KMÜ 396
MATERIALS SCIENCE AND TECH. I
PRESENTATION

ELECTRON ENERGY LOSS SPECTROSCOPY (EELS)

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CONTENTS

1.Introduction
1.1. What Is Spectroscopy ?

Spectroscopy was originally the study of the interaction between radiation and matter as a function of wavelength ("λ"). In fact, historically, spectroscopy referred to the use of visible light dispersed according to its wavelength, e.g. by a prism. [5]

Spectroscopy/spectrometry is often used in physical and analytical chemistry for the identification of substances through the spectrum emitted from or absorbed by them.

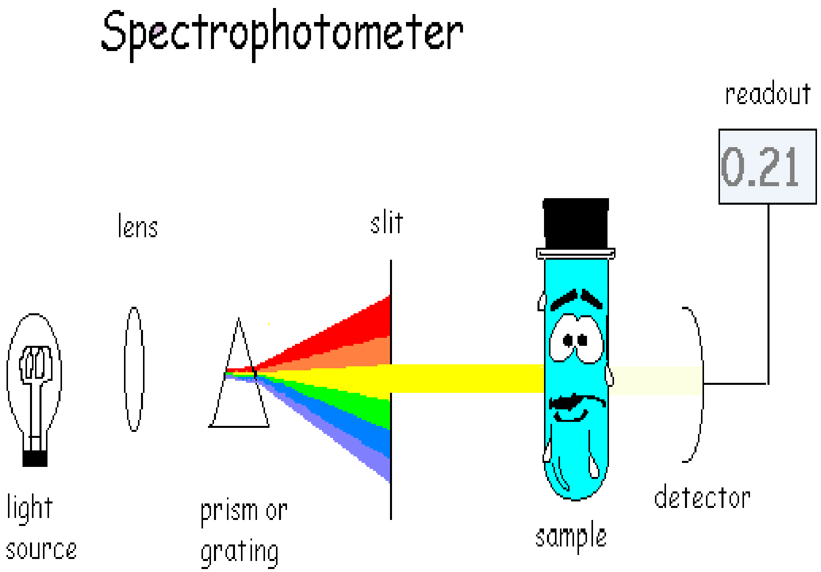


Figure 1.1.: Spectrophotometer

1.2. What Is Nanoanalysis?

- Nanoanalysis, as applied to the investigation of solids,encompasses the determination of a number of interdependent types of information about a specimen(sample), all of which ultimately govern the resultant physical and chemical properties. [1]

- Nanoanalysis refers to techniques for determining the atomic structures of materials, especially crystals. The technology is similar to that used for microanalysis, except it is done on a nanometer scale.[2]

NANOANALYSIS CAN BE CLASSIFIED AS FOLLOWS:

- The morphology
- The crystal structure
- The chemistry
- The electronic structure

2. Basis Of EELS (Electron Energy Loss Spectroscopy)

- ‘ EELS involves analysis of the inelastic scattering suffered by the transmitted electron beam via measurement of the electron energy distribution. ’ [1]

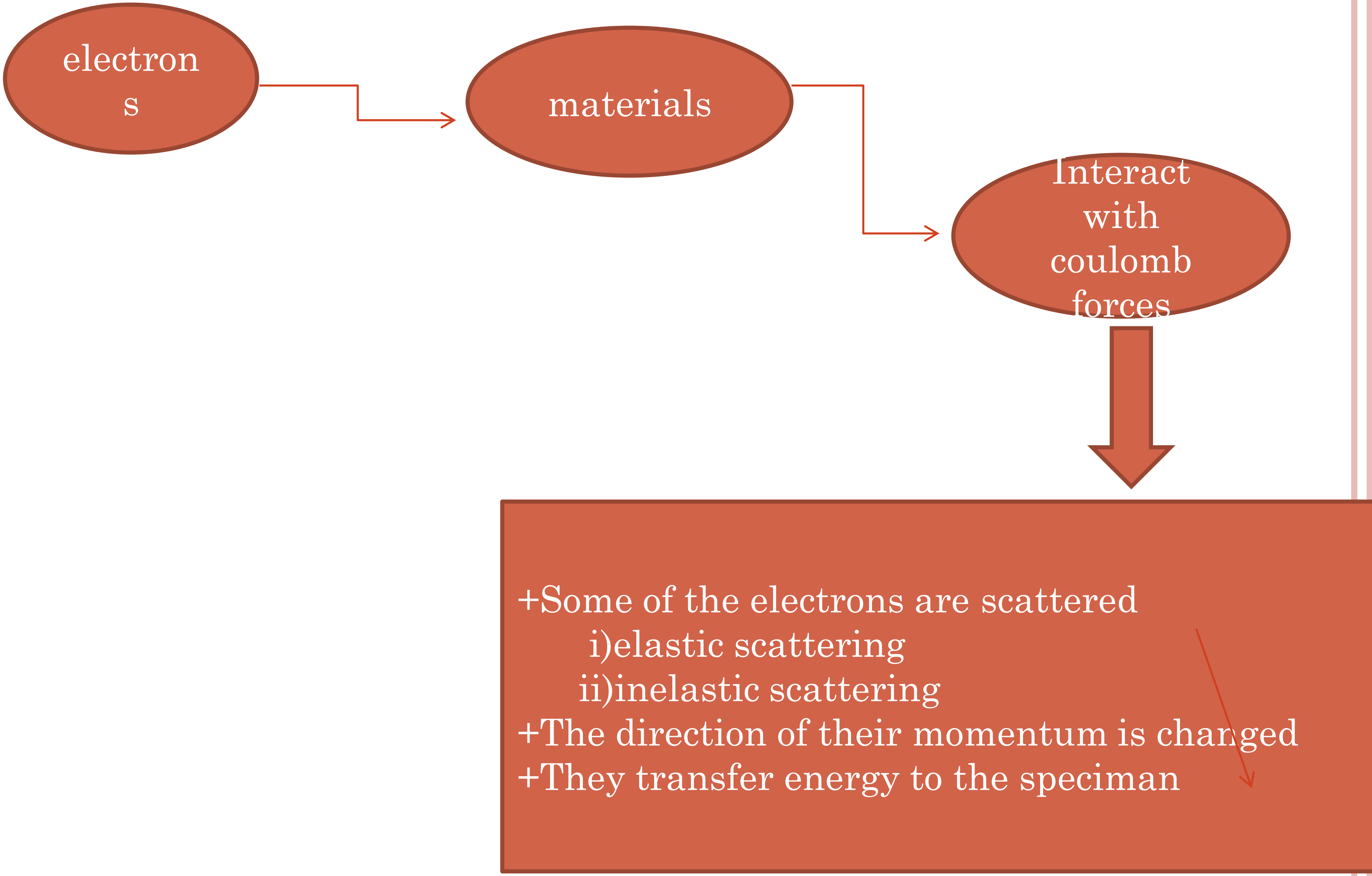
- ‘ EELS involves analyzing the energy distribution of initially monoenergetic electrons, after they have interacted with a specimen. ’ [3]

- “A nearly monochromatic beam of high energy electrons passes through a material, perhaps as a tightly focused probe beam .Coulombic interactions with the electrons in the material cause inelastic scattering of the high energy electrons is measured after they pass through the matarial .Energy is conserved, so the energy lost from the high energy electron is gained by the electrons in the material.The excitation spectrum of the material therefore can be deduced from an EELS spectrum. ” [6]

- Elastic scattering:The elastic scattering is an essentially Coulomb interaction with an atomic nucleus screened by the atomic electrons. In a gas or (to some extent) in an amorphous solid, the constituent atoms can be regarded as independent electron scatterers. In a crystalline solid, the interference between the scattered electron waves should, generally speaking, be taken into account. The elastic scattering is then reffered to as diffraction. The necessity for taking into account the diffraction effects is not related solely to the energy region but also to what information one tries to get. [4]

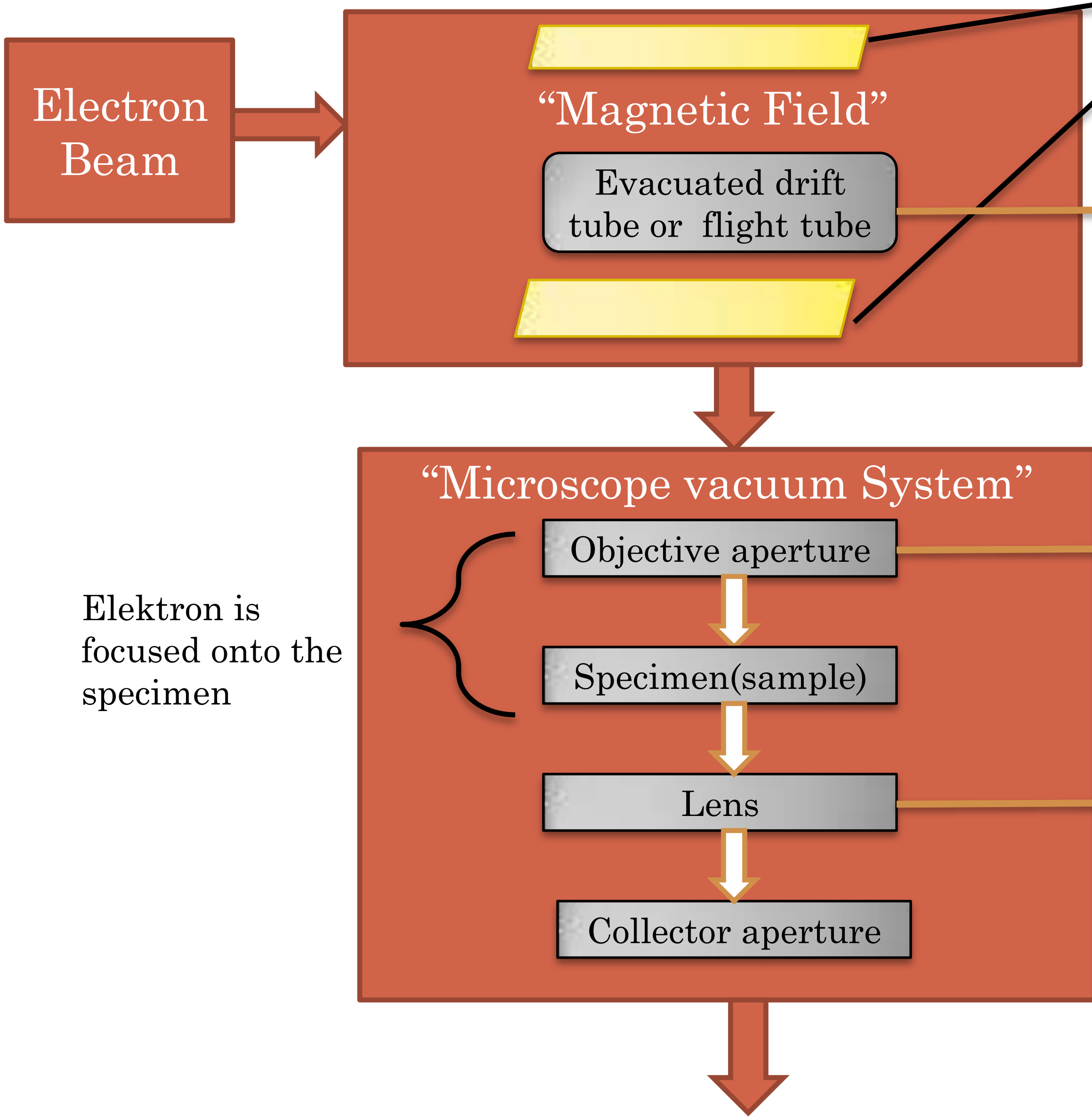
- Inelastic scattering:Inelastic scattering occurs as a result of Coulomb interaction between incident electron and the atomic electrons. The inelastic scattering may not only lead to a single-electron excitation but involve many atoms of the solid (plasmon excitation). Therefore, it is convenient to represent the inelastic scattering properties of solids on per-unit-length basis (instead of per-unit-atom basis in the case of elastic scattering). [4]

- Monoenergetic electrons: electrons which all have practically the same energy.


electrons
materials
Interact with coulomb forces
+Some of the electrons are scattered
i)elastic scattering
ii)inelastic scattering
+The direction of their momentum is changed
+They transfer energy to the speciman

- The energy range of EEL is typically from 0 to 3 keV.
- The energy resolution of an EELS spectrometer is typically factor of a hundred better than that of an energy dispersive X-ray spectrometer.
- EELS is a analytical technique for nanoanalysis which is affected by sample thickness, elemental compositions, chemical phase compositions and electronic structure.
- EELS allows quick and reliable measurement of local thickness in transmission electron microscope.[8]
  - → energy range about 5-200 eV
  - → ~1 nm resolution

3.Instrumentation for EELS



Magnetic field is provided by two parallel polepieces.

Drift tube alter the kinetic energy of all the electrons and shift the whole energy-loss spectrum across the detector system.

+ to minimize the deviation
+ have angle of spectrometer to be limited
+ limit the collection angle of scattered electrons.

There will be magnetic induction after the specimen and this will act as a postspecimen lens.

“Detector System”

+record in parallel using a scintillor
Or
+either one or two dimensional photodiode

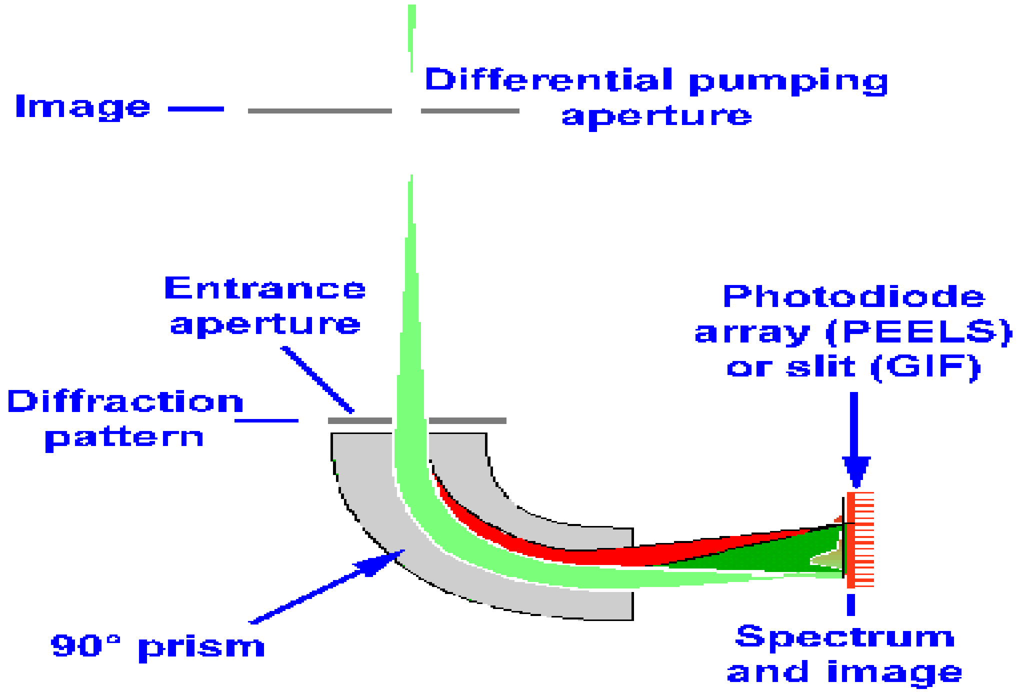


Figure 3.1. :Schematic diagram of magnetic-sector

❖The heart of most EELS spectrometers is a magnetic sector which provides the energy dispersion.
❖A well-designed magnetic sector provides goog focusing action.

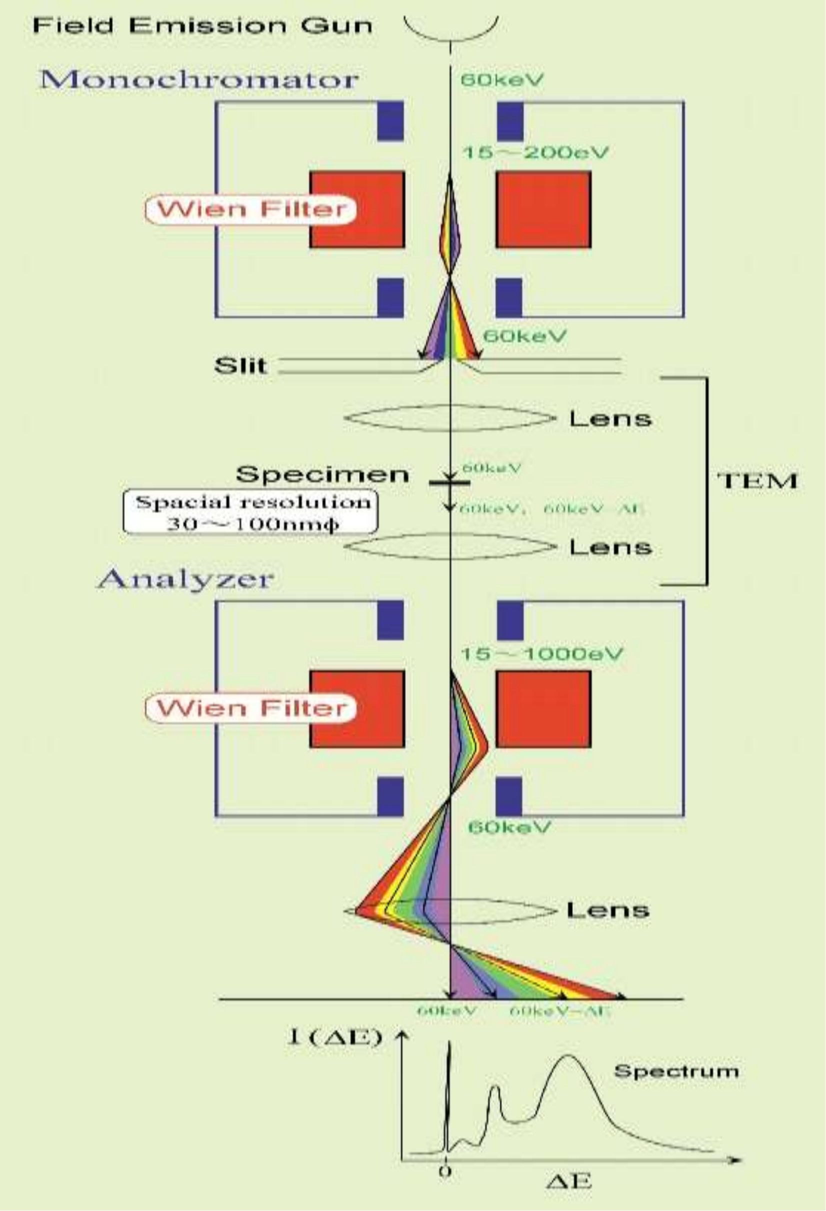


Figure 3.2. : schematic ray diagram of coupling between a magnetic prism spectrometer.

4.Overview of the EELS Spectrum

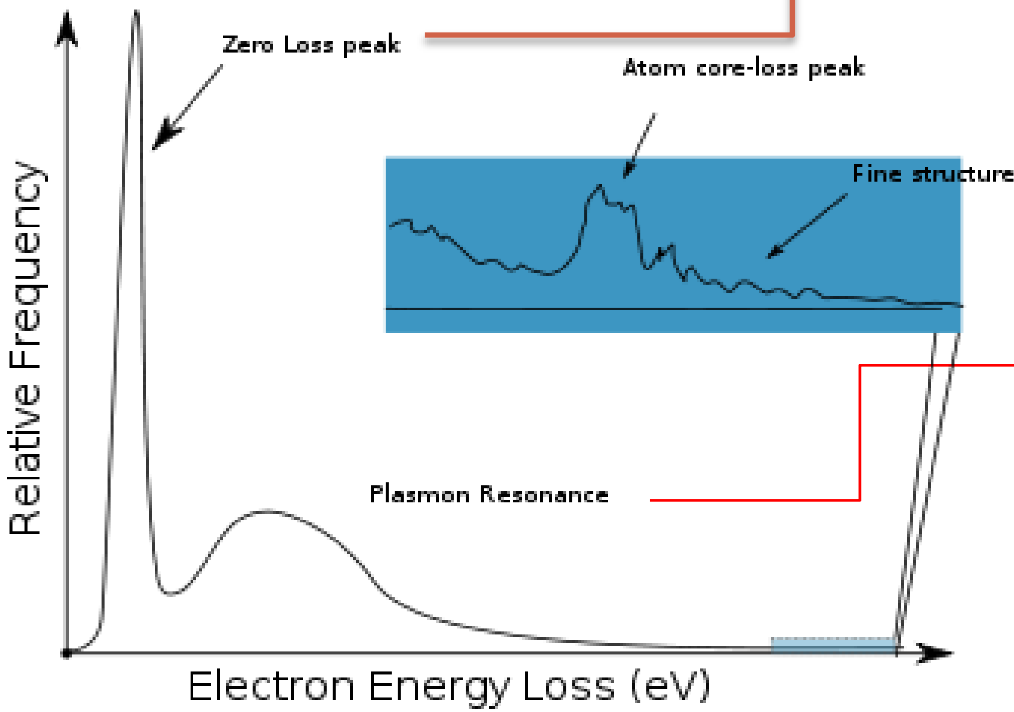


Figure 4.1. :Schematic diagram of a general EELS spectrum

❖Those electrons that have given up no energy to the sample.
❖Zero loss electrons are the elastic unscattered electrons.
❖Intensitiy is depend on the sample thickness.

Include low energy(7-30eV) plasman excitation which inelastic scattering is dominant.

In gain region, there will be excitation of 3p electrons.

ELNES=Electron near-edge fine structure
❖Features are typical of transition metals and their alloys
❖Indicative of the filling 3d band.

- The EELS measures the energy distribution of the electrons.
- EELS spectra can be quantified in terms of concentration of the elements with the help of the software program.
- EELS spectra also contain chemical bonding, surface properties, valence and conduction band electronic properties information.
- EELS method suitable for the qualitative and quantitative analysis of the elements Li to Np at nanometer resolution.

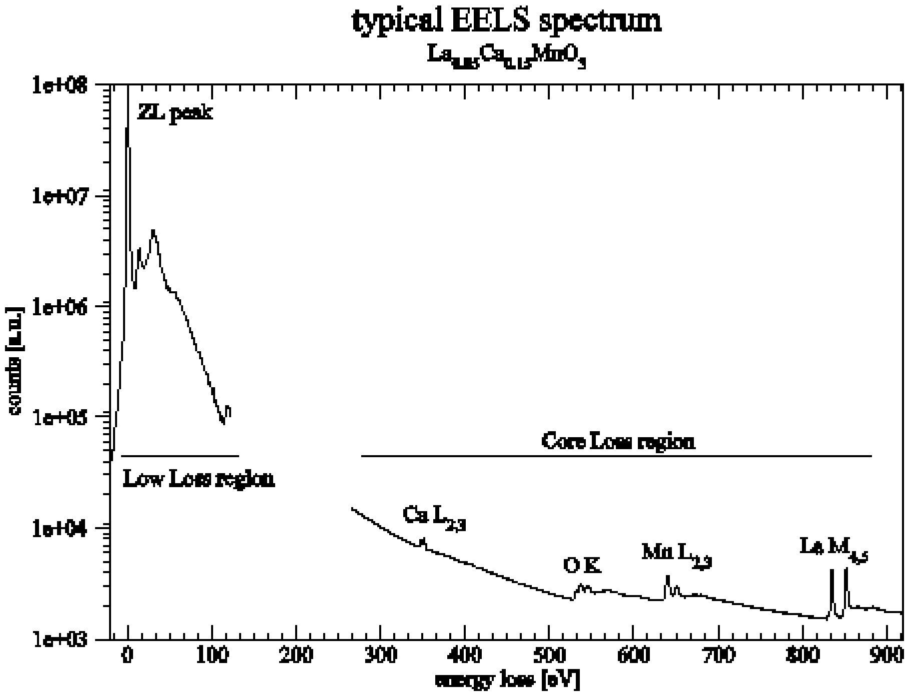


Figure 4.2. :A typical EELS spectrum from an thin film

5.EELS Quantitative Analysis

EELS has been developed ove the past few years into a highly sensitive microanalytical tool of detecting very small number of atoms.

The technique clearly offers an adventage over energy-dispersive X-ray spectroscopy (EDXS) for analyzing the light elements that have a low fluorescence yield. [6]

Furthermore, EELS is also preferable to EDXS for analyzing heavier elements.

Quantitative analysis requires:

- Extraction of the characteristic inner-shell signals.
- Determination of the suitable ionization cross-sections.

Cross sections for inner-shell excitations can be derived from quantum mechanical calculations or from measurements on standard specimens.

Accuracy of determining elemental concentrations depends on these techniques: [6]

- Methods of linear-least-squares fitting
- Digital filtering
- Multiple least-squares fitting of referance spectra.

6. HISTORY OF EELS

The technique was developed by **James Hillier** and RF Baker in the mid 1940s but was not widely used over the next 50 years, only becoming more widespread in research in the 1990s due to advances in microscope instrumentation and vacuum technology. With modern instrumentation becoming widely available in laboratories worldwide, the technical and scientific developments from the mid 1990s have been rapid.

ABOVE: James Hillier shows Vladimir Zworykin a table-top version of his electron microscope during World War II. Hillier developed the first commercial electron microscope in 1940 at RCA Victor.

LEFT: Les Flory views color video of red blood cells in 1957 as part of a project to develop a sanguinometer.

7.REFERENCES

- [1] Augus I Kirkland and John L Hutchison, Nanocharacterisation, Department of Materials, Oxford University, RSC Publishing, Oxford, pages 94,95,108-131.
- [2] http://whatis.techtarget.com/definition/0,,sid9_gci517748,00.html
- [3]http://www.google.com/books?hl=tr&lr=&id=ieMqIzeHdC4C&oi=fnd&pg=PA1&dq=electron+energy+loss+spectroscopy&ots=_D3BD84BRe&sig=D6qn3ZK40Sf9yTF9PrIG_wFLJ6E#v=onepage&q&f=false
- [4] http://www.ioffe.rssi.ru/ES/
- [5] http://www.news-medical.net/health/Spectroscopy-What-is-Spectroscopy.aspx
- [6]http://www.google.com/books?id=GiKVrm1fiMYC&printsec=frontcover&hl=tr#v=onepage&q&f=false
- [7] http://www.emat.ua.ac.be/ResProgr.%20a.html
- [8] R. F. Egerton 1996 "Electron Energy Loss Spectroscopy in the Electron Microscope", 2nd ed., Plenum, New York