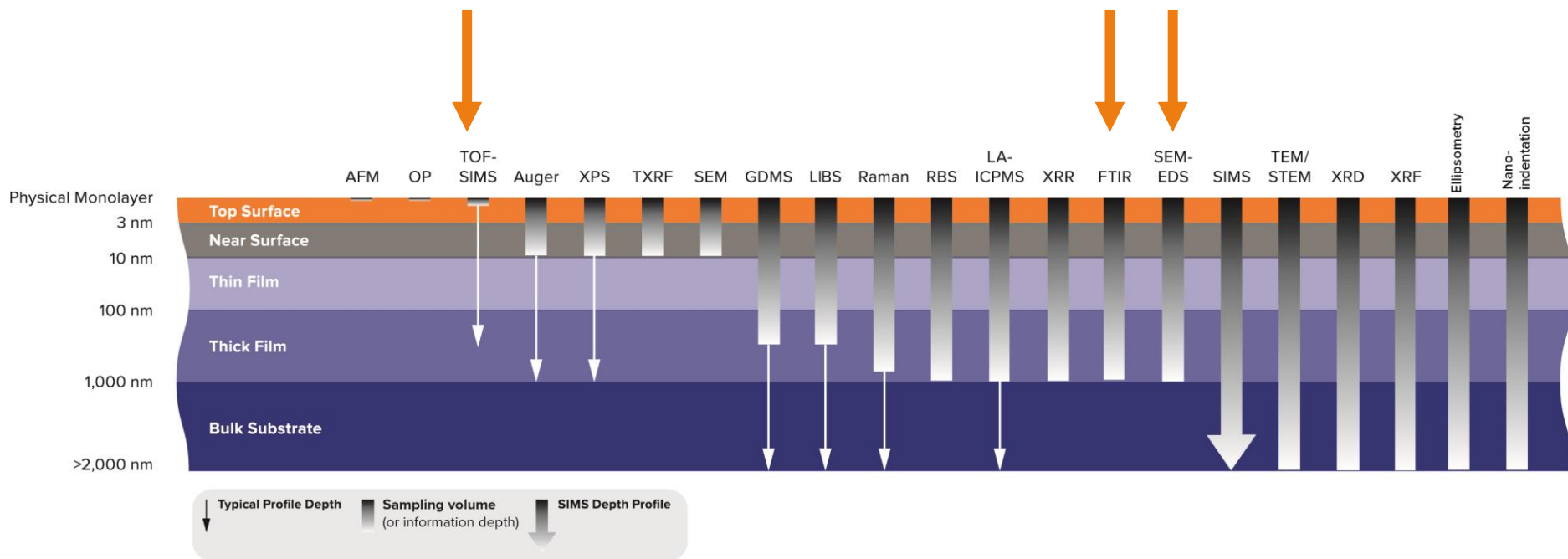




Surface Contamination Analysis

Time-of-Flight Secondary Ion Mass Spectrometry
(TOF-SIMS) - 2021

Depth of Analysis

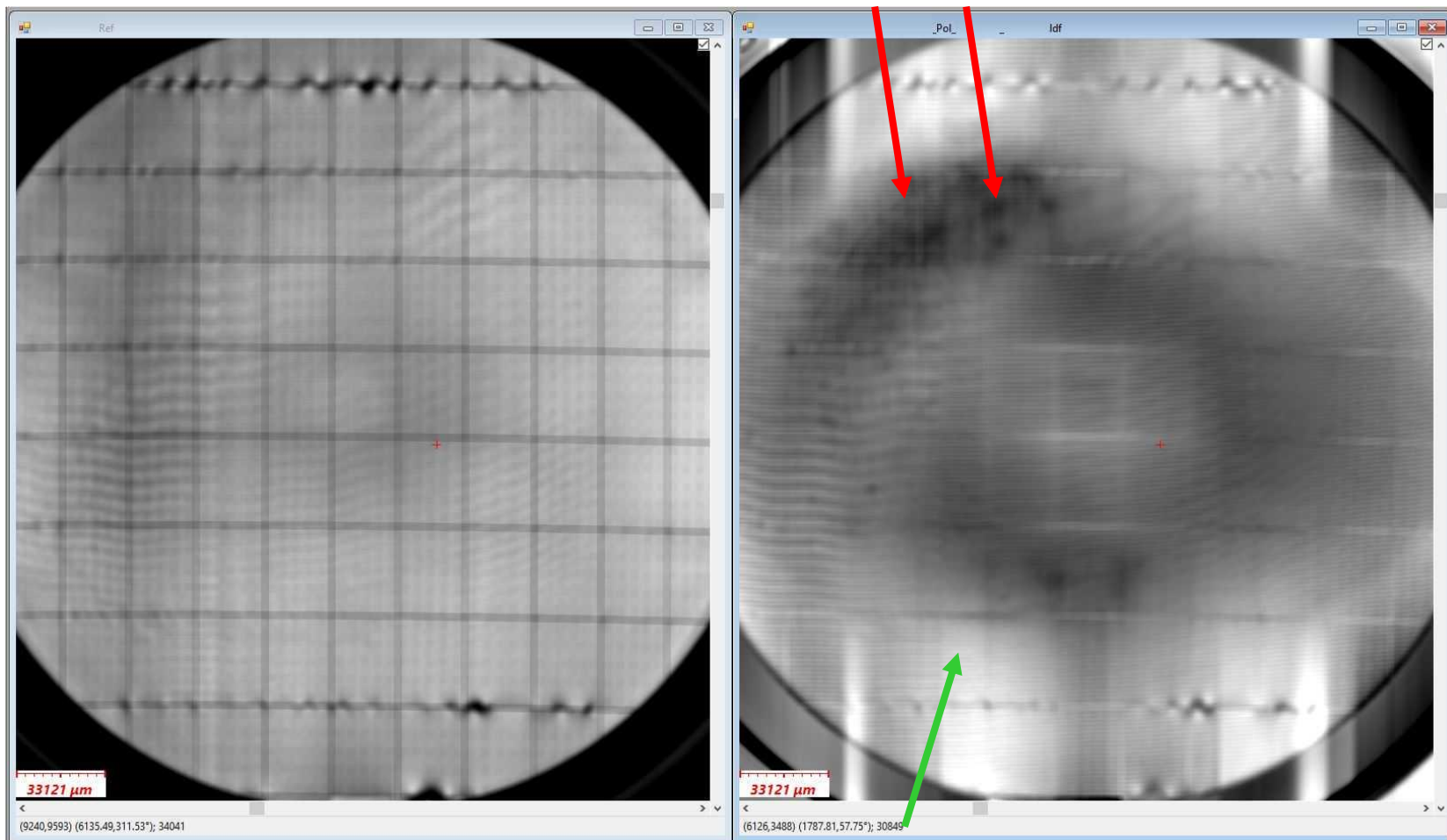


Don't forget the z-direction!
It's equally important in determining your analytical choices

To identify the contamination observed

- We applied several techniques to identify the material observed by The Lumina AT Optical Scanner
 - FTIR – No signal detected at all.
 - SEM/EDS
 - TOF-SIMS
 - Conclusions

Wafer view in Lumina AT Optical Scanner



To identify the contamination observed

- FTIR detects organic species and can fingerprint the material.
- In this case a contaminated die and a “clean” die were analyzed, and no signal was found.
- Typically for contamination less than 50 nm there is no signal.
- FTIR not the appropriate technique for this type of contamination.

To identify the contamination observed

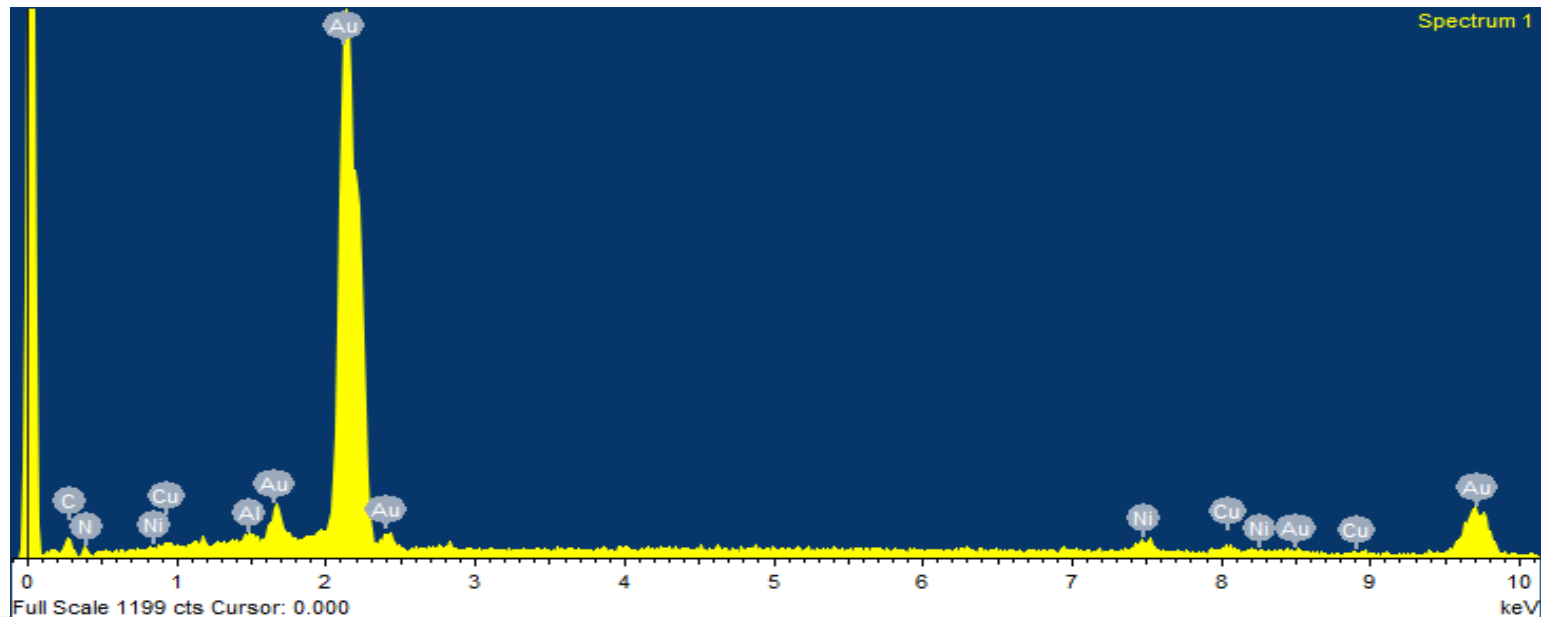
- SEM/EDS images the area and provides an atomic concentration of the elements present except H and He.
- In this case a contaminated die and a “clean” die were analyzed and ??? was found.

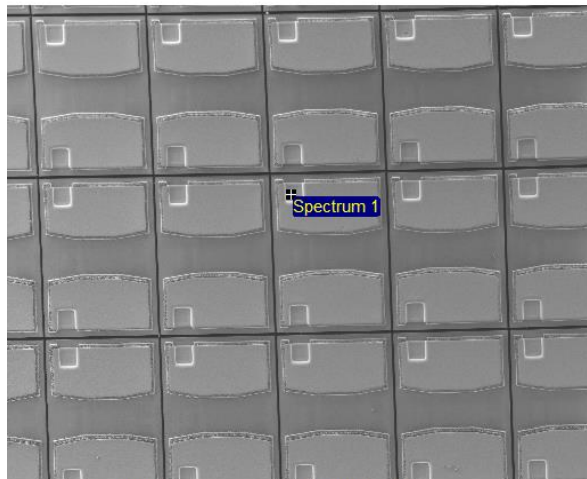


700µm

Electron Image 1

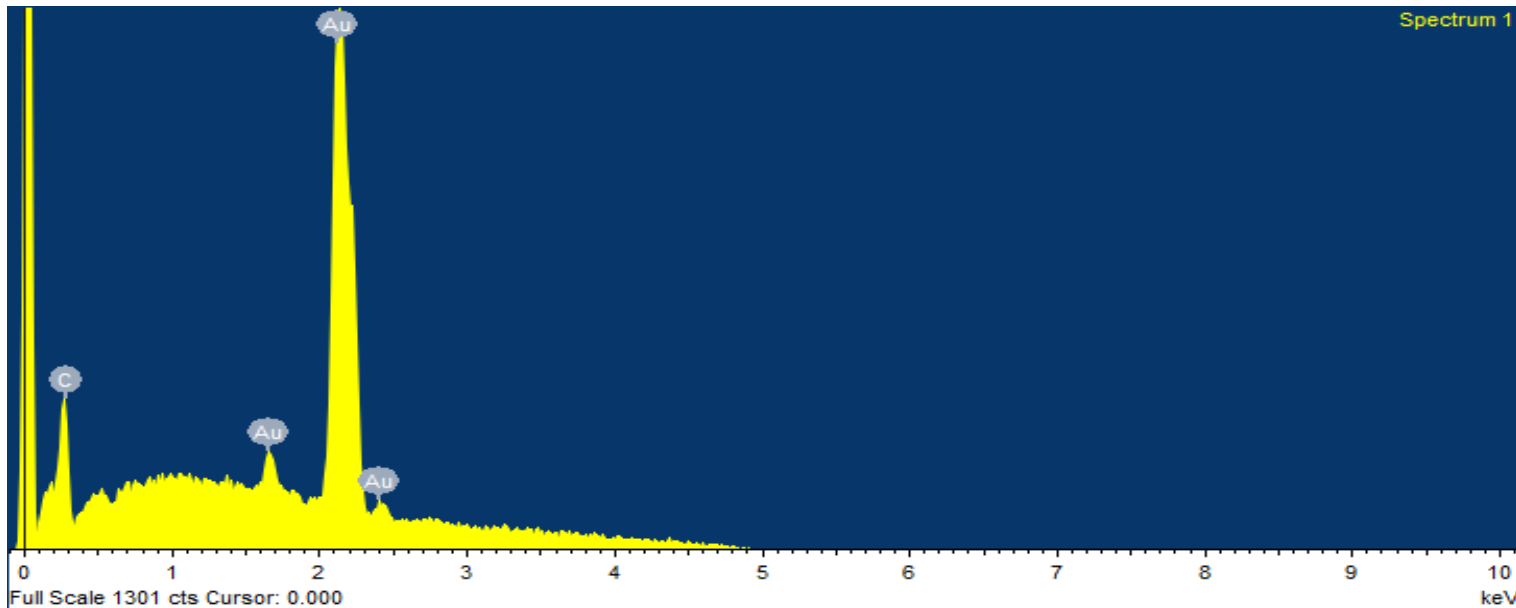
Element	Weight%	Atomic%	
C K	6.71	38.99	
N K	5.10	25.41	
Al K	0.35	0.90	
Ni K	2.74	3.26	
Cu K	1.76	1.94	
Au M	83.33	29.51	
Totals	100.00		





700µm Electron Image 1

Element	Weight%	Atomic%
C K	2.86	32.56
Au M	97.14	67.44
Totals	100.00	

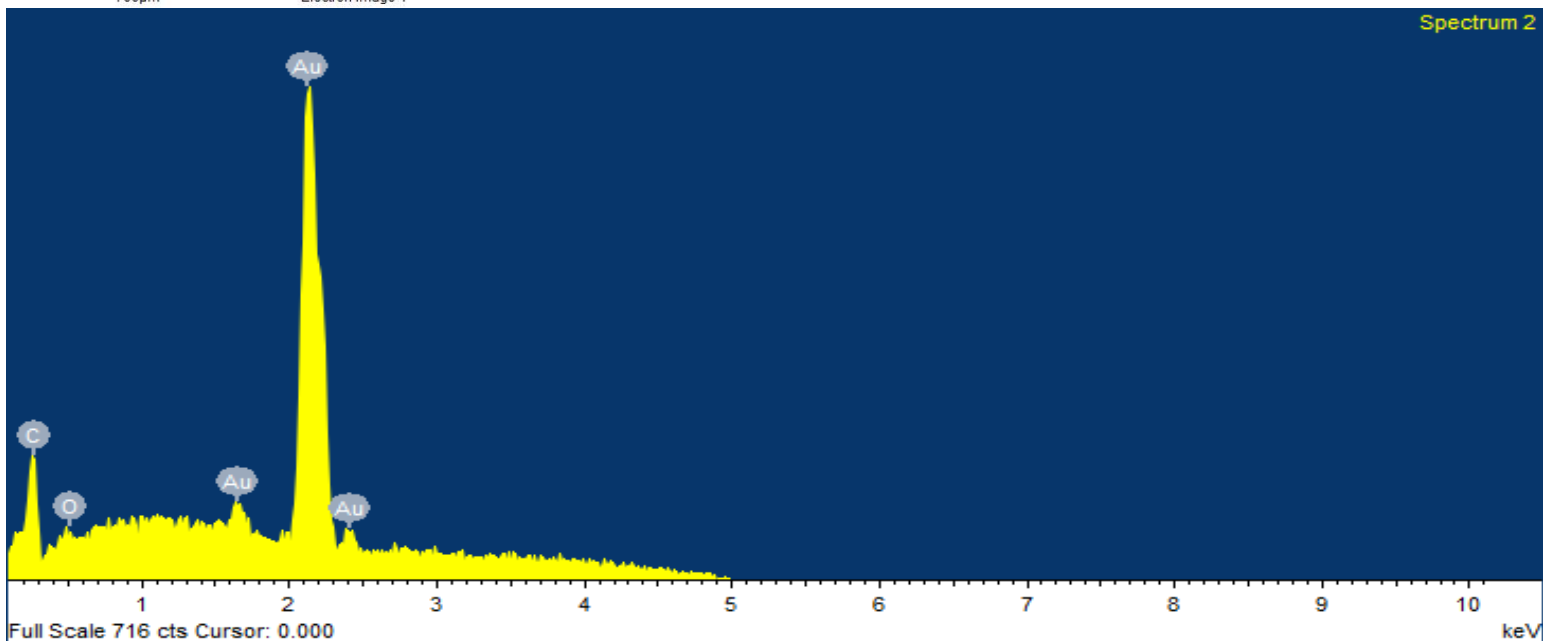


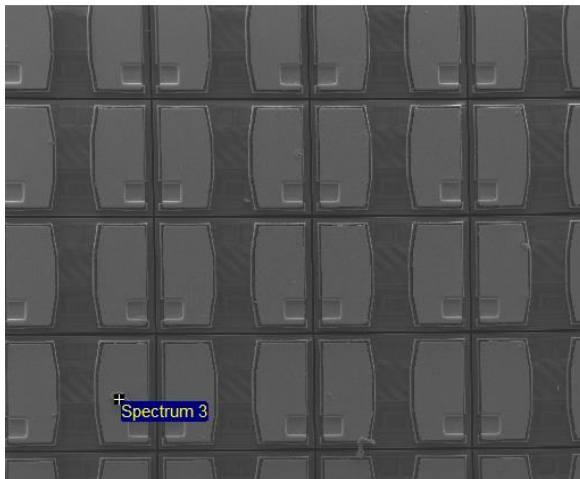


700µm

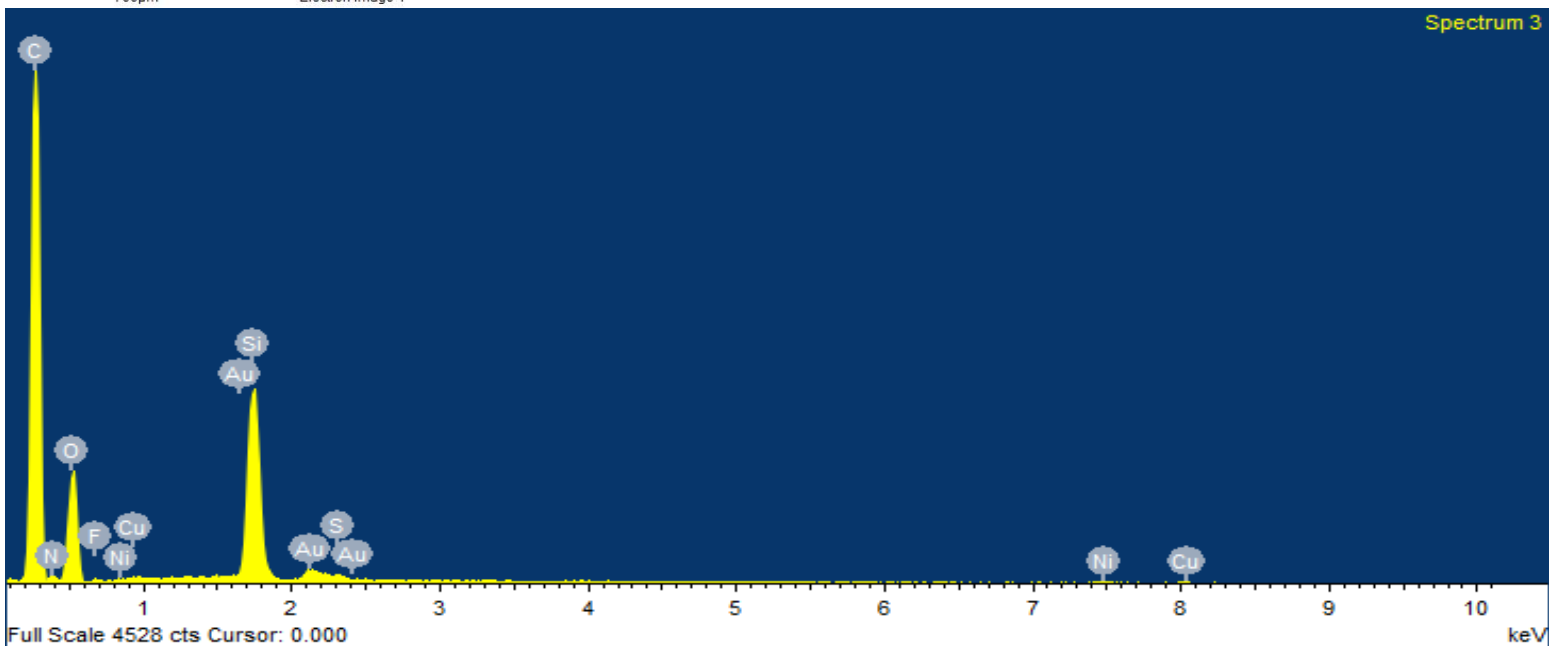
Electron Image 1

Element	Weight%	Atomic%	
C K	2.73	31.37	
O K	0.07	0.57	
Au M	97.20	68.06	
Totals	100.00		





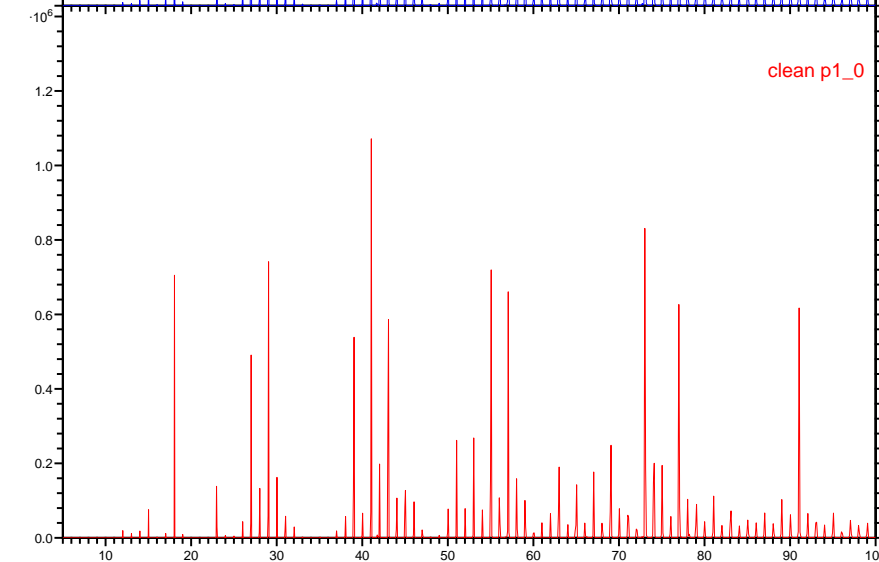
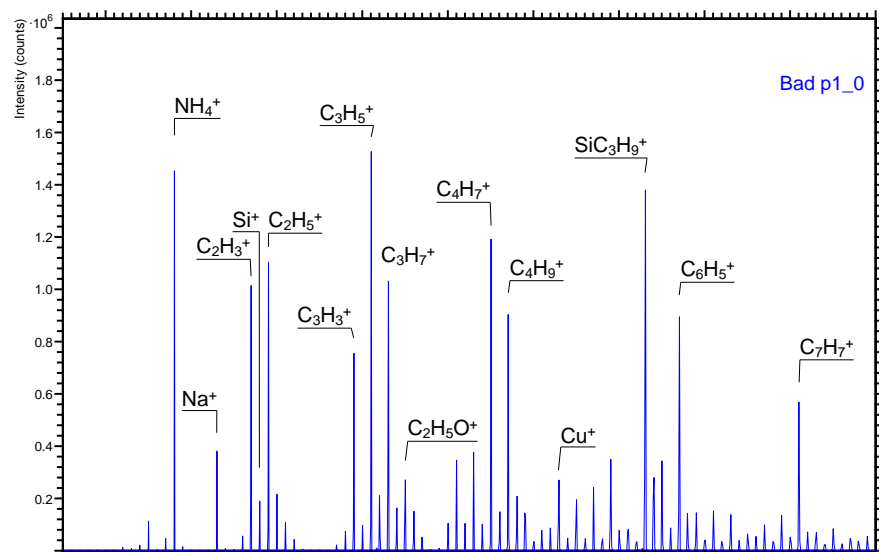
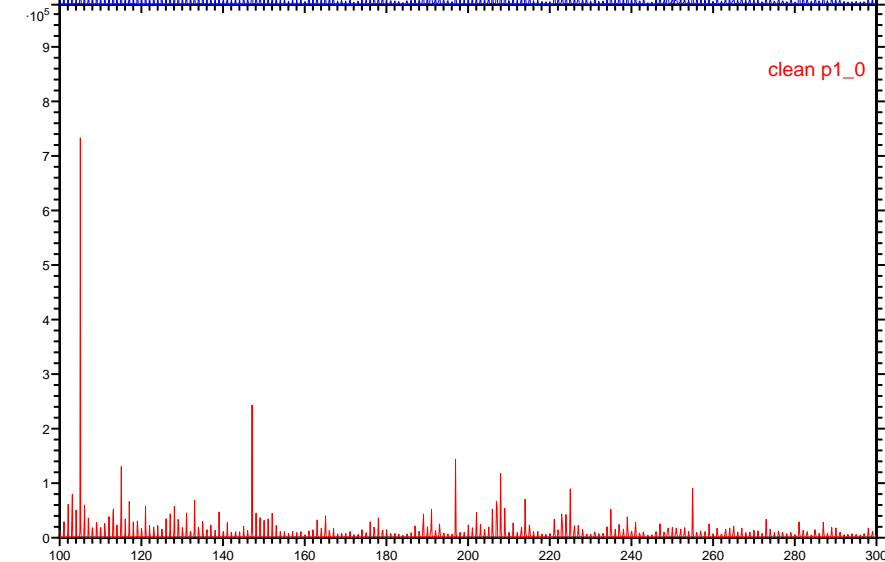
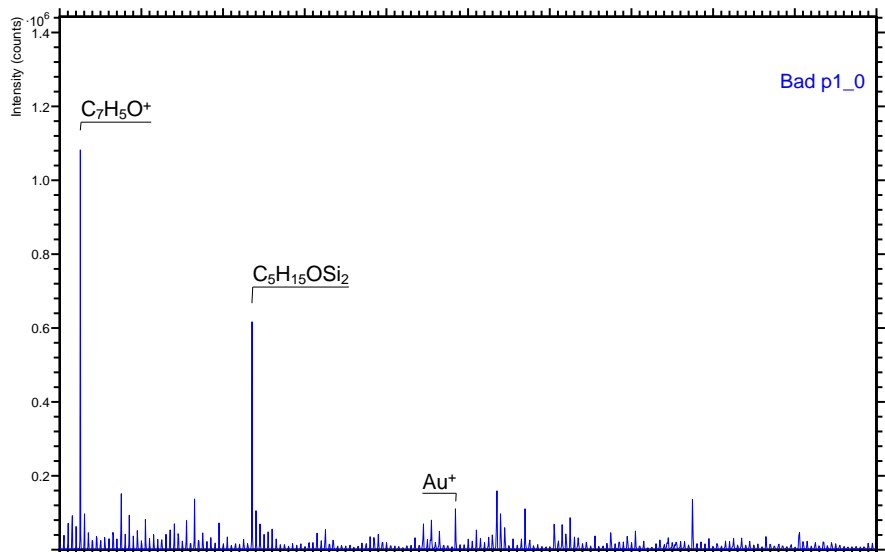
Element	Weight%	Atomic%
C K	60.24	68.70
N K	5.92	5.79
O K	25.97	22.23
F K	0.64	0.46
Si K	5.14	2.51
S K	0.19	0.08
Ni K	0.32	0.08
Cu K	0.30	0.07
Au M	1.26	0.09
Totals	100.00	



- The SEM did not see large contamination overall, but a few large particles.
- 5 kV shows more surface than 20kV and the underlying layers are not detected in 5 kV.
- The “Dirty” area shows basically the same as the “Clean” area.
- The depth of analysis is 0.5 – 5 microns depending on the beam voltage and is too deep for this type of contamination.

- TOF-SIMS analyzes the very top surface of the sample and provides a Mass spectrum of the materials.
- In this case the die was analyzed, and Elemental species were observed including:
 - Na, Mg, Al, Si, K, Ti, Mn, Fe, Cu, F, S, Cl, Au and SO_x species. Gold (Au) is higher from the clean area indicating a ‘cleaner’ region.
- Also detected were Molecular species observed including:
 - fluorocarbons, hydrocarbons, some nitrogen containing species, oxygen containing species and polydimethylsiloxane (PDMS).

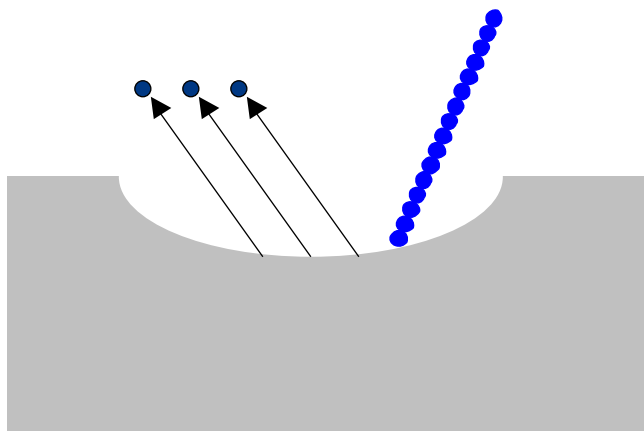
Example Mass Spectrum



- We used a clean appearing die as the control.
- We are now getting an unprocessed die to run as a control.
- We suspect there is a very thin layer of contamination all over the wafer and this is what we are picking up in the current control.

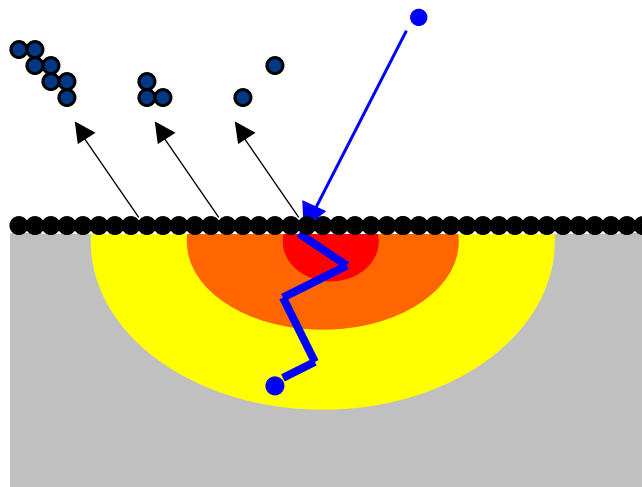
- Surface characterization of organic and elemental materials
- Mapping distributions of surface species
- Contaminant/trace identification (< ppm detection limits)
 - Elemental
 - Molecular
- Failure analysis
 - Adhesion
 - Contamination
 - Coatings
- Evaluation of cleaning processes (QA/QC)
- Identification of stains, discolorations, and hazes

Dynamic SIMS = magnetic sector or quadrupole MS (usually)



- DC constant current (Cs, O)
- Material removal
- Elemental analysis
- Depth Profiling
- Specific species
- Magnetic sector, quadrupole, time-of-flight (TOF) mass spectrometer

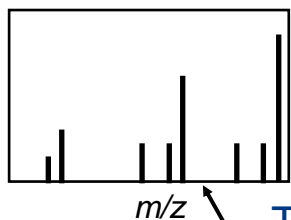
Static SIMS = TOF-SIMS (usually)



- Pulsed ion beam (Ga^+ , Au_n^{x+} , Bi_n^{x+})
- No material removal
 - Analysis complete before significant fraction of molecules destroyed.
 - Ultra surface analysis
- Elemental, inorganic or molecular analysis
- Survey technique
- TOF mass spectrometer

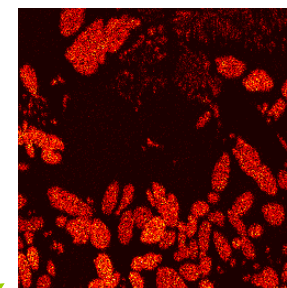
TOF-SIMS Imaging of Alumina-Zirconia-Silica Materials

Region 1 Spectrum

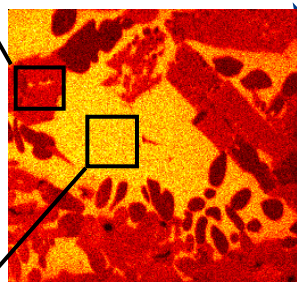


Primary Ion Beam

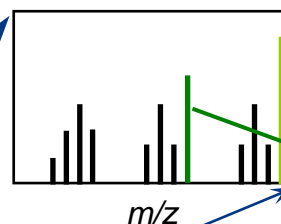
Chemical Map 1



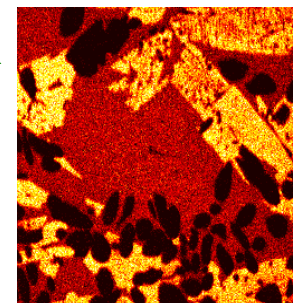
Total Ion Image



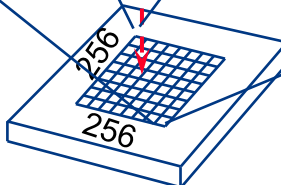
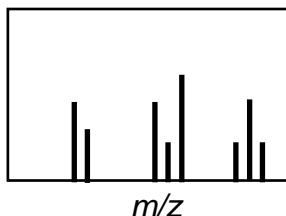
Total Area Spectrum



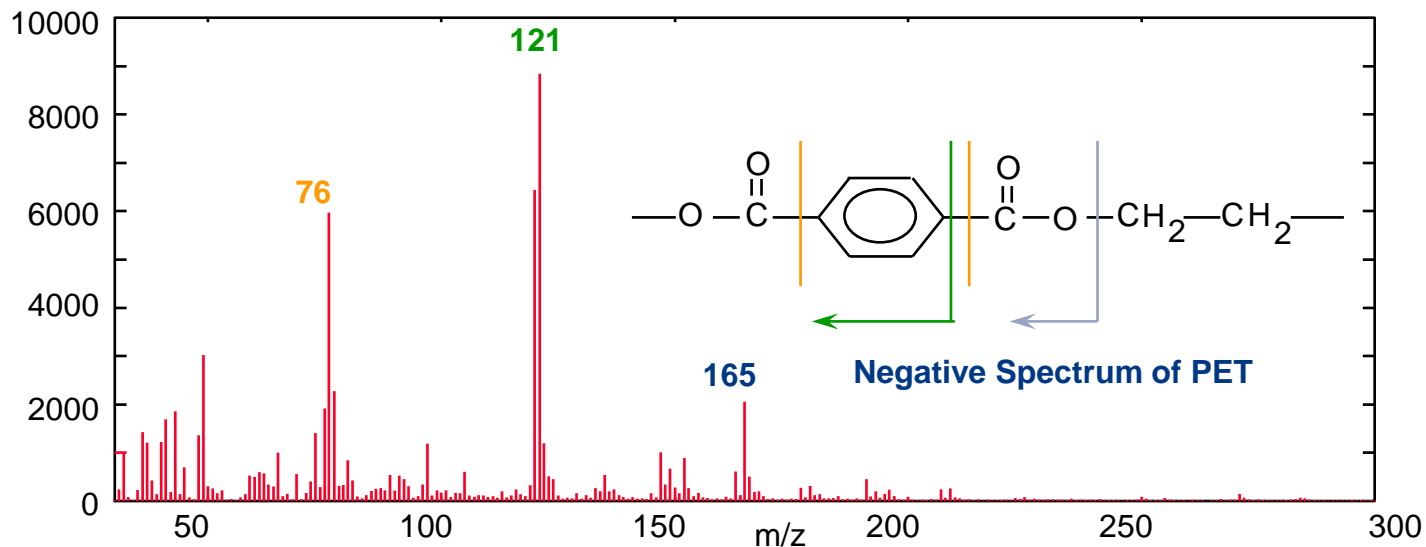
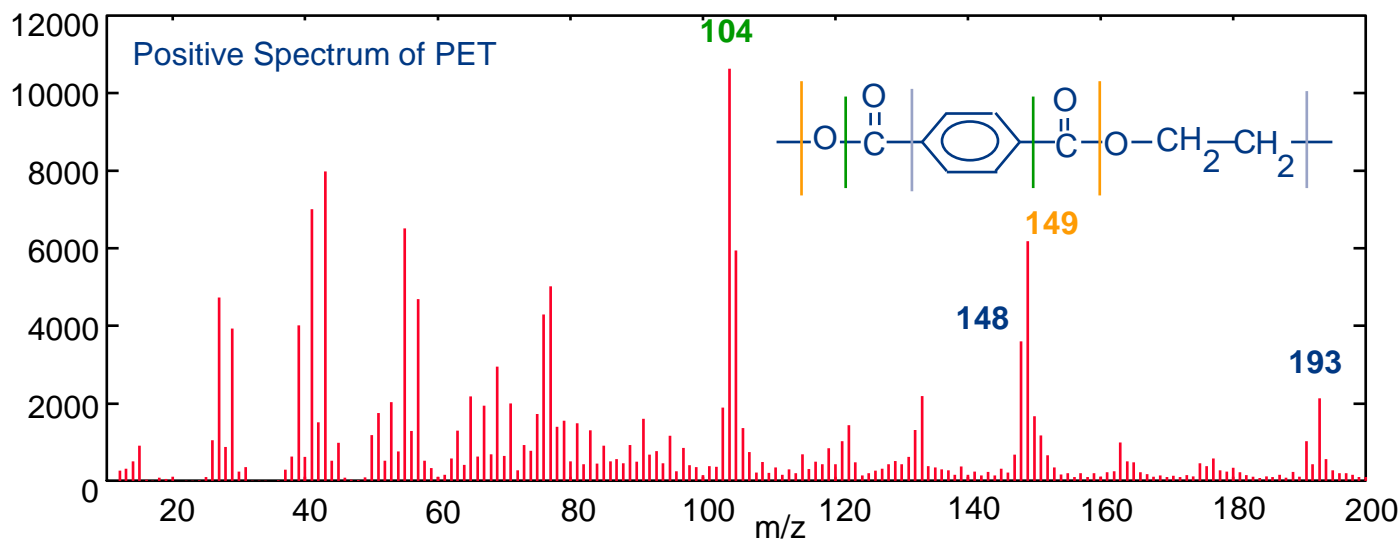
Chemical Map 2



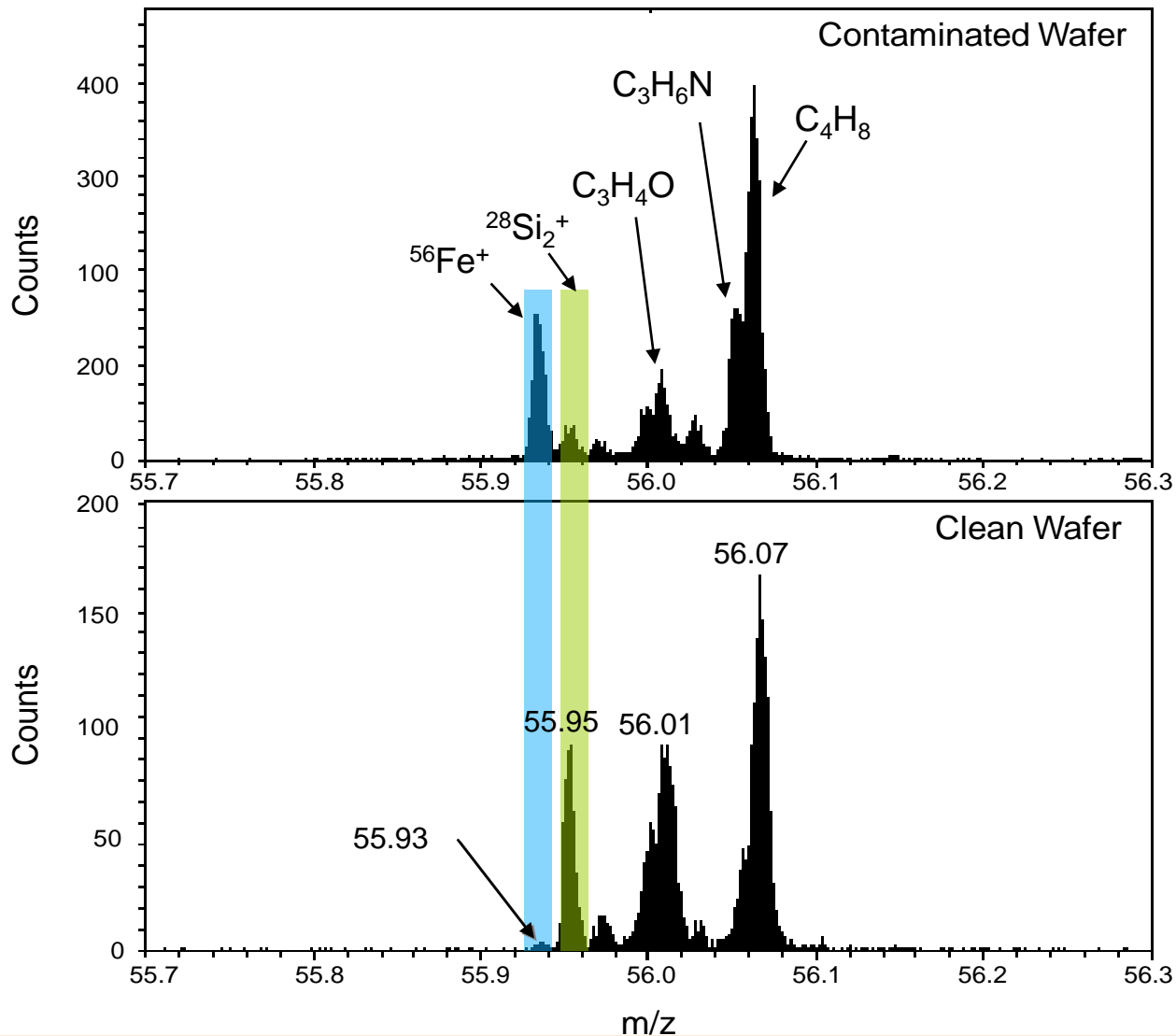
Region 2 Spectrum



Sample



High Mass Resolution: Si wafer: m/z 56 detail

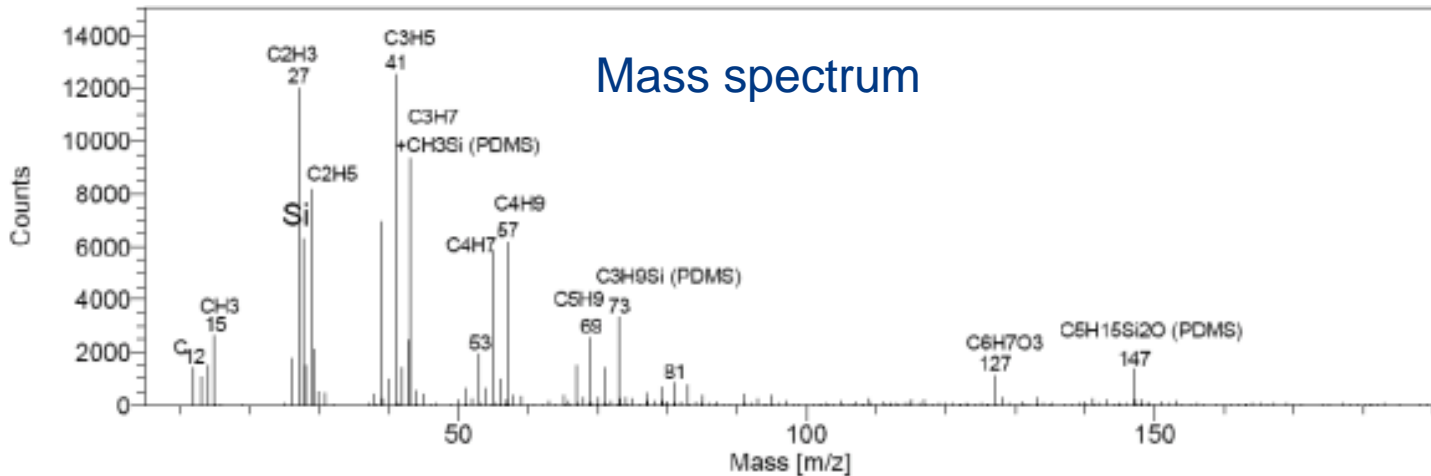
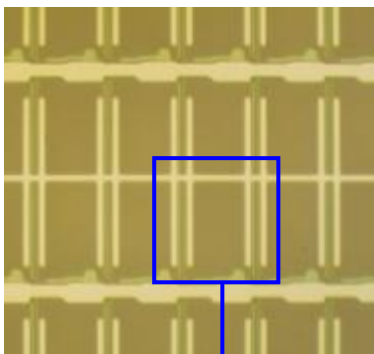


Species	Possible Sources
Silicone, (Polydimethylsiloxane, PDMS)	Machine lubricant, release agent, tape
Polyethylene oxide, polyethylene glycol	Surfactants, plasticizer, printing inks
Fatty acids	Finger oils, lubricants, polymer additives
Glycerides	Soap, polymer additives, release agents
Phosphates, sulfates, etc.	Cleaning reagent, surfactants, additives
Phthalate, etc.	Polymer additives, plastic parts, containers

Organic contaminants are often accompanied by elemental and inorganic species such as Na, K, Mg, Ca, F, Cl, SO₄, PO₃ etc.

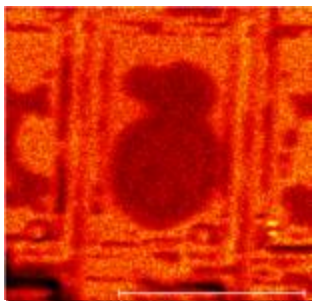
Residue on Flat Panel TFT

Photo of surface

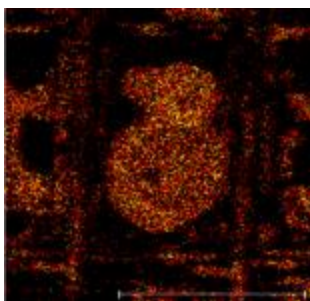


Mass spectrum

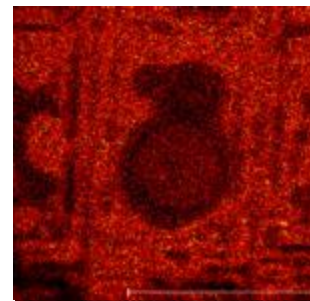
Total ion image

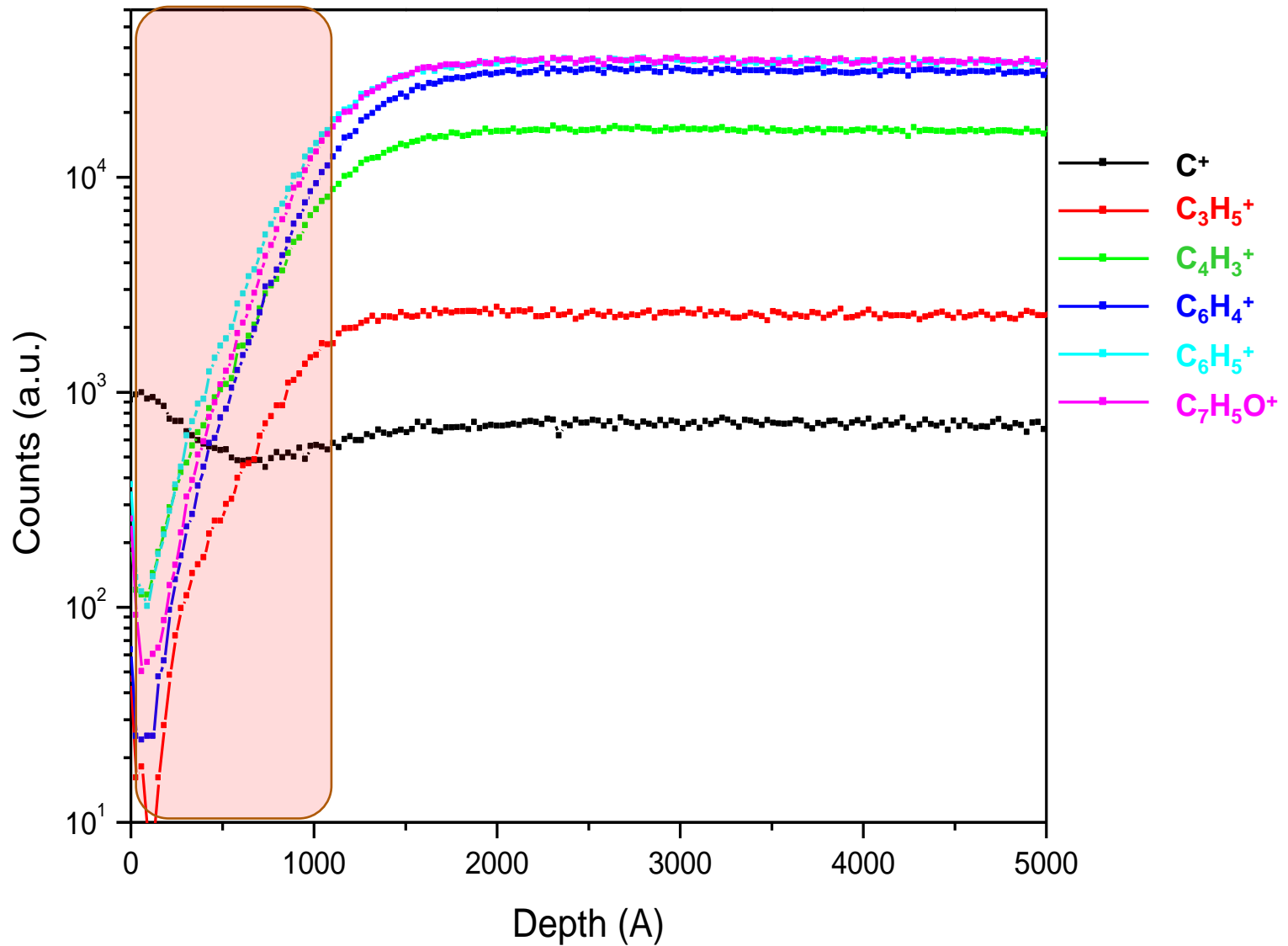


C_3H_9Si image
(silicone)

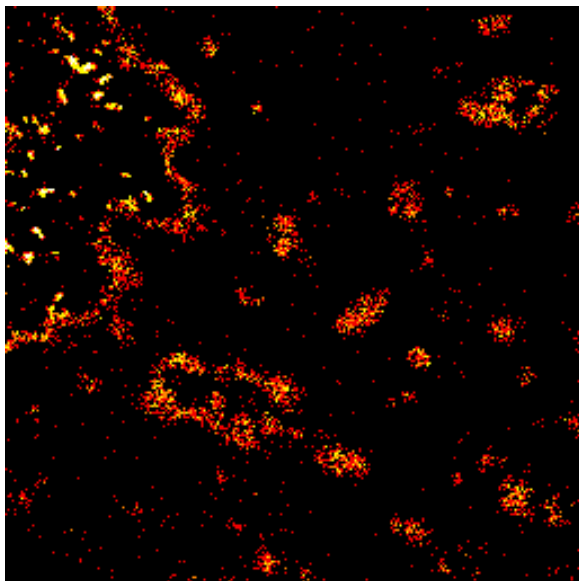


C_2H_3 image
(general hydrocarbon)

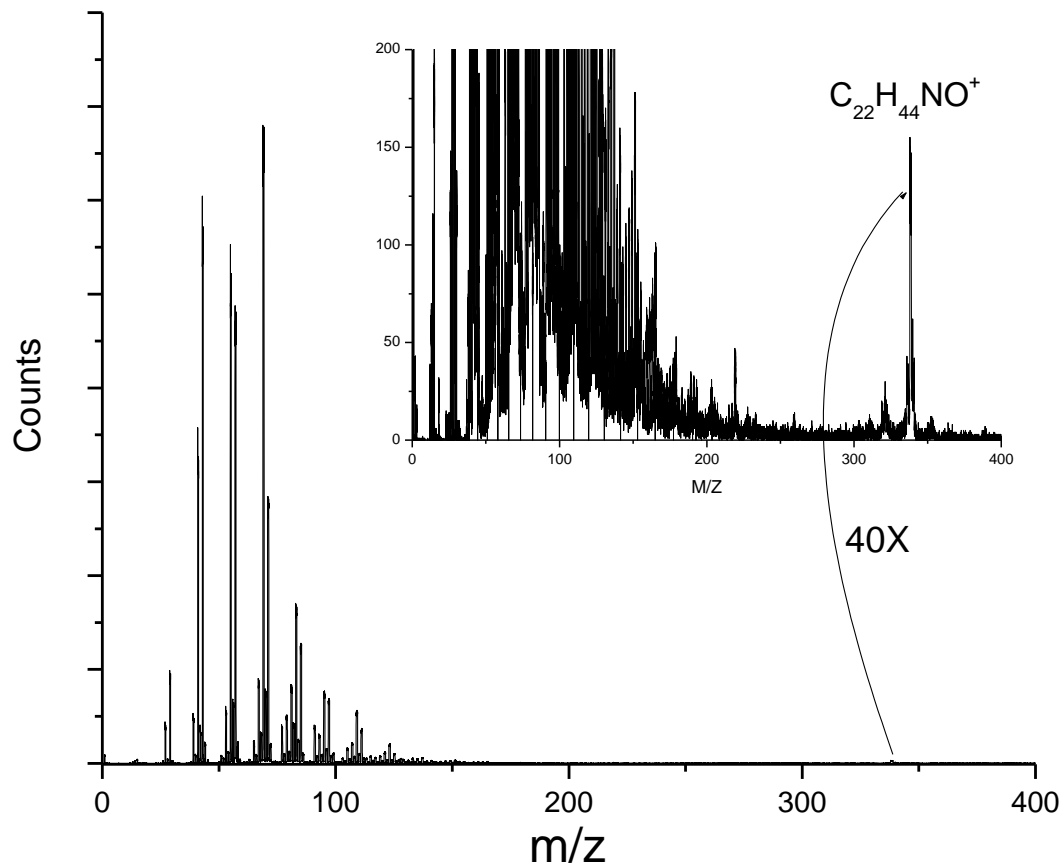




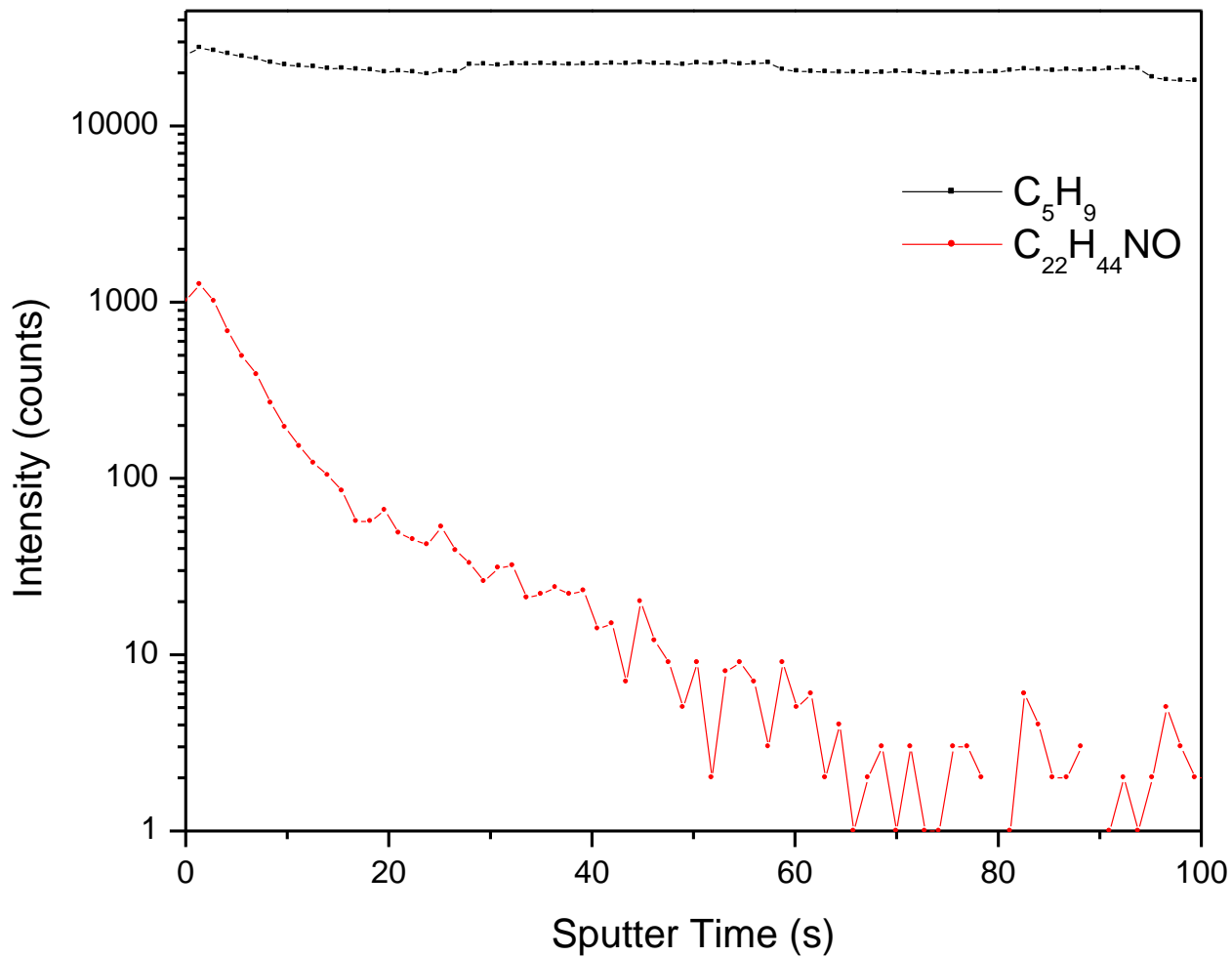
300 μm X 300 μm field of view



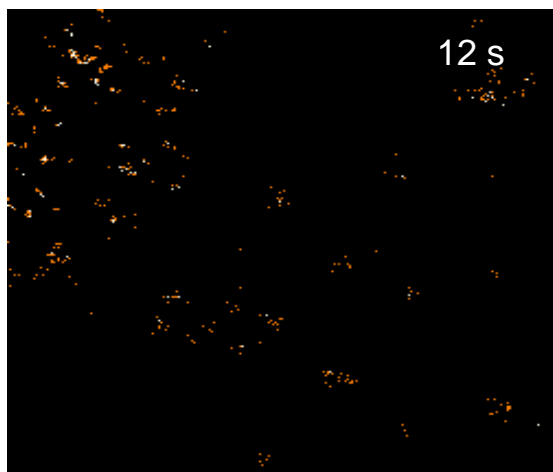
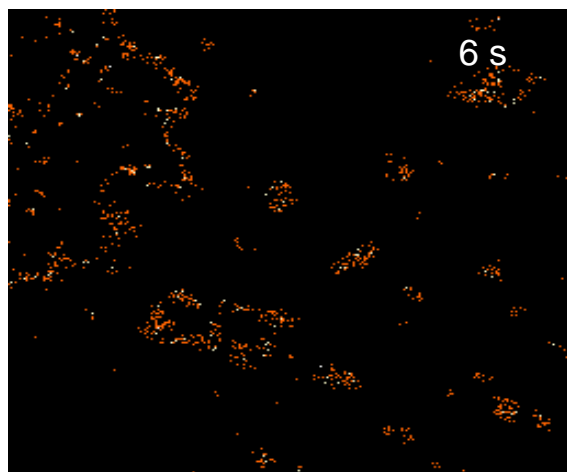
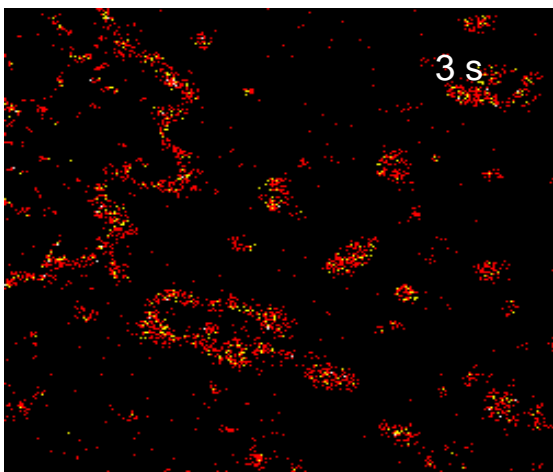
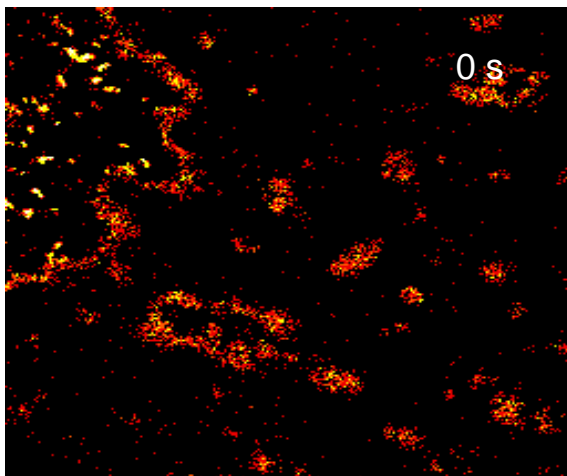
Erucamide



Erucamide on Polyolefin Depth Profile



Erucamide on Polyolefin Ion Images following sputter cycles



Summary

Strengths

- Elemental and molecular information on thin (submonolayer) organic films/contaminants
 - Survey analysis
 - ppm detection limits
 - Small spot size (0.2 μ m) and mapping
 - Unique profiling capabilities
 - Can analyze insulators and conductors
 - Applicable to a wide range of samples and industries
 - Bridge technique between surface analysis and chromatographic methods such as GC-MS and LC-MS
-

Limitations

- Organic information can be hard to interpret without control samples, reference material or database spectra
- Vacuum compatibility required
 - Wet samples possible but challenging
- At times, too surface sensitive
 - Sample handling and storage may dominate data obtained



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