# Terimakasih

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## Acknowledgement

JEOL
Solutions for Innovation

https://www.jeol.co.jp/

# Technical Terms

**BSEI: Backscattered Electron Image:**
After incident electrons are scattered within the specimen some of them are backscattered while keeping a relatively high energy and emitted again from the specimen surface. These electrons are called backscattered electrons. The contrast of the backscattered electron image depends on the topography of the specimen surface and on the mean atomic number of the substances which constitute the specimen. Use of a paired detector allows separate observation of a topography (TOPO) image and a composition (COMPO) image.

**X-ray image:**
A mapping image used to investigate the distribution of a characteristic X-ray image of a specific element.

**CL and OL: Condenser lens and objective lens:**
CL controls the probe current and OL focuses the electron probe on the specimen surface.

**WD: Working distance:**
The distance from the underside of the objective lens to the specimen surface.

**Probe diameter:**
Generally, this means the minimum probe diameter that depends on the accelerating voltage, probe current, and working distance.



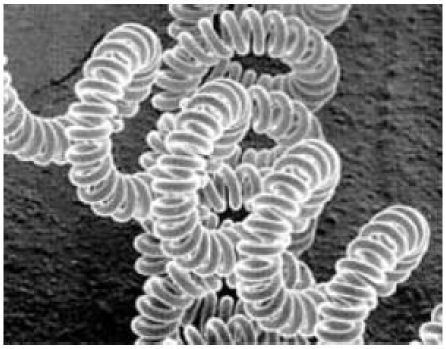
# Technical Terms

**FE-SEM**:
Field Emission Scanning electron microscope

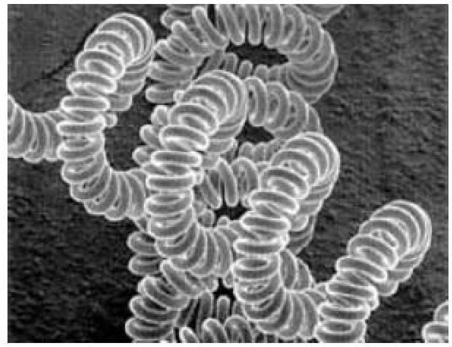
**Probe current:**
The total amount of current to be irradiated on the specimen. Itis controlled between approx. 10-12A to 10-6A. The control is done by varying the excitation of the SEM's condenser lens. The name of this knob with this function varies with the type of the instrument having that function, like CONDENSER LENS, PROBE CURRENT and SPOT SIZE.

**SEI: Secondary Electron Image**:
Secondary electrons are excited secondarily by electrons incident on the specimen. Since their generation region is as shallo was approx. 10nm, the diffusion of incident electrons within  the specimen has little influence on the image, thus allowing the best resolution to be obtained. The contrast of secondary electron images depends mainly on the tilt angle and topoqraphy of the specimen surface

# Influence of Working Distance and Aperture Size



(d) OL aperture diameter: 200μm WD: 38mm

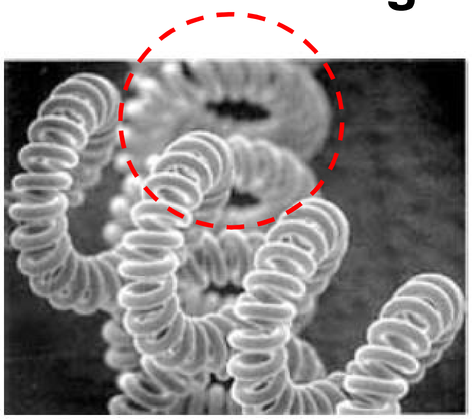


(e) OL aperture diameter: 100μm WD: 38mm

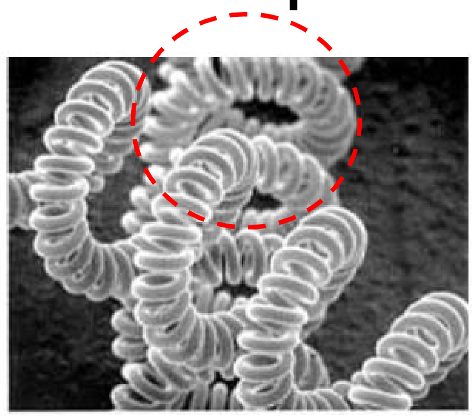
Specimen Electric bulb coil
5 kV x540
The smaller the OL aperture diameter and the longer the WD, the greater the depth of field.



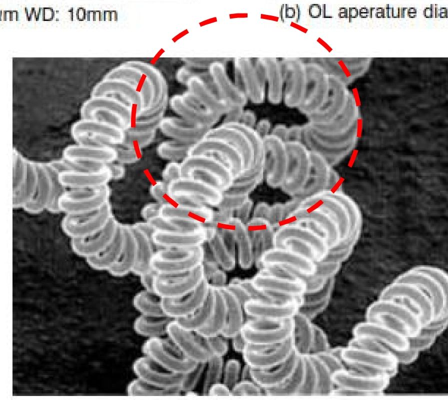
# Influence of Working Distance and Aperture Size



(a) OL aperature diameter: 600μm WD: 10mm

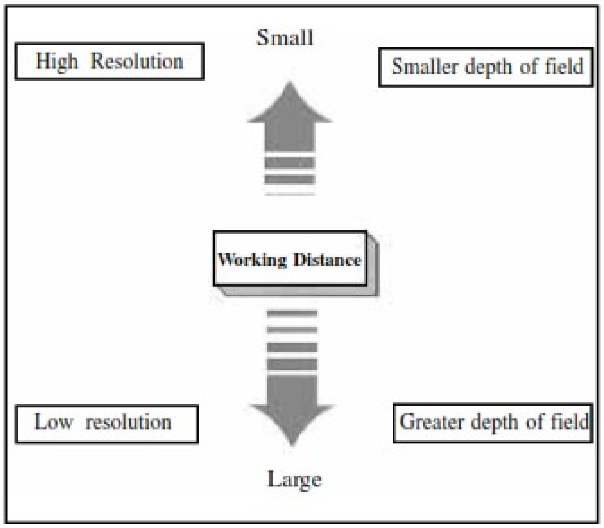


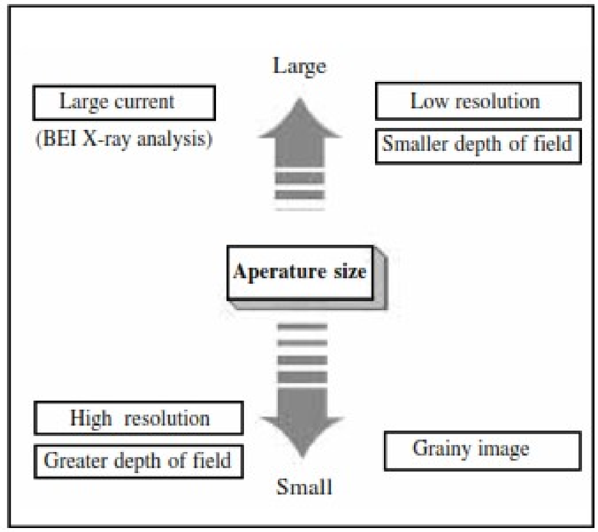
(b) OL aperature diameter: 200μm WD: 10mm



(c) OL aperture diameter: 200μm wd:20mm

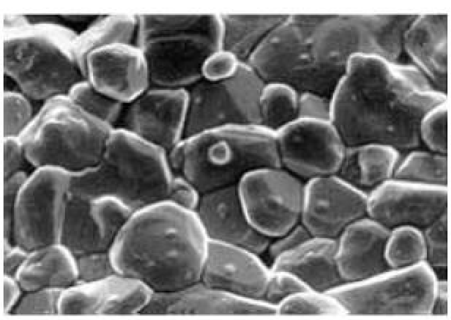
# Influence of Working Distance and Aperture Size



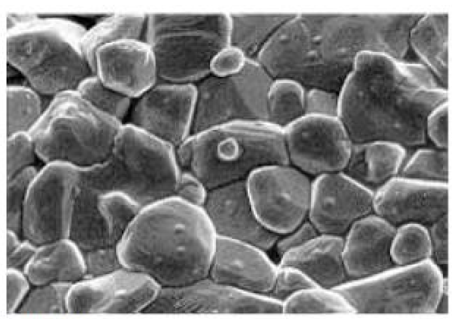





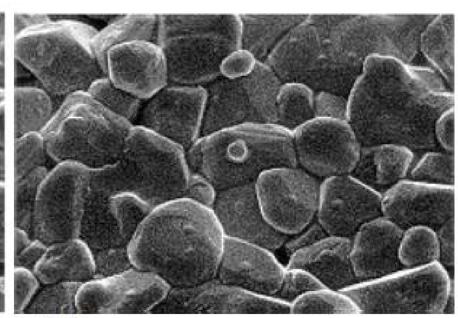

# Probe Current



(a) 1 nA



(b) 0.1 nA

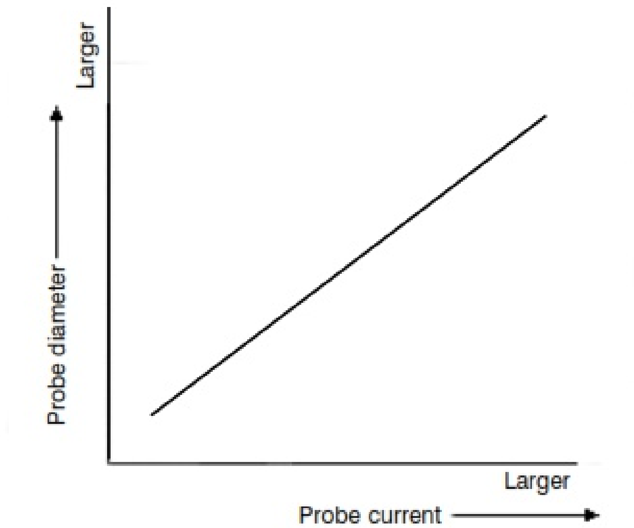


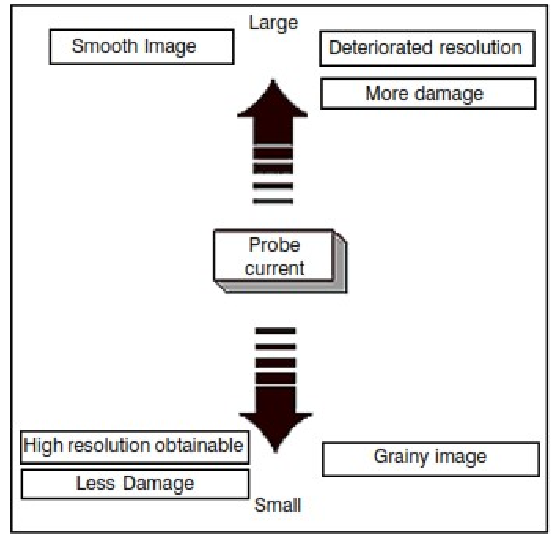
(c) 10 pA

Specimen: Ceramic
10 kV x 5,400

The smaller the probe current, the sharper is the image, but the surface smoothness is lost

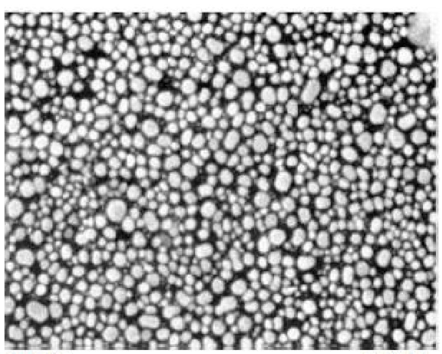
# Probe Current and Probe Diameter



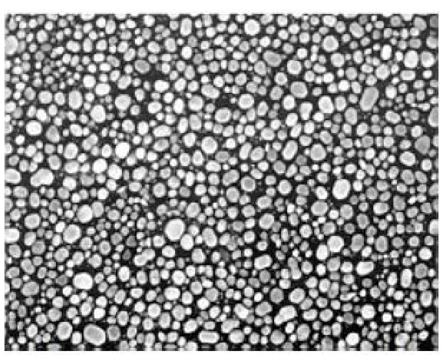






# Effect of Accelerating Voltage



(a) 5 kV x 36,000

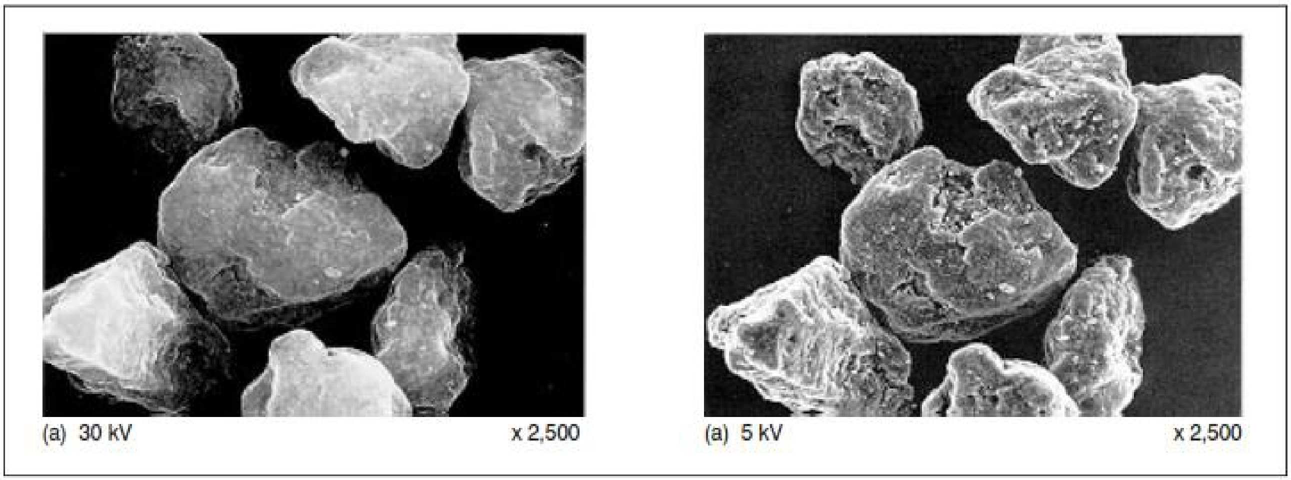


(b) 25 kV x 36,000

Specimen: Evaporated Au particles

The image sharpness and resolution are better at the higher accelerating voltage, 25 kV.

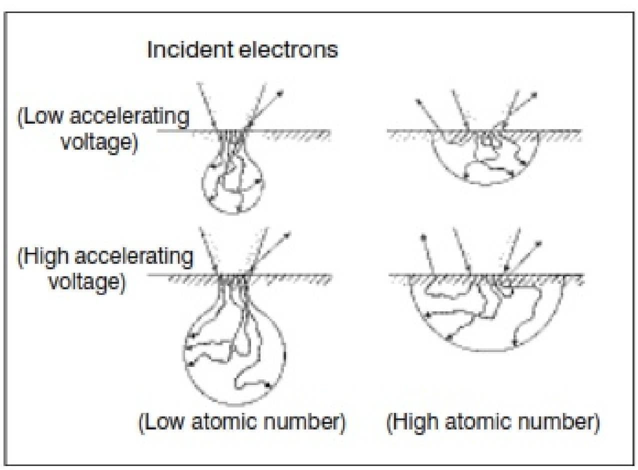
# Effect of Accelerating Voltage

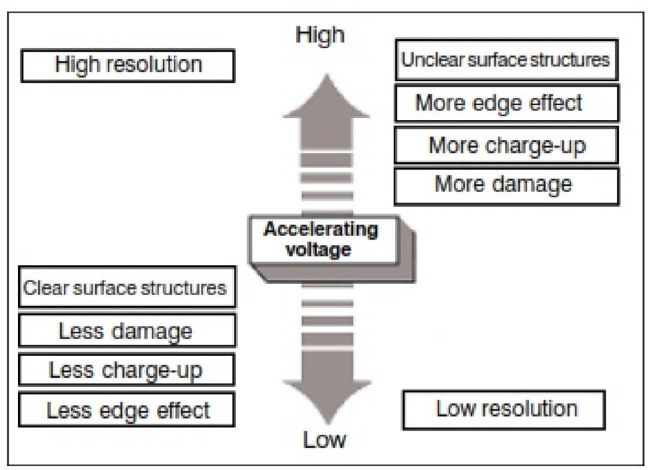



Specimen: Toner
When high accelerating voltage is used as at (a), it is hard to obtain the contrast of the specimen **surface structure**. Besides, the specimen surface is easily charged up. The surface microstructures are easily seen at (b).



# Effect of Accelerating Voltage



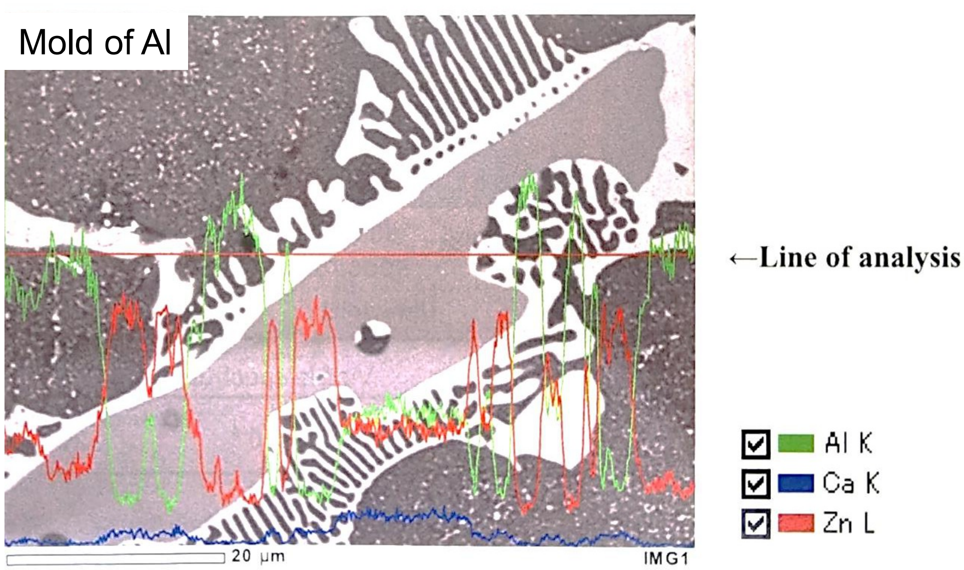



# For Better Images



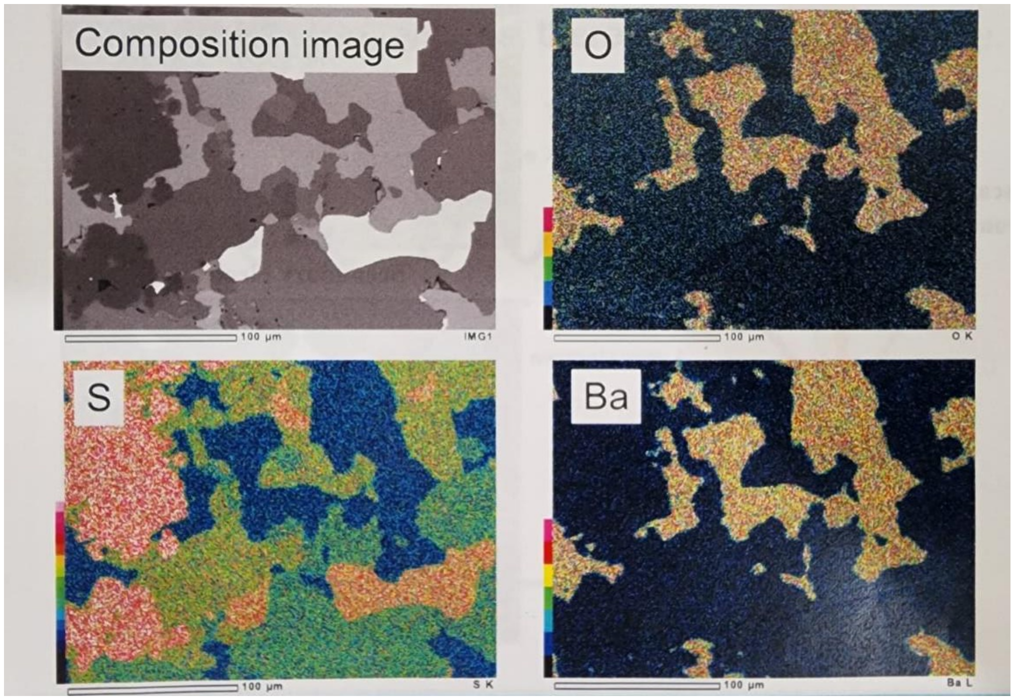
## Energy Dispersive X-ray Spectroscopy (EDS)

**Analisis Line**



# Energy Dispersive X-ray Spectroscopy (EDS)

**Mapping** → Letak setiap unsur diperlihatkan oleh titik-titik






# Energy Dispersive X-ray Spectroscopy (EDS)

$$\frac{\text{mol Ca}}{\text{mol } P} = \frac{\frac{\text{massa Ca}}{\text{Mr Ca}}}{\frac{\text{massa P}}{\text{Mr P}}} = \frac{\text{massa Ca}}{\text{massa P}} \times \frac{\text{Mr P}}{\text{Mr Ca}}$$

Mr P: massa atom relatif P = 30,973762

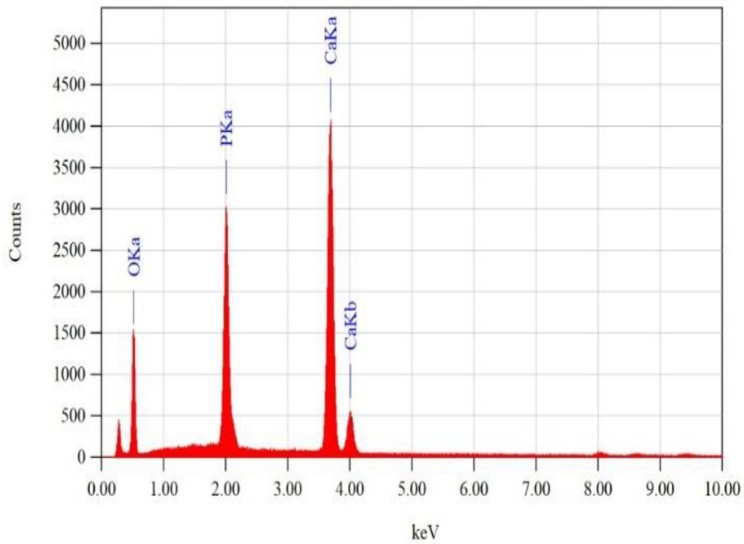
Mr Ca: massa atom relatif Ca = 40,078

$$\frac{\text{mol Ca}}{\text{mol P}} = \frac{\text{massa Ca}}{\text{massa P}} \times \frac{\text{Mr P}}{\text{Mr Ca}}$$

$$\frac{\text{mol Ca}}{\text{mol P}} = \frac{29.01}{13.64} \times \frac{30{,}973762}{40{,}078}$$

$$\frac{\text{mol Ca}}{\text{mol P}} = \frac{29.01}{13.64} \times \frac{30{,}973762}{40{,}078} = 1.64$$

# Energy Dispersive X-ray Spectroscopy (EDS)




ZAF Method Standardless Quantitative Analysis
Fitting Coefficient : 0.0742

| Element | (keV) | Mass% | Sigma | Atom% | Compound | Mass% | Cation | K |
|---|---|---|---|---|---|---|---|---|
| O K | 0.525 | 57.35 | 0.53 | 75.48 | | | | 38.9060 |
| P K | 2.013 | 13.64 | 0.10 | 9.28 | | | | 19.1981 |
| Ca K | 3.690 | 29.01 | 0.17 | 15.24 | | | | 41.8959 |
| Total | | 100.00 | | 100.00 | | | | |

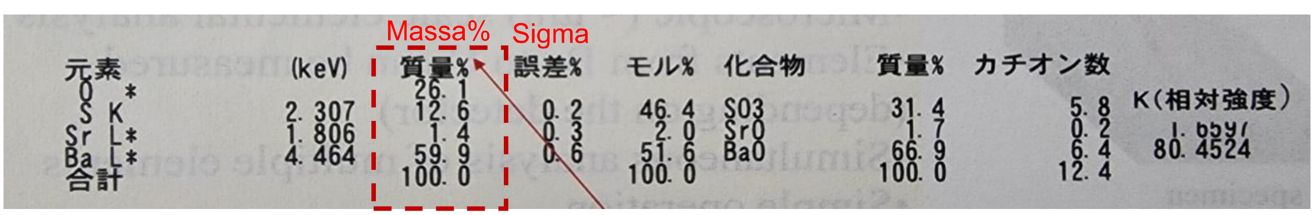
- **Untuk sample HA, rasio Ca dan P sebesar 1,67**. Rasio kedua unsur ini dapat dilihat melalui %mass pada hasil EDS.
- Persentase massa pada hasil EDS menunjukkan persentase massa untuk tiap unsur pada sampel, sedangkan rasio Ca/P merupakan rasio molar yang ada pada unsur, sehingga nilai **%mass** ini tidak bisa langsung dibandingkan untuk memperoleh nilai rasio Ca/P, tetapi harus diubah menjadi nilai molar Ca dan P.



# Energy Dispersive X-ray Spectroscopy (EDS)

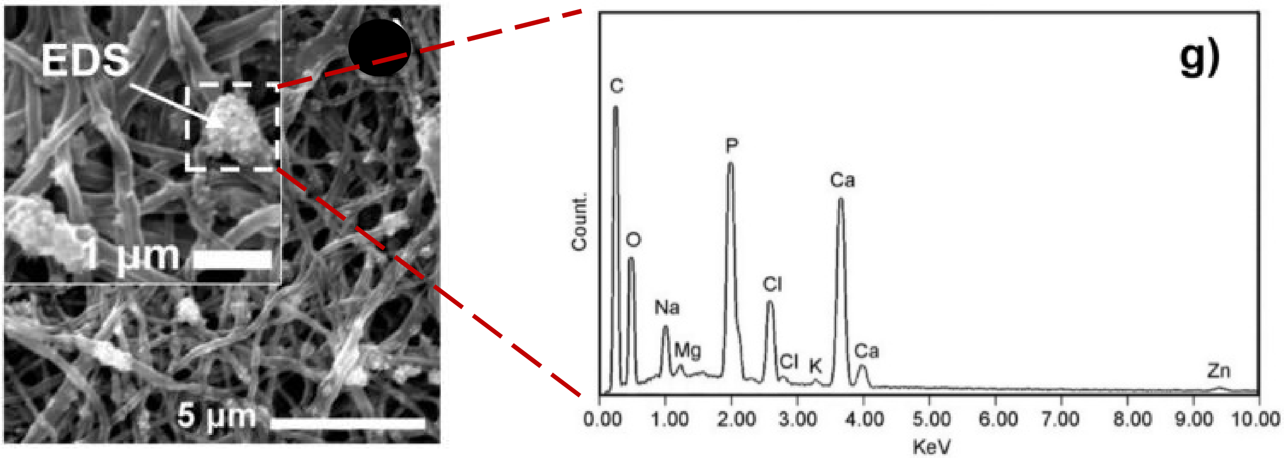
**Analisis Quantitative**

→ Jumlah dari unsur dari sample dianalisis




| 元素 | (keV) | 質量% | 誤差% | モル% | 化合物 | 質量% | カチオン数 | K(相対強度) |
|---|---|---|---|---|---|---|---|---|
| O * | | 26.1 | | | | | | |
| S K | 2.307 | 12.6 | 0.2 | 46.4 | SO3 | 31.4 | 5.8 | |
| Sr L* | 1.806 | 1.4 | 0.3 | 2.0 | SrO | 1.7 | 0.2 | 1.6597 |
| Ba L* | 4.464 | 59.9 | 0.6 | 51.6 | BaO | 66.9 | 6.4 | 80.4524 |
| 合計 | | 100.0 | | 100.0 | | 100.0 | 12.4 | |

# Energy Dispersive X-ray Spectroscopy (EDS)



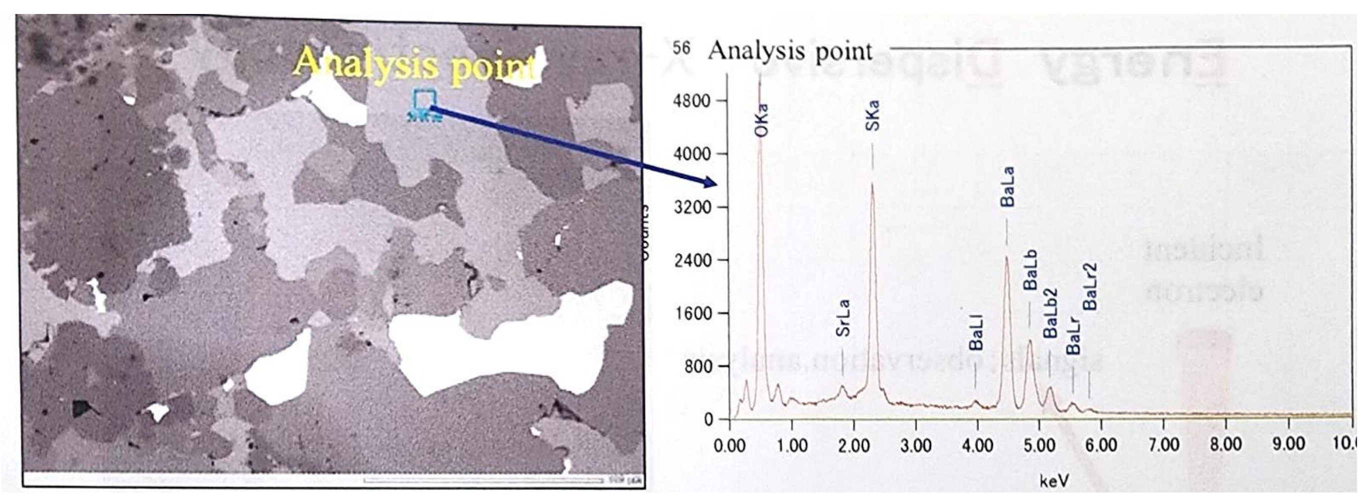

PVA/CS/CHAp 15 wt% (7 days in FBS)



# Energy Dispersive X-ray Spectroscopy (EDS)

**Analisis Qualitative**

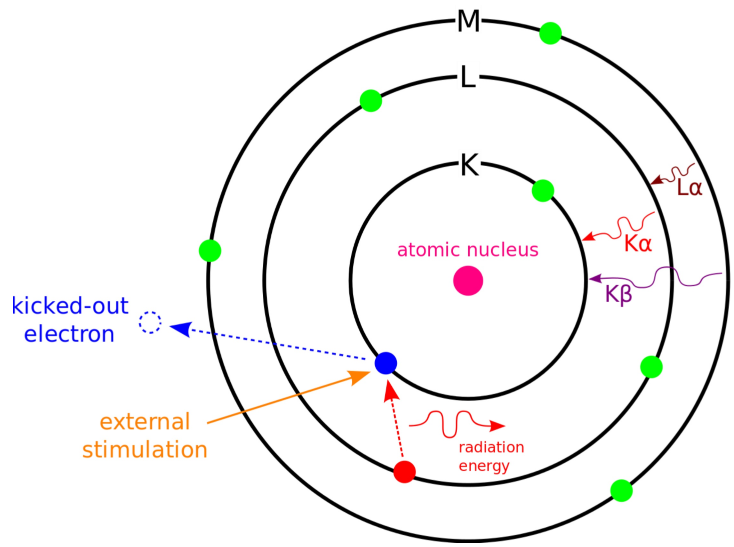
→ unsur yang terkandung di sample dianalisis dari puncak-puncak energi pada spektrum



# **E**nergy **D**ispersive X-ray **S**pectroscopy (EDS)

- **Garis- garis spektrum EDS** biasanya dinamakan sesuai dengan kulit *(shell*) ke mana elektron jatuh dan kulit dari mana elektron berasal .

- Jika kulit yang kosong (tujuan) adalah kulit **K** dan kulit dari mana elektron berasal adalah kulit **L**, maka sinar-X Kα/Ka diradiasikan. Jika elektron jatuh dari kulit **M** yang berada dua tingkat di atas kulit K, maka sinar-x yang diradiasikan dinamakan sinar-X Kβ/Kb.

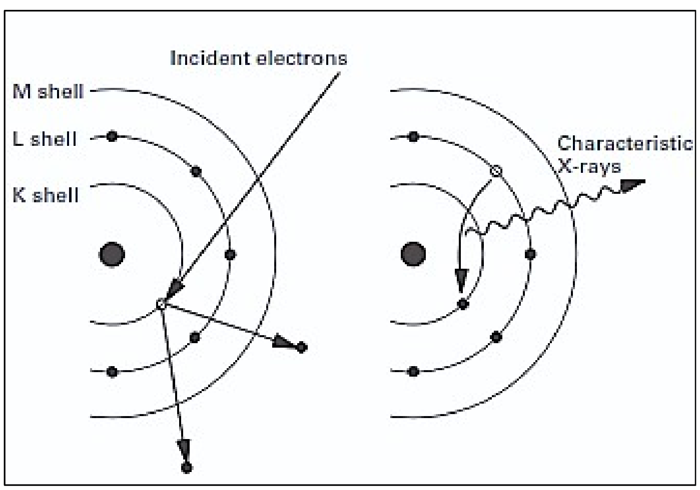





# **E**nergy **D**ispersive X-ray **S**pectroscopy (EDS)

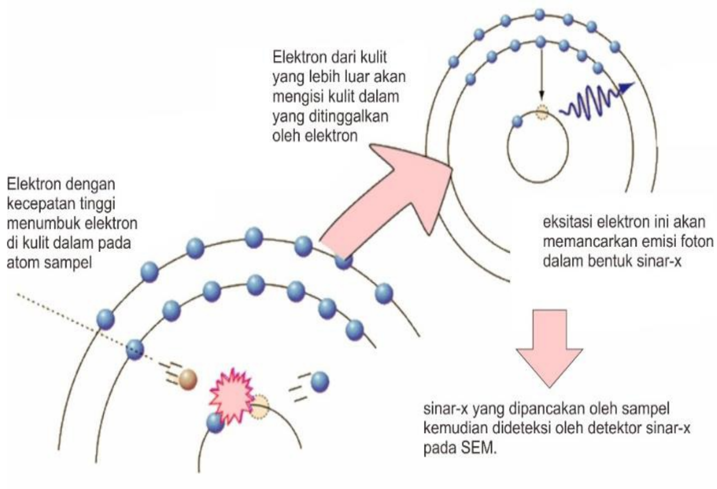
- When electrons in **the inner shells** are emitted from the constituent atoms in the substance **due to the irradiation of the incident electrons**, the vacant orbits are **filled with outer-shell electrons,** and the substance emits X-rays whose energies correspond to the energy difference between the outer-shell electrons and the inner shell electrons.

- These X-rays are called **"characteristic X-rays"** because their energies (wavelengths) are characteristic of individual elements.



# Energy Dispersive X-ray Spectroscopy (EDS)

- **EDS** merupakan fasilitas tambahan pada SEM yang digunakan untuk mengetahui kandungan unsur pada sampel.
- **Prinsip kerja EDS** hampir sama dengan pengambilan *image* SEM, yaitu memanfaatkan tumbukan elektron dari electron gun dengan elektron pada sample. Jika SEM mendeteksi elektron-elektron pada kulit terluar yang keluar dari orbitnya, maka EDS memanfaatkan tumbukan **elektron yang terjadi pada kulit yang lebih dalam**




Prinsip kerja EDS

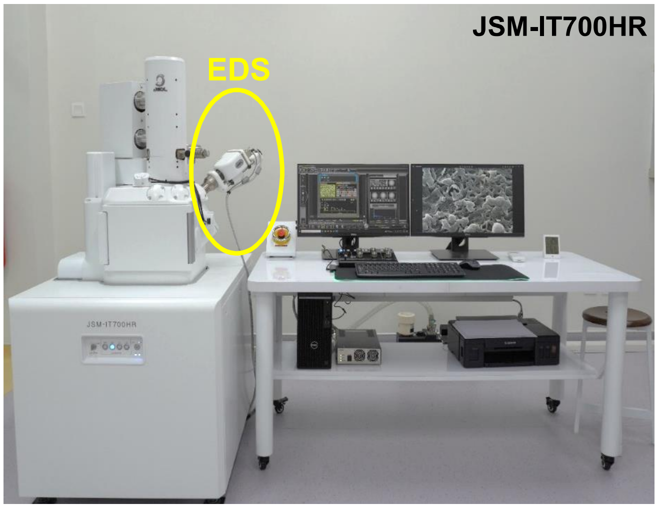


# Energy Dispersive X-ray Spectroscopy (EDS)

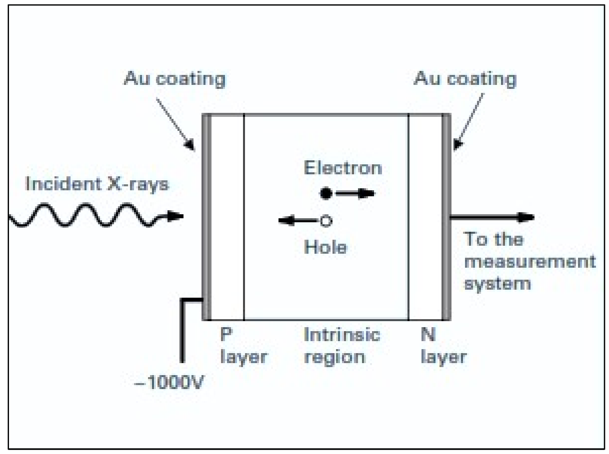
**Apa yang bisa dilakukan dengan EDS**

| | |
|---|---|
| Analisis Qualitative | : unsur-unsur apa saja yang ditemukan pada sample |
| Analisis Quantitative | : jumlah unsur |
| Analisis Map.Line | : Dimana di dalam sample unsur tersebut berada, variasi intensitas |

# Energy Dispersive X-ray Spectroscopy (EDS)




EDS semiconductor detector

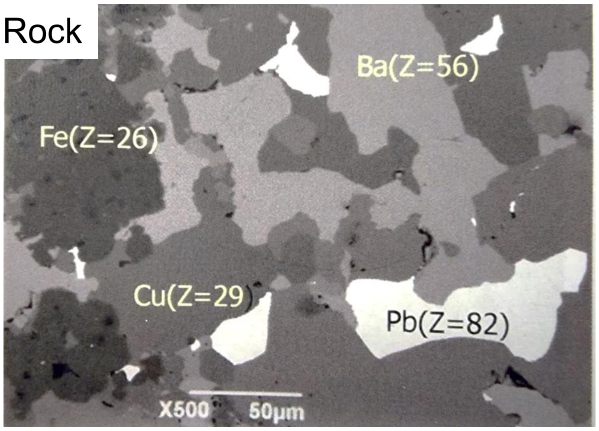



When the X-rays emitted from the specimen enter *the semiconductor detector*, **electron-hole pairs** are generated whose quantities correspond to **the X-ray energy**. Measuring these quantities (electric current) enables you to obtain the **values of X-ray energy**. The detector is cooled by liquid nitrogen, in order to reduce the electric noise.



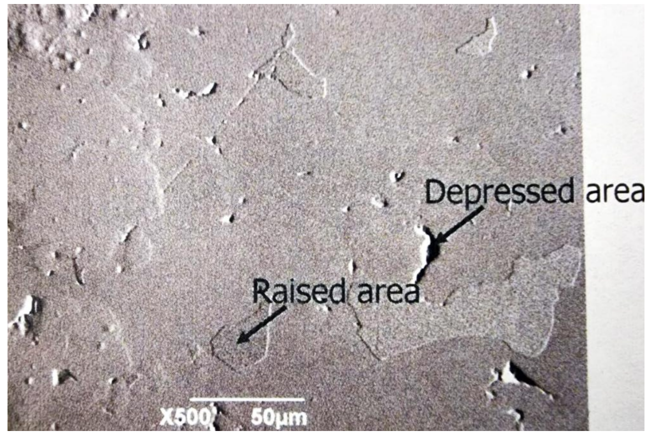
# Introduction of EDS

# Why Images are Visible (BSE)




**Composition image**

Composition image shows contrast created by difference of atomic number




**Topography image**

Topography image shows illumination from right side of image

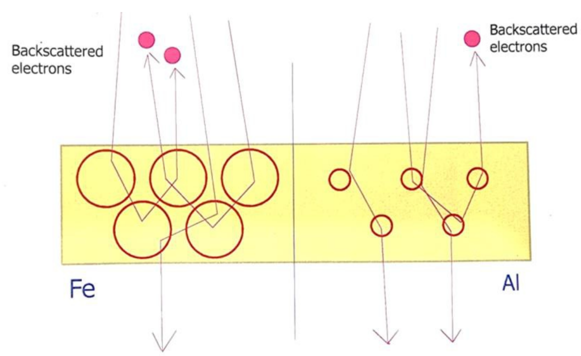


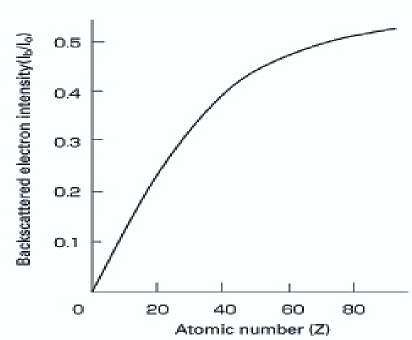
# Why Images are Visible (BSE)

- **Feature**:
  - Distribution of different material (composition)
  - Roughness of specimen surface (topography)
- Backscattered electrons (BSE) are those scattered backward and emitted out of the specimen, when the incident electrons are scattered in the specimen. They are sometimes **called reflected electrons**.
- Since BSE possess higher energy than secondary electrons, information from a relatively deep region is contained in the BSE. The BSE are sensitive to the **composition of the specimen**
- As the atomic number of the constituent atoms in the specimen is larger, the BSE yield is larger. That is, an area that consists of a **heavy atom appears bright in the BSE image**.

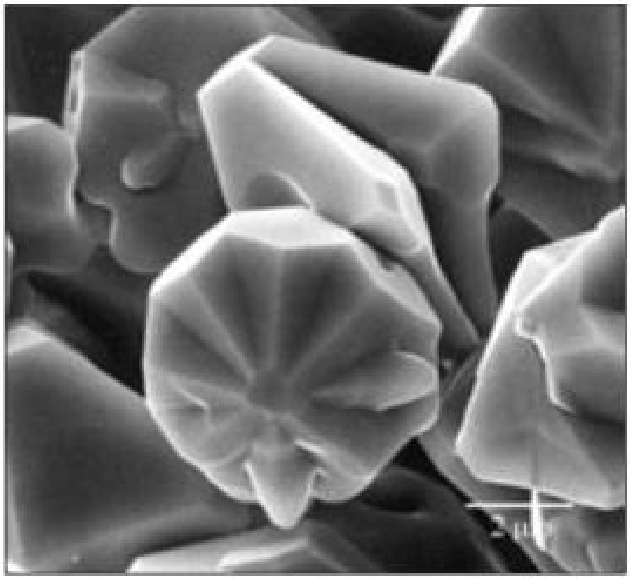
**Brighter**, Z = 26
High density(7.9g/cm3)

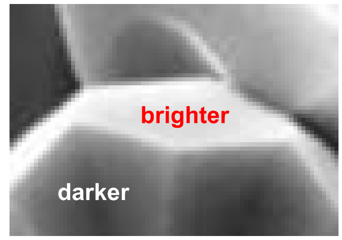
**Darker**, Z =13
Low density (2.7g/cm3)



# Why Images are Visible (SE)

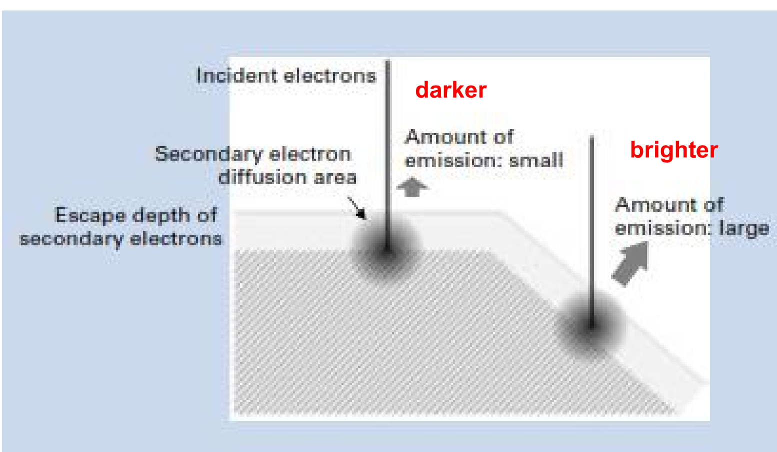


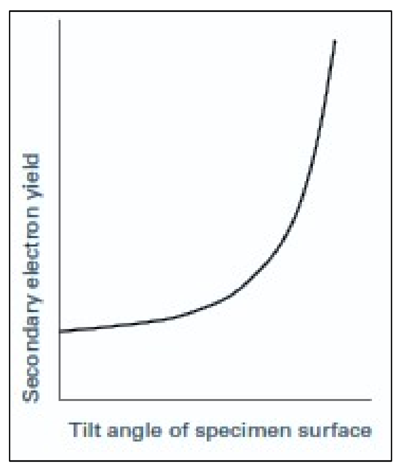



SE image of tungsten oxide crystal.



# Why Images are Visible (SE)




- Energy of SE is very small → **quickly absorbed by the specimen**. Only those generated at the top surface of the specimen are emitted outside of the specimen. This means that the SE are very sensitive to the surface.
- Compared to when the incident electron beam enters **perpendicularly to the specimen**, the amount of the **SE emission is larger when the electron beam enters obliquely**
- The difference in **the brightness** of the crystal surface is due to the difference of the incidence angle of the electron beam. Thus, the secondary electron is used to observe the **topography** of the specimen surface

# OM vs. SEM

| | Light microscope | SEM |
|---|---|---|
| Illumination source | Light λ: 200 - 750nm | Electron λ: 0.007 - 0.055nm |
| Resolution | Visible light/Ultra violet: 200/100nm | Secondary electron: 3nm(JSM-6X90) |
| Color | Visible | No color information |
| Depth of focus | Small: 0.1μm(×1000) | Large: 30μm |
| Magnification | A few - ×2,000 | A few - ×100,000 |
| Lens | Glass lens | Magnetic lens |
| Image | Transmitted image Reflected image | Secondary electron image Backscattered electron image |
| Environment for specimen | Atmosphere 101,300Pa | Vacuum $10^4$ - $10^{-5}$Pa |

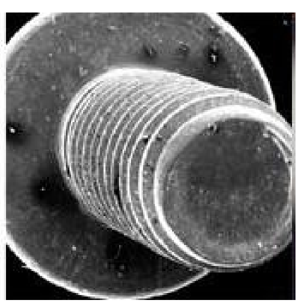
*** Resolution of human eye: Approximately 0.2mm**



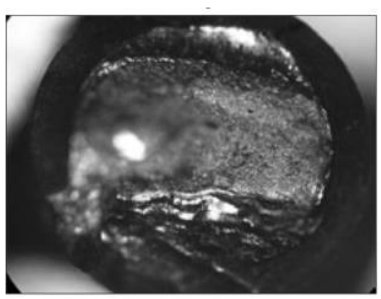
# Depth of Focus

OM image

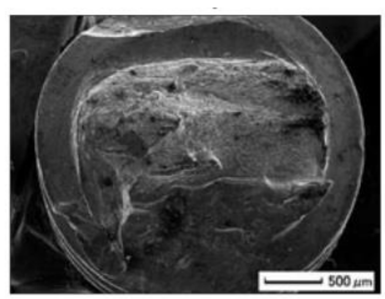
SEM image



Compares the OM and SEM images of a fractured surface of a **screw**



OM image



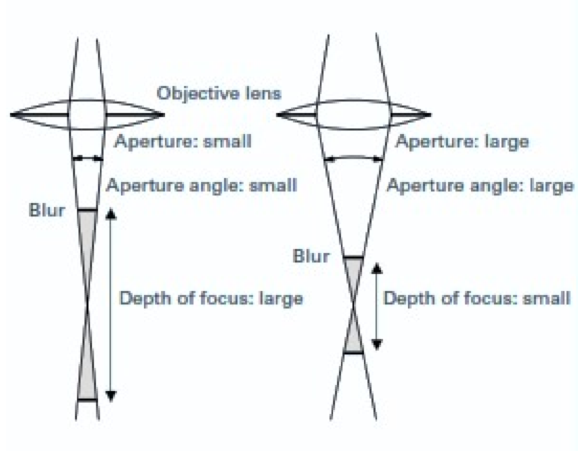

SEM image

# Depth of Focus

**The depth of focus is changed by**;
- Aperture angle
- Magnification

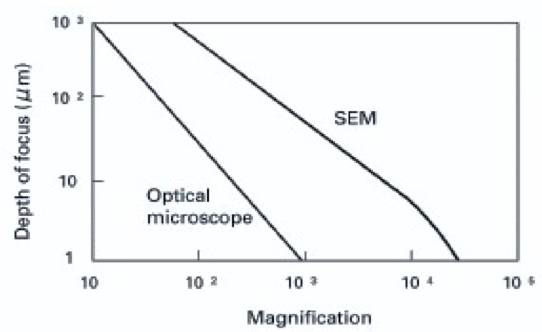
➢ If the range between upper and lower image blur is large → **the depth of focus is large**

➢ if the range between upper and lower image blur is small → **the depth of focus is small**




➢ Although a optical microscope (OM) provides an image with a relatively large depth of focus between OM, we can obtain a much larger depth of focus with the SEM.

➢ Larger magnification → **the depth of focus is small**



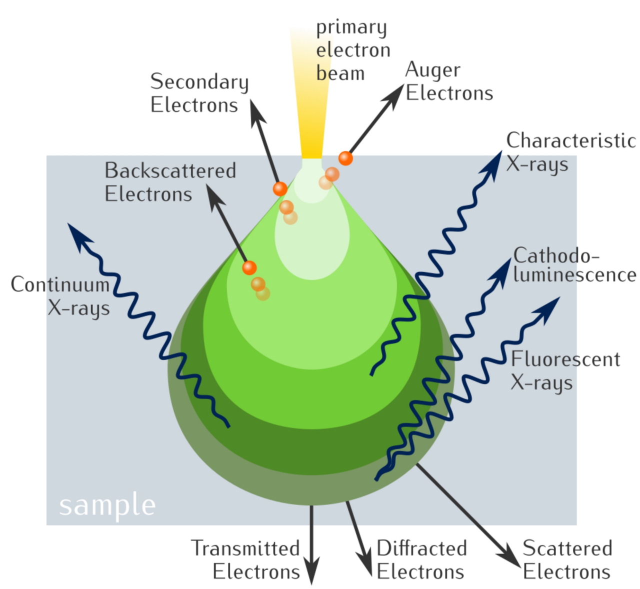


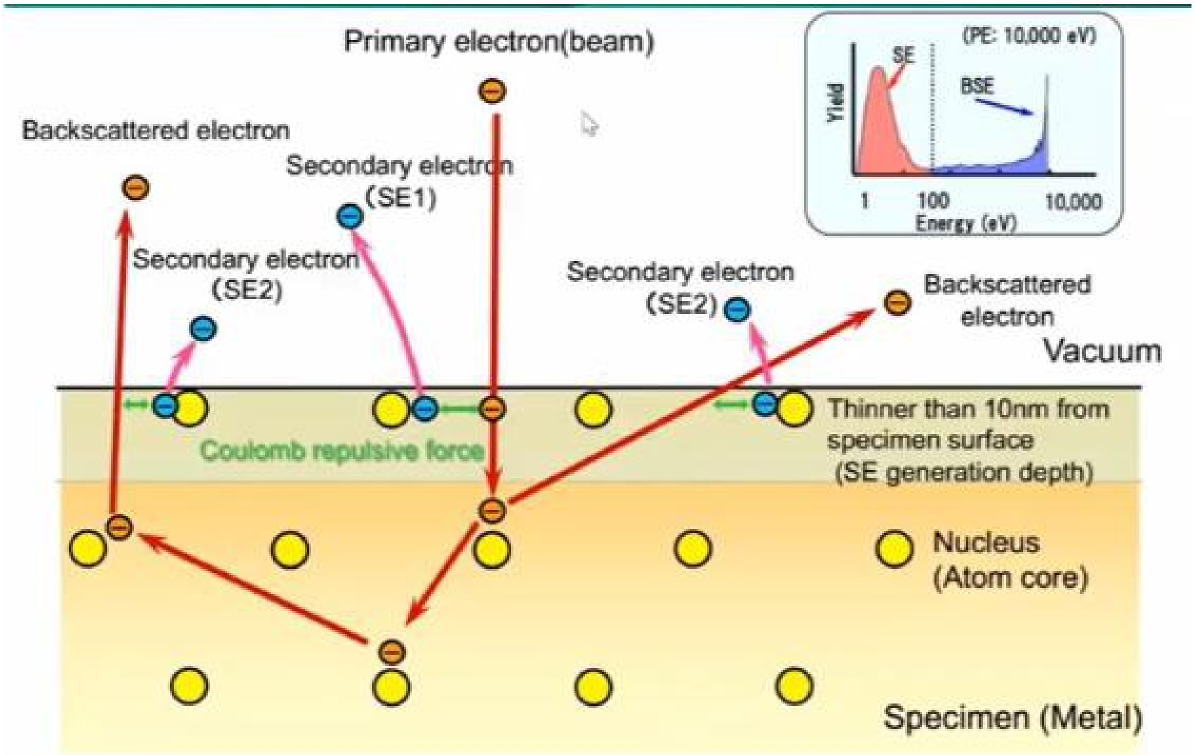

# Range of Electron Penetration

➢ **SE** : ~ nm

➢ **BSE** : ~ 10 nm – 100nm

➢ **X-Ray** : ~ μm



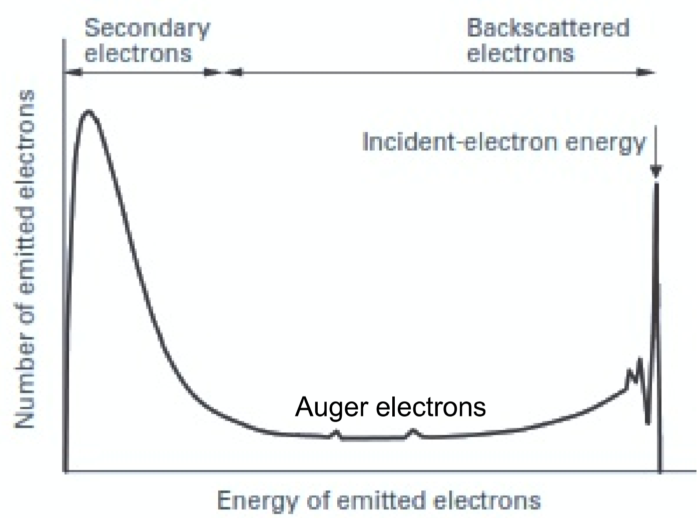



# Fungsi dan Distribusi Energi

**Fungsi;**

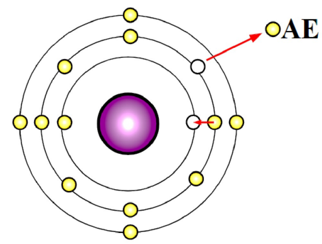
- ***SE*** – *surface morphology*
- ***BSE*** – *composition/topography*
- ***Characteristic X-Ray*** – *element*

The energy of **SE is limited to 50 eV or less**; however the energy distribution of **BSE is very wide**, ranging from an energy equal to the incident-electron energy down to 50 eV, which is far lower than the incident-electron energy. Small peaks that appear in the range of backscattered electrons correspond to **Auger electrons**.

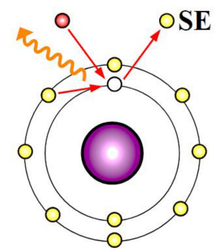


# Electron-Specimen Interaction

**Auger Electron (AE)**
Dalam kasus yang jarang terjadi, sebuah elektron dari electron beam dapat ***knock out a core electron*** dari sebuah atom. Hal ini akan menyebabkan *higher-level electron to drop down*, melepaskan sejumlah energy. Meskipun paket energi ini biasanya berupa *foton*, terkadang bisa berupa elektron. Jika berupa elektron, elektron tersebut disebut **Auger electron**. Elektron Auger biasanya tidak terdeteksi di SEM.



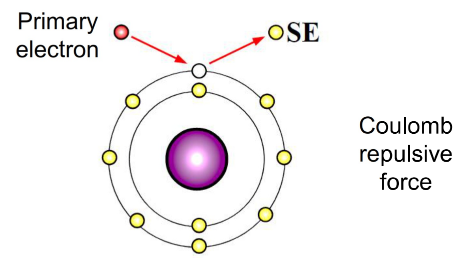

**Characteristic X-Ray Diffraction Spectroscopy (EDS)**
Tumbukan elektron dengan atom dapat melepaskan radiasi sinar-X. Radiasi ini berkaitan dengan jarak antar suborbital atom, dan bersifat unik untuk setiap unsur. Sinar-X ini disebut *characteristic X-rays*. *Continuum* dan Fluorescent X-rays juga ada, namun ini biasanya tidak useful di SEM. Difraksi Sinar-X Dispersif Energi (EDS) adalah sebuah teknik SEM untuk mendeteksi karakteristik sinar-X



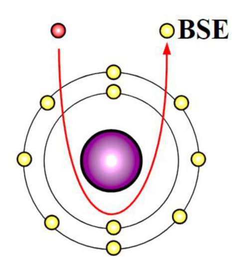



# Electron-Specimen Interaction

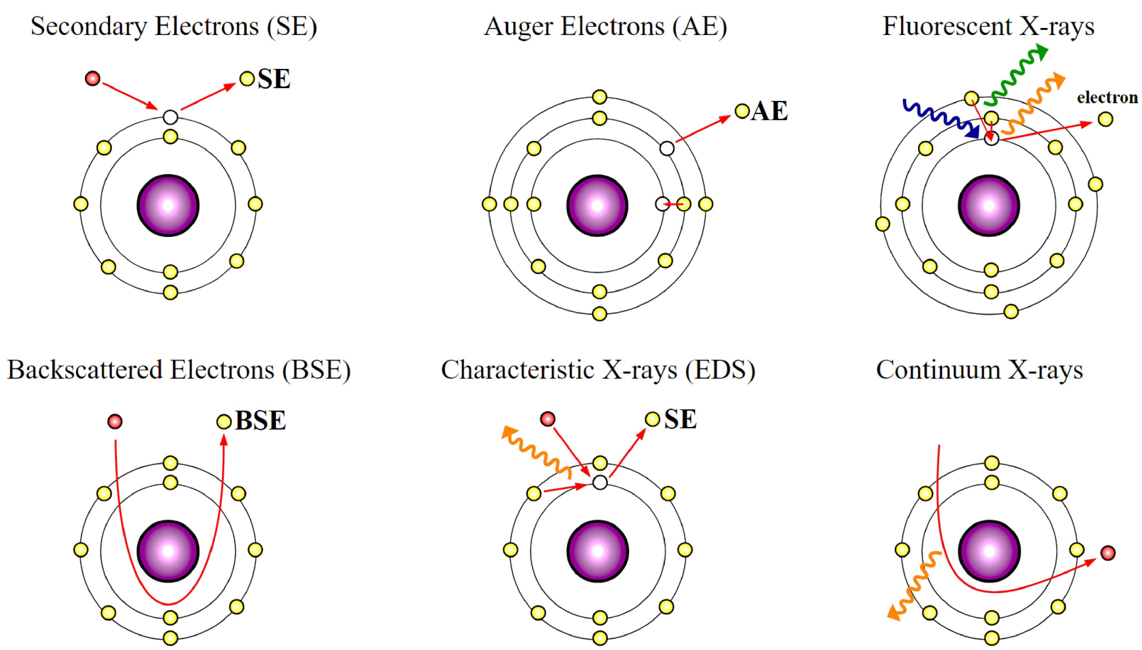
**Secondary Electrons (SE)**
*Primary electron* dari *electron beam* dapat bertumbukan secara inelastis dengan atom. Karena energi hilang dari elektron, energi tersebut perlu dipindahkan ke tempat lain. Biasanya, elektron berenergi lebih rendah dari atom juga dikeluarkan. Elektron ini disebut ***secondary electrons****(SE)*.




**Backscattered Electrons (BSE).**
Jika elektron dari berkas elektron bertumbukan secara elastis dengan atom, lintasan elektron akan berubah. Elektron ini disebut ***backscattered electrons*** **(BSE).**



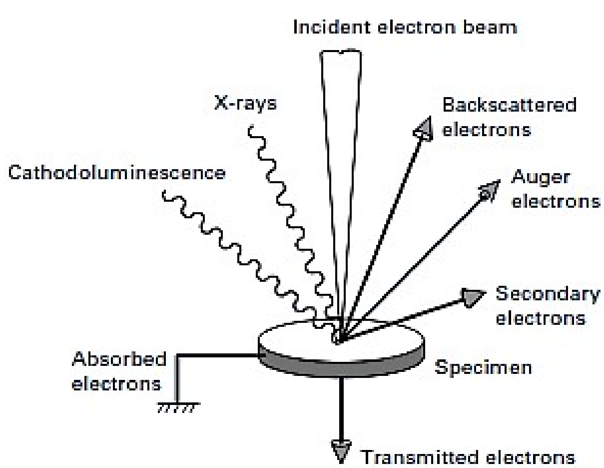
# Electron-Specimen Interaction

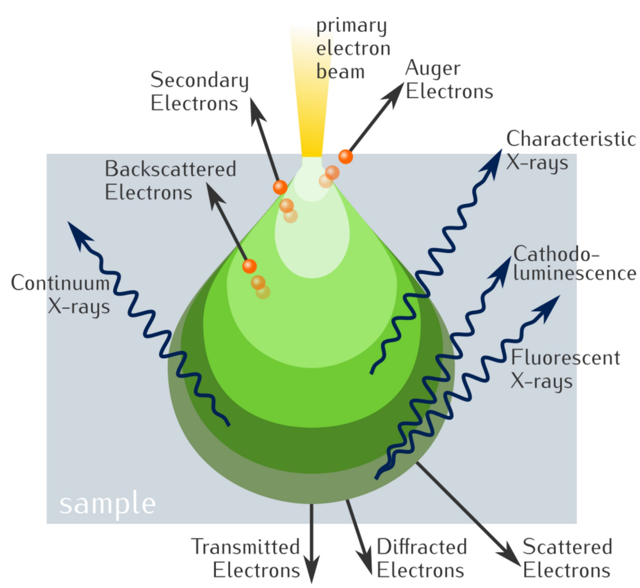





# Electron-Specimen Interaction

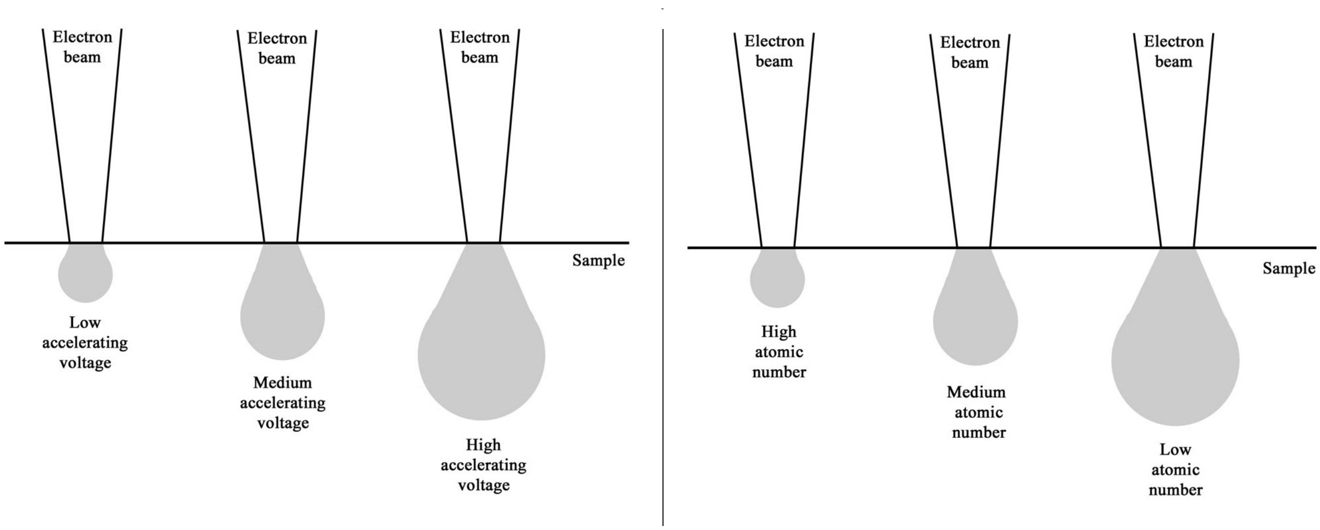
**Various signals** emitted from the specimen when the incident electron beam enters the specimen. The SEM utilizes these signals to observe and analyze the specimen surface (atau tepat di bawah permukaan)



# Electron-Specimen Interaction

- As **the energy** (**accelerating voltage**) is higher, the scattering range is larger.
- If **the atomic number** and density are large, the scattering range is smaller.



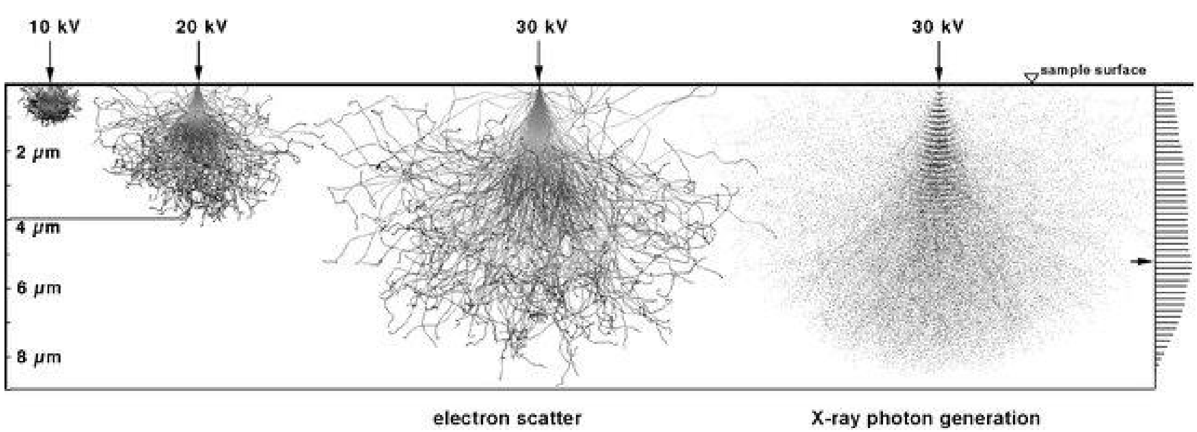

Images: Smith College Northampton, Massachusetts



# Electron-Specimen Interaction

When electrons enter the specimen, **the electrons are scattered** within the specimen and gradually lose their energy, then they are absorbed in the specimen.

**The scattering range** of the electrons inside the specimen is different depending on the electron energy, the atomic number of the elements making up the specimen and the density of the constituent atoms. **As the energy is higher, the scattering range is larger**. To the contrary, **if the atomic number and density are large, the scattering range is smaller**.




https://www.researchgate.net/publication/227667368_Middle_Cambrian_pterobranchs_and_the_Question_What_is_a_graptolite/figures?lo=1

Principle of SEM

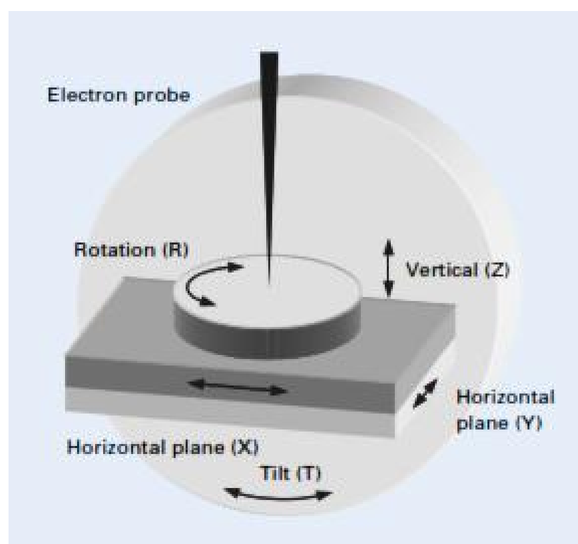


## Speciment Stage

In general, the specimen is observed at a high magnification in an electron microscope. **Thus, a specimen stage, which stably supports the specimen and moves smoothly, is required**. The specimen stage for a SEM can perform the following movements:

- horizontal movement (X, Y)
- vertical movement (Z)
- specimen tilting (T)
- rotation (R).

The X and Y movements are used for the selection of a field of view. While the Z movement provides the change of image resolution and the depth of focus



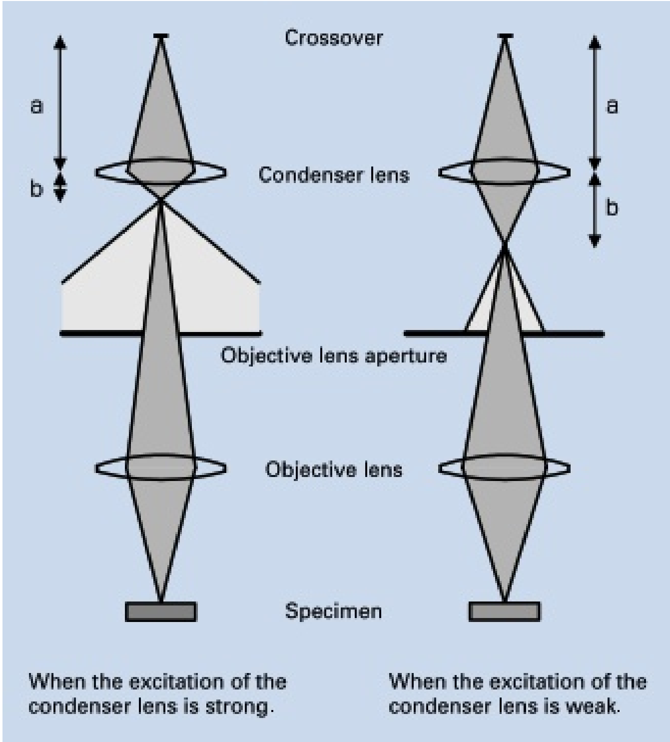

construction of the specimen stage.

# Electron Probe

**Electron probe :** a fine electron beam

Two-stage lenses, which combine the **condenser and objective lenses**, are located below the electron gun. The electron beam from the electron gun is focused by the two-stage lenses, and **a small electron probe** is produced

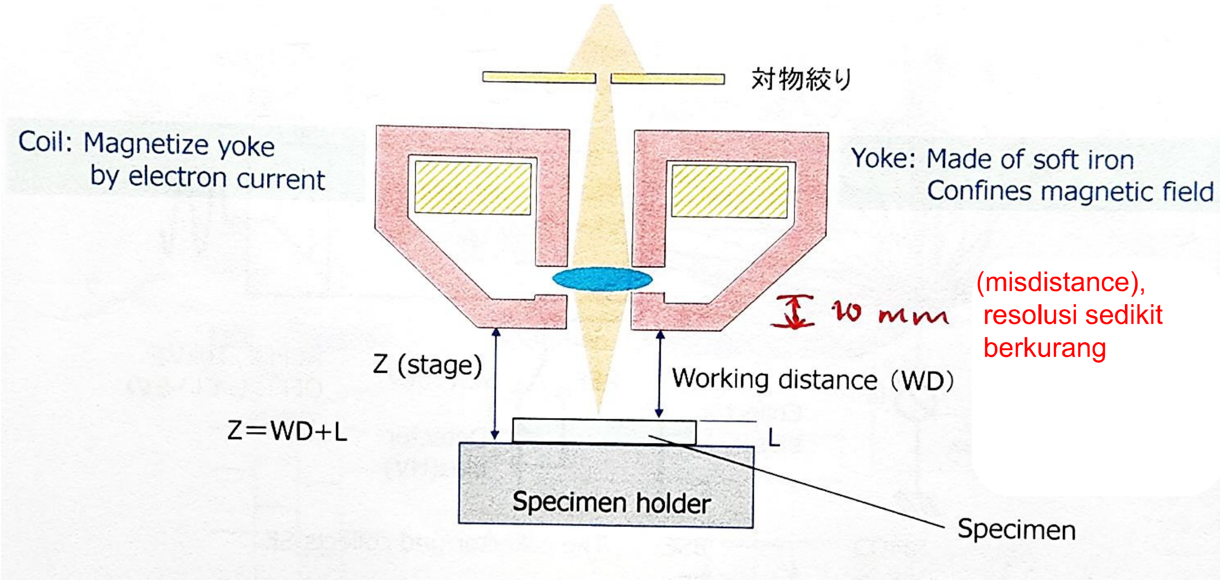
If the lens action of the condenser lens is strengthened, the electron probe becomes narrower with a smaller **ratio of b/a**, whereas if weakened, the electron probe becomes broader. The **"aperture"** is placed between the condenser lens and objective lens. The "aperture," made of a thin metal plate, has a small hole.




**Formasi dari sebuah *fine electron probe***

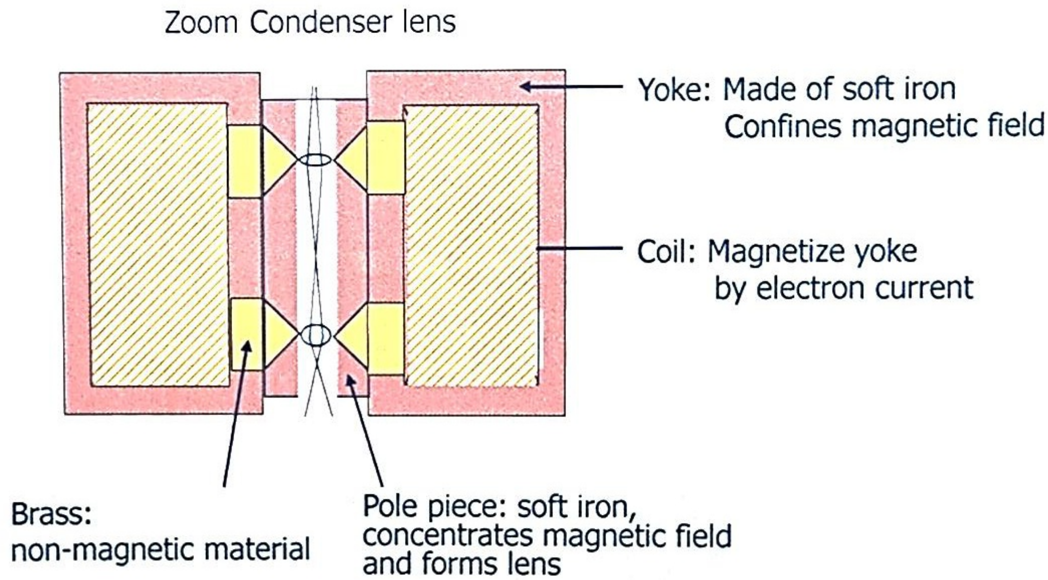


# Objective Lens




**The objective lens** is used for focusing, and this lens is a very important lens that determines the final diameter of the electron probe. The objective lens reduce the probe formed by condenser lens to approximately 1/10 in diameter

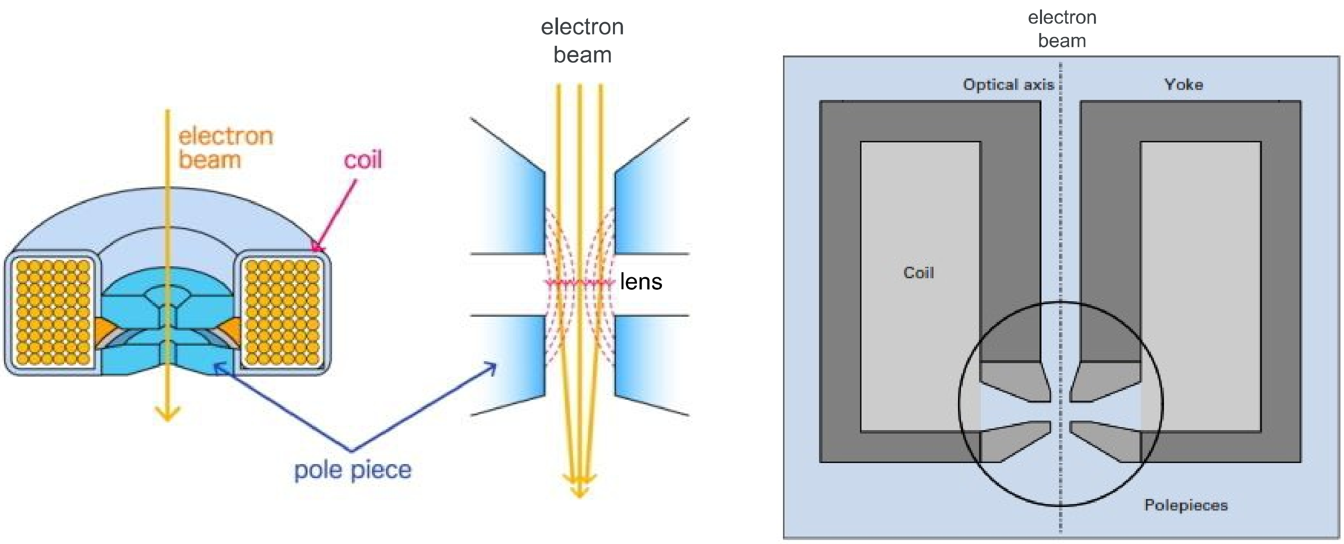
# Condenser Lens




The condenser lenses reduces the electron source (20μmϕ) to 1/200 in diameter.



# Magnetic Lens




- Ketika arus listrik searah melalui *coil-wound electric wire*, ***rotationally-symmetric magnetic field*** terbentuk dan sebuah *lens action* dihasilkan pada *electron beam*
- Sifat utama dari lensa magnetik adalah bahwa ketika arus yang melewati koil dirubah, maka kekuatan lensa juga berubah.

# Electron Optics

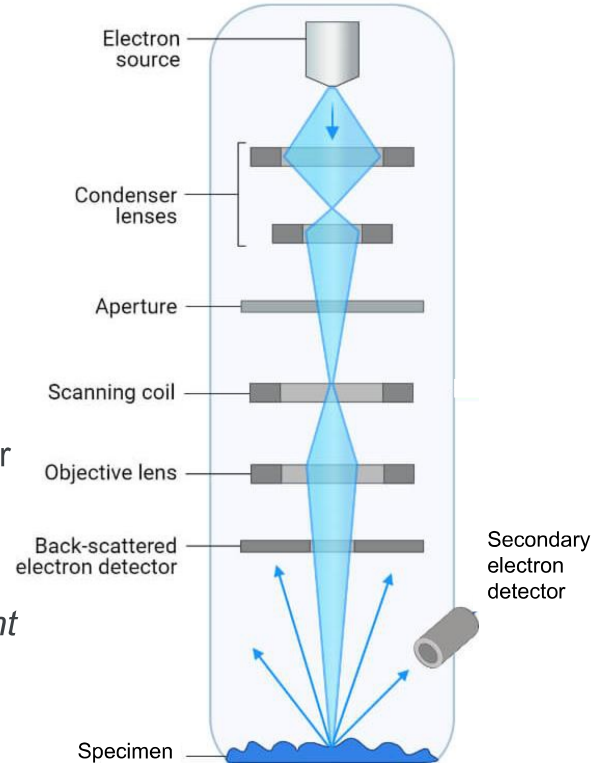
***Condenser* lens;** *control of sharpness of image and probe current*

***Objective aperture*;** *control of probe current and sharpness of image*

***Objective* lens;** *Focuses electron probe and specimen*

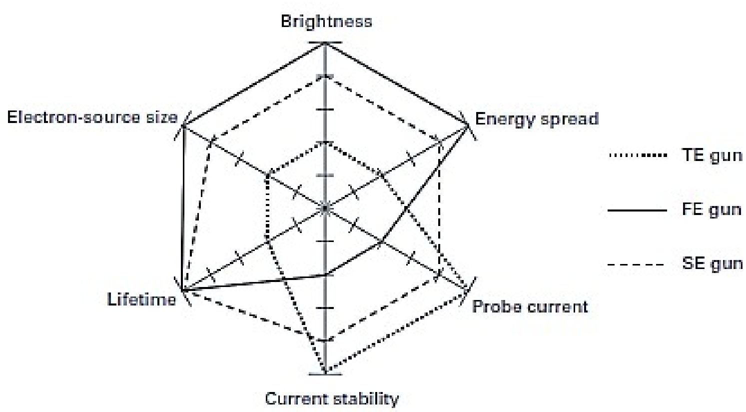
Empat bagian penting dari SEM;

1. ***Accelerating voltage*** (1 – 30kV); mengatur kecepatan electron beam
2. ***Probe current (PC)****; the number of the electrons*
3. **Aperture size (AP);** *control of probe current and sharpness of image*
4. **Working distance (WD);** jarak antara specimen dan *obejective lens*






# Feature of Three Electron Guns




| | TE gun | | FE gun | SE gun |
|---|---|---|---|---|
| | Tungsten | $LaB_6$ | | |
| Electron-source size | 15 ~ 20 μm | 10 μm | 5 ~ 10nm | 15 ~ 20nm |
| Brightness ($Acm^{-2} rad^{-2}$) | $10^5$ | $10^6$ | $10^8$ | $10^8$ |
| Energy spread (eV) | 3 ~ 4 | 2 ~ 3 | 0.3 | 0.7 ~ 1 |
| Lifetime | 50 h | 500 h | Several years | 1 to 2 years |
| Cathode temperature (K) | 2800 | 1900 | 300 | 1800 |
| Current fluctuation (per hour) | <1% | <2% | >10% | <1% |

Note that the brightness is obtained at 20 kV.

# Tipe-tipe Electron Guns

- **Field emission** sources (also called field emission guns or FEGs) use a strong electrostatic field to induce electron emission. This field is applied to the sharp tip of a tungsten wire, where quantum mechanical tunneling allows high-energy electrons to be released. The emission area is substantially smaller for an FEG (nanometers) than a thermionic source (micrometers), resulting in superior brightness and, in turn, enhanced image quality (i.e. higher spatial resolution and increased signal to noise). FEG sources also have the highest longevity, often lasting over a year without replacement. The primary downside of FEG sources is cost; the use of an electrostatic fields means that ultra-high vacuum is required, making it more expensive than most thermionic

- **Schottky FEG vs. cold FEG (CFEG):** FEG sources can broadly be divided into Schottky or cold FEGs. As the names might imply, Schottky FEGs are thermally assisted, combining the benefits of thermionic and field emission sources. This is done by **coating the tungsten tip in zirconium oxide**, which facilitates the thermal emission of electrons when the source is heated. Note that although Schottky sources have a shorter lifetime than CFEGs and worse image quality under certain conditions (i.e. lower voltages, where the Schottky emitter has a larger energy spread), they generally have better stability



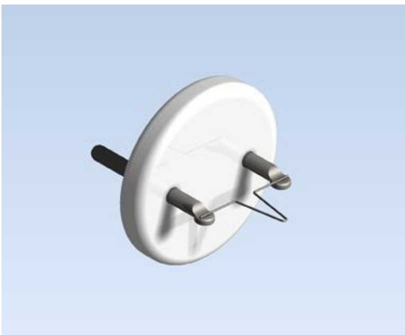
# Tipe-tipe Electron Guns

- **Tungsten filament:** Tungsten filaments are comparatively cheap and easy to maintain; users can be taught to replace them, removing the need for ongoing external maintenance. Just like lightbulb filaments, however, they gradually lose mass to evaporation and eventually break, giving them the shortest lifetime of all the sources. Additionally, due to their high operating temperature, they have a lower brightness and a broader beam spread, resulting in generally reduced image quality (i.e. reduced image resolution)

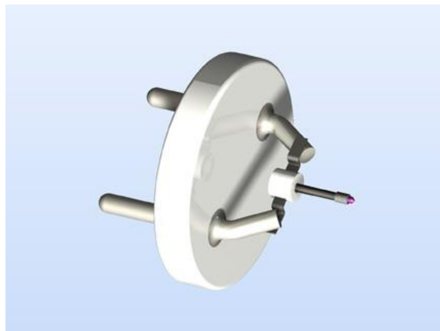
- **$LaB_6$ and $CeB_6$;** Lanthanum hexaboride and cerium hexaboride sources are composed of a single crystal of the respective molecule. Just like a tungsten filament, these crystals are heated by an applied current until there is enough energy to emit electrons. Compared to tungsten, lower temperatures are required to emit electrons, resulting in lower beam spread and higher brightness. They are also less volatile than tungsten and therefore have a significantly longer lifetime. However, they also need higher vacuum, thereby increasing the overall cost of the source.

# Tipe-tipe Electron Gun

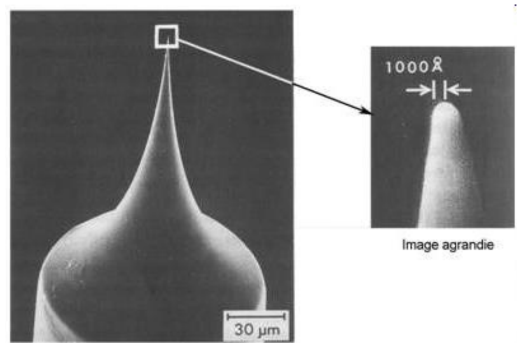
- With **field emission** guns we get a smaller spot and higher current densities compared to thermionic guns
- Vacuum requirements are tougher for a **field emission** guns



Tungsten wire



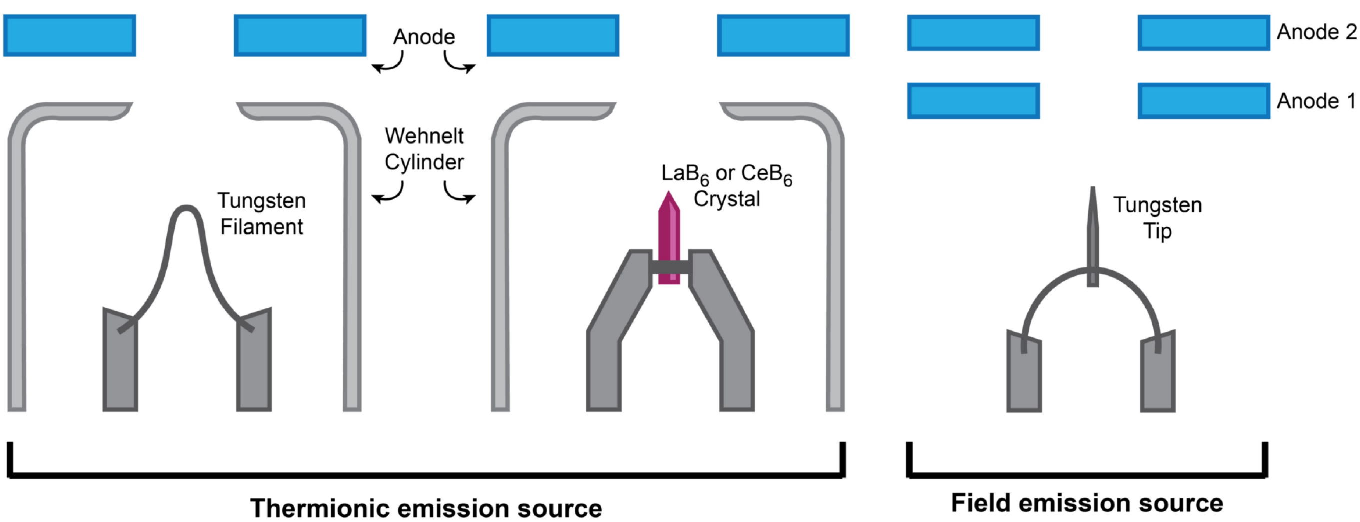
Single crystal of $LaB_6$




Field emission tip



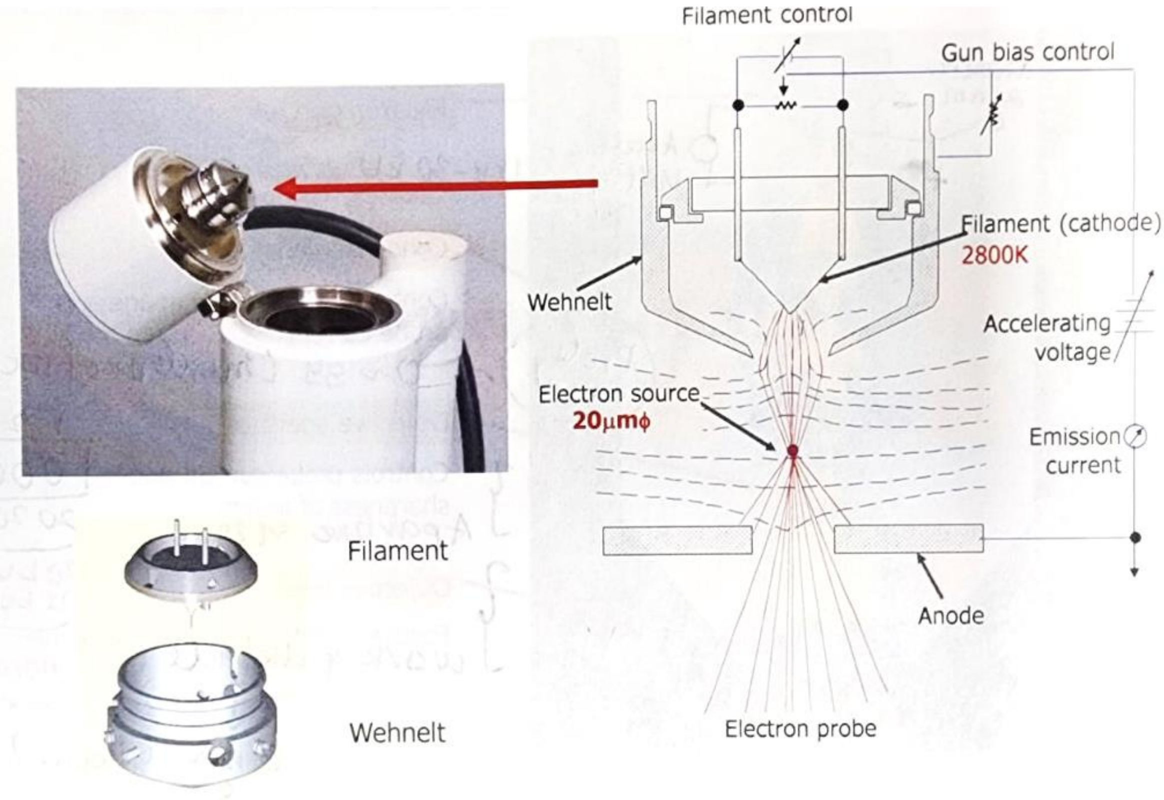
# Tipe-tipe Electron Gun




There are several commonly used sources, broadly divided into:

1. **Thermionic** (Tungsten filament, $LaB_6$, $CeB_6$)
2. **Field emission** (Tungsten tip, Schottky)

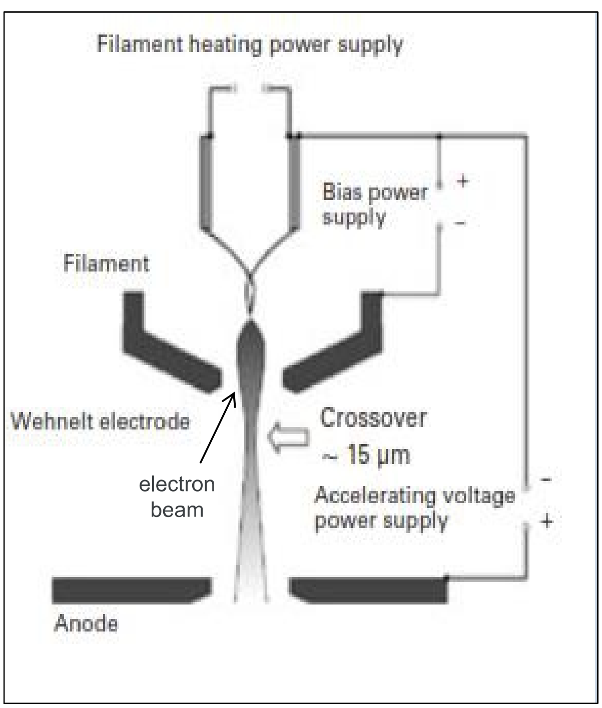
# Electron Guns





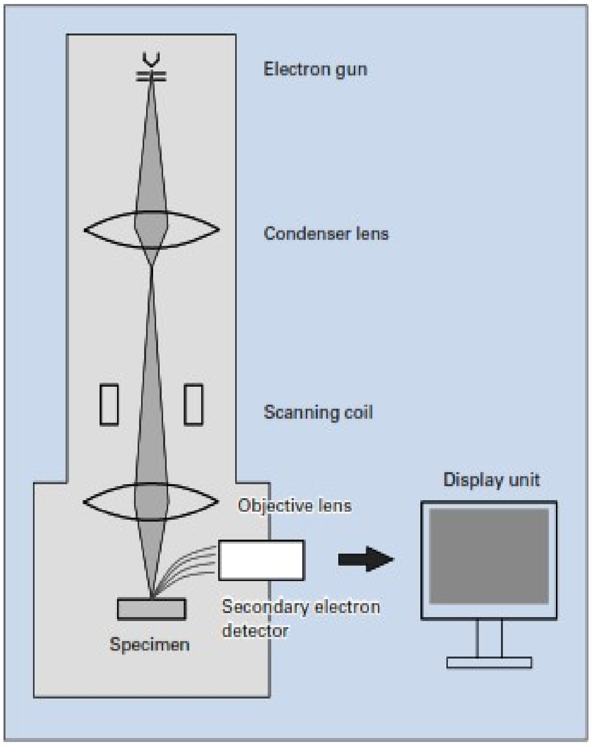

# Electron Gun

### Thermionic Emission gun (TE gun)




- Termoelektron dipancarkan dari **filamen (katoda)** yang terbuat dari kawat tungsten tipis (kira-kira 0,1 mm) dengan memanaskan filamen pada suhu tinggi (**sekitar 2800K**).
- Termoelektron ini dikumpulkan sebagai *electron beam* (bermuatan negatif), tertarik oleh plat logam anoda dg diberi tegangan positif (**1 - 30 kV**).
- Pengaturan kecepatan *electron beam* ini dilakukan dengan mengatur *accelerating voltage* dari anoda dan katoda.
- **Wehnet electrode** (tegangan negatif); dapat mengatur arus dari *electron beam*
- *Finest point* dari *beam* disebut ***crossover***, yang dapat dianggap sebagai *actual electron source* (diameter **15 – 20 μm**)

# Construction of SEM Instrument



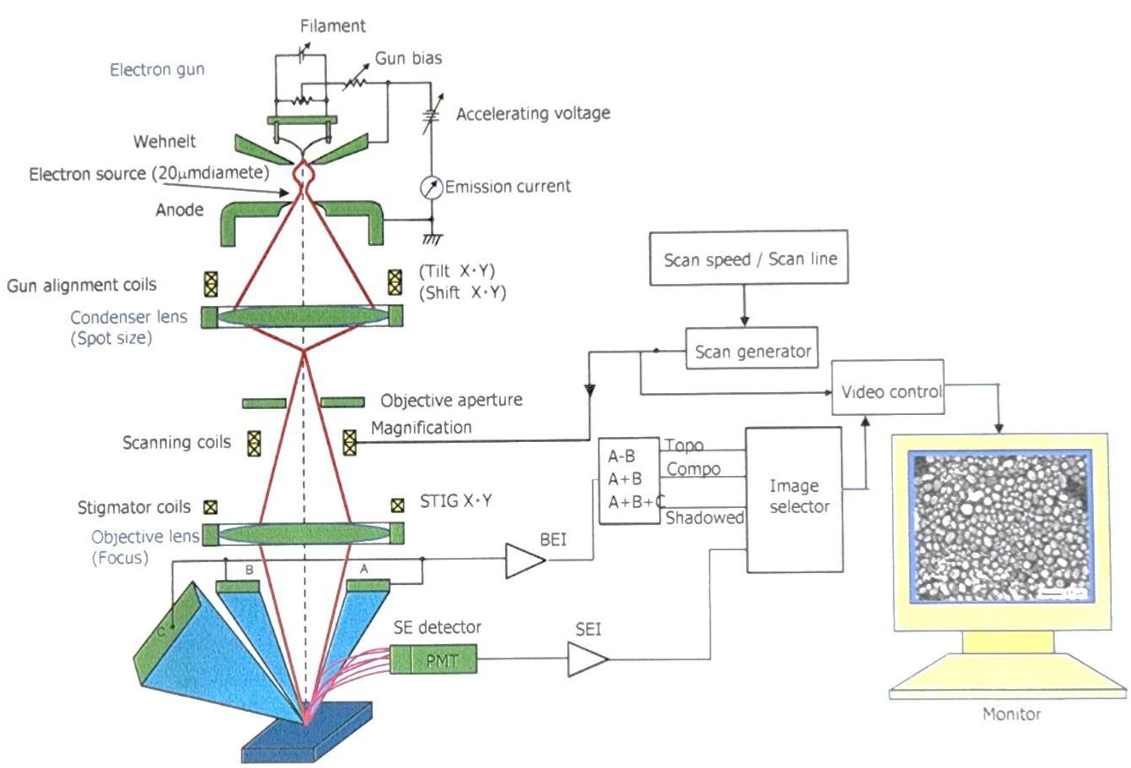

Sistem *electron optic* dari SEM;

- **Electron gun**; menembakkan electron ke arah *specimen*. Berisi filament berfungsi sebagai katoda
- **Specimen stage**; untuk menempatkan *specimen*
- **Detector *secondary electron***; untuk mengumpulkan *secondary electron*
- ***Condenser and objective lens***; untuk menghasilkan sebuah *electron probe*
- ***Scanning coil***; untuk *scan the electron probe*
- Unit *image display*

Semua *system electron optic* dan ruang *specimen* dijaga dalam kondisi vakum



# The Scanning Electron Miccroscope (SEM)



# Field Emission SEM (FE SEM)

## JSM-IT700HR: Compact Field Emission SEM

### JSM-IT700HR InTouchScope™

Introducing a new addition to our JEOL InTouchScope™ series SEMs, the JSM-IT700HR, a new compact FE SEM In-Lens Schottky gun.
Increase your productivity with our fully-integrated software, from specimen navigation to analysis and report creation.
This state-of-the-art SEM, with its high-brightness electron gun system with high probe current (~ 300nA), provides amazing high-resolution imaging along with high sensitivity and high spatial resolution analysis at even faster speeds.

- ✓ Zeromag and high-resolution imaging
- ✓ Instant Element analysis
- ✓ High speed mapping and long acquisition analyses
- ✓ Montage
- ✓ Integrated data management software: SMILE VIEW™ Lab

### Specifications

Electron gun: In-Lens Schottky field emission electron gun

Accelerating voltage: 0.5 to 30 kV

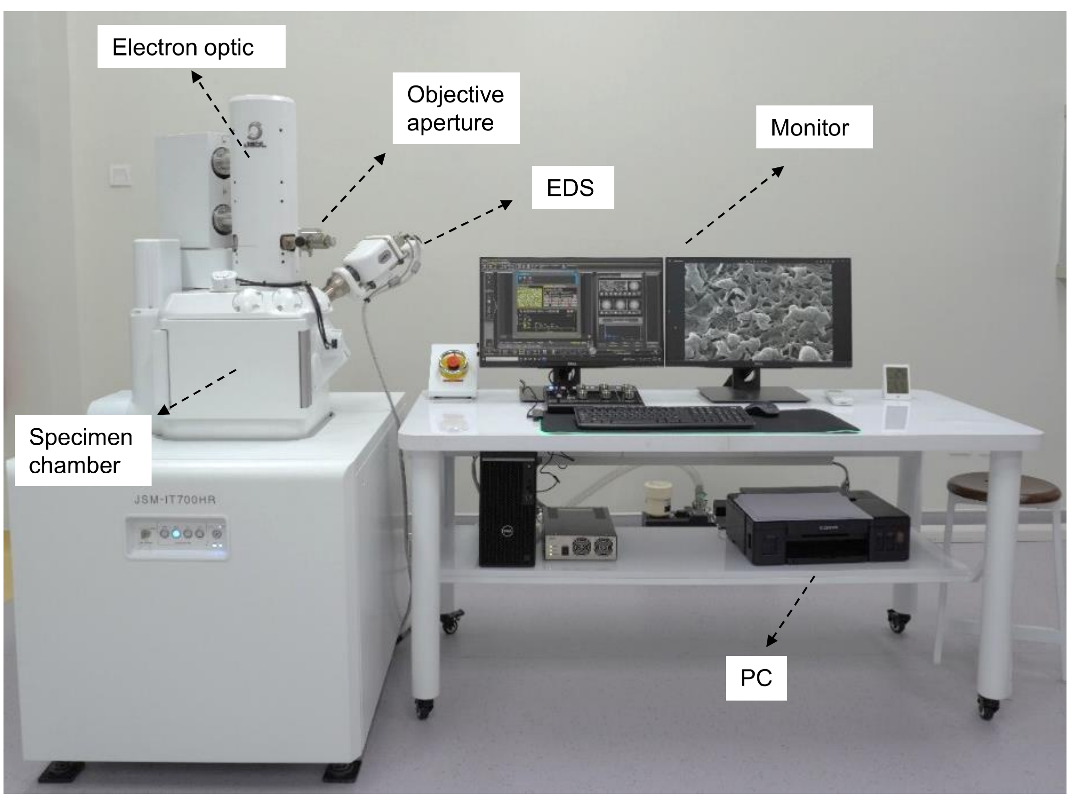
Max probe current: ~ 300 nA

Magnification
- ・Direct magnification: × 5 to 600,000X
- ・Display magnification: × 14 to ~1,680,000X

Resolution 1 nm@ 20.0 kV



# The Scanning Electron Microscope (SEM)



# The Scanning Electron Microscope (SEM)

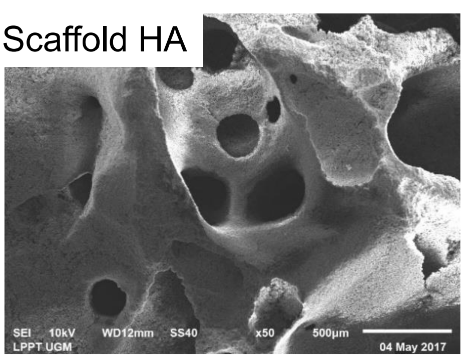
- SEM ada sebuah alat untuk mengamati topografi permukaan dari sebuah *specimen/sample.*

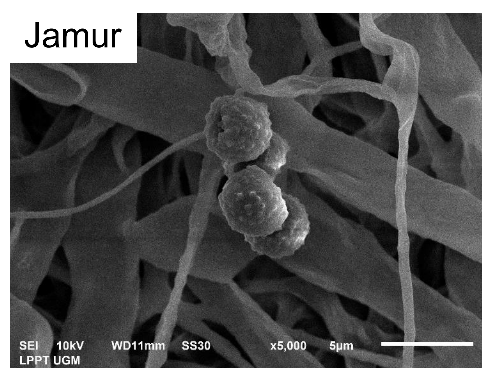
- Ketika *specimen* diirradiasi dengan sebuah *fine electron beam* (*electron probe*), maka *secondary electrons* akan dipancarkan dari specimen.

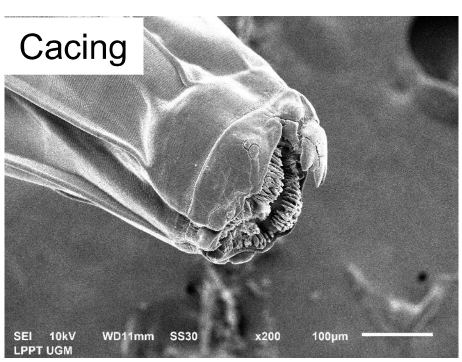
- Topografi permukaan dapat diamati dengan pemindaian dua dimensi dari probe elektron di atas permukaan dan perolehan gambar dari hasil mendeteksi *secondary electrons*.

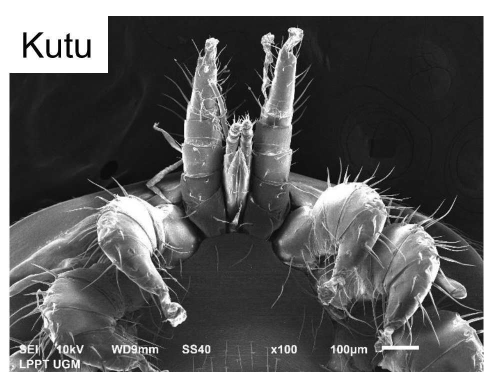


# Beberapa SEM Images



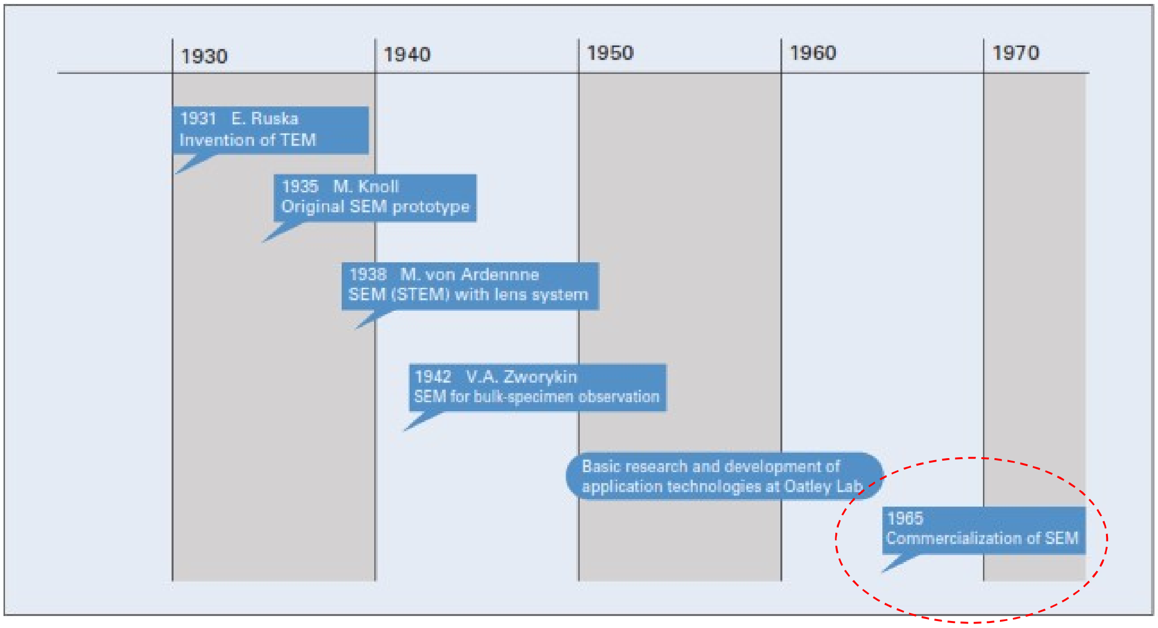
# The Scanning Electron Microscope (SEM)


**JSM-6510LA** **JSM-IT700HR**



# Structure of SEM

# History




**In 1965**, Cambridge Scientific Instrument (UK) and JEOL (Japan) first commercialized a SEM, individually. During the four decades after the first commercialization of the SEM, about several tens of thousands of SEMs have been manufactured. Now, the SEM has made significant advances in its performance and functions, and it continues to develop into a more sophisticated instrument.



# Outline

- Structure of SEM
- Principle of SEM
- Introduction of EDS
- For Better Images
- Technical Term

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# Principle of Field Emission Scanning Electron Microscopy (FE SEM)

By: Tim LPPT
Universitas Gadjah Mada

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**http://lppt.ugm.ac.id**