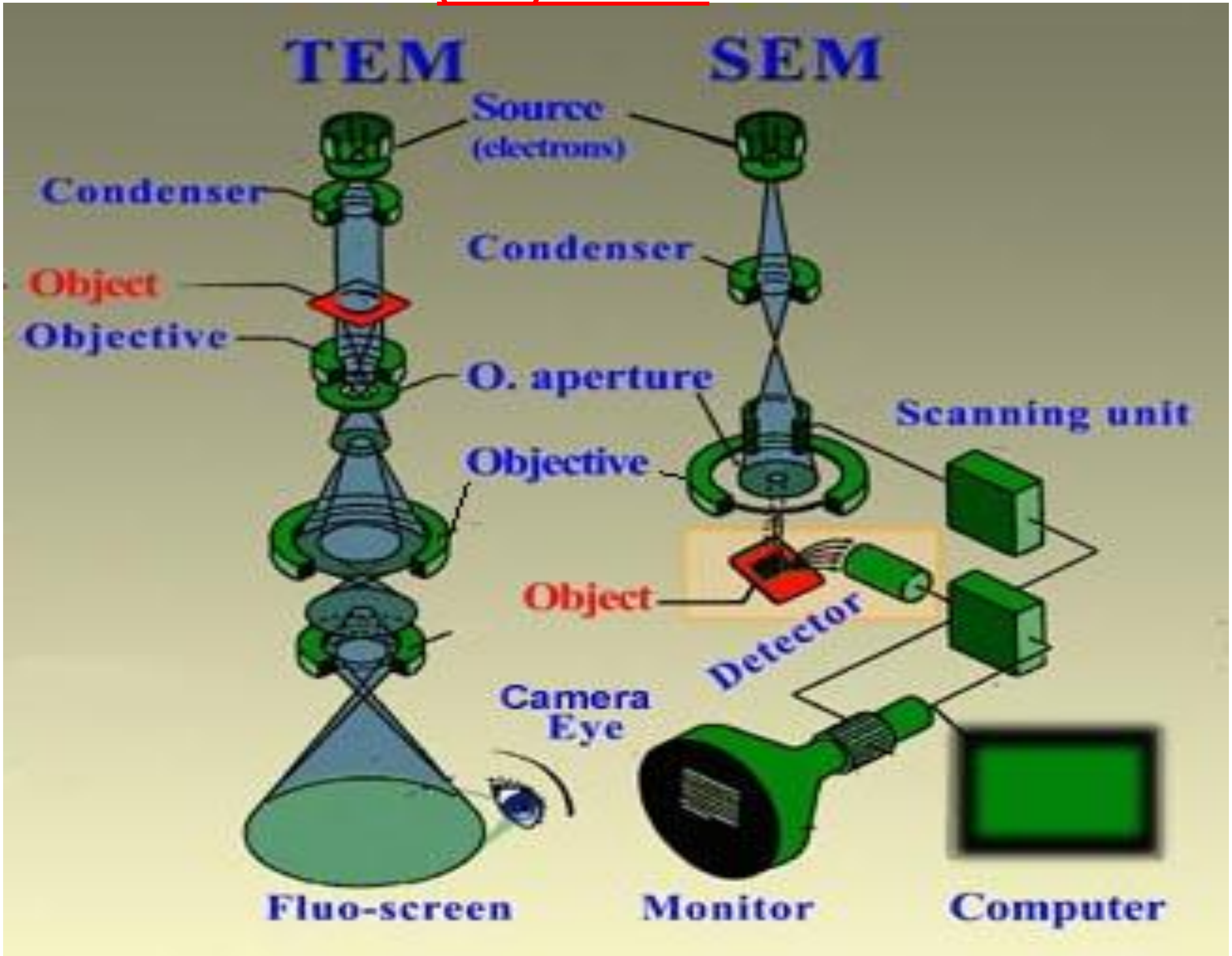
Scanning Electron Microscopy (SEM)

Dr. Asst. Prof. Aseel B.AL-Zubaydi

(SEM) and TEM


TEM
SEM
Source
(electrons)
Condenser
Condenser
Object
Objective
O. aperture
Scanning unit
Objective
Object
Detector
Camera
Eye
Fluo-screen
Monitor
Computer

JEOL 6700F Ultra High Resolution
Scanning Electron Microscope


XL 30 S

Scanning Electron Microscopy (SEM)

Scanning electron microscopy is used for: inspecting topographies of specimens at very high magnifications using a piece of equipment called the scanning electron microscope. SEM magnifications can go to more than 300,000 X but most semiconductor manufacturing applications require magnifications of less than 3,000 X only. SEM inspection is often used in the analysis of:
die/package cracks and fracture surfaces, bond failures, and physical defects on the die or package surface.
During SEM inspection, a beam of electrons is focused on a spot volume of the specimen, resulting in the transfer of energy to the spot. then translated into a signal.

To produce the SEM image, the electron beam is swept across the area being inspected, producing many such signals. These signals are then amplified, analyzed, and translated into images of the topography being inspected. Finally, the image is shown on a CRT.

Scanning Electron Microscopy (SEM)

The energy of the primary electrons determines the quantity of secondary electrons collected during inspection. The emission of secondary electrons from the specimen increases as the energy of the primary electron beam increases, until a certain limit is reached. Beyond this limit, the collected secondary electrons diminish as the energy of the primary beam is increased, because the primary beam is already activating electrons deep below the surface of the specimen. Electrons coming from such depths usually recombine before reaching the surface for emission.

Aside from secondary electrons, the primary electron beam results in the emission of backscattered (or reflected) electrons from the specimen. Backscattered electrons possess more energy than secondary electrons, and have a definite direction. As such, they can not be collected by a secondary electron detector, unless the detector is directly in their path of travel.

All emissions above 50 eV are considered to be backscattered electrons.

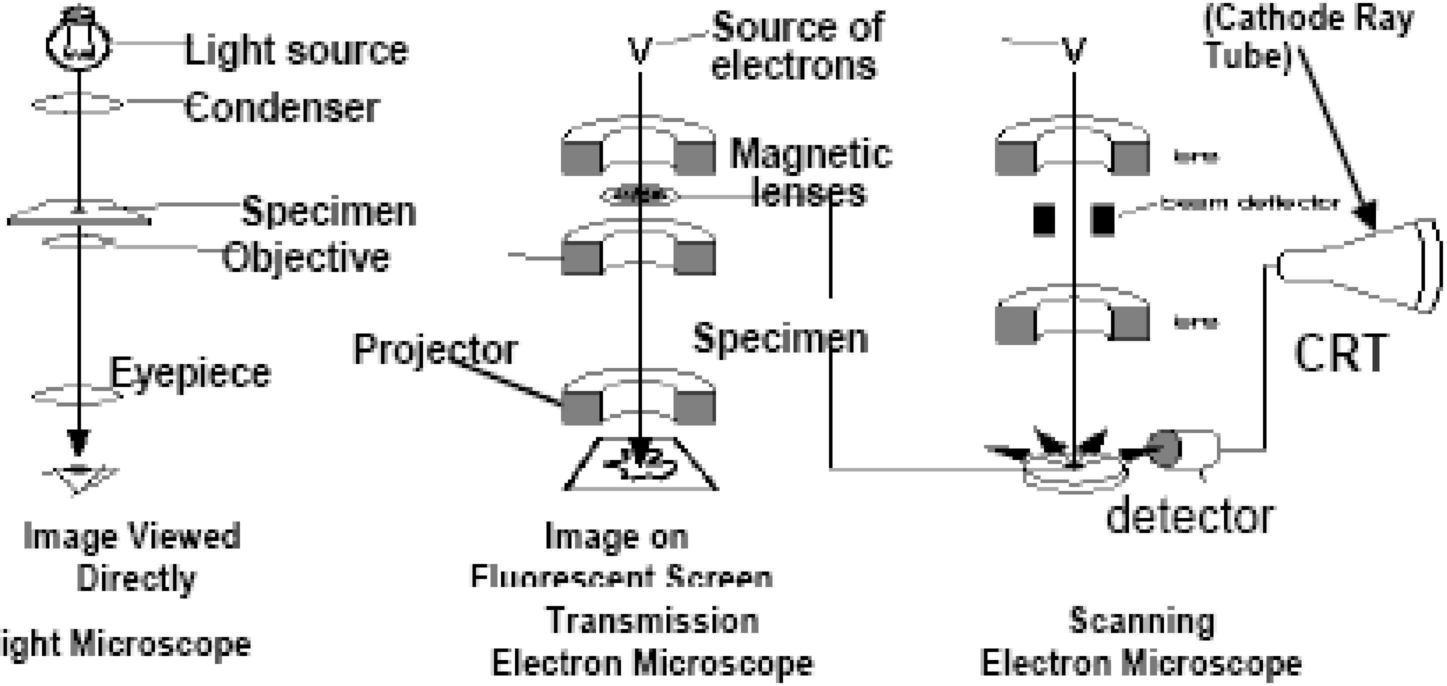
Scanning Electron Microscopy (SEM)

Backscattered electron imaging is useful in distinguishing one material from another, since the yield of the collected backscattered electrons increases with the specimen's atomic number. Backscatter imaging can distinguish elements with atomic number differences of at least 3, i.e., materials with atomic number differences of at least 3 would appear with good contrast on the image.

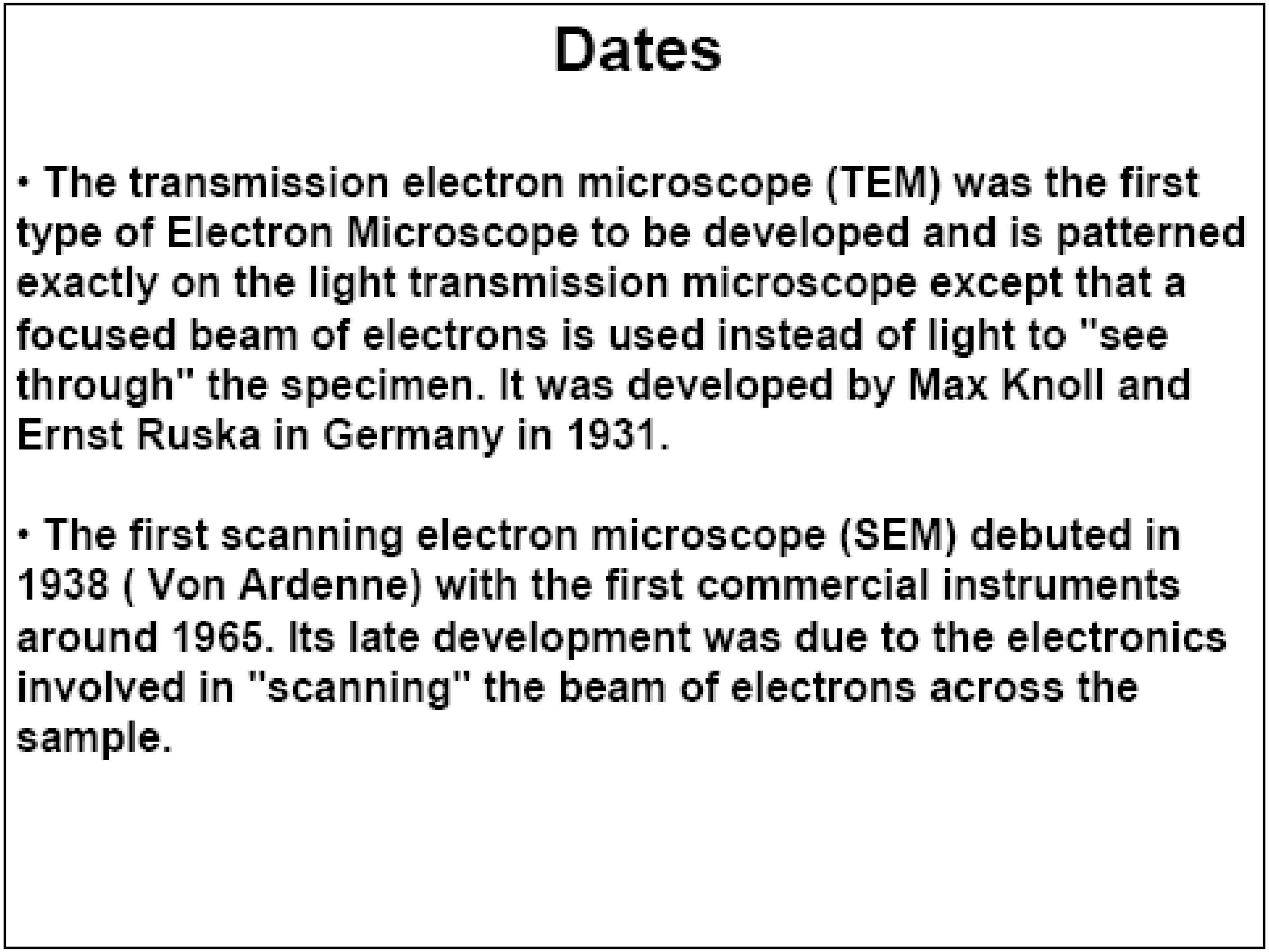
would stand out from the Al background.

A SEM may be equipped with an EDX analysis system to enable it to perform compositional analysis on specimens. EDX analysis is useful in identifying materials and contaminants, as well as estimating their relative concentrations on the surface of the specimen.

Comparison of OM,TEM and SEM



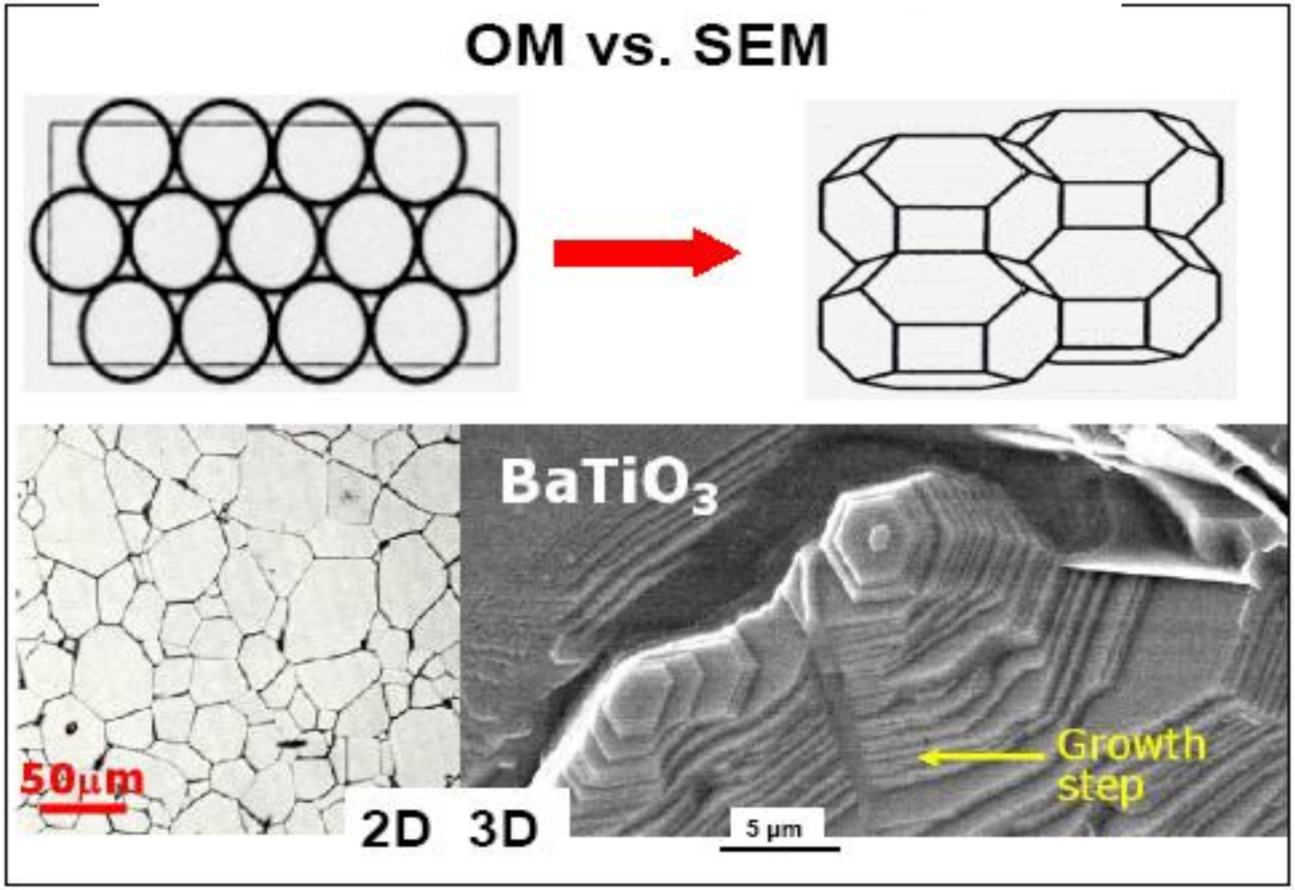
Principal features of an optical microscope, a transmission electron microscope and a scanning electron microscope, drawn to emphasize the similarities of overall design.

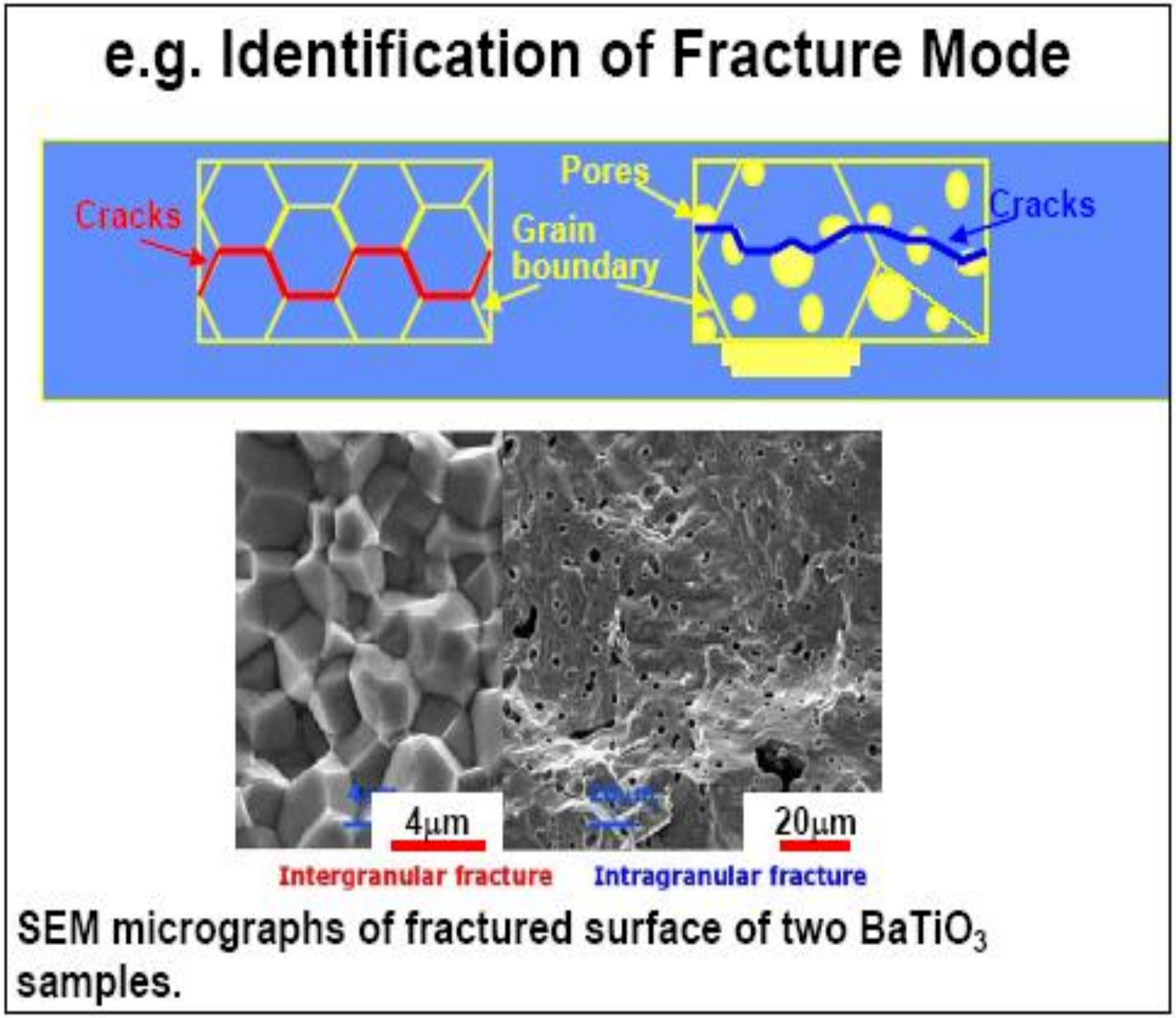


Dates

- The transmission electron microscope (TEM) was the first type of Electron Microscope to be developed and is patterned exactly on the light transmission microscope except that a focused beam of electrons is used instead of light to "see through" the specimen. It was developed by Max Knoll and Ernst Ruska in Germany in 1931.

- The first scanning electron microscope (SEM) debuted in 1938 (Von Ardenne) with the first commercial instruments around 1965. Its late development was due to the electronics involved in "scanning" the beam of electrons across the sample.


OM vs. SEM
BaTiO$_3$
Growth step
50µm
2D
3D
5 µm

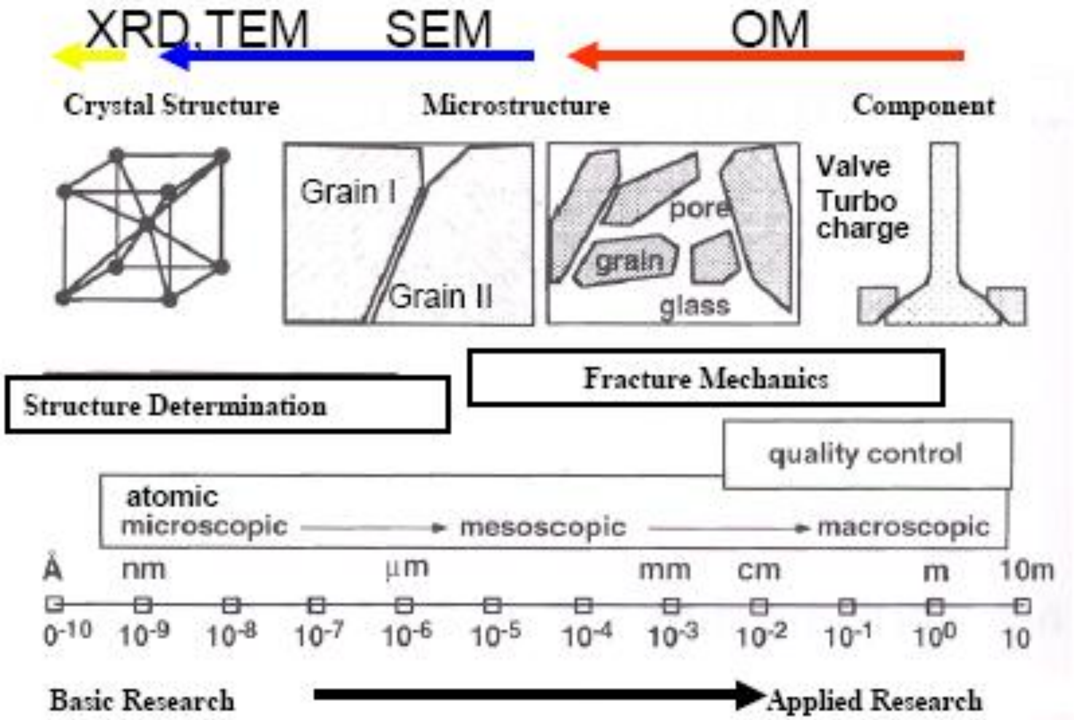


e.g. Identification of Fracture Mode

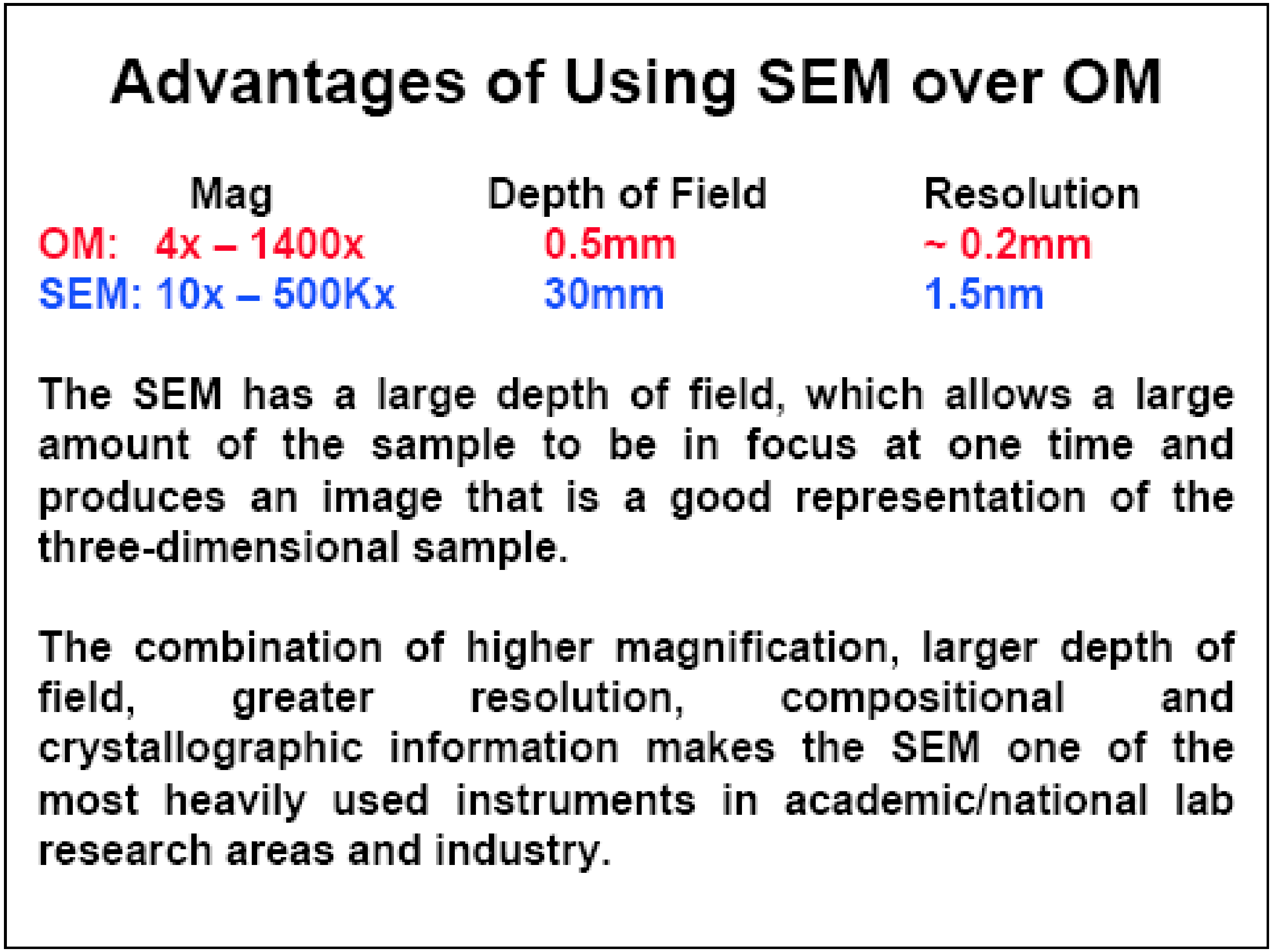
Intergranular fracture **Intragranular fracture**

SEM micrographs of fractured surface of two $BaTiO_3$ samples.

Scale and Microscopy Techniques



Microstructure ranging from crystal structure to engine components (Si_3N_4)



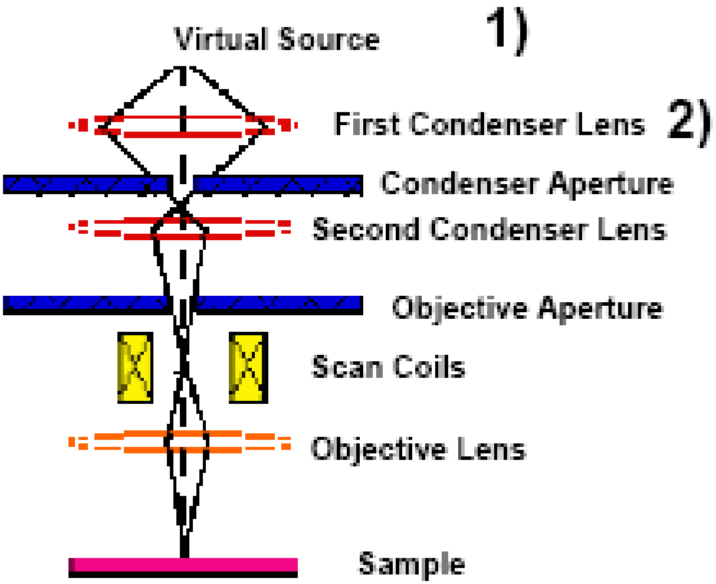
Advantages of Using SEM over OM

	Mag	Depth of Field	Resolution
OM:	4x – 1400x	0.5mm	~ 0.2mm
SEM:	10x – 500Kx	30mm	1.5nm

The SEM has a large depth of field, which allows a large amount of the sample to be in focus at one time and produces an image that is a good representation of the three-dimensional sample.

The combination of higher magnification, larger depth of field, greater resolution, compositional and crystallographic information makes the SEM one of the most heavily used instruments in academic/national lab research areas and industry.

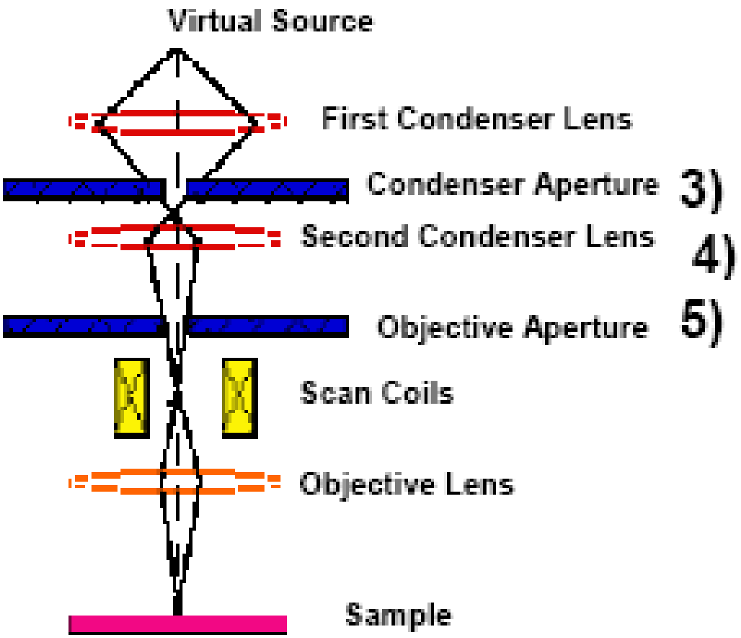
Scanning Electron Microscope



1) The "Virtual Source" at the top represents the electron gun, producing a stream of monochromatic electrons.

2) The stream is condensed by the first condenser lens (usually controlled by the "<u>coarse</u> probe current knob"). This lens is used to both form the beam and limit the amount of current in the beam. It works in conjunction with the condenser aperture to eliminate the high-angle electrons from the beam.

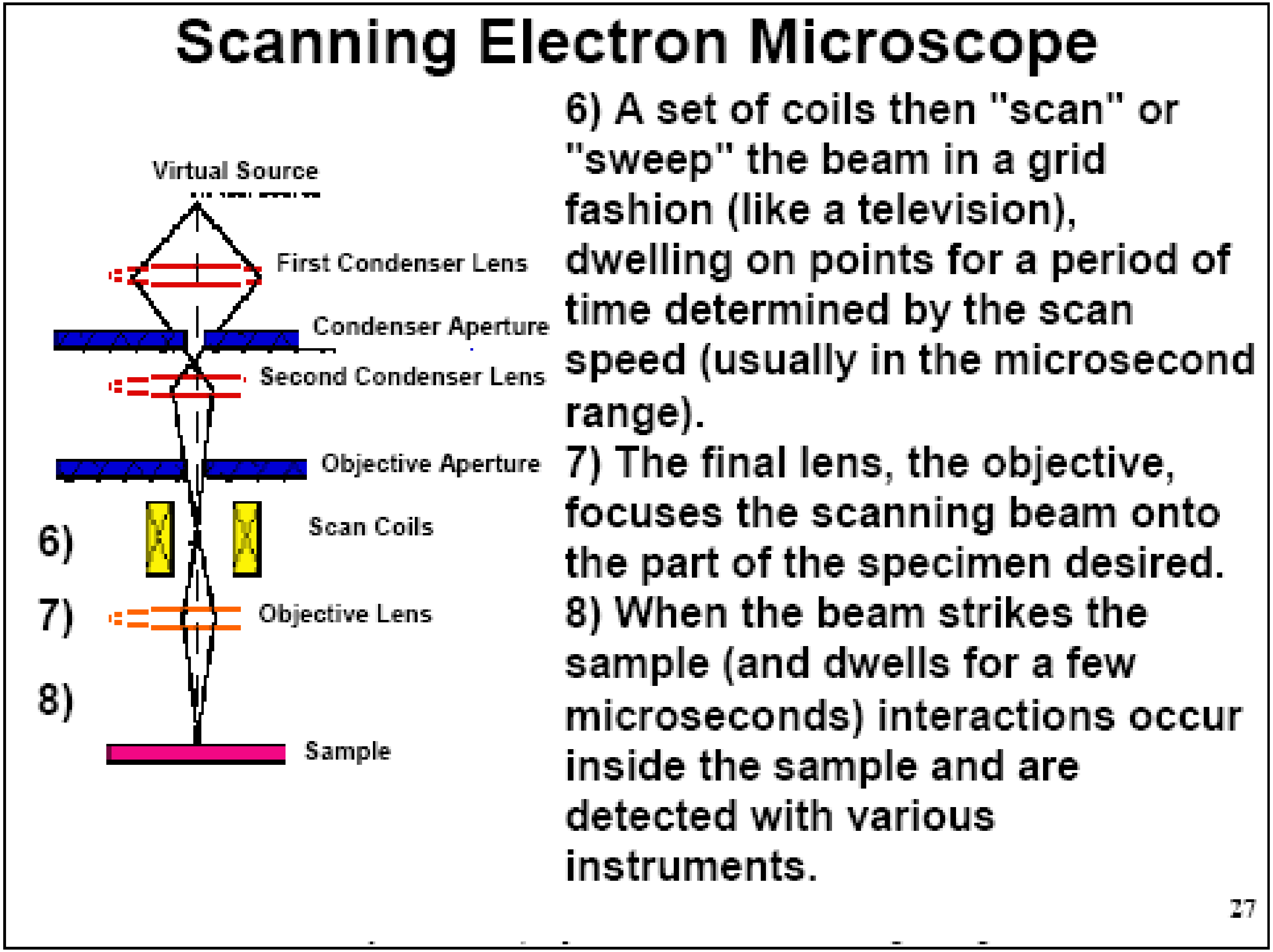
Scanning Electron Microscope



3) The beam is then constricted by the condenser aperture (usually not user selectable), eliminating some high-angle electrons.

4) The second condenser lens forms the electrons into a thin, tight, coherent beam and is usually controlled by the "fine probe current knob".

5) A user selectable objective aperture further eliminates high-angle electrons from the beam.

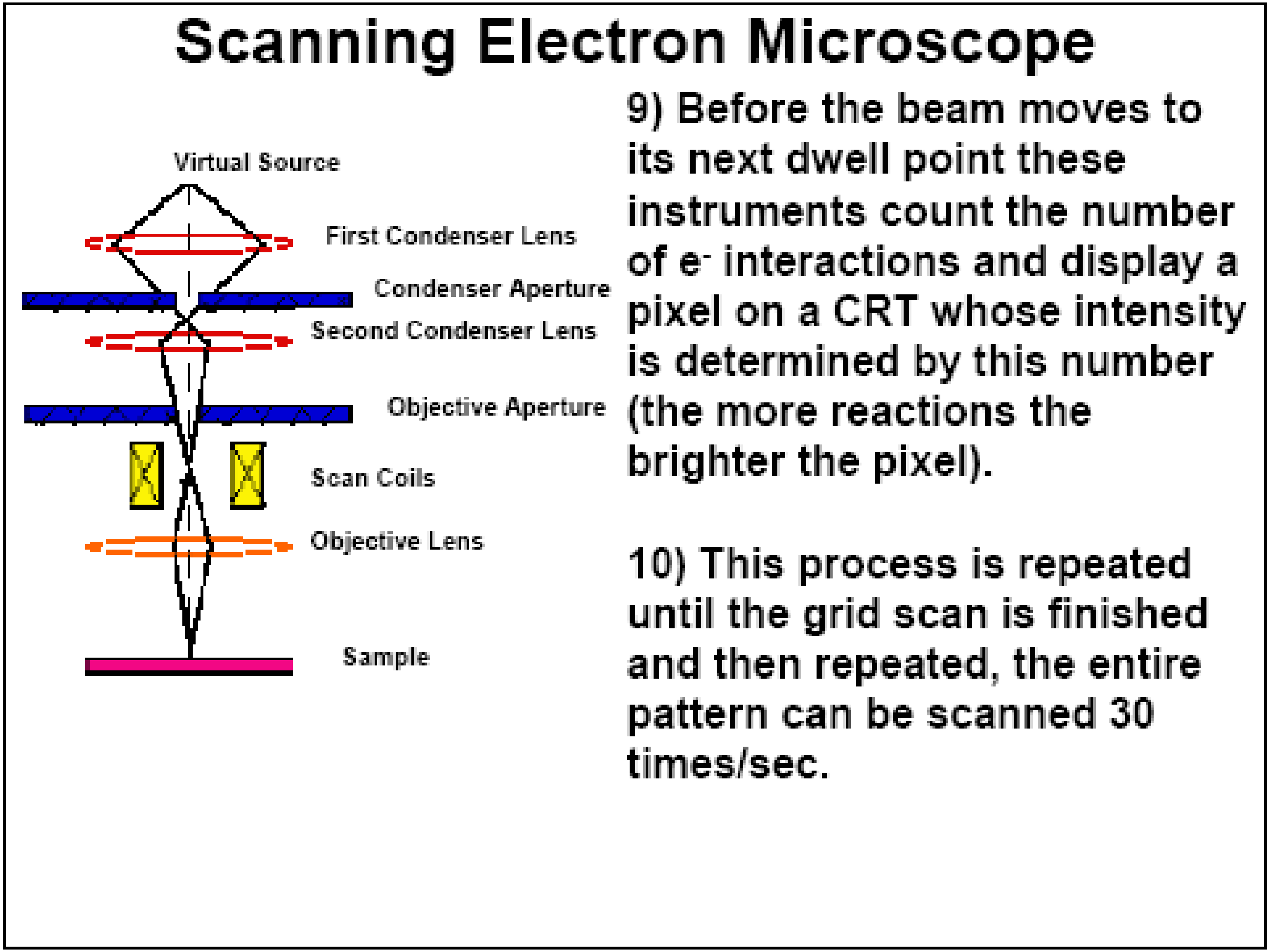


Scanning Electron Microscope

6) A set of coils then "scan" or "sweep" the beam in a grid fashion (like a television), dwelling on points for a period of time determined by the scan speed (usually in the microsecond range).

7) The final lens, the objective, focuses the scanning beam onto the part of the specimen desired.

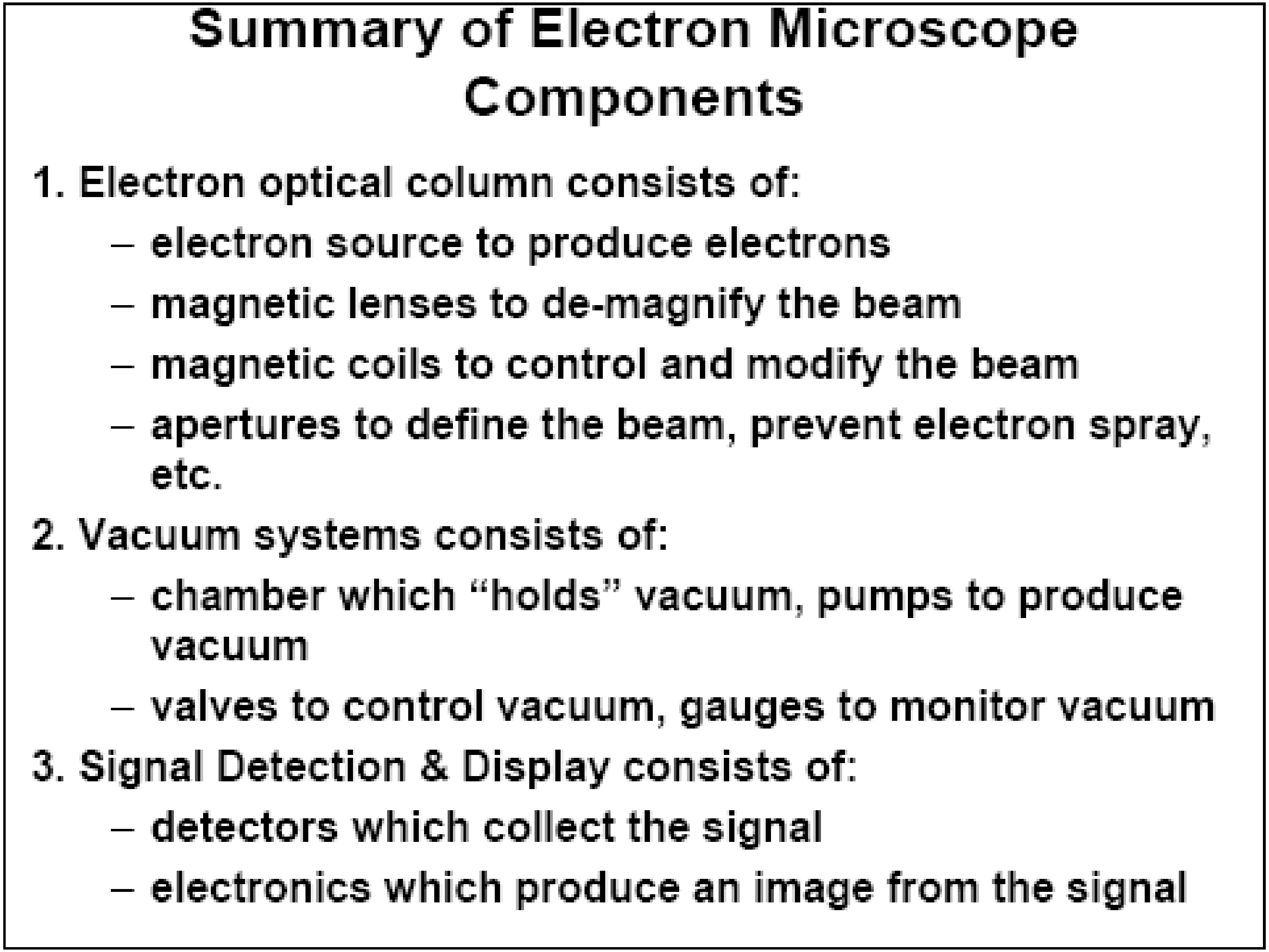
8) When the beam strikes the sample (and dwells for a few microseconds) interactions occur inside the sample and are detected with various instruments.



Scanning Electron Microscope

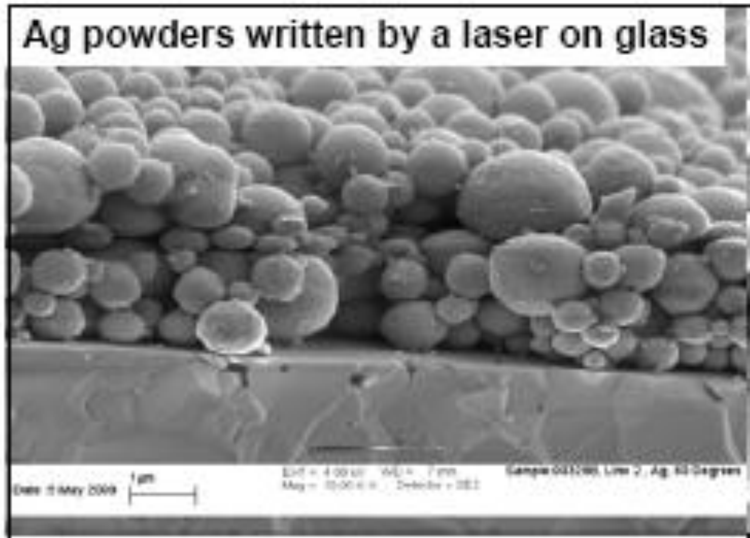
9) Before the beam moves to its next dwell point these instruments count the number of e^- interactions and display a pixel on a CRT whose intensity is determined by this number (the more reactions the brighter the pixel).

10) This process is repeated until the grid scan is finished and then repeated, the entire pattern can be scanned 30 times/sec.

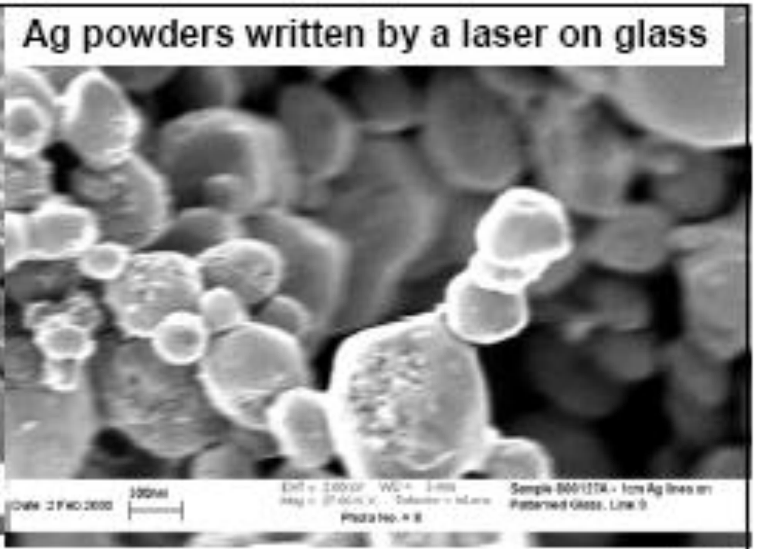


Summary of Electron Microscope Components

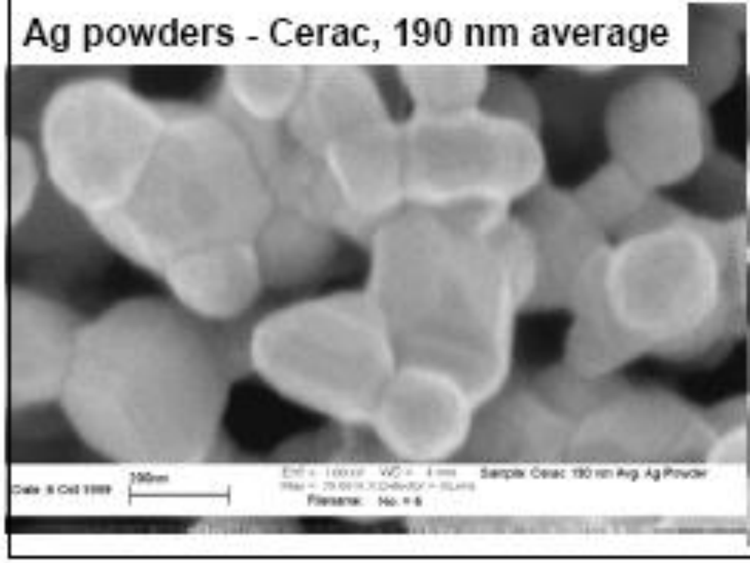
1. Electron optical column consists of:
   - electron source to produce electrons
   - magnetic lenses to de-magnify the beam
   - magnetic coils to control and modify the beam
   - apertures to define the beam, prevent electron spray, etc.
2. Vacuum systems consists of:
   - chamber which “holds” vacuum, pumps to produce vacuum
   - valves to control vacuum, gauges to monitor vacuum
3. Signal Detection & Display consists of:
   - detectors which collect the signal
   - electronics which produce an image from the signal



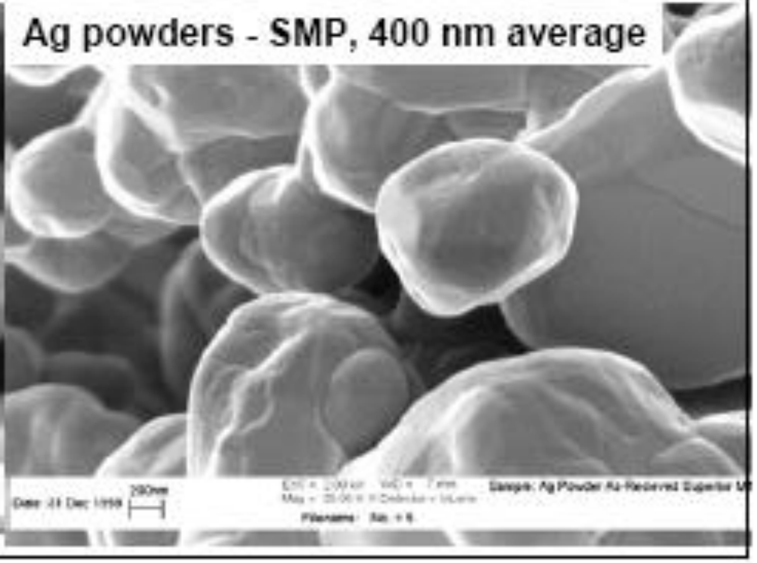
Ag powders written by a laser on glass



Ag powders written by a laser on glass

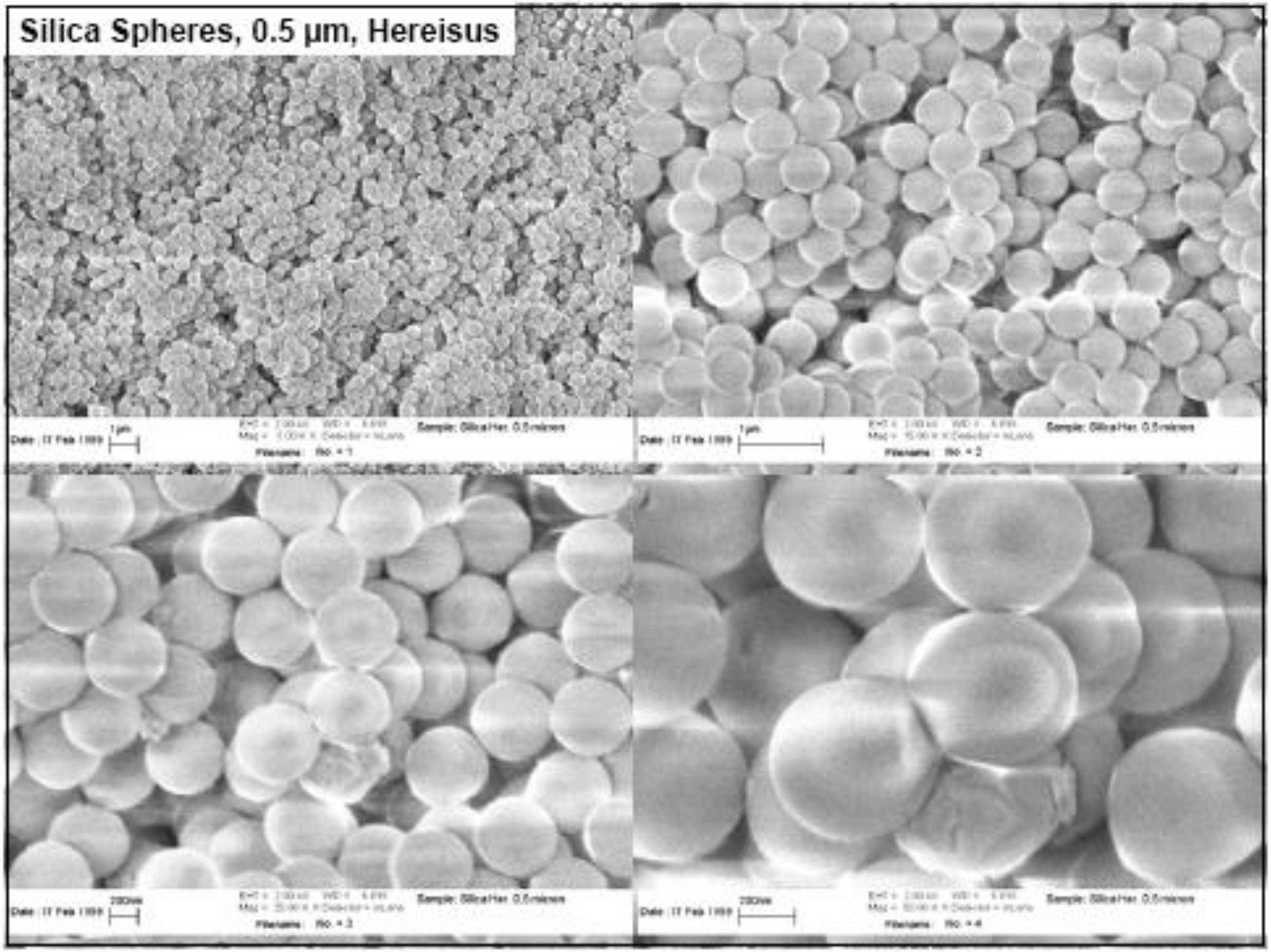


Ag powders - Cerac, 190 nm average

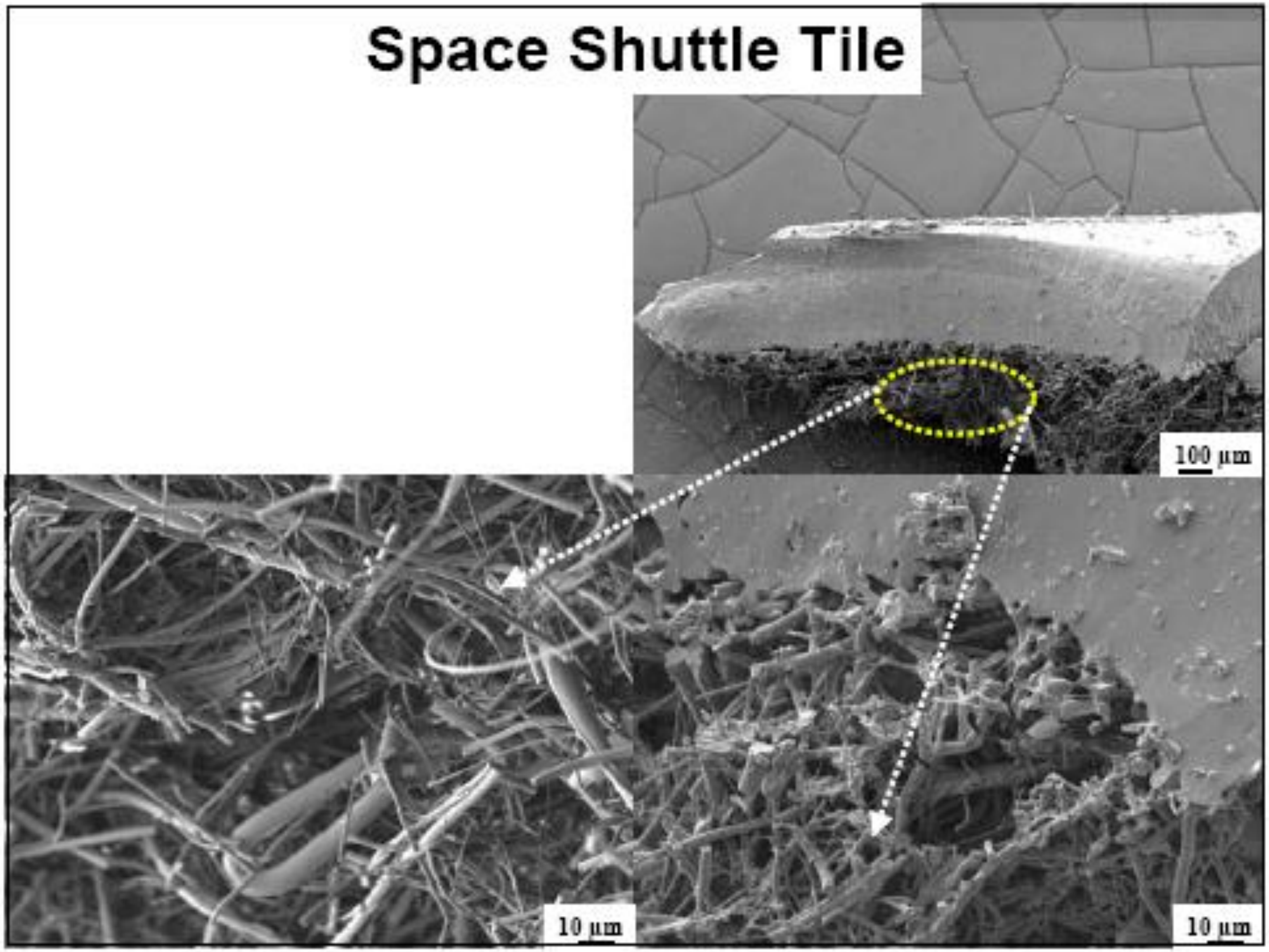


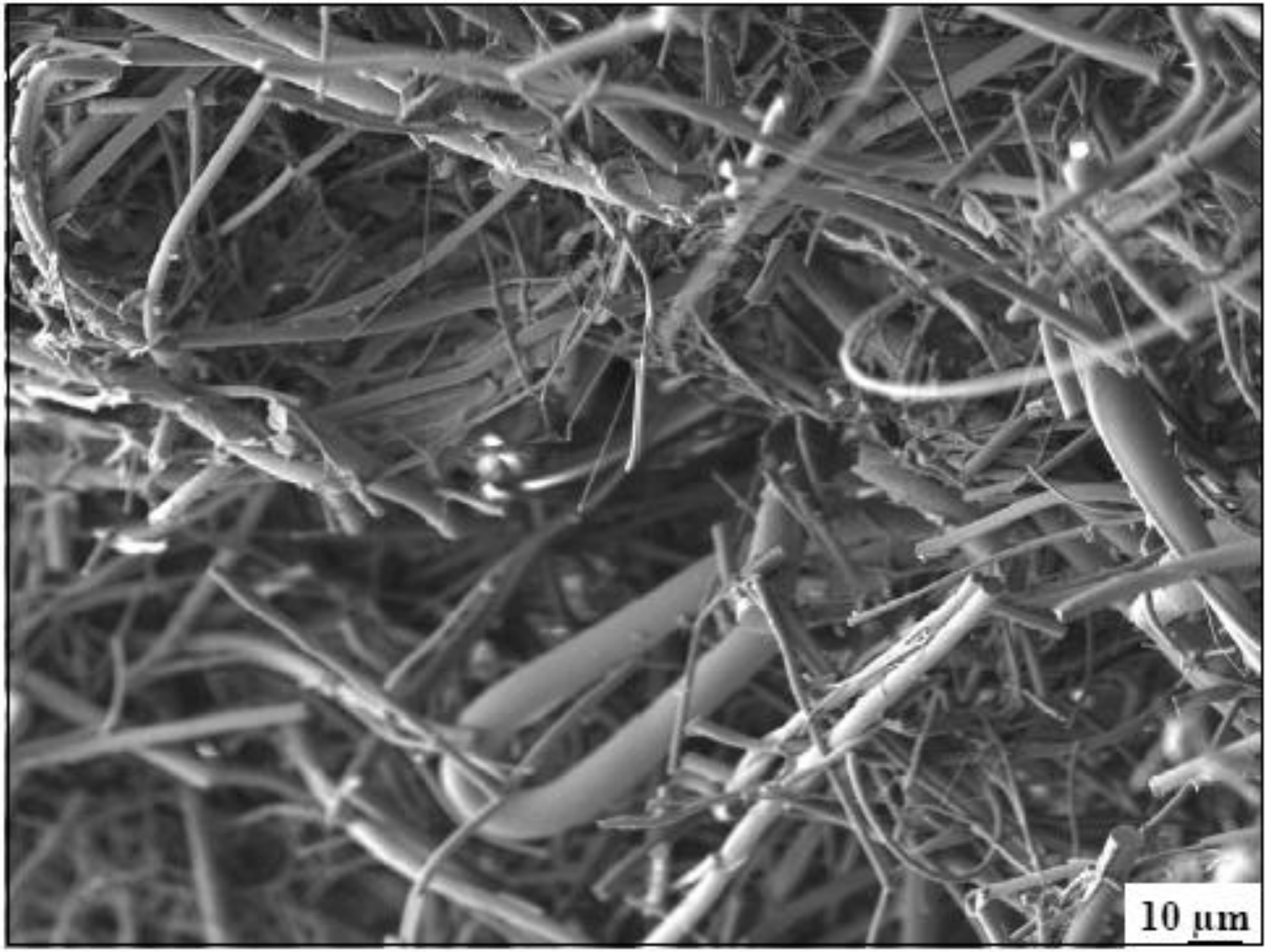
Ag powders - SMP, 400 nm average

Silica Spheres, 0.5 µm, Hereisus



Space Shuttle Tile




10 µm

Evex Mini-SEM

Evex Mini-SEM is a high resolution desktop digital imaging tool that is fast and easy to use. Go from sample insertion to 30,000 x (120,000 digital Zoom) magnification in less than seconds.

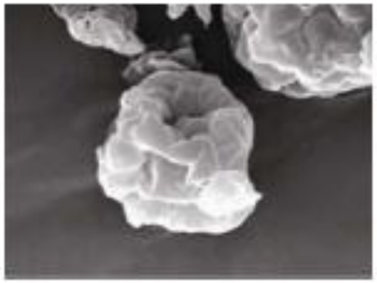
Evex Mini-SEM is so easy to operate even a caveman can use it! Use it in research to discover next generation materials. Use it in manufacturing to investigate failures. Use in it educators so you can inspire the next generation of scientists.

Super Fast

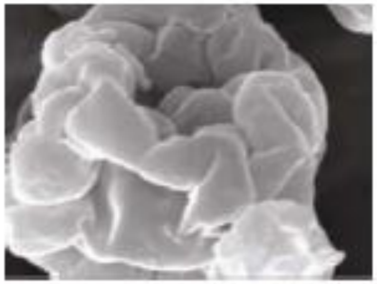
0 to 120,000 - Less Than 2 Minutes

2,000 X

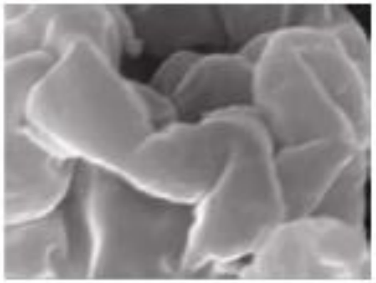
5,000 X



10,000 X



20,000 X



Optical Microscope vs Evex Mini-SEM

Magnification – Maximum 1,000 X	**Magnification – 10 X to 120,000 X**
Image quality – Limited depth of focus	Image Quality – Great depth range
Image gray scale – limited shades/poor contrast	Image Gray Scale – thousands of shades
Operation – Easy	Operation – Easy
Size – Small	Size – Slightly large than Optical Microscope
Power – 110 Volts	Power – 110 Volts
Results – Fast	Results – Fast
No X-ray - No Elemental Composition	Elemental Composition

SEM vs Evex Mini-SEM

Capital Cost = High Greater than $250,000	**Capital Cost - Moderate Less than $200,000**
High Maintenance Costs	Low or No Maintenance Cost
High Operating Cost	Low Operating Cost
Training – Extensive Knowledge Required	Training - Limited Knowledge required
Size – Equal to the size of a SMART CAR	Size – Equal to that of a Color Laser Printer
Sample Preparation time = Long time	Sample Preparation time = Minutes
Sample Analysis time = hours	**Sample Analysis time = minutes**
Magnification – Ultra High > 100,000 X	**Magnification = High 30 X to 100,000 X**