Auger Electron Spectroscopy

- Auger Electron Spectroscopy is an analytical technique that provides compositional information on the top few monolayers of material.

- Detect all elements above He

- Detection limits: ~1 - 0.1 atomic %

- Surface sensitive: top 4-50 Å

- Spatial resolution: < 80 Å Auger spatial resolution with Field Emission electron gun
Common Auger Applications

- Problem solving & failure analysis of nanostructures
- Advanced metallurgy impurity segregation and fracture analysis
- Corrosion
- Thin film analysis
- Semiconductor and electrical components defect analysis
What Information does Auger provide?

- **Surface composition at high spatial resolution**
  - SEM imaging
    - Provides high magnification visualization of the sample
  - Elemental analysis
    - Determines what elements are present & how much
  - Elemental imaging
    - Illustrates two-dimensional elemental distribution

- **Sputter depth profiling**
  - Reveals thin film and interfacial composition
ELECTRON BEAM - SAMPLE INTERACTION

- Primary Electron Beam
- Auger Electrons (4-50 Å Analysis Depth > Element No. 3)
- Characteristic X-rays (> Element No. 4)
- Secondary Electrons
- Backscattered Electrons
- Sample Surface
- Volume of Primary Excitation <1 - 3 mm
Auger & X-ray Emission

X-ray Fluorescence

Auger Electron Emission

Incident Beam

Auger Electron

Incident Beam

X-ray Photon
Auger and Fluorescence Yields

\[ \rho_A + \rho_X = 1 \]
Auger Electron Spectroscopy

\[ E_{KLL} = E_K - E_L - E'_L \]

Incident Beam

\[ E_{KLL} = E_K - E_L - E'_L \]

Auger Electron

\[ 2p^{3/2} \]
\[ 2s^{1/2} \]
\[ 1s \]

EdN(E)/dE

Cu MNN

Cu LMM

\[ E N(E) \times 5 \]

\[ E N(E) \]

Kinetic Energy (eV)
AES Surface Sensitivity

Incident electron beam

Escaping Auger Electrons

Mean Free Path: Mean distance traveled before undergoing inelastic scattering.
Various thicknesses of Au on Si. The high energy Si KLL peak has a greater analysis depth than the low energy Si LMM peak.
Schottky Field Emission Optics

Typical Beam Size - PHI 680
(20% - 80%)

Beam Diameter (Å)

Beam Current (nA)

20 kV
10 kV
5 kV
3 kV
Auger Line Scan across Abrupt Interface

Primary beam
20 keV

Ag MVV
@ 355 eV

Beam Diameter (fwhm)
- A = 10 nm
- B = 20 nm
- C = 30 nm
- D = 40 nm
Analysis Area - Defects on Al Metallization

Sample Description

- Metallization in semiconductor device manufacturing
  - TiN / Al(Cu) on SiO₂

- Defects are found along edge of metal lines after a plasma etch processing step

- Auger analysis is required to determine the defect composition
Aluminum lines at 20,000X, showing nodules
Analysis Area - Defects on Al Metallization

Pseudocolor Auger Map of Cu, showing the concentration of Cu in the nodules

SEM image

Cu Auger map

Auger maps resolve 1000 Å Cu particles
Spectra on the particle includes Auger signal from the surrounding material due to backscatter electrons.
Primary electron scattering results in a minimum feature size from which all of the Auger signal originates.

This minimum feature size depends on sample geometry, feature composition, and primary beam energy.

SEM of ~1.3µm Particle on SiO₂

SEM of Particle in f.e. AES
Backscatter Effects vs. Beam Voltage

~1.3µm Si Particle on SiO₂

O, C and Ti are from the substrate
Low voltage minimizes backscatter signal
Quantification
Sensitivity Factors

- Assuming Auger yield varies linearly with concentration

- Assuming homogeneous distribution

\[ C_X = \left( \frac{I_X}{S_X} \right) / \left( \sum_i \left( \frac{I_i}{S_i} \right) \right) \]

- \( S_X \) may depend on sample matrix & chemistry, as well as specific analytical instrument
Sensitivity Factors:
Si and SiO$_2$

Using sensitivity factors for elemental Si
Si:O => 74:26

Using sensitivity factors for Si Oxide
Si:O => 33:67
Compucentric Zalar Rotation Depth Profiling

Compucentric Zalar Depth Profile of 10 µm Via Contact

Secondary Electron Image (Before Sputtering)

Graph showing atomic concentration over sputter time for Al (metal), Al (oxide), and Si.
Depth Profile Comparison With and Without Zalar Rotation

With Rotation

Without Rotation
Compucentric Zalar Rotation Depth Profiling

SE Images of 10 µm Via Contacts after Depth Profiling

2500X

With Rotation

Without Rotation