UNIVERSITY OF NEBRASKA–LINCOLN
Physics & Astronomy

Introduction and Simple Application of Auger Electron Spectroscopy

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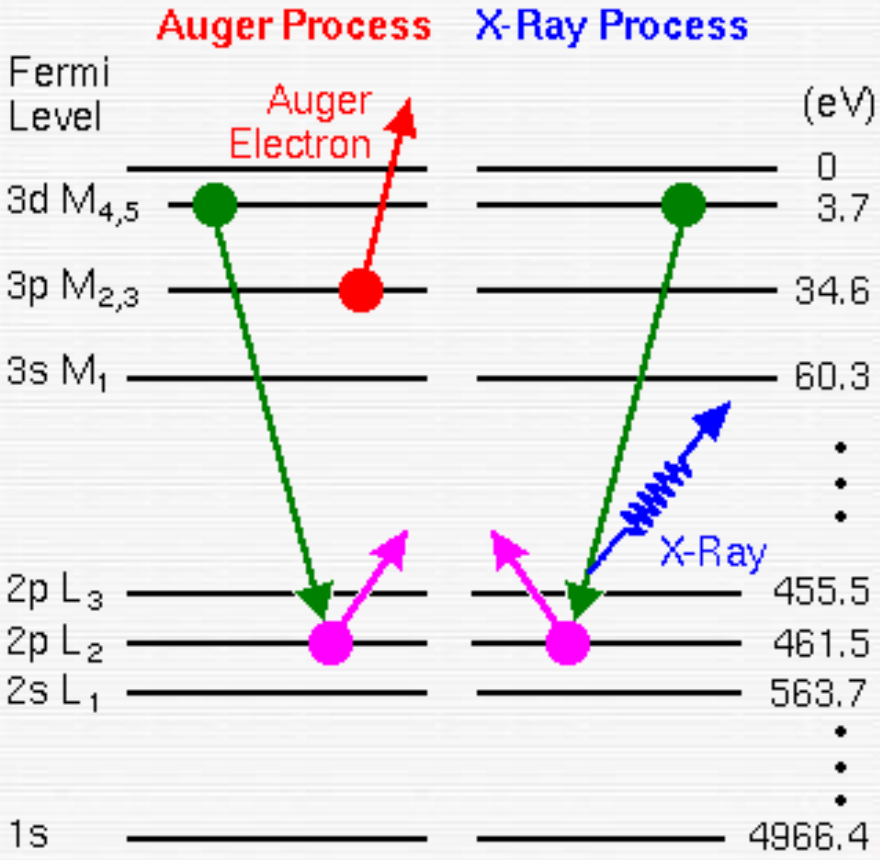
What is auger electron?

X-ray and high energy electron bombardment of atom can create core hole. Core hole will eventually decay via 2 ways:

- Photon emission (x-ray fluorescence -XRF, X-Ray process)
- Radiationless internal rearrangement (Auger process)



Sensitivity of auger electroscopy

- Element: for isolated atoms, all elements except H, He, and Li. For solid, all elements except H and He.

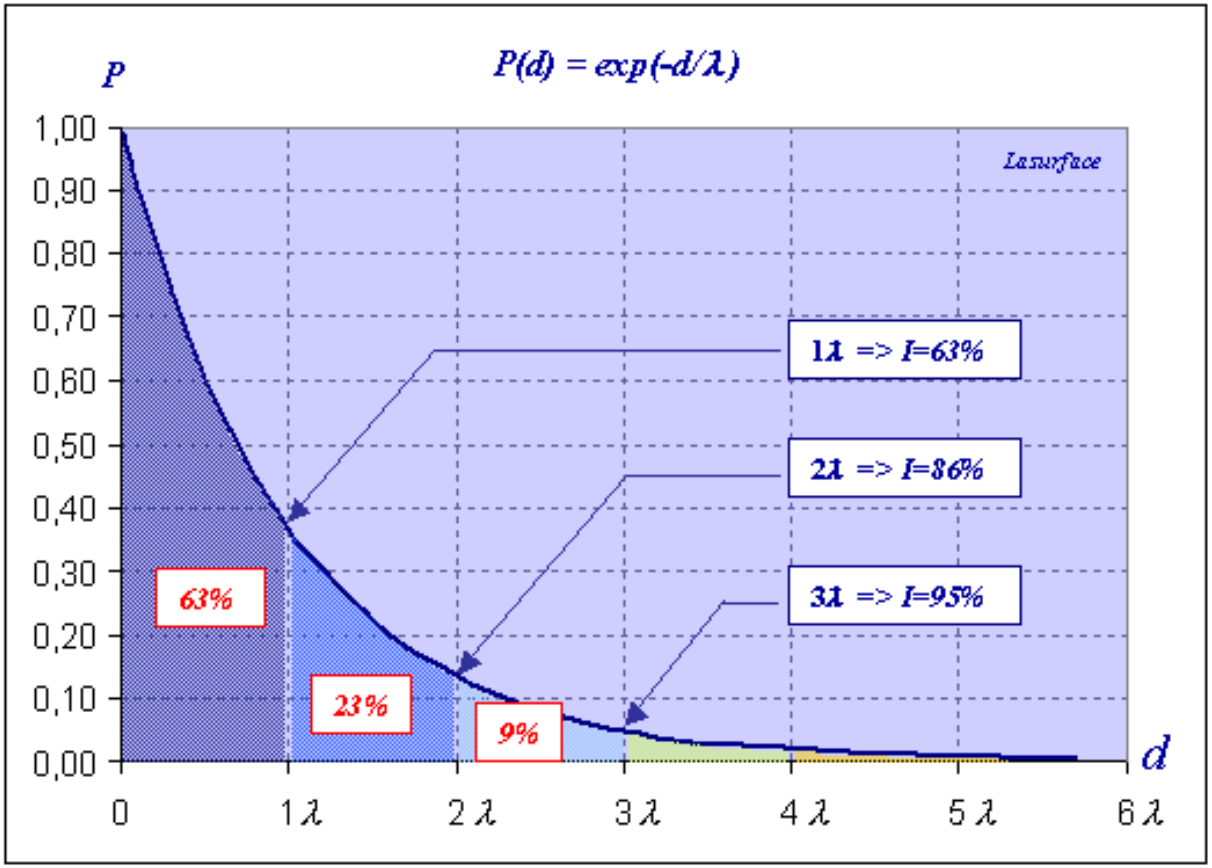
➢ Question for discussion: why Li solid can emit auger electrons, but isolated lithium atoms cannot?

Sensitivity of auger electroscopy

- Surface sensitivity depends on electron kinetic energy.
- The mean free path: distance covered by an electron between two inelastic shocks is called "mean free path". This distance is noted: λ (a distribution average, Electrons can traverse a larger or smaller distance.)

Sensitivity of auger electroscopy

While crossing the matter, the electrons are submitted to absorption laws. The probability (*P*) that the emitted electron reaches the surface as a function of the depth *d*

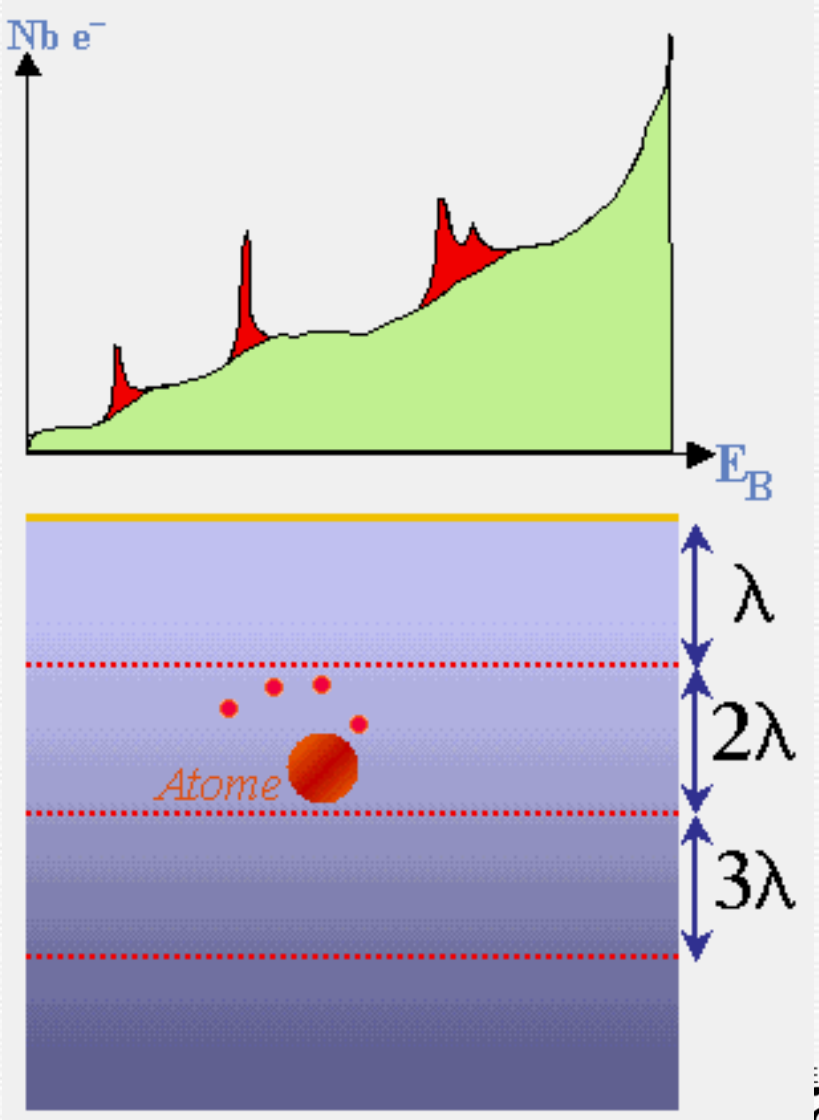


$$P(d) = e^{-d/\lambda}$$

λ is the average travel distance of an electron in a given material

Sensitivity of auger electroscopy

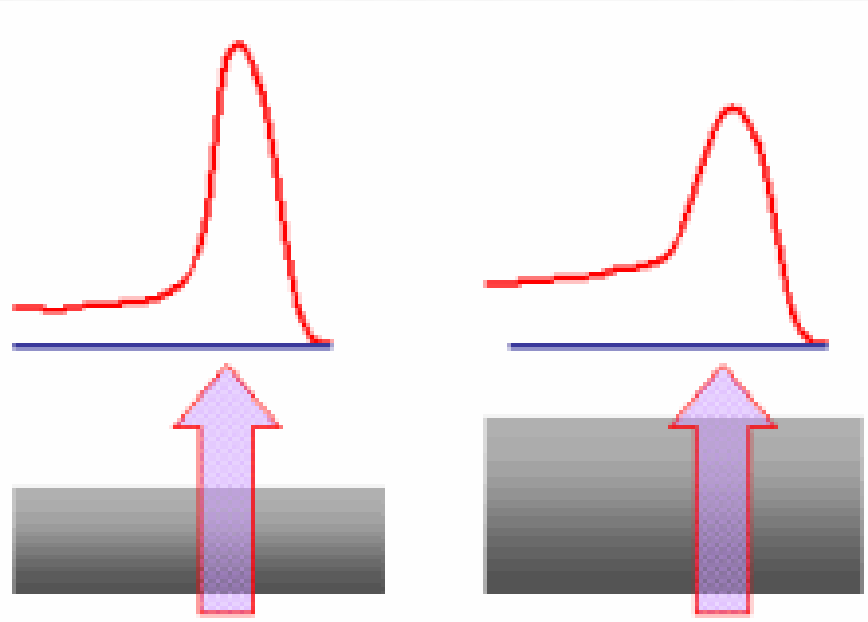
In an XPS or AES spectrum, the background noise results from electrons which underwent an inelastic shock and the peaks result from electrons having reached the surface without any inelastic interaction.



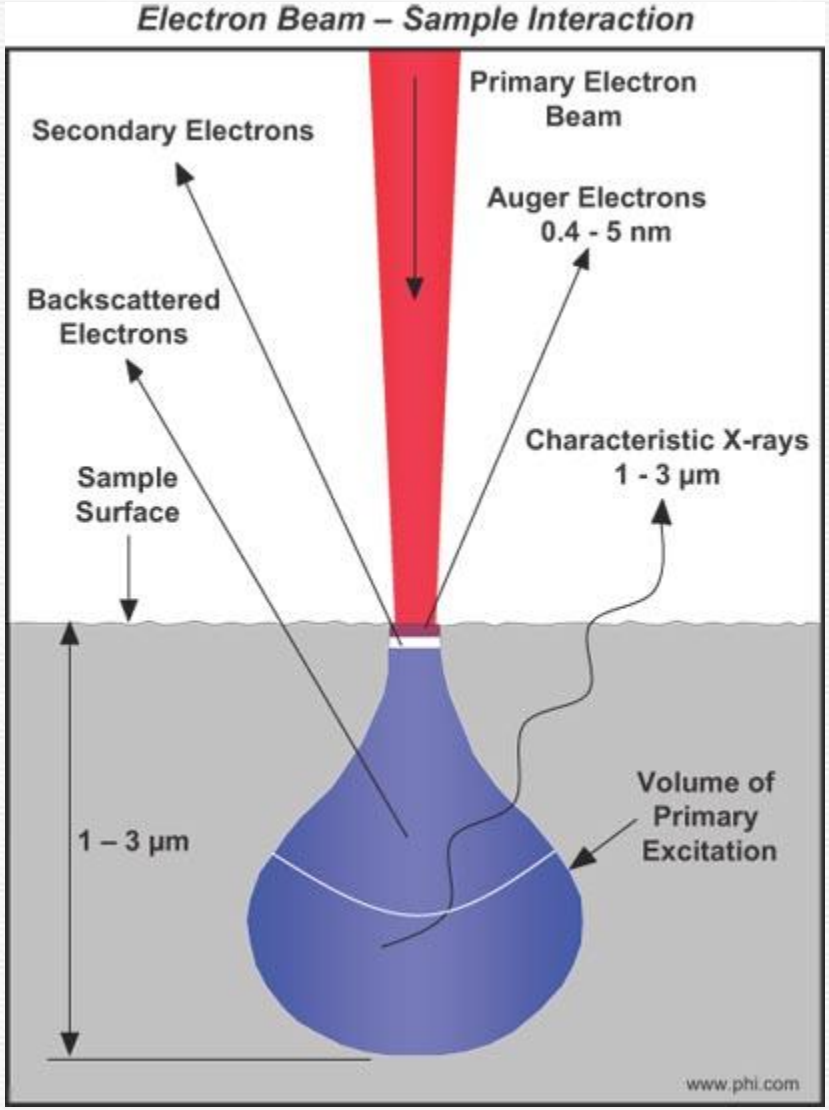
Sensitivity of auger electroscopy

From which depth do these electrons come from?

These inelastic shocks and thus the background noise of the spectrum have been found to be related to the layer thickness of the matter crossed by the electron. The following drawing illustrates this phenomenon.



Electron beam-sample interaction



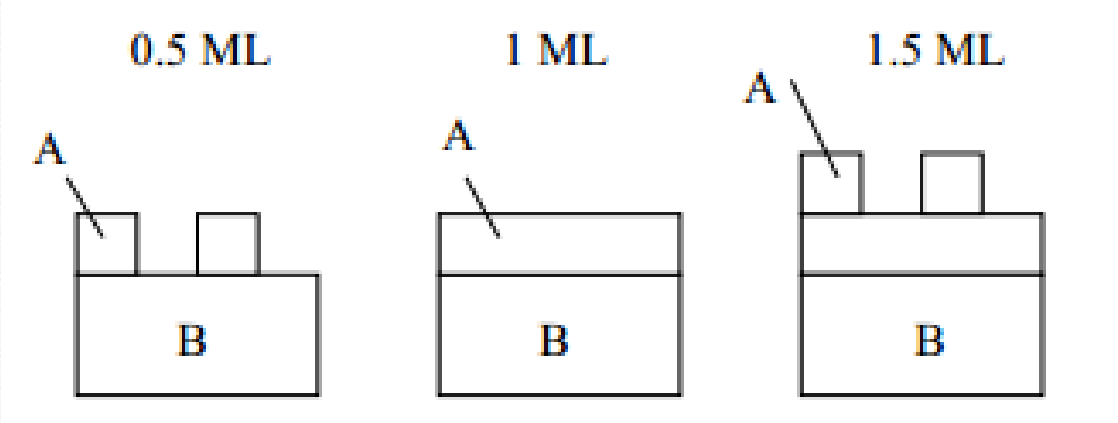
Emission depth under surface:

- Characteristic X-rays: 1~3 µm
- Secondary electrons: 5~10 nm
- Auger electrons: 0.4~5 nm

Film Growth Mechanisms

AES signals in layer-by-layer growth?

- Linear decrease in B due to attenuation
- Linear increase in A submonolayer as concentration increases

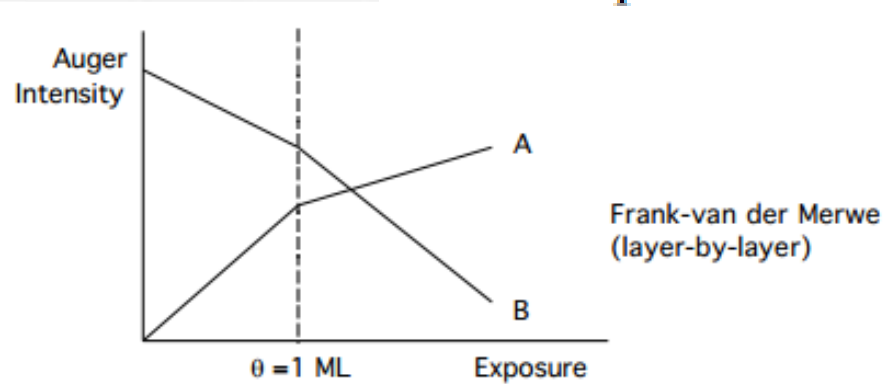


Slower increase in A after 1 ML due to attenuation of second layer

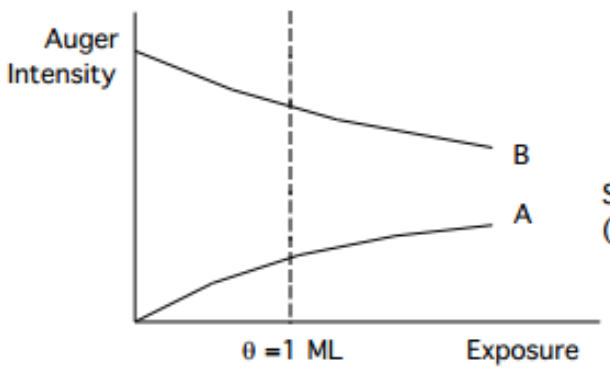
Film Growth Mechanisms

- In principle, can determine growth mode by examining behavior of AES (or
- XPS) signal with exposure - ignores changes in sticking probability S

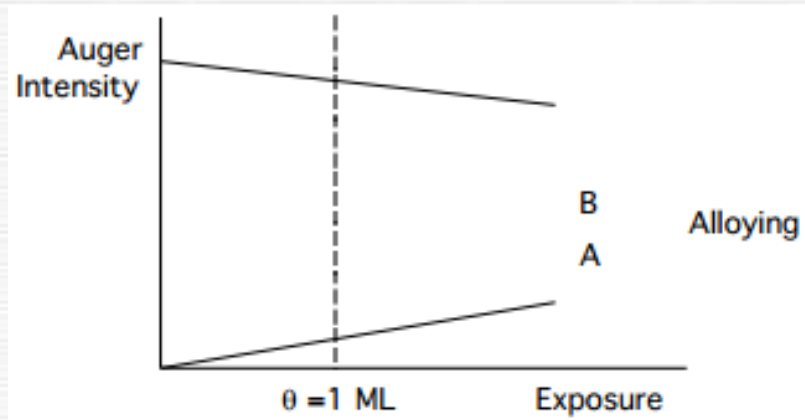
$$S = \frac{\#\ \text{species that remain adsorbed}}{\#\ \text{species that strike surface}} \qquad 0 < S < 1$$



Frank-van der Merwe (layer-by-layer)



Stranski-Krastinov (3-D islands)



Alloying

Elemental Mapping - The Scanning Auger Microprobe (SAM)

Electron beam can be rapidly scanned in x ory direction across surface

- line scan
- monitor intensity of Auger peaks
- need narrow primary electon beam (affects lateral resolution) as function of x or y position

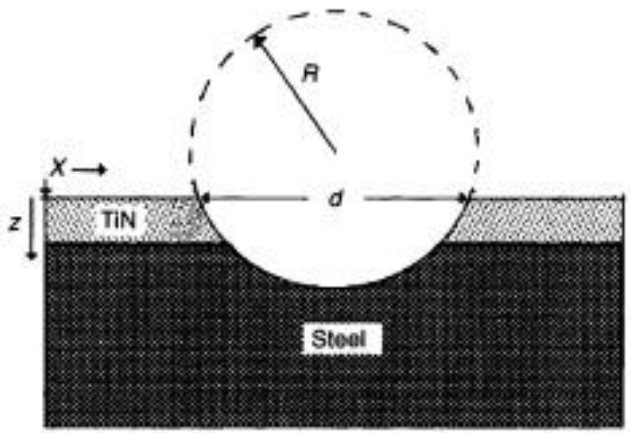


Figure 4.19. Section of a stainless steel sample covered with a layer of TiN of thickness *d*. The vertical arrows indicate the limits of displacement of the electron beam

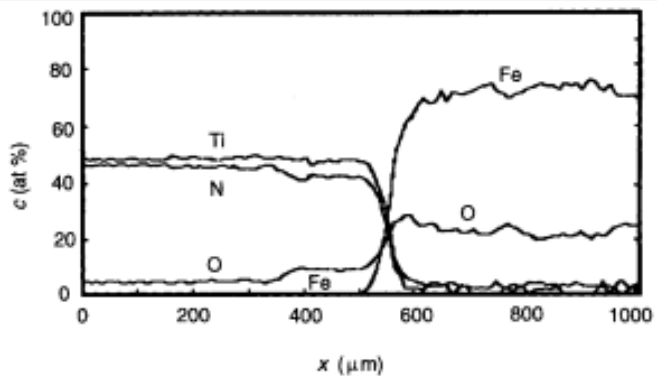


Figure 4.18. Example of a line scan over the crater edge produced by ball cratering showing the atomic concentration as a function of the displacement of the electron beam. The crater edge is located approximatively at $x = 500$ μm

Elemental Mapping - The Scanning Auger Microprobe (SAM)

If primary beam is scanned in x andy directions

- - can map elemental composition
- - scanning Auger microprobe
- - resolution <1 µm possible
- - image acquired in <10 s (dynamic surfaces?)

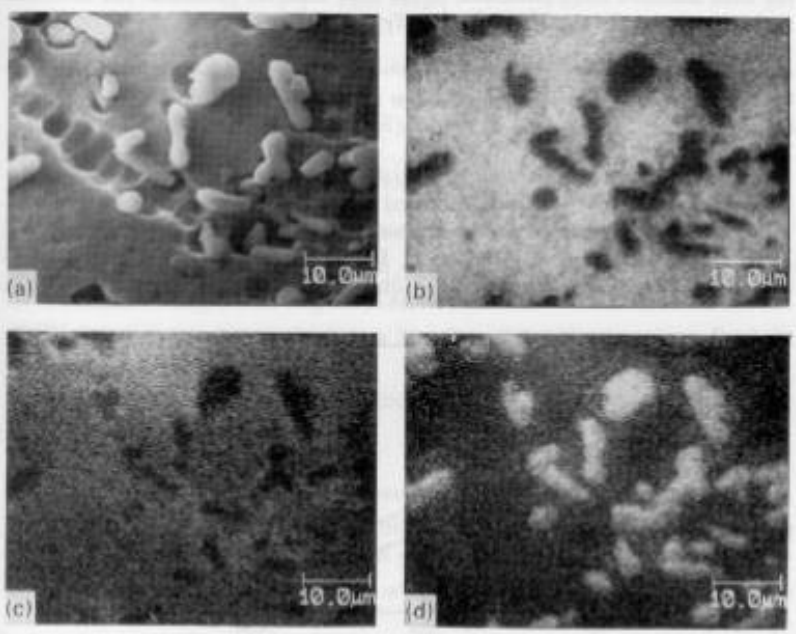
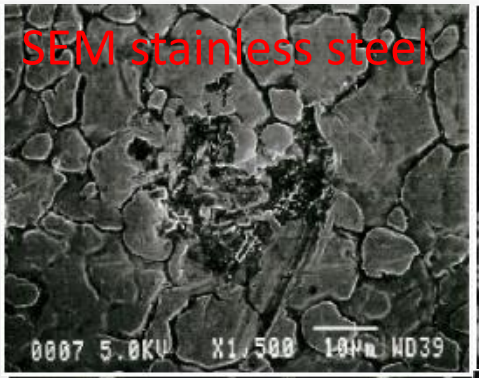
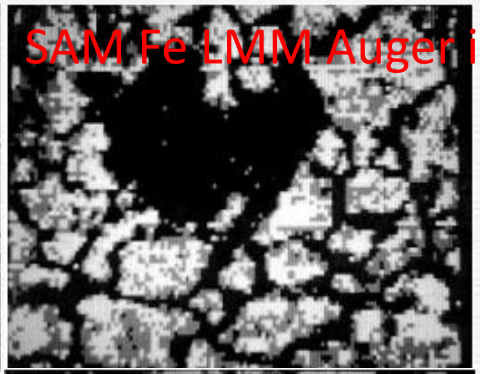
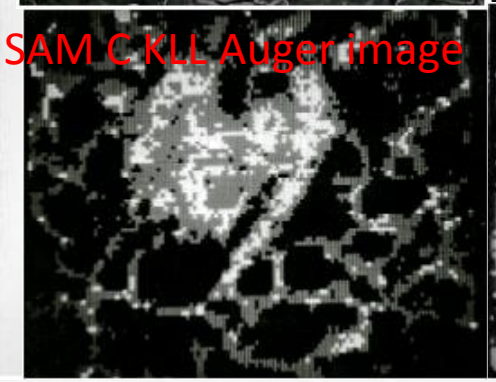
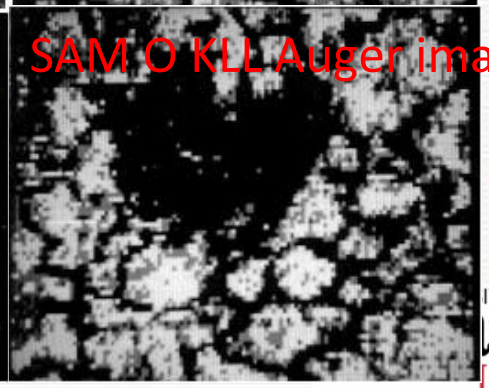


Figure 4.20 Example of an Auger map of AlSiMg alloy showing the secondary electron image. White pixels indicate the presence of an element. (a) SEM; (b) Al; (c) S; (d) Si









Summary

Auger Electron Spectroscopy (AES) is a surface-sensitive spectroscopic technique used for elemental analysis of surfaces ;

- It offers high sensitivity for all elements except H and He.
- A means of monitoring surface cleanliness of samples
- Quantitative compositional analysis of the surface region of specimens, by comparison with standard samples of known composition.

In addition, the basic technique has also been adapted for use in :

- Auger Depth Profiling : providing quantitative compositional information as a function of depth below the surface Scanning
- Auger Microscopy (SAM) : providing spatially-resolved compositional information on heterogeneous samples


Thank you for your time!