Auger Effect

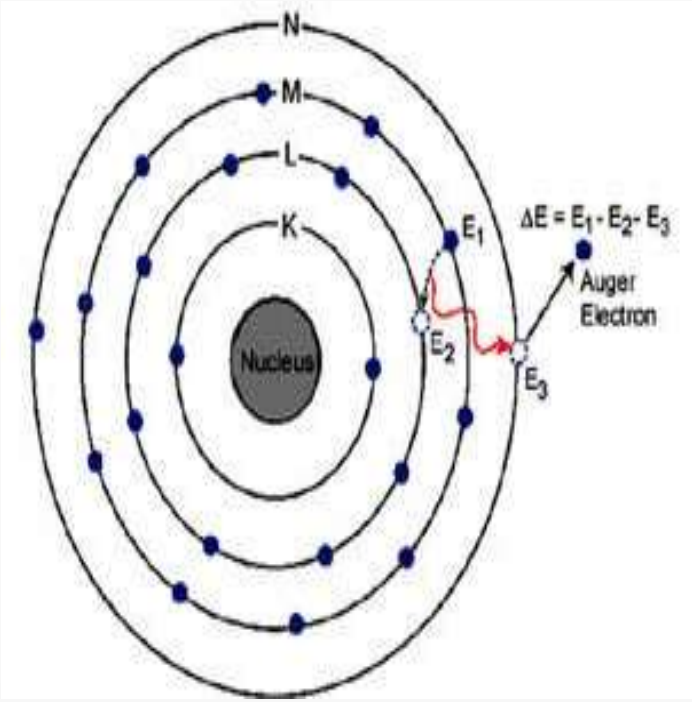
The Auger effect is the filling of a vacancy in an inner electron **energy level** in an **atom** by an **electron** from an outer energy level of the same atom. The excess energy involved causes emission of another electron known as an **Auger electron**. Auger electrons were discovered independently by Lise **Meitner** (in 1923) and the French physicist Pierre Victor **Auger** (in 1925), but the English-speaking scientific community attached Auger's name to the effect.

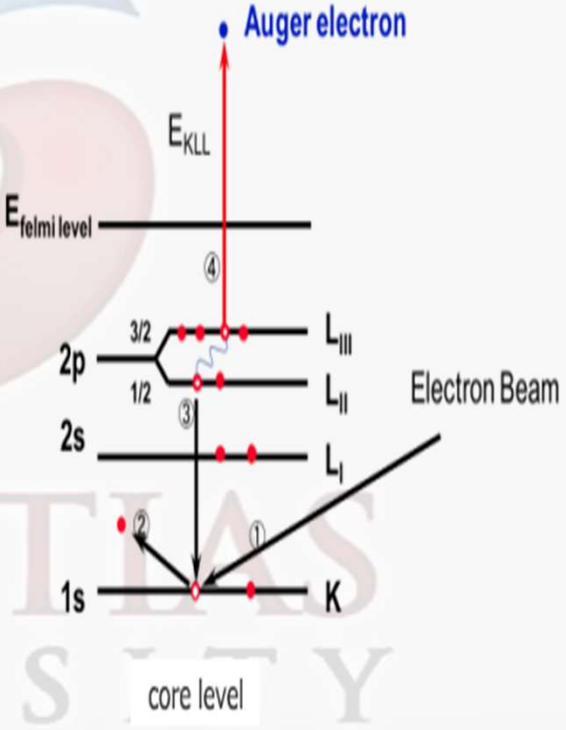
Auger electrons are produced when a sample is bombarded with electrons and a characteristic **X-ray** produced by inner shell ionization is reabsorbed, ejecting an electron. For example, a Si-Kα (K-L1) X-ray (energy of 1690 eV) may be emitted from a sample or transfer its energy to the L2,3 shell (binding energy ~70 eV), ejecting a Si KL1L2,3 Auger electron (energy 1620 eV).

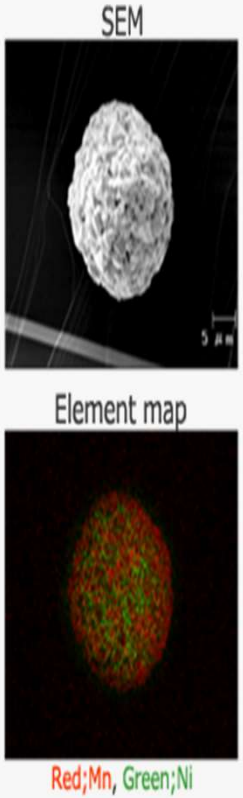
Auger Effect

Auger electron production is quantified by **fluorescent yield**, ω, which is the fraction of inner shell ionization that produce X-rays (thus, 1 - ω gives the fraction of Auger electrons). Auger electron have energies characteristic of their atom of origin, ranging from ~280 eV (C) to 2.1 keV (S). Given these low energies, Auger electrons only escape from the surface of a sample.

Auger Electron Auger Effect







Auger Effect

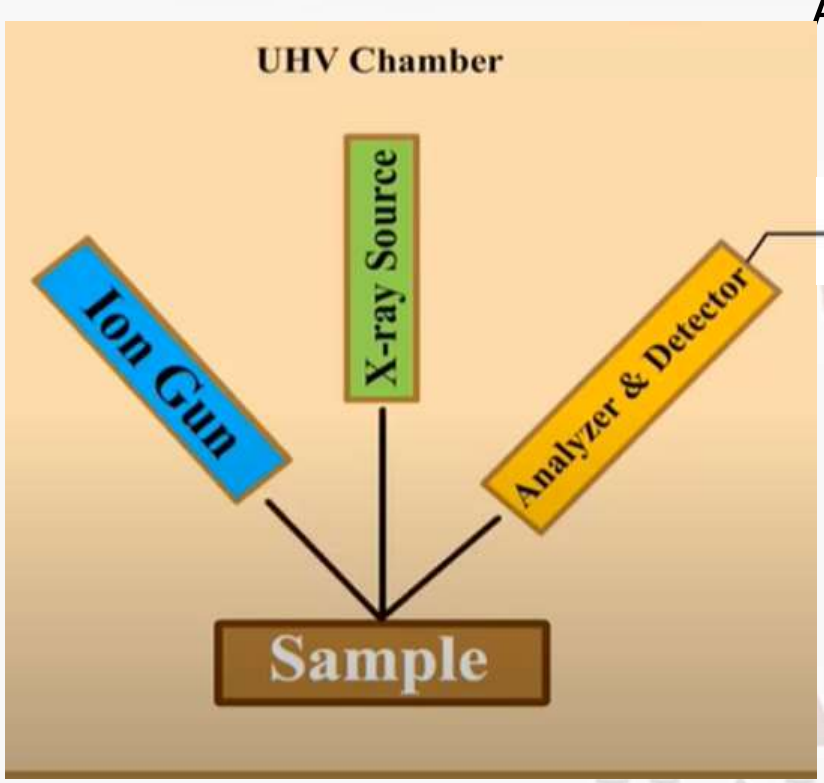
Auger Effect: History ; LEED, Light emitting Electron Diffraction

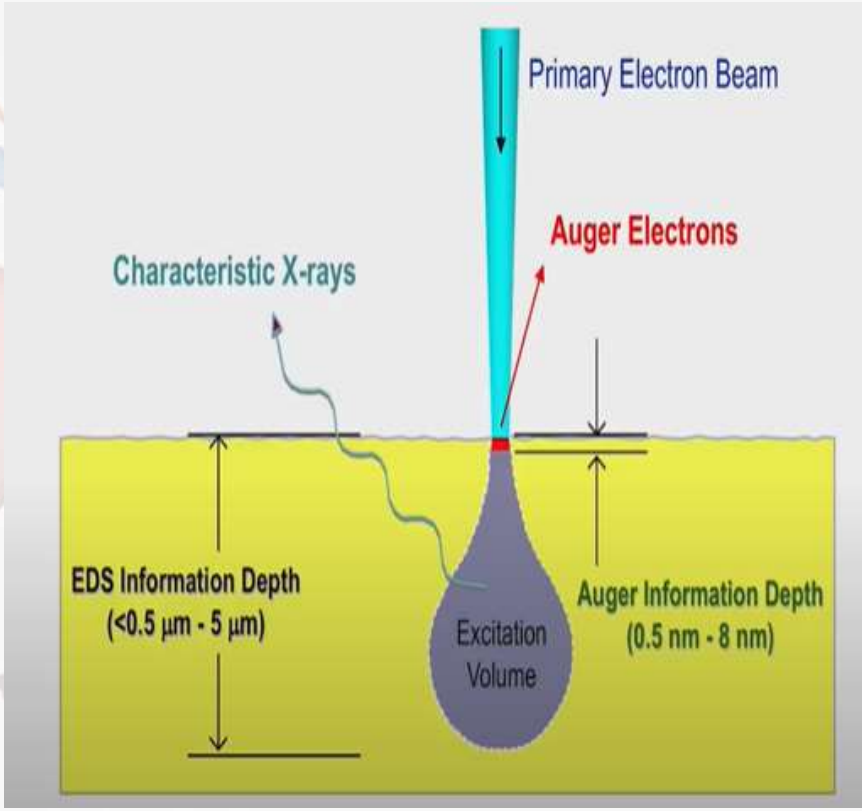
- **The Auger electrons were discovered by Lise Meitner in 1923 but name Auger was given at later stage after the name of Pierre Auger.**
- **French physicist Pierre Victor Auger independenly studied this phenomenon and reported in Journal "Radium" in 1925.**
- **Corrected theoretical explanation of Auger electron was given by in this Doctoral thesis in 1926.**
- **Then in 1953, electron excited Auger electrons were used by J, Lander to study surface impurities and obtained Auger peaks which he observed as secondry electron emission spectrum of electron –irradiated solids.**
- **L.Harris demonstrated the high sensitivity attainable and the practicality of this technique for surface analysis in 1968 and the same time weber and Peria used light emitted electron diffraction optics i.e. LEED As Auger Spectrometers.**

Auger Effect

- After this in 1969 Palmberg used the electrostatic analyzer and showed that it was more sensitive than any analyser used before
- Use of Lanthanum hexaboride filaments and better electron optics improved the spatial resolution to about 50nm by the end of 1970.
- About 10 years later, introduction of Schottky filed emitters led to spatial resolution values nearly 3-10nm.
- Though , AES has good application as in surface and grain boundary separation studies resolution, in high spatial resolution , in depth related profiling such as diffusion and interfacial reactions.

Auger Effect

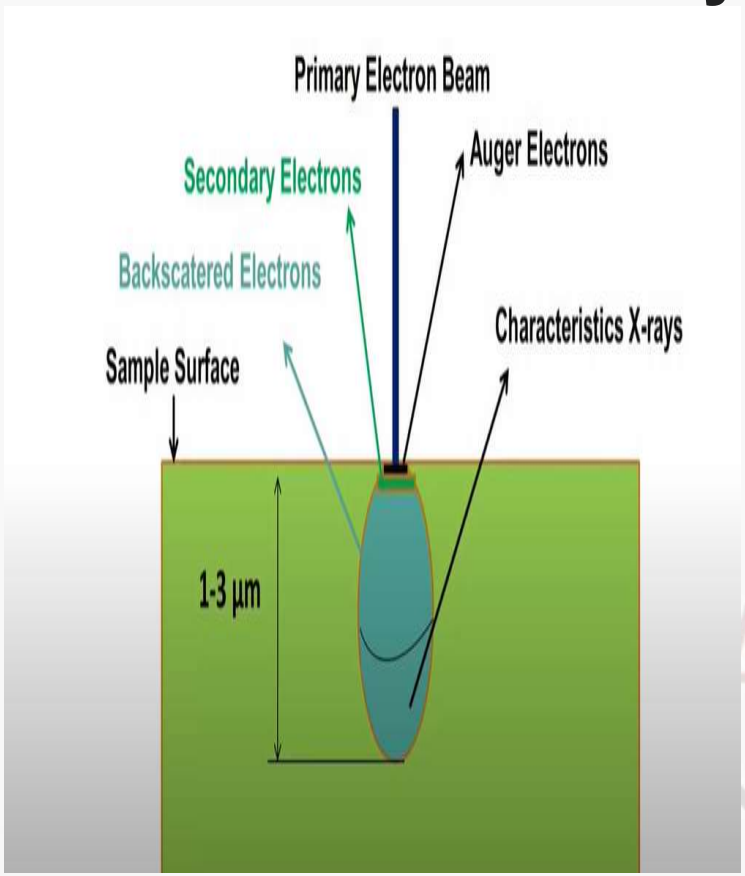


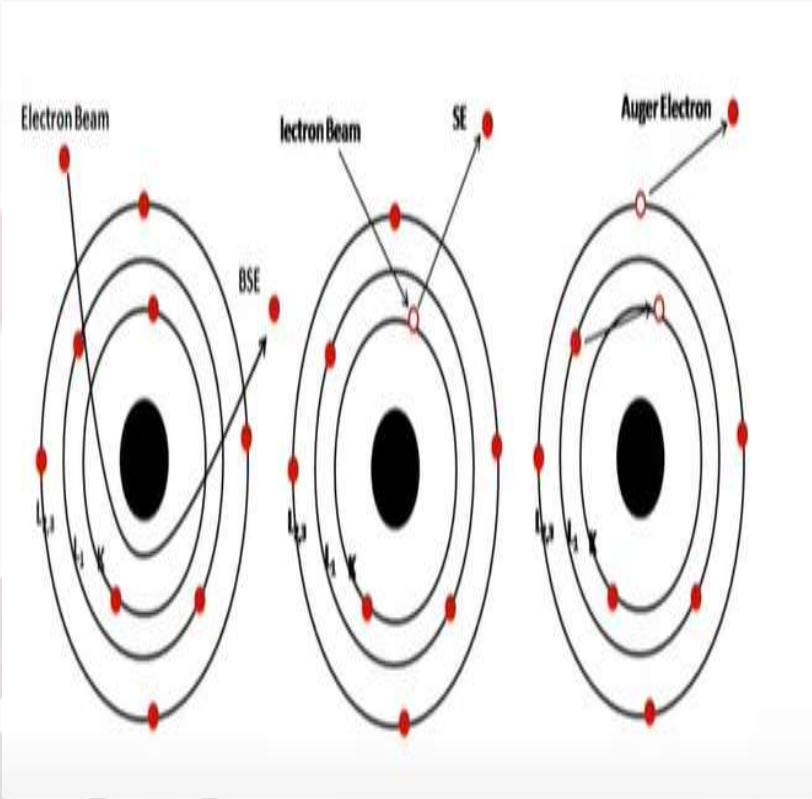


Auger Effect

- Well suited for the surface characterization of very small features Inherent analysis depth of -5nm. Can provide analysis of feature as small as -20nm diameter
- Routinely used by scientist in applications involving semiconductors., microelectronics, metallurgy, Corrosion and thin film coatings- Characterization of small area defects, particle contaminants and thin layers.
- Challenging to analysze insulating samples due to uncompensated charge build-up that occurs during electron bombardment.
- With careful sample preparation and appropriate operating conditions, excellent data can be obtained from catalysts on insulating supports (typically metal oxides)

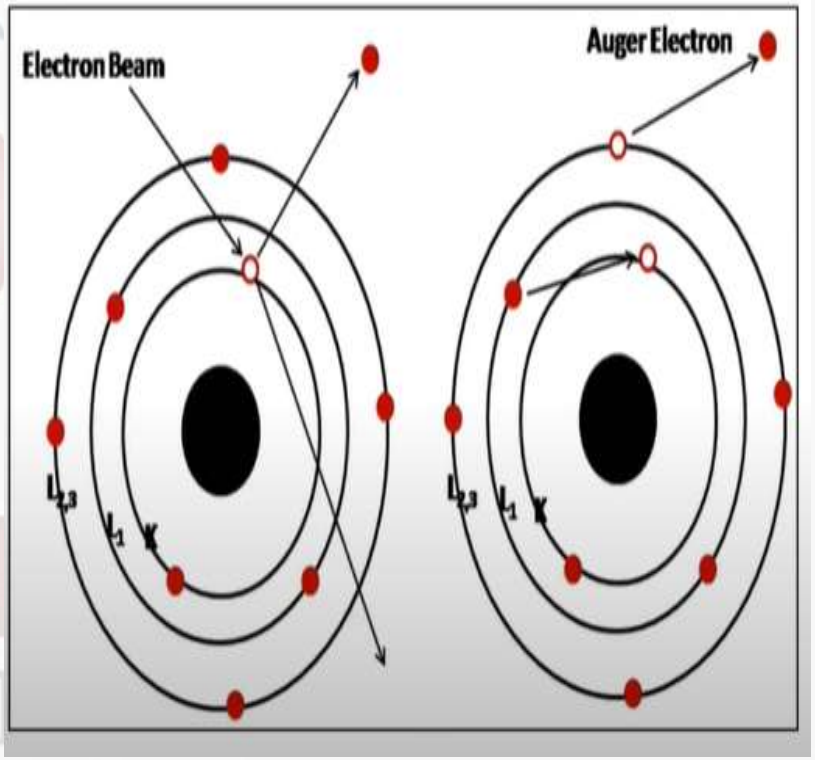
Secondary and Backscattered Electron





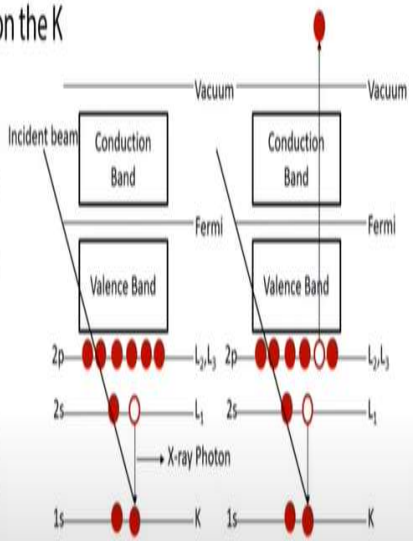
Representations of Auger Electron

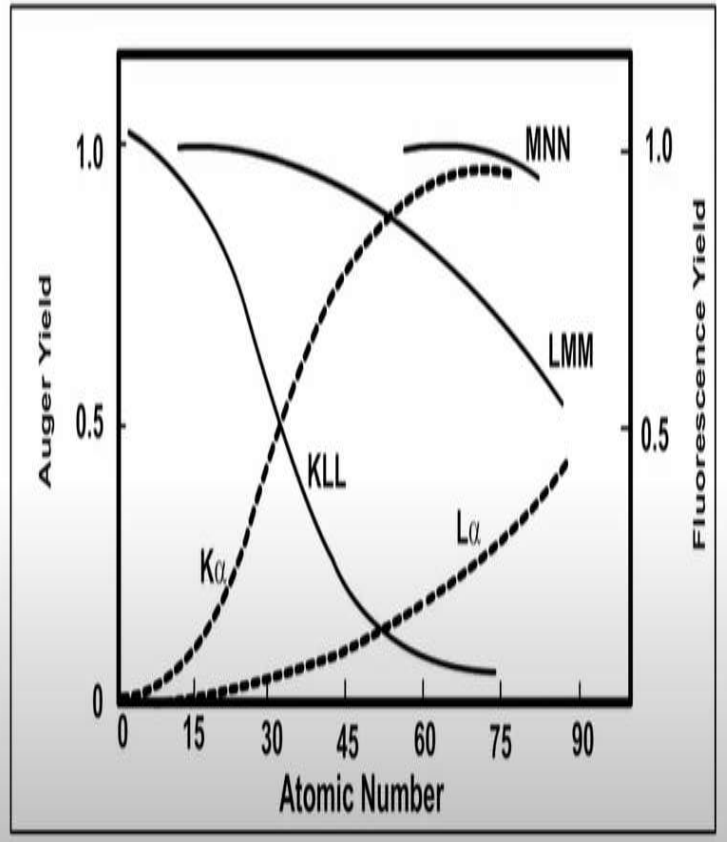
n	l	j	Level Symbol	Auger Notations
1	0	1/2	$1s_{1/2}$	K
2	0	1/2	$2s_{1/2}$	L_1
2	1	1/2	$2p_{1/2}$	L_2
2	1	3/2	$2p_{3/2}$	L_3
3	0	1/2	$3s_{1/2}$	M_1
3	1	1/2	$3p_{1/2}$	M_2
3	1	3/2	$3p_{3/2}$	M_3
3	2	3/2	$3d_{3/2}$	M_4
3	2	5/2	$3d_{5/2}$	M_5



Principle of AES

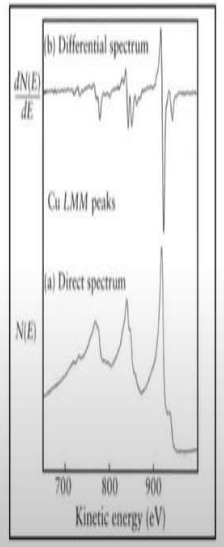
- From the figure it can be seen that a hole is created on the K level in the initial ionization step.
- For the ionization to be efficient, a primary energy of about 5 times the binding energy is taken. In practice, typical primary energies are 5 and 10 keV.
- As a result, the energy difference $E_K - E_{L1}$ becomes available as excess energy, which can be used in two ways.
- The emission of an X-ray at that energy may occur or the energy may be given to another electron, either in the same level or in a more shallow one, as is the case in the example, to be ejected.





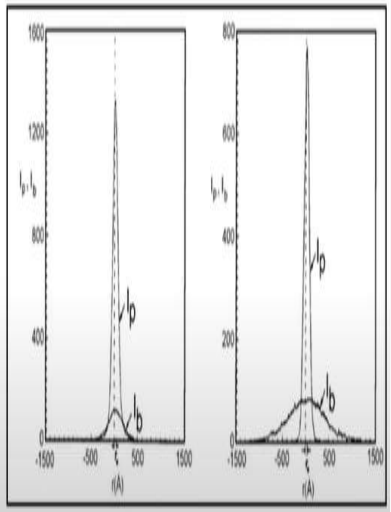
Spectra OF AES (Auger Electron Spectroscopy)

- In general, since the initial ionisation is non-selective and the initial hole may therefore be in various shells, there will be many possible Auger transitions for a given element - some weak, some strong in intensity.
- AUGER SPECTROSCOPY is based upon the measurement of the kinetic energies of the emitted electrons.
- Each element in a sample being studied will give rise to a characteristic spectrum of peaks at various kinetic energies.
- AES spectra are represented in the differentiated form because AES peaks are superimposed on an important background of different types of secondary electrons.



An Introduction to Surface Analysis by XPS and AES, John F. Watts., University of Surrey, UK John Wolstenholme Thermo VG Scientific, East Grinstead, UK (2003)

- Back-scattering factors depend on the energy and the angle of incidence of the primary beam, and they influence the intensities as well as the spatial distribution of the detected Auger electrons.
- This figure shows Al KLL peak and the sample consists of a 40 nm thick Al layer on Au.
- It can be seen that by increasing the energy of primary beam, peak of back-scattering intensity is reduced, where Ip is the primary beam induced signal and Ib is the signal induced by backscattered electron.



Primary beam at (a) 5 keV, (b) 20 keV and 40° angle of incidence

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