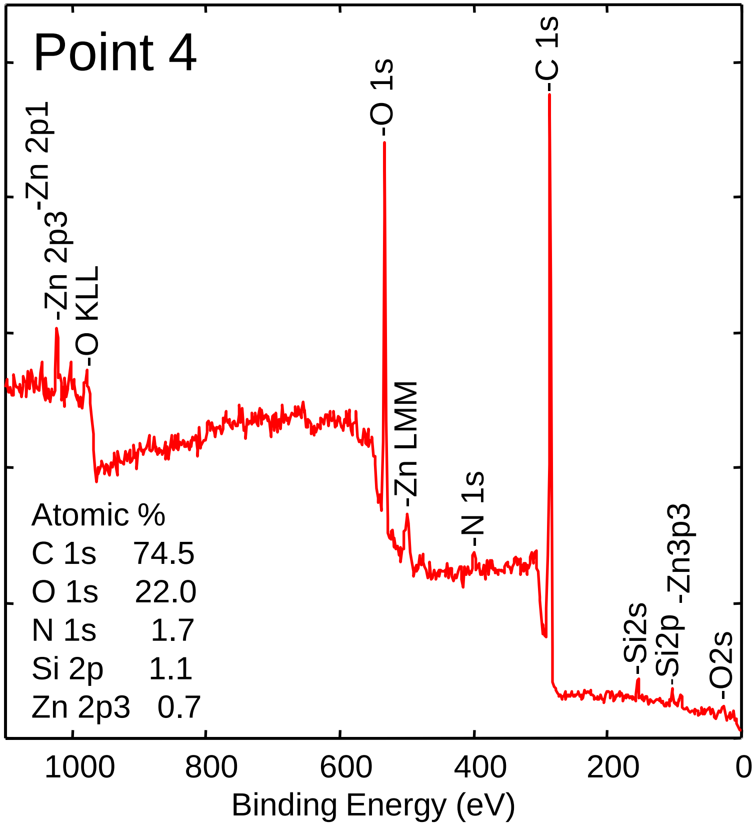
What are they?

Scanning X-ray Beam Located on Micro-defects for Elemental and Chemical State Identification

Secondary electron images, maps, and micro-area spectroscopy identified a contaminant that would go undetected in a non-microprobe system



Secondary Electron Image



Atomic %	
C 1s	74.5
O 1s	22.0
N 1s	1.7
Si 2p	1.1
Zn 2p3	0.7

Spectrum obtained using 10 µm diameter x-ray beam detected Zn, probably Zn stearate

ULVAC-PHI, INC.

Typical XPS Applications

Semiconductor Devices

- Defect particles
- Etch residue
- Shorting problems
- Contact contamination
- Multilayer thin film analysis

Magnetic Storage Media

- Surface Particles
- Inter-diffusion of layers
- Pinhole defects
- Surface corrosion
- Magnetic head defects

Display Devices

- Defect particles
- Shorting problems
- Inter-diffusion
- Cleaning residue

Metals, Glass and Ceramics

- Grain boundary segregation
- Cleaning failures
- Precipitates

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