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Auger Electron Spectroscopy (AES) Services

Auger Electron Spectroscopy (AES or Auger) is an extremely useful tool for elemental analysis of small surface features.

The Auger Electron Spectroscopy technique (named after Pierre Auger, who described this process in 1925) uses a primary electron beam, typically in the 3 to 25 keV range. Atoms that are excited by the primary electron beam can relax through the emission of Auger electrons as an energy loss mechanism. The kinetic energies of the emitted Auger electrons are measured and are characteristic of elements present at the surface (~3-10nm) of a sample. The resulting spectrum is usually plotted as the derivative of the signal intensity vs. kinetic energy, with each element showing a unique "fingerprint" for elemental identification. The electron beam can be scanned over a large or small surface area, or it can be directly focused on a specific surface feature. This scanning electron beam also generates secondary electron (SEM) images that are used to locate the features of interest.

Auger maps and linescans show the lateral distribution of elements on a surface, while depth profiles, obtained through the use of an additional sputtering ion beam, can reveal the composition as a function of depth.

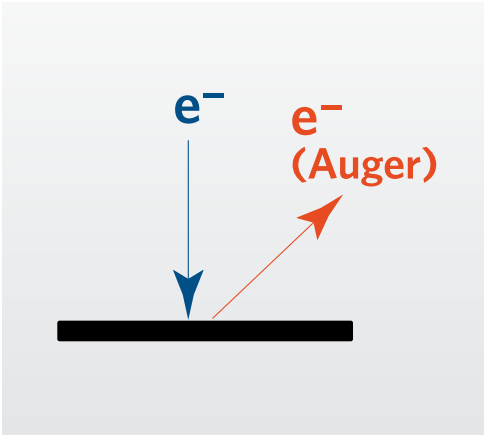


Figure 1: General schematic of how Auger works

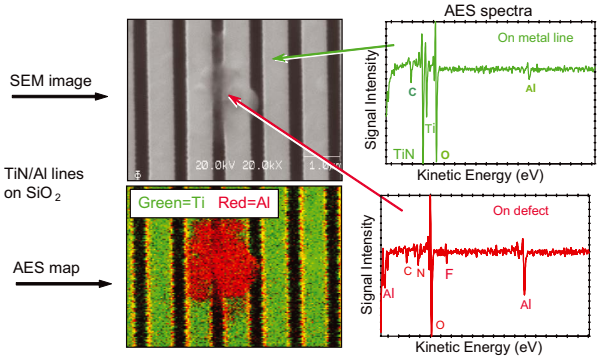


Figure 2: Auger analysis shows the thin residue is an Al flake, probably originating from the etch chamber.

Auger Electron Spectroscopy (AES, Auger, pronounced with a soft 'g') is an analytical technique used to determine the elemental composition of the top few atomic layers (~3-10nm depth of analysis) of features as small as ~20nm. This technique is widely used to identify the composition of sub-micron particles, defects and features of interest. Auger can detect all elements except H and He and provides semiquantitative information with detection limits of 0.1 to 1 atomic percent for most species. Auger is normally used for analyzing conductive and semiconductive solids, although some insulating materials can also be analyzed. When used in combination with an ion sputter source, Auger can perform small-area compositional depth profiling, and when used in combination with Focused Ion Beam (FIB), it can be useful for analyzing cross sectioned samples. The information obtained by Auger can be very complementary to other more common electron microscopy-based techniques such as EDS (Energy Dispersive X-ray Spectroscopy). The unique advantage that Auger brings is the shallow information depth, meaning that the information obtained is very surface specific

(within the top 10nm or less) compared to the µm scale for EDS in many cases.

Strengths

- High Spatial Resolution: ≥10nm minimum spot size
- Surface Sensitive; top 3-10nm
- Identification of all elements except H and He
- 2D and 3D elemental distribution of small areas
- Rapid analysis for elemental composition
- Can analyze up to 300mm wafers

Limitations

- Minimal chemical state information
- Insulators are difficult
- Samples must be vacuum compatible
- Detection limits of ~0.1% to 1% atomic

Common Applications

- Analyzing sub-µm particles to determine contamination sources
- Identifying defects in electronic devices to investigate failure causes
- Small-area depth profiling of bond pads on die and oxide layer thickness of electro-polished devices
- Mapping of elemental distributions on discolored or corroded regions
- Cross-sectional analysis of buried defects in film stacks
- Identifying grain boundary contamination in metal fracture failures
- Integrity and uniformity of thin film coatings such as diamond-like-carbon (DLC)

Industry Sectors and Technologies

- Medical devices
- Semiconductors
- Electronics
- Aerospace materials testing
- Data storage
- Energy storage and batteries; Solar/PV
- Lighting and LED

Case Study: Bond Pad Analysis

Contamination and/or the presence of relatively thick oxide layers on bond pad surfaces can lead to poor adhesion and electrical connectivity of the wire or ball to the bond pad. The source of such bonding problems can be readily identified via Auger analysis. Auger can be used effectively to monitor the cleanliness of the outermost surface of bond pads, as well as measure the thickness of the oxide layer, thus identifying the probable cause of bonding problems. Figures 3a and 3b show Auger spectra from good and poor-performing bond pads. The failed bond pads showed poor bond strengths during adhesion testing. The Auger data show a much larger concentration of fluorine contamination on the surface of the bad pad. These results led to a search for sources of fluorine contamination which was found on a foam material used to separate samples at the wafer level, which then adsorbed onto the wafer and reacted with the pad surface.

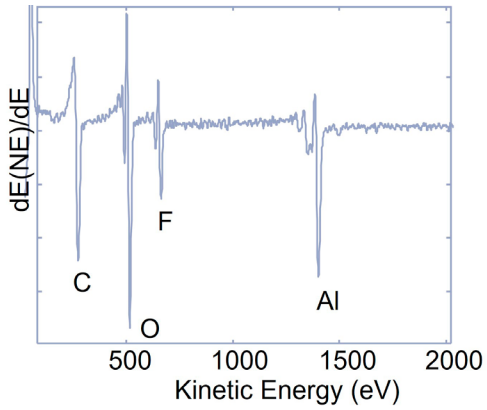


Figure 3a: Normal Chip Auger Spectrum of Bond Pad

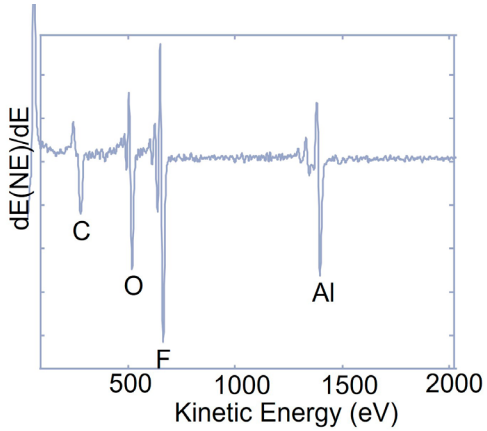


Figure 3b: Contaminated Chip Auger Spectrum of Bond Pad

Case Study: Defect Analysis of FIB Processed Cross-Section Using AES

The small size of many buried defects in semiconductor wafers requires that they be exposed by etching or cross-sectioning for effective and accurate analysis using AES analysis. Auger is ideal for compositional analysis of these small defects because of its high spatial resolution. The SMART-Tool combines high performance Auger capabilities with FIB (Focused Ion Beam) for in-situ cross-sectioning of defects and with EDS (Energy Dispersive X-ray Spectroscopy) for analysis of larger defects and structures. FIB, Auger and EDS can be performed on a buried defect without having to reposition the wafer, providing efficient and effective defect identification to quickly solve process problems or recover from yield excursions. Figures 4a and 4b show SEM images and Auger maps of a bubble defect after in-situ FIB cross-sectioning. The Auger data were acquired without repositioning the sample.

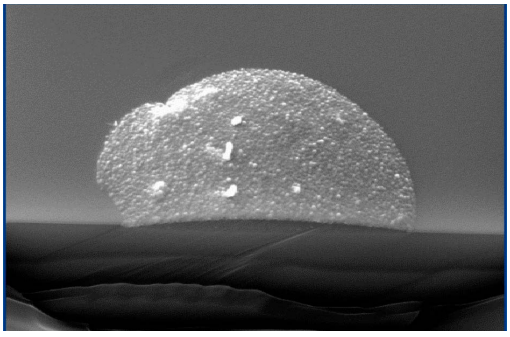
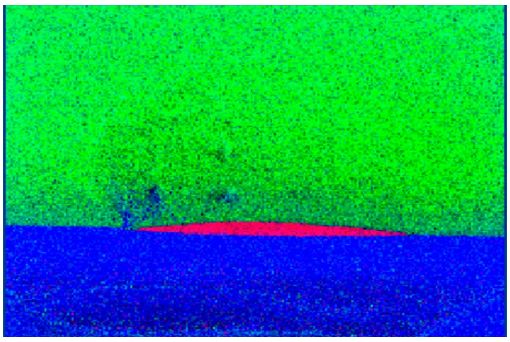


Figure 4a: SEM image of the FIB cross-sectioned bubble defect.



Green=W Red=C Blue=Si

Figure 4b: Auger map of the bubble defect after in-situ FIB cross-sectioning.

Complementary Techniques

Other analytical techniques that provide complementary information with AES, but with varying limitations, include XPS/ ESCA (X-ray Photoelectron Spectroscopy) and EDS (Energy Dispersive X-ray Spectroscopy).

XPS is a surface sensitive technique that provides short-range chemical bonding information from the top 5-10nm of the surface. However, XPS has a minimum beam size of ~10µm, whereas AES has a minimum beam size of as small as 10nm. The strength of XPS is the chemical information available from the spectra, while AES provides mainly elemental composition with limited chemical information. Insulating materials, including organic compounds, are routine for XPS, but are difficult for Auger.

Similar to AES, EDS also uses a focused electron beam to generate the analysis signal, but the sampling volume for EDS (~0.5µm wide by a few µms deep) is much larger than AES. The smaller sampling volume of AES offers advantages over EDS for the analysis of sub-micron particles and thin films. The Auger process is favored in lower atomic number elements over the emission of x-rays for EDS, making AES more sensitive than EDS for the analysis of lighter elements, such as B, C N, O, and F.

Auger at EAG

EAG has unmatched experience handling both routine and non-routine Auger analysis requests and, for decades, has used Auger Electron Spectroscopy to address a wide variety of industrial analytical applications.

EAG has many Auger instruments located throughout the world. Some of these instruments contain special capabilities such as an in-situ fracture stage for metallurgical applications, or the capability to analyze 200mm and 300mm wafers under clean room conditions. FIB (Focused Ion Beam) capabilities on some of our Auger systems aid in the preparation and analysis of cross-sectioned samples. Our Auger experience is unsurpassed with our Auger scientists having an average of over 20 years' experience.