

# Scanning Electron Microscopy

X-ray microanalysis in SEM

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October 10, 2024



Czech Academy  
of Sciences

**MBU**



**light microscope** **TEM** **SEM**

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$$d = \frac{1.22 \cdot \lambda}{2 \cdot n \cdot \sin \alpha} = 0.61 \cdot \frac{\lambda}{n \cdot \sin \alpha}$$

**The Diffraction Barrier**  
Rayleigh criterion

**LM & TEM**  
The diffraction barrier influences the quality of the image point projection

**SEM**  
The diffraction barrier influences the quality of the electron beam spot

Credits: FEI - <https://www.fei.com> & EMG IMC CAS, v.1.1 - <https://imbcas.cz/>

**Events at sample level**

**LM & TEM**  
The diffraction barrier influences the quality of the image point projection

**SEM**  
The diffraction barrier influences the quality of the electron beam spot

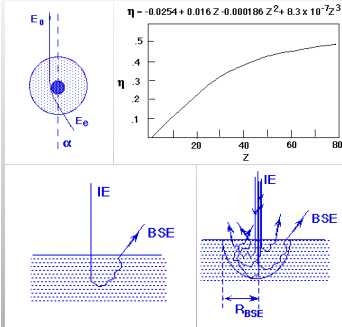
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**Physical Basics of Scanning Electron Microscopy**

**Upon electron beam interaction with the bulk specimen**

- Reflects electrons - backscattered electrons - BSE
- Emits electrons - secondary electrons - SE
- Transmits electrons (if thin enough) - primary electrons, elastically and inelastically scattered electron
  - STEM-BF, STEM-DF, ESI, EELS in STEM
- Absorbs electrons - sample current
- Emits electromagnetic radiation - characteristic radiation - EDXS, EDXS imaging
- Emits positively charged ions

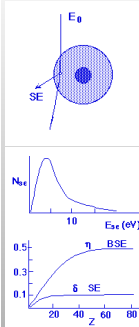
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## BSE - Backscattered Electrons

### SEM BSE

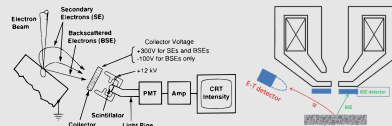
- Elastic collision. The energy loss is lower than 1 eV.
- Amount of BSE electrons depends on atomic number.
- There are many of elastic collision events leading to electron escape from sample.
- $R_{BSE}$  is the radius of sample volume releasing BSE from.



## SE - Secondary Electrons

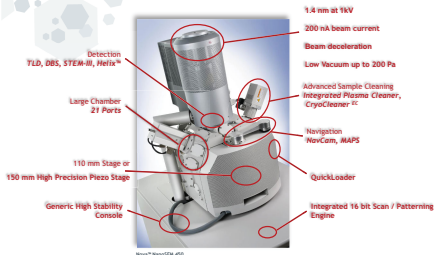
### SEM SE

- Produced by inelastic interactions of high energy electrons with valence electrons of atoms in the specimen which cause the ejection of the electrons from the atoms.
- Arbitrarily, such emergent electrons with energies less than 50 eV are called secondary electrons; 90% of secondary electrons have energies less than 10 eV; most, from 2 to 5 eV.



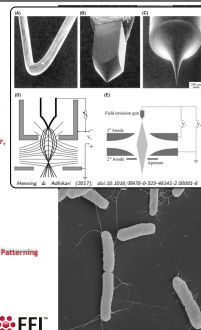
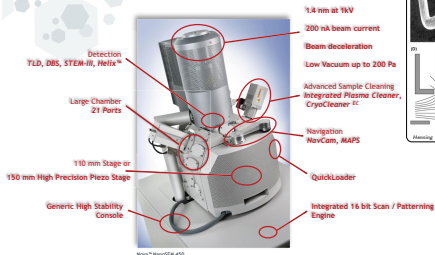
## FEG SEM - High resolution

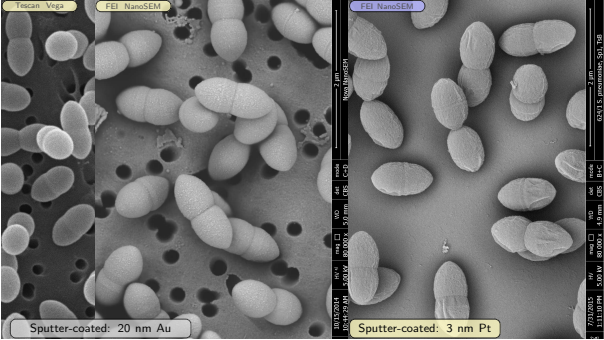
The Nova NanoSEM 50 Series - New Features



## FEG SEM - High resolution

The Nova NanoSEM 50 Series - New Features



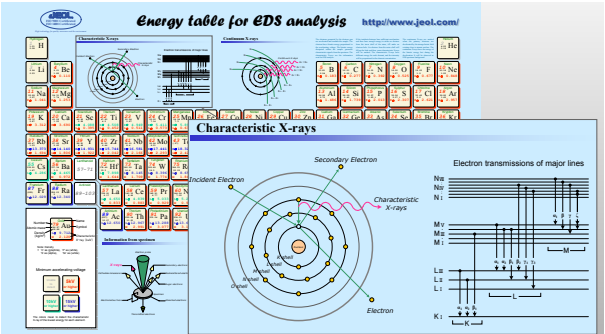
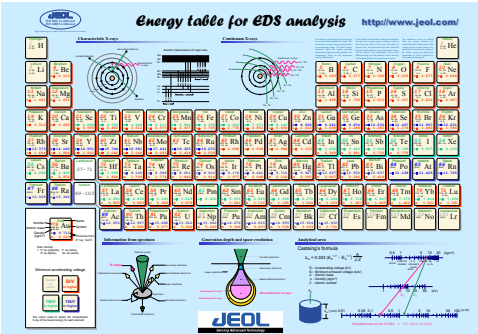


## Essential background

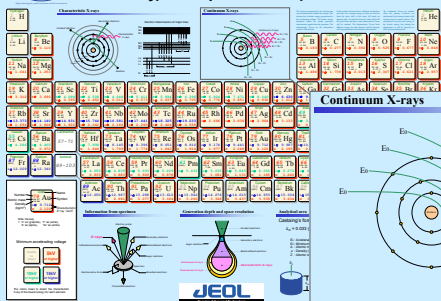
Image formation in the scanning electron microscopes  
Scanning electron microscopy & X-ray microanalysis  
Other factors HR-SEM performance, image interpretation

## A comment on sample preparation

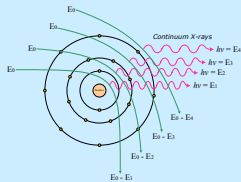
Scotch Magic Tape method



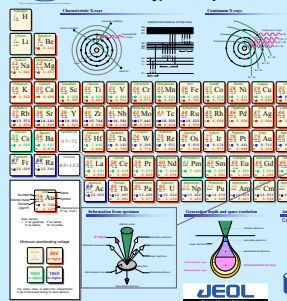
# Energy table for EDS analysis <http://www.jeol.com/>



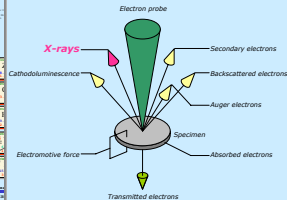
## Continuum X-rays



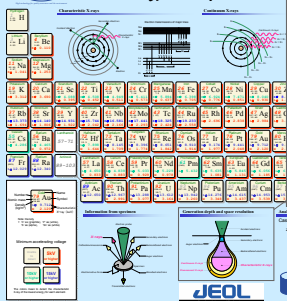
# Energy table for EDS analysis



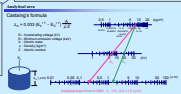
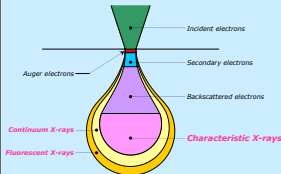
## Information from specimen



# Energy table for EDS analysis



## Generation depth and space resolution

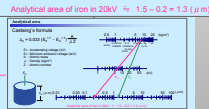
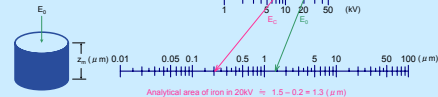


## Analytical area

### Castaing's formula

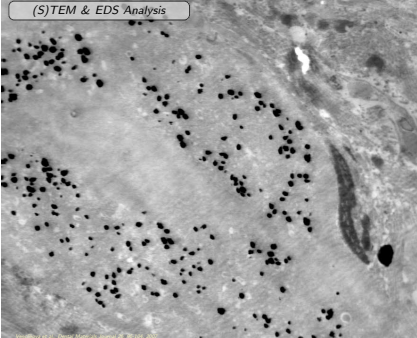
$$z_m = 0.033 (E_0^{1.7} - E_C^{1.7}) \frac{A}{\rho Z}$$

$E_0$ : Accelerating voltage (kV)  
 $E_C$ : Minimum emission voltage (keV)  
 $A$ : Atomic mass  
 $\rho$ : Density (kg/m<sup>3</sup>)  
 $Z$ : Atomic number



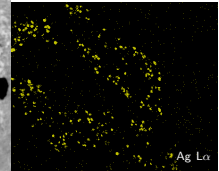
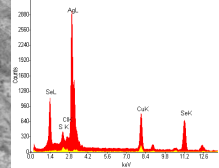


(S)TEM & EDS Analysis

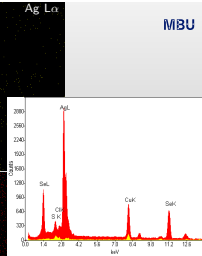
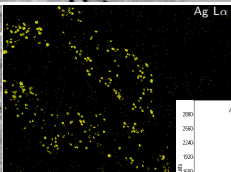
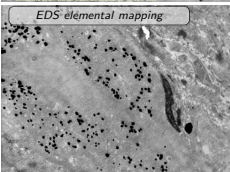


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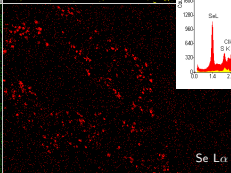
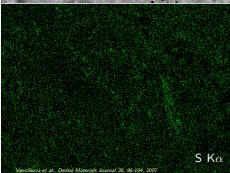
(S)TEM & EDS Analysis



EDS elemental mapping



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### Essential background

Image formation in the scanning electron microscopes  
Scanning electron microscopy & X-ray microanalysis  
Other factors HR-SEM performance, image interpretation

### A comment on sample preparation

Scotch Magic Tape method



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Crossed tape  
is split off

