Multi-Technique Scanning Auger Nanoprobe

PHI *710*

PHYSICAL ELECTRONICS
A DIVISION OF ULVAC-PHI

PHI *710*

Multi-Technique Scanning Auger Nanoprobe

NO COMPROMISE!

Features

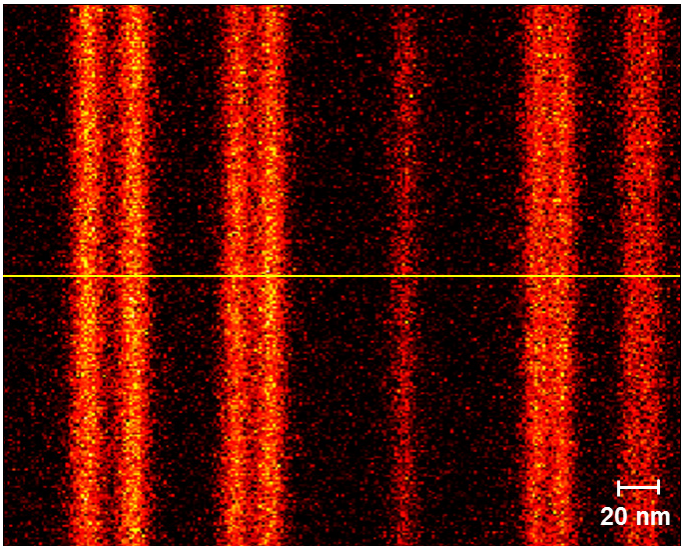
- ✓ High spatial resolution Auger and secondary electron (SE) imaging
- ✓ Superior Auger imaging of real world (rough) surfaces
- ✓ Cylindrical Mirror Analyzer (CMA) with high energy resolution capability
- ✓ Robust insulator analysis capability
- ✓ Multi-technique solutions for *in-situ* characterization

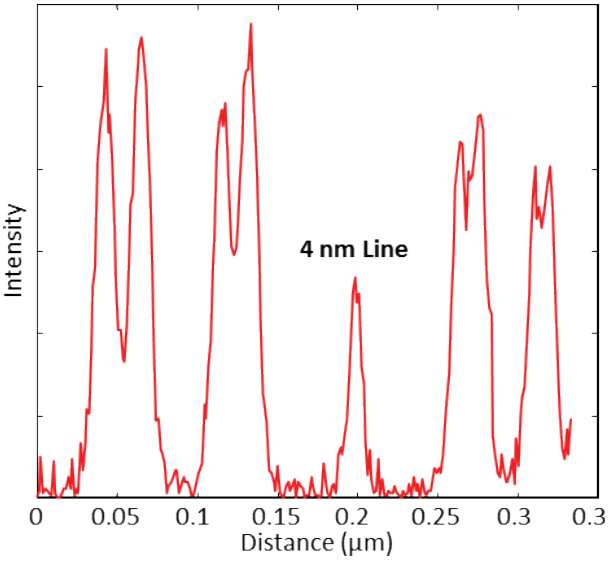
PHI *710*

Multi-Technique Scanning Auger Nanoprobe

Exceptional Spatial Resolution

High performance electronoptics, precision sample handling, and advanced vibration and thermal isolation provide a superior environment for nano-scale Auger imaging and analysis at working magnifications of 500,000 X and higher. A robust imaging registration capability ensures long term image stability when it is needed.

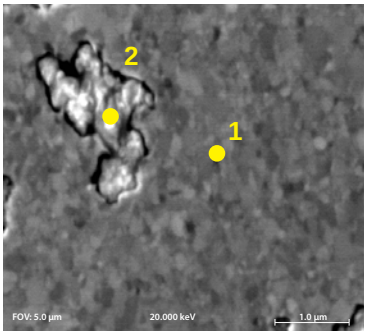


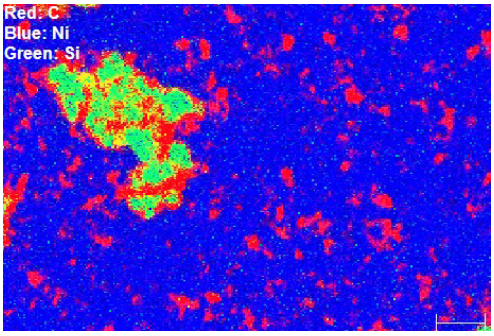


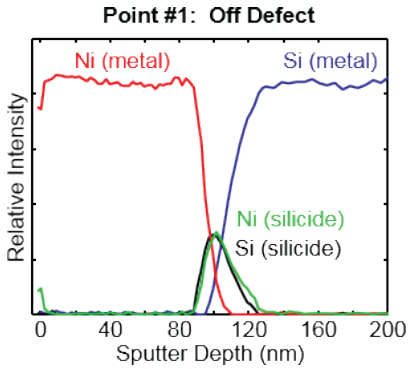
The sample above presents the cross-section of alternating layers of GaAlAs and GaAs of known thickness in a spatial resolution reference sample. On the left is an Al Auger map and to the right is an Al line scan that was extracted from the map data.The shape of the single 4 nm line acquired for 24 hours demonstrates the high stability of the 710 and the effectiveness of its image registration software.

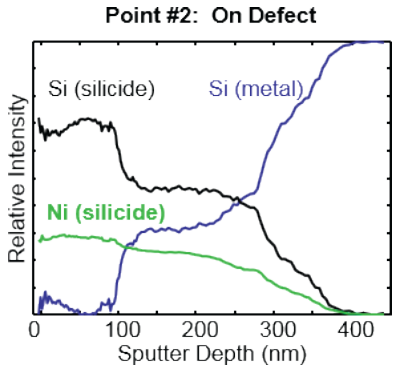
Nanoscale Thin Film Analysis

The PHI *710*'s floating column ion gun provides a broad range of depth profiling capabilities. At higher ion beam energies (2-5 keV) structures several microns thick can be routinely depth profiled. For thin and ultra-thin films (< 5 nm) the floating ion column can be used to efficiently sputter with ion beam energies of 100-500 eV. The use of lower accelerating voltages reduces sputter mixing that could broaden the observed interfaces in an ultra-thin film structure.







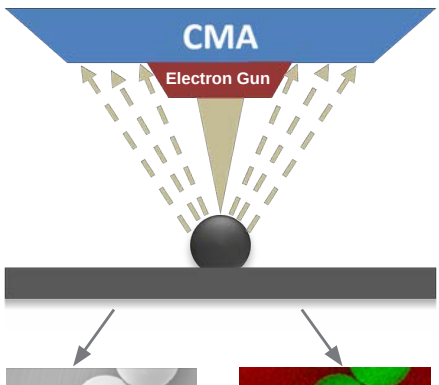


The sample shown in the SE image to the left contains a defect that appeared in a thin nickel film deposited on silicon substrate after it was annealed to form a nickel silicide at the interface. A 500 V multi-point argon sputter depth profile showed the expected formation of Ni silicide at the interface at point 1. However, at point 2 a complex multiphase silicide is observed at the defect. The chemical state information was obtained using linear least squares fitting to process the high energy resolution spectra that were collected.

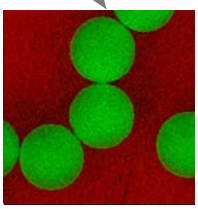
Unobstructed Visualization

PHI's coaxial electron gun and analyzer geometry provides the sensitivity and unobstructed vision needed to fully characterize the microstructures that exist on most real-world samples. Instruments with non-coaxial geometry suffer from geometric effects that dramatically reduce instrumental sensitivity and create shadows that limit the usefulness of compositional images. With the 710's coaxial geometry, Auger data is obtained from all sides of particulates and between particles with equally high sensitivity providing Auger maps with meaningful compositional information.

PHI 710 Coaxial Geometry

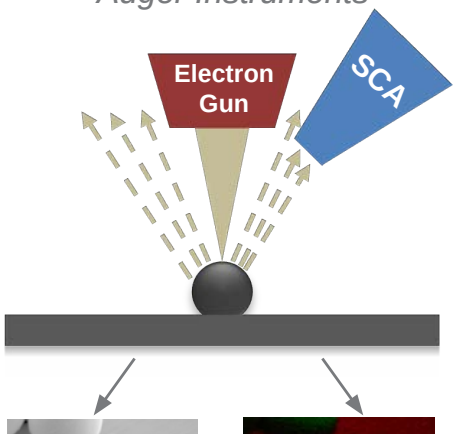


Secondary Electron Image

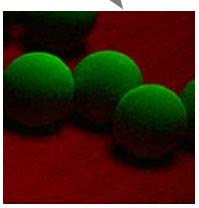


Sn and Cu Auger Maps No Shadowing

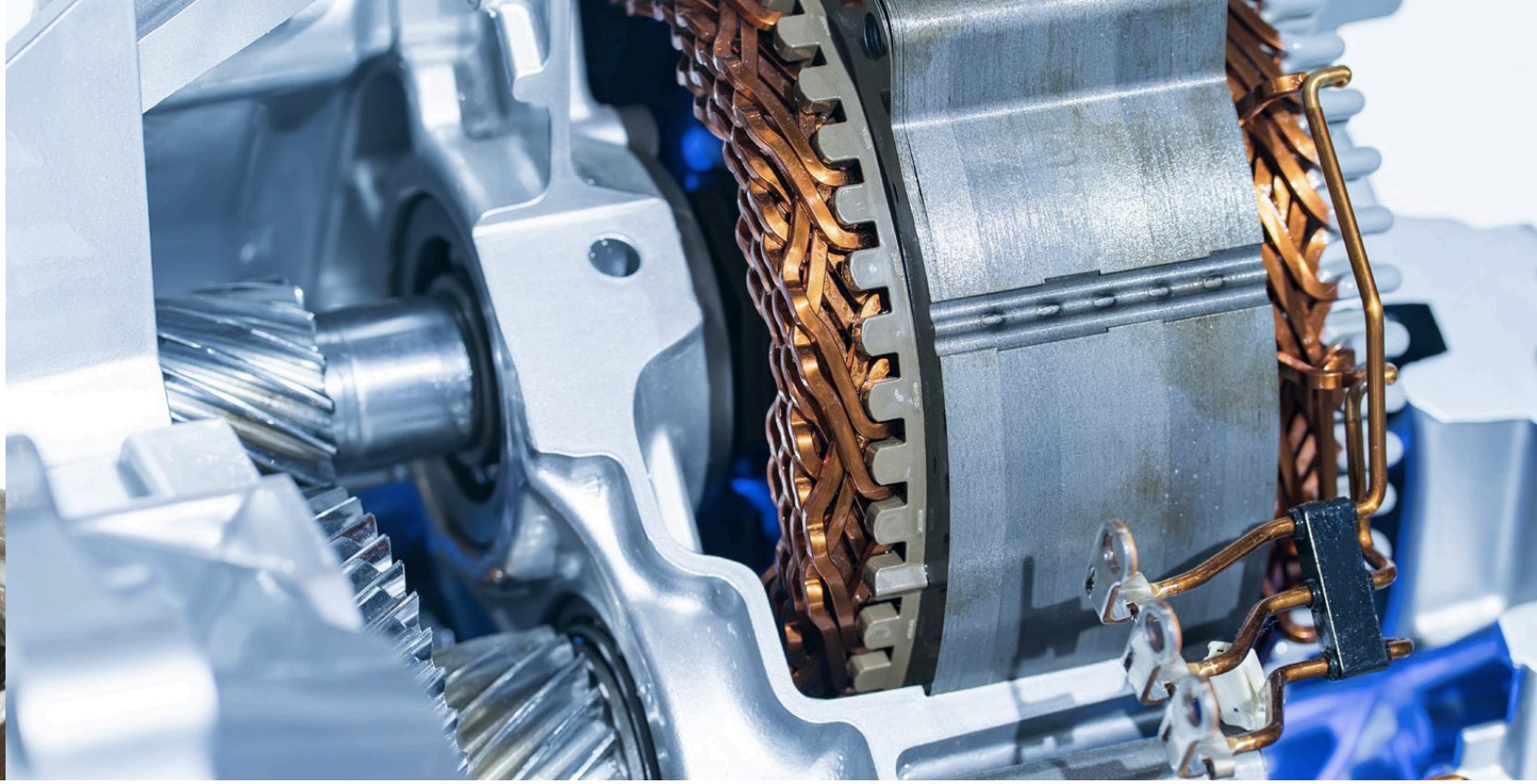
Other Non-Coaxial Auger Instruments



Secondary Electron Image

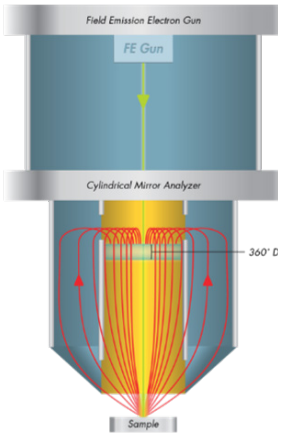


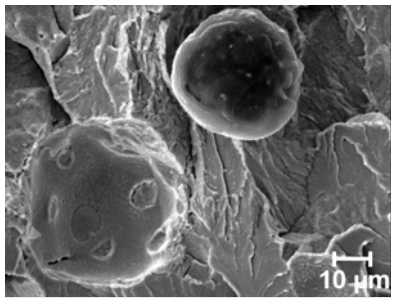
Sn and Cu Auger Maps Shadowing



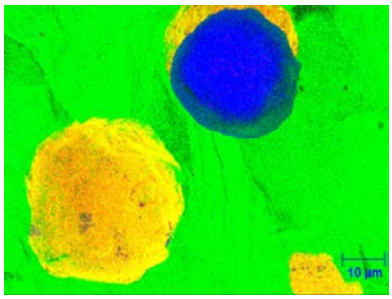
Excellent Imaging on Real-World Materials

The coaxial analyzer and electron gun geometry provided by the PHI *710* produces a complete compositional picture of the area selected for analysis. The analyzer will provide data from every location the electron gun probes. Black areas in maps are usually not caused by sample roughness and analyzer shadowing, but instead indicate the presence of another element.

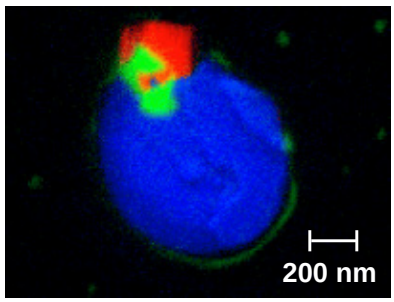




SE Image



Fe, C, and Sn
Auger Maps

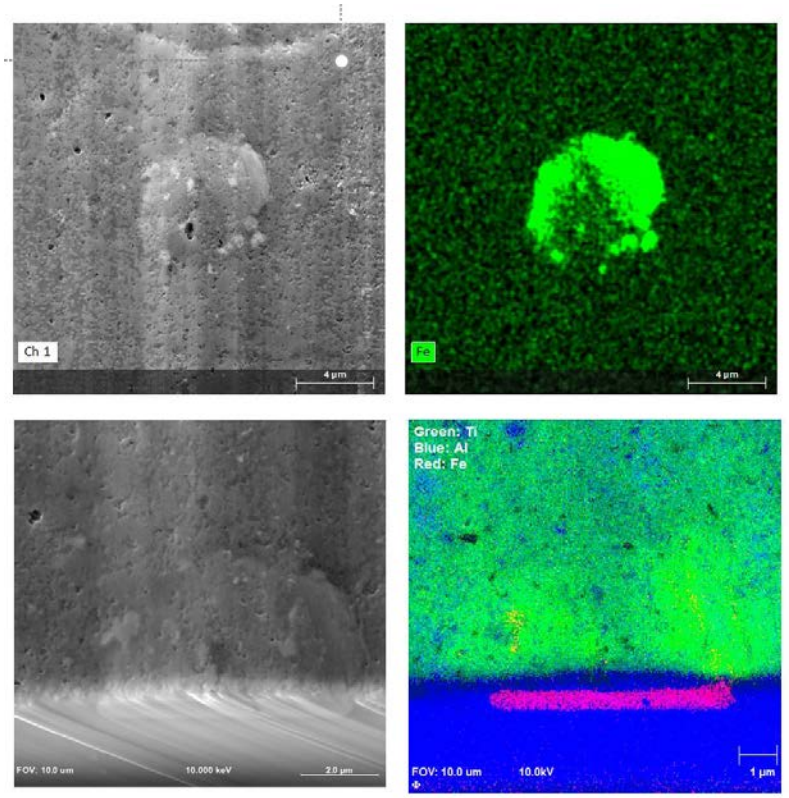


Mg, Ca, and Ti
Auger Maps

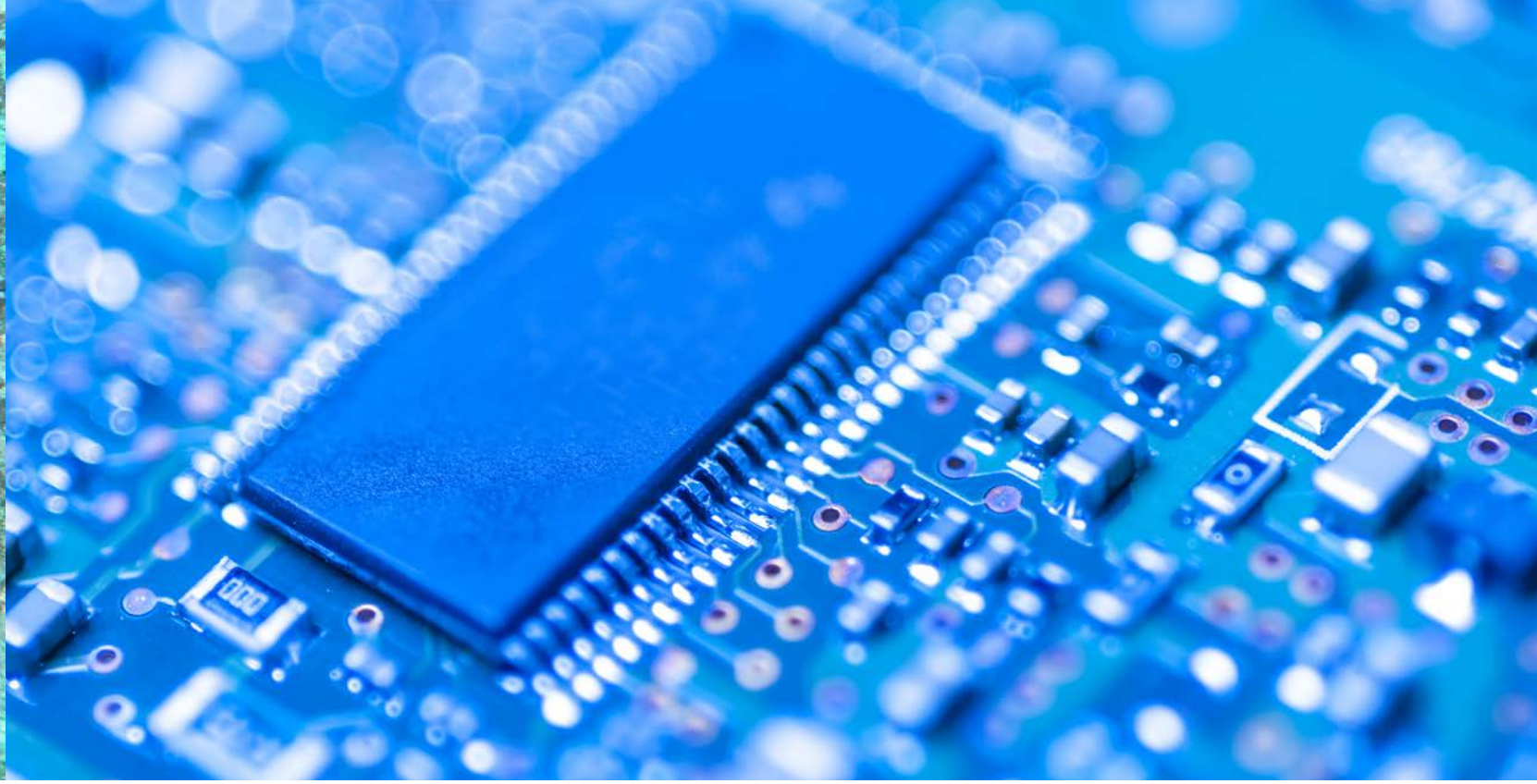
The secondary electron image (top) shows the microstructure of a ductile iron fracture surface including graphite nodules and craters where graphite nodules have fallen out because of the fracture. The AES maps (left) show the ability to map across the graphite nodule and the crater where Sn has segregated to the nodule / iron interface. AES maps (right) show the complex composition of a small precipitate. Only PHI Auger instruments with coaxial electron gun and analyzer geometry provide such a complete compositional picture of a rough sample surface.

Specialized Solutions for *In-Situ* Characterization

The PHI *710* has multiple optional technique add-ons and accessories for specialized experiments. Liquid metal focused ion beam (FIB) allows for *in-situ* cross-sectioning of particles, defects and coatings. Energy Dispersive X-ray Spectroscopy (EDS) detector provides qualitative and quantitative elemental information. The windowless software driven motor-controlled detector has a short working distance for wide acceptance angles. Backscattered Electron Detector (BSE) provides topographic information and compositional information of the sample by using a four-quadrant detector. Electron Backscatter Diffraction (EBSD) detector provides information about crystal structure and grain orientation.



The secondary electron image (top left) shows a particle within a titanium zirconium passivated aluminum sample. The particle was first observed by SEM/EDS and the EDS map (top right) of the region showed that the particle contained iron. A FIB cut across the center of the particle (SEM image, bottom left) reveals the iron containing particle is platelet shaped and buried beneath the sample surface (bottom right). Analysis of these types of buried features requires the complementary analytical capabilities of EDS, FIB, and AES.

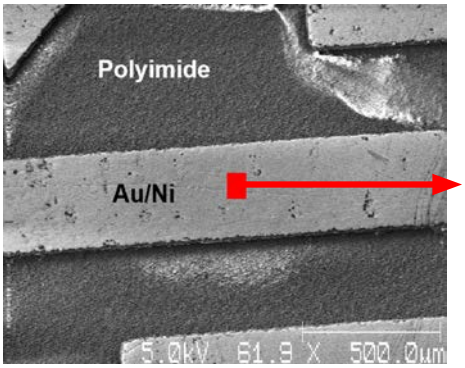


Solutions for Insulating Materials

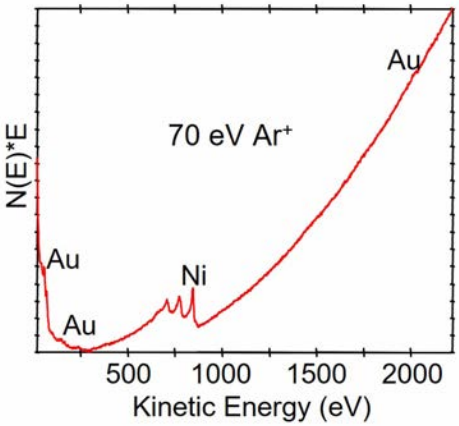
The PHI *710*'s floating column ion gun can be effectively used at very low energies to facilitate the analysis of many electrically insulating samples. This method is particularly effective on inorganic materials such as ceramics and electronics packages.

Photograph of printed circuit board

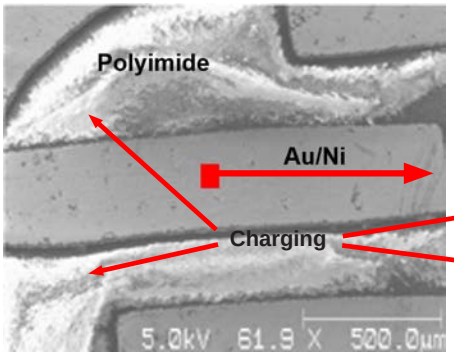
<u>With</u> charge neutralization



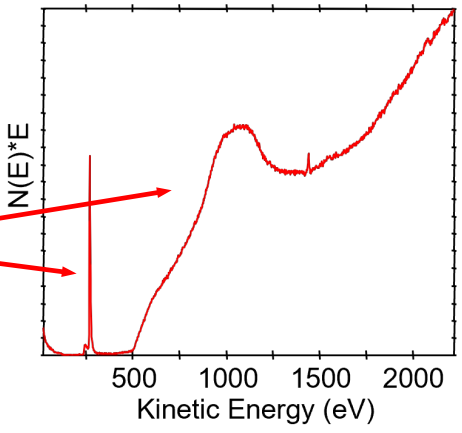
Secondary electron image



<u>Without</u> charge neutralization

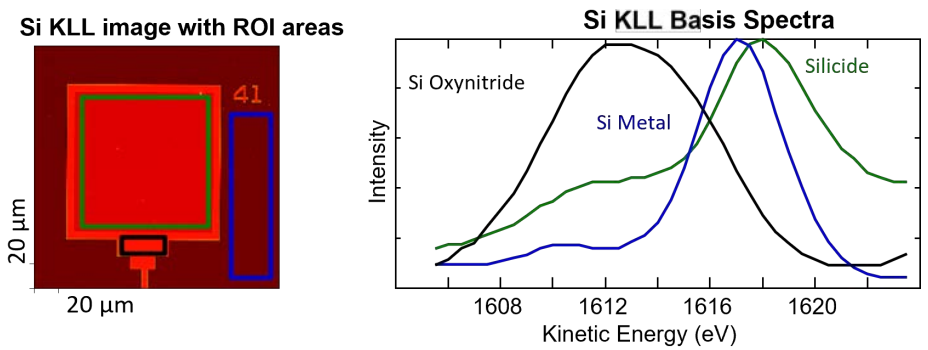


Secondary electron image

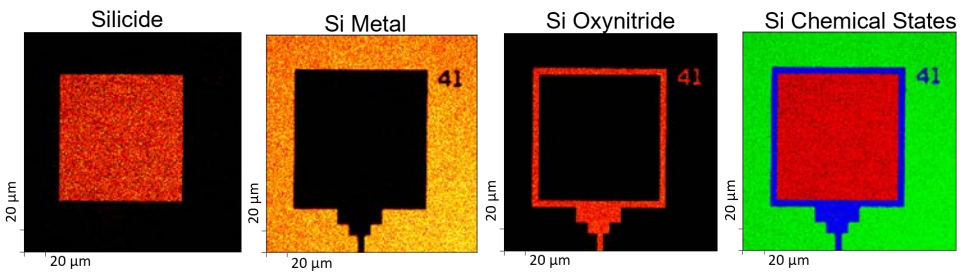


High Energy Resolution

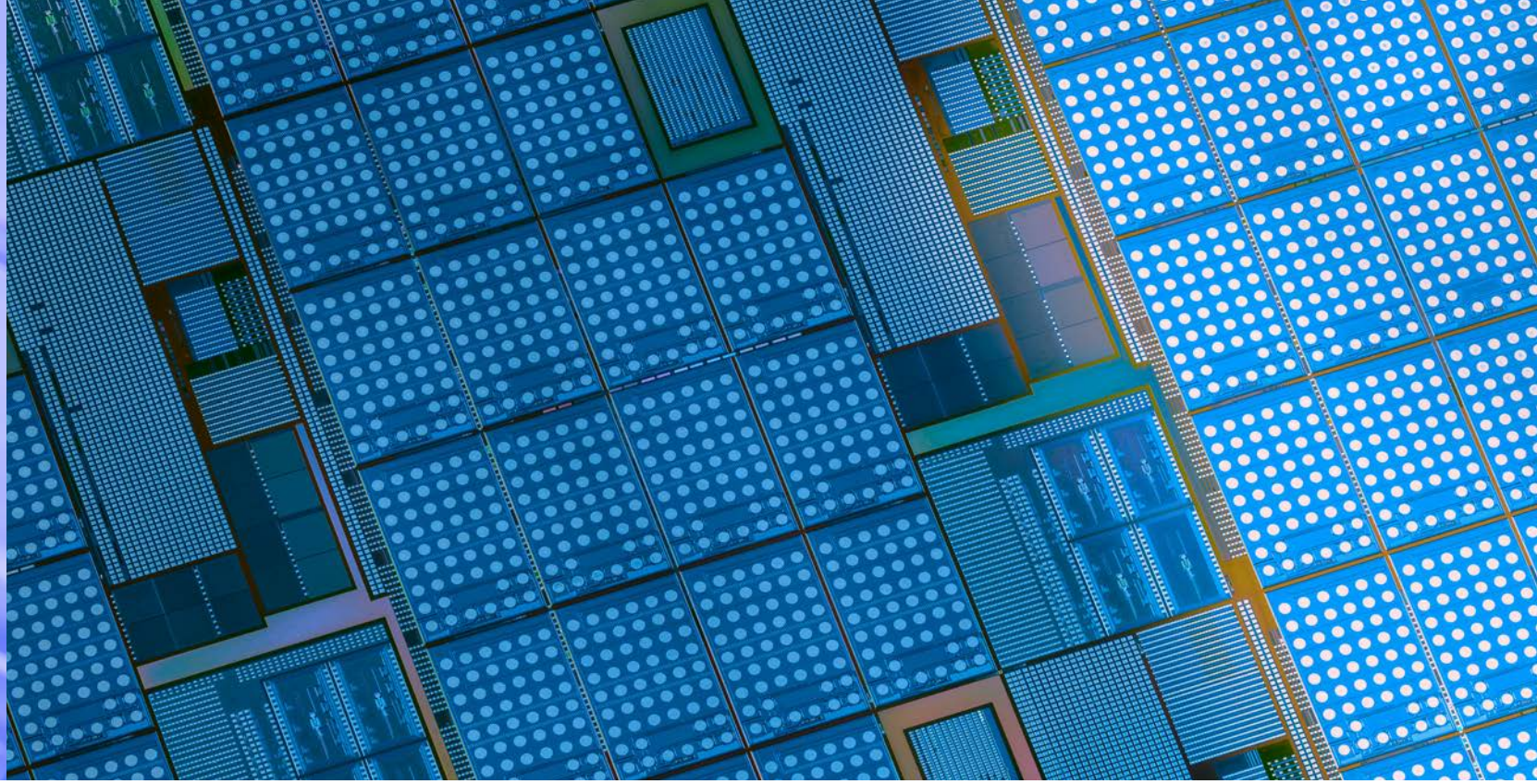
The 710's high energy resolution mode of operation provides for continuous adjustment of the analyzer energy resolution to as low as 0.1%. The high energy resolution capability can be used to enhance the chemical information content of spectra and AES images while maintaining all the advantages of the CMA with a coaxial electron source for obtaining data with high sensitivity and nearly eliminating topography induced artifacts. Additionally, the PHI *710* Scanning Auger Nanoprobe has now incorporated new electronics and data interpretation software to facilitate chemical state mapping based on images that contain a spectrum at each pixel.



The Si KLL peak area image from a semiconductor bond pad (left) is shown with three regions of interest. The extracted basis spectra from each ROI (right) reveals three distinct chemical states of silicon. This is enabled by the spectral window imaging mode, wherein a Si KLL spectrum is collected and stored for each image pixel.

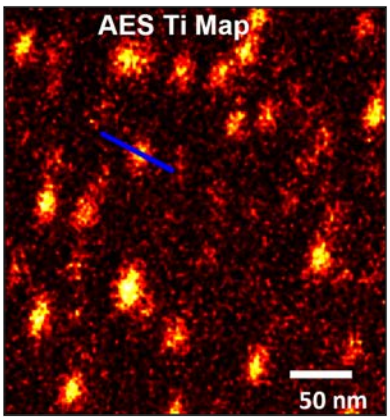


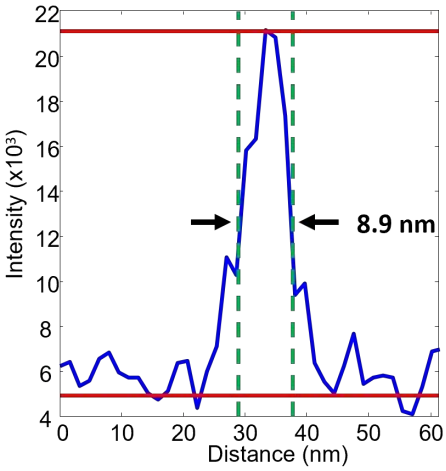
High energy resolution mapping of the bond pad shows chemical state images of silicide, elemental Si and Si oxynitride. The color overlay of elemental silicon, silicide and silicon oxynitride images clearly shows three chemical states of silicon.

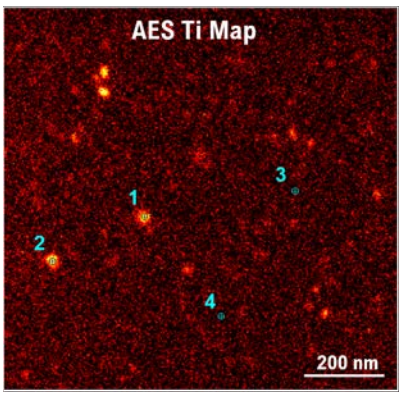


Nanovolume Analysis

The PHI *710*'s high spatial resolution combined with the coaxial CMA analyzer and the inherent shallow information depth of Auger Electron Spectroscopy enable nano-volume characterization of small particles. Defect particles, which can be detrimental to semiconductor device performance, are readily imaged and elementally quantified using state of the art technology.







	On particle		Off particle	
At. %	1	2	3	4
Si	38.7	34.5	81.8	80.0
Ti	15.6	15.9	2.5	3.1
O	15.7	17.1	4.3	3.9
C	30.0	32.5	11.5	13.0

Defect particles present during an atomic layer deposition/atomic layer etching process are readily imaged and characterized. These particles were found to consist of an elevated titanium concentration compared to the surrounding substrate. From then titanium map (above), a <9 nm diameter nanoparticle is clearly identified, demonstrating the PHI *710*'s superior nano-volume analysis capability.

Integrated Isothermal Atomic Layer Deposition/Atomic Layer Etching Supercycles for Area-Selective Deposition of TiO2, Seung Keun Song, Holger Saare, and Gregory N. Parsons, Chemistry of Materials 2019 31 (13), 4793-4804

Standard Features

- Cylindrical mirror analyzer
- Coaxial 25 kV field emission electron gun
- Scintillation secondary electron detector
- High energy resolution module
- 5 axis sample stage
- 5 kV floating column Ar^+ ion gun
- SmartSoft-Auger instrument control software
- Multipak data reduction software
- Acoustic enclosure
- Ion pumped analysis chamber

Optional Accessories

- Intro camera
- In situ sample parking
- In situ sample fracture
- Sample transfer vessel
- EDS detector
- EBSD detector
- Intro cold cathode gauge
- BSE detector
- Active vibration isolation
- Die navigation software
- 4 contact stage with heating capability
- Focused Ion Beam

PHYSICAL ELECTRONICS
A DIVISION OF ULVAC-PHI

Physical Electronics - USA
Phone: 952-828-6100
Email: sales@phi.com
Web: www.phi.com

ULVAC - PHI Inc. - Japan
Phone: 81-467-85-4220
Email: webmasterjp@phi.com
Web: www.ulvac-phi.co.jp