S-5200

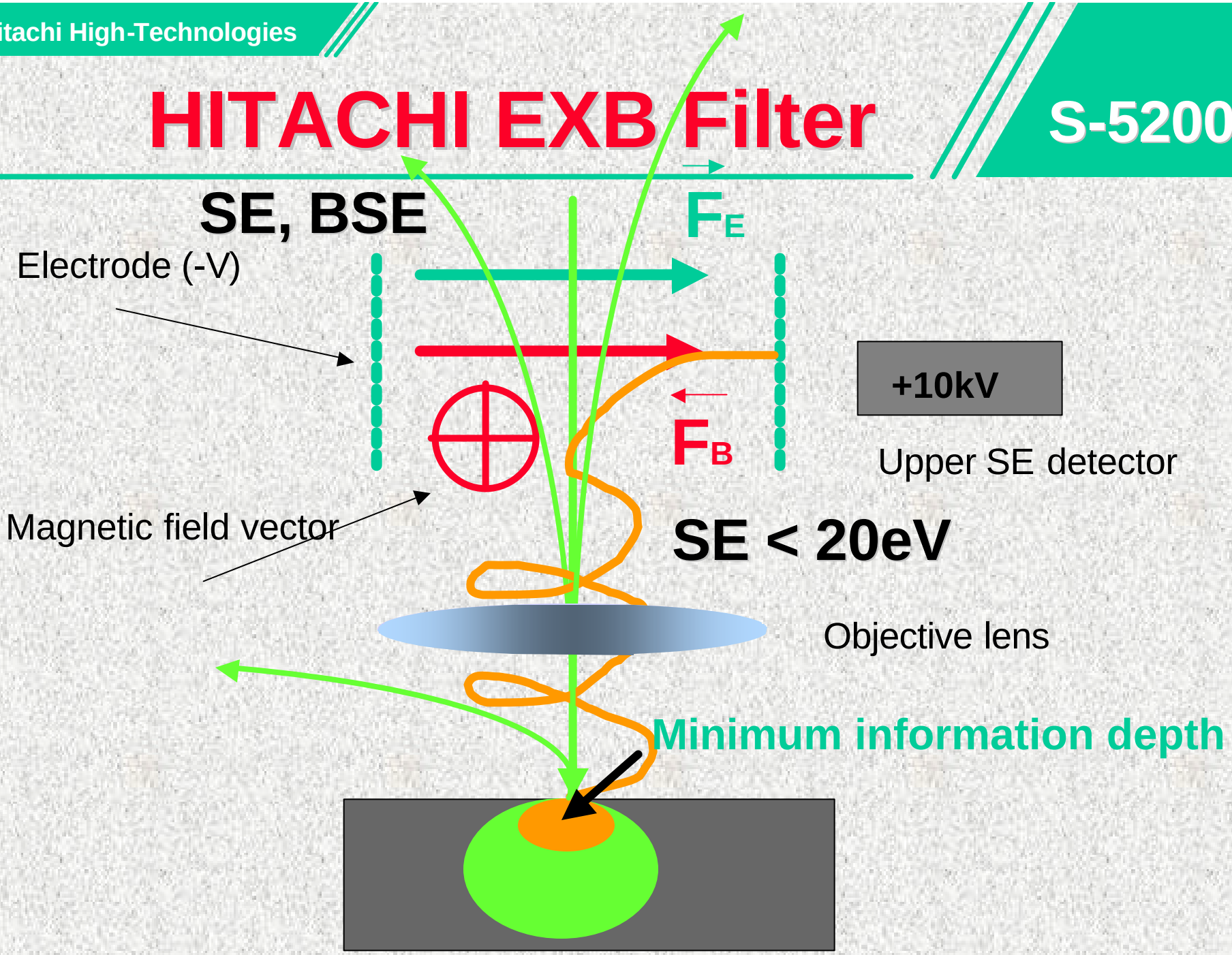
Development
of the new generation
Hitachi In-lens
Ultra High-Resolution SEM
S-5200

Contents

- History of Hitachi Scanning Electron Microscopes
  - Standard SEM, FE-SEM, TTL detector, ExB Filter
- Keypoints of S-5200
  - Theory of the SEM resolution
  - Artefacts limiting the SEM reolution
  - S-5200 countermeasures
- Applications
- Summary

HITACHI EXB Filter

S-5200



History of Hitachi Dual Detector SEM's

S-5200

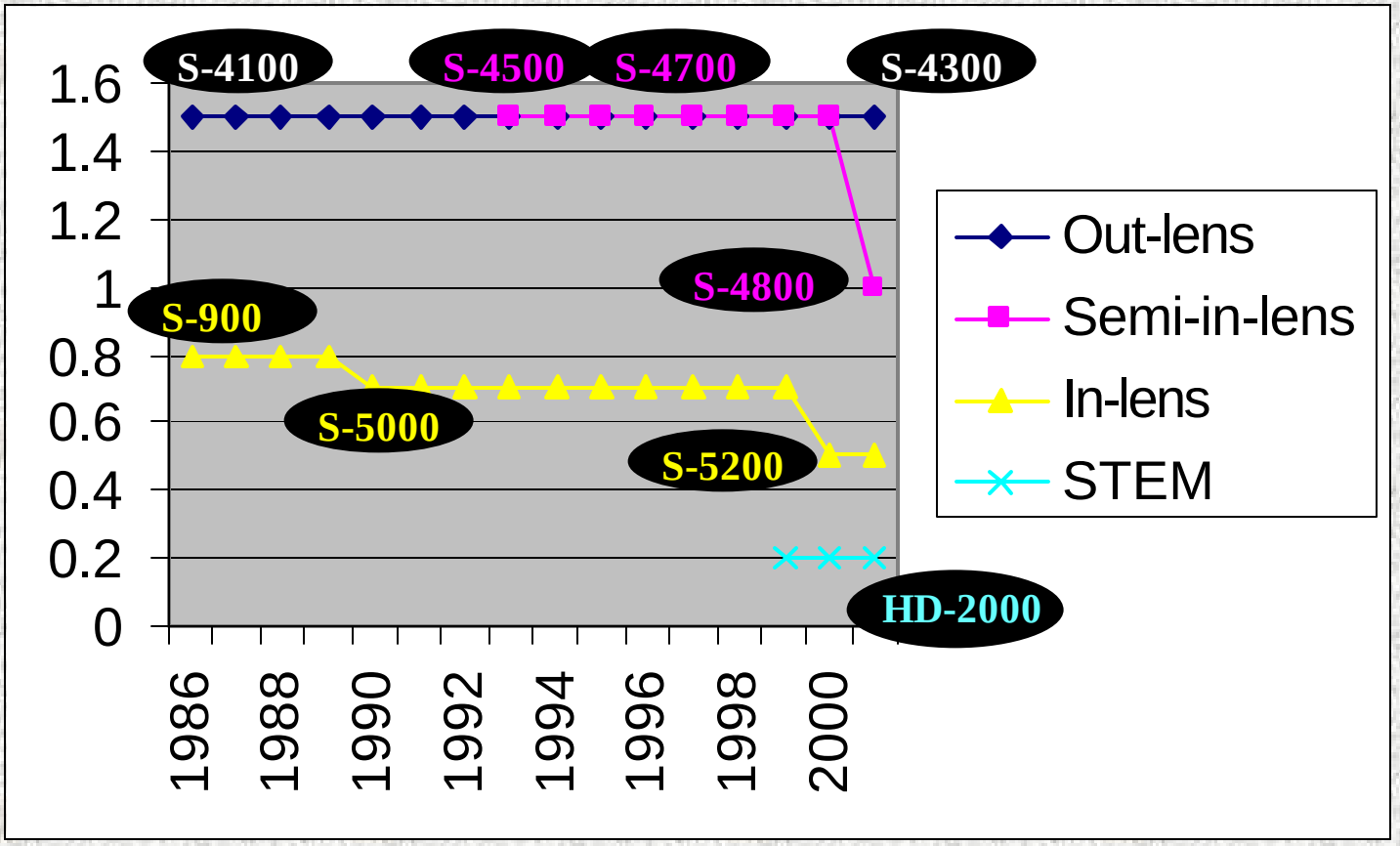
Model	S-570	S-4500	S-4700	S-4700 New	S-5200
Year	1985	1993	1997	2000	2001
Lower Detector	X	X	X	X	
Upper Detector	X	X	X	X	X
with ExB Filter		X	X	X	X
with Topo/Compo Mix				X	X
Second Upper detector					X
Resolution @ 1kV		4nm	2.5nm	2.1nm	1.8nm

Standard

Semi -in-lens

In-lens

Introduction



„High kV“ resolution improvement of different Hitachi FE-SEM types

Comparison of in-lens FE-SEM

S-5200

S-5000 S-5000H S-5200

	S-5000	S-5000H	S-5200
Resolution* high kV	0.6nm (30kV)	0.6nm (30kV)	0.5nm (30kV)
Resolution* 1kV	3nm	2.5nm	1.8nm
sample size	9.5x 5x 2.4mm (Std.) 9.5 x 5.5 x 2mm (CS)	9.5 x 5 x 2.4mm (Std.) 9.5 x 5.5 x 2mm (CS)	9.5 x 5 x 3.5mm (Std.) 12 x 6.5 x 2mm (CS)
tilt range	-40 - 40	-15	-40 - 40
EDX Signal	available	not available	available
YAG BSE Signal	available	not available	available
Auto memory alignment	not available	yes	yes
lens gap	standard	small	small
Topo/Compo Mix with TTL* SE detector	not available	not available	standard
2. TTL* detector	not available	not available	available

* guaranteed values
* TTL: Through-the lens (SE detector is above the objective lens)

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THEORY: Key Points of S-5200

Resolution ~ Final Probe size

Effective spot diameter*: $d^2 = d_o^2 + d_S^2 + d_C^{2+} d_B^2$

d_o^2 = geometrical spot diameter

d_S^2 = spherical aberation ($d_S = 0.5 \cdot Cs \cdot \alpha^3$)

d_C^2 = chromatic aberation ($d_C = C_C \cdot \Delta E/E \cdot \alpha$)

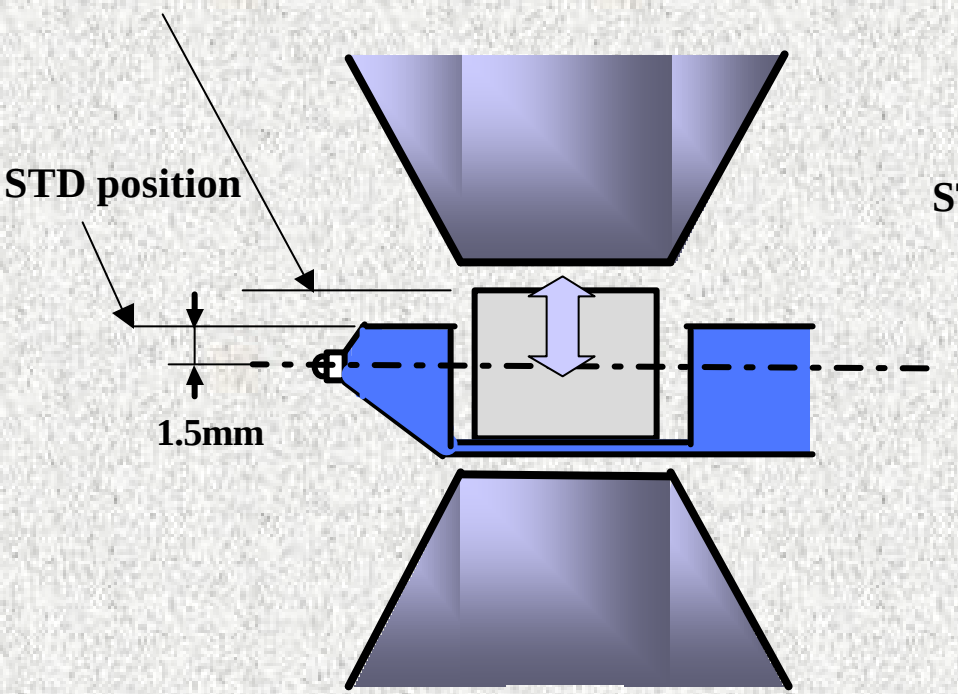
d_D^2 = diffraction error ($d_D = 0.6 \cdot \lambda / \alpha$)

* Image Formation in LV-SEM, L. Reimer (1993)

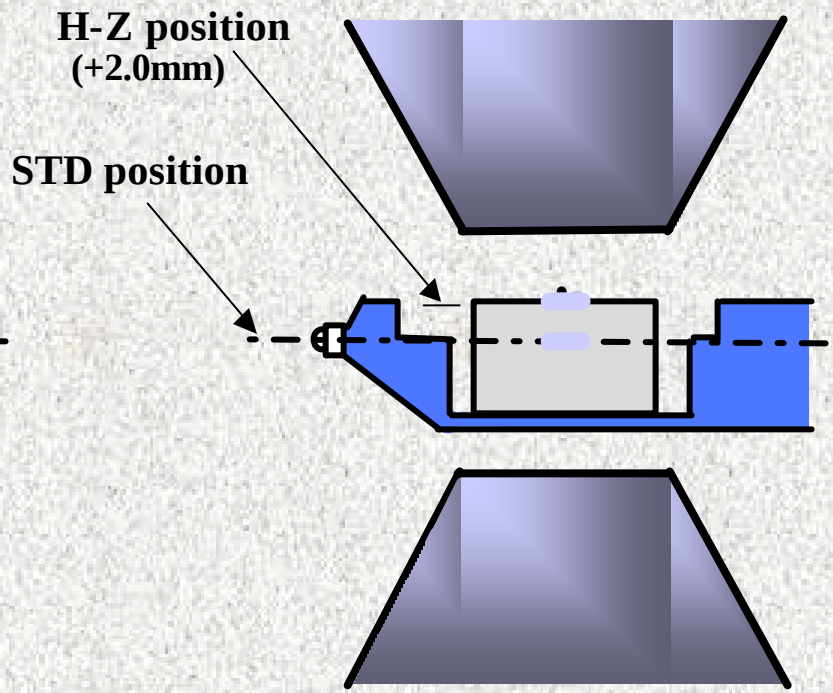
New objective lens

S-5200

S-5200



S-5000



Sample position	(-1.5 - +2.0 mm)	0 mm, +2.0 mm
Focusing range	H: -1.9 - +2.3 mm	H-Z +/- 0.5 mm STD +/- 0.6 mm

THEORY: Key Points of S-5200

Resolution ~ Final Probe size

Effective spot diameter*: $d^2 = d_o^2 + d_S^2 + d_C^{2+} d_B^2$

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d_D^2 = diffraction error ($d_D = 0.6 \cdot \lambda / \alpha$)

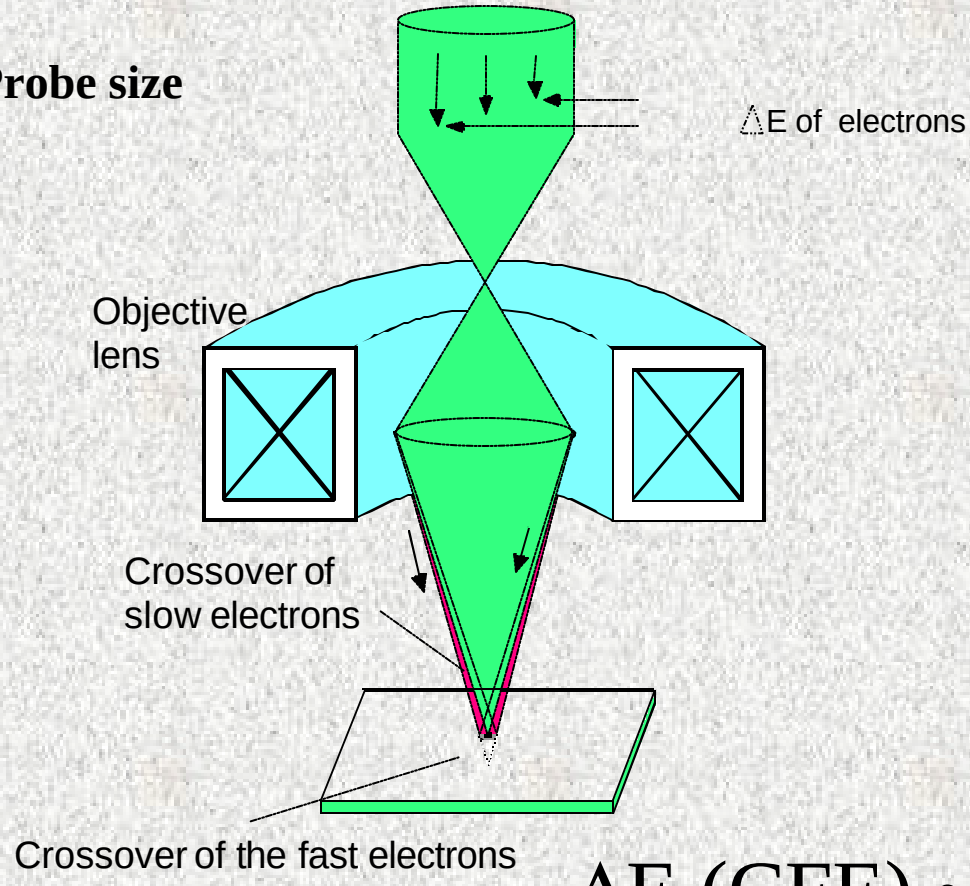
* Image Formation in LV-SEM, L. Reimer (1993)

Key Points of S-5200

S-5200

THEORY:

Resolution ~ Final Probe size

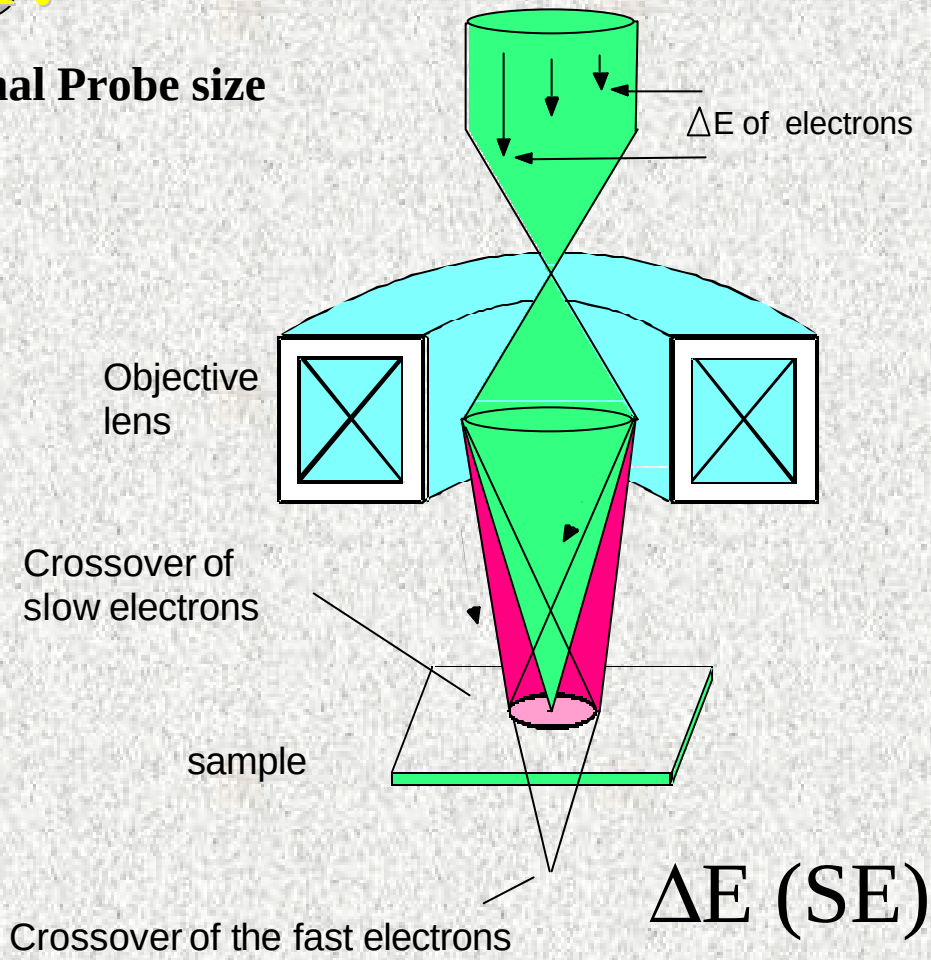


ΔE (CFE) ~ 0.2-0.3eV

Key Points of S-5200

THEORY:

Resolution ~ Final Probe size



ΔE (SE) ~ 0.3-1.0 eV

Key Points of S-5200

THEORY:

Resolution ~ Final Probe size

Effective spot diameter*: $d^2 = d_o^2 + d_S^2 + d_C^{2+} d_B^2$

d_o^2 = geometrical spot diameter

d_S^2 = spherical aberation ($d_S = 0.5 \cdot Cs \cdot \alpha^3$)

d_C^2 = chromatic aberation ($d_C = C_C \cdot \Delta E/E \cdot \alpha$)

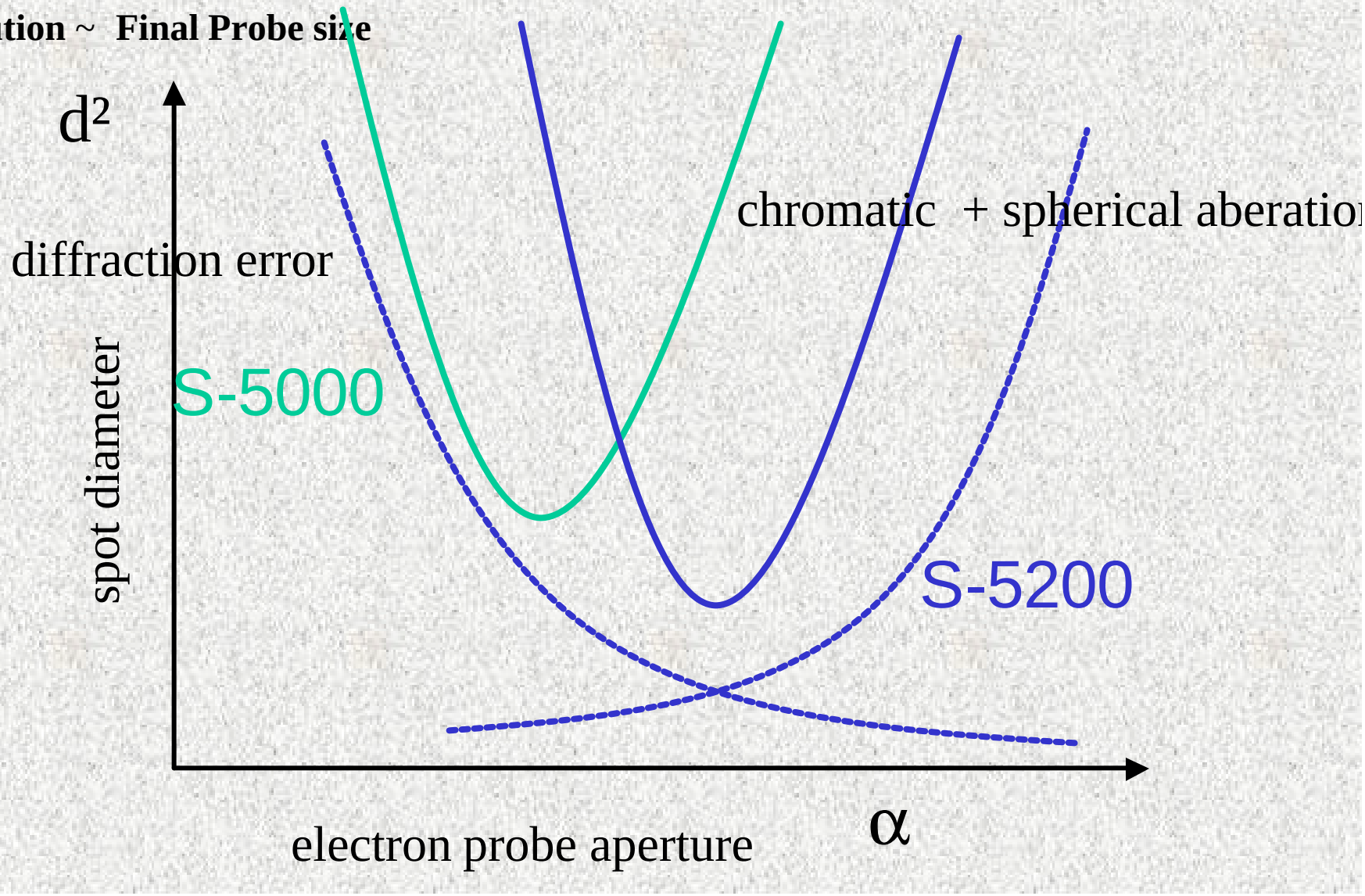
d_D^2 = diffraction error ($d_D = 0.6 \cdot \lambda / \alpha$)

* Image Formation in LV-SEM, L. Reimer (1993)

Key Points of S-5200

THEORY:

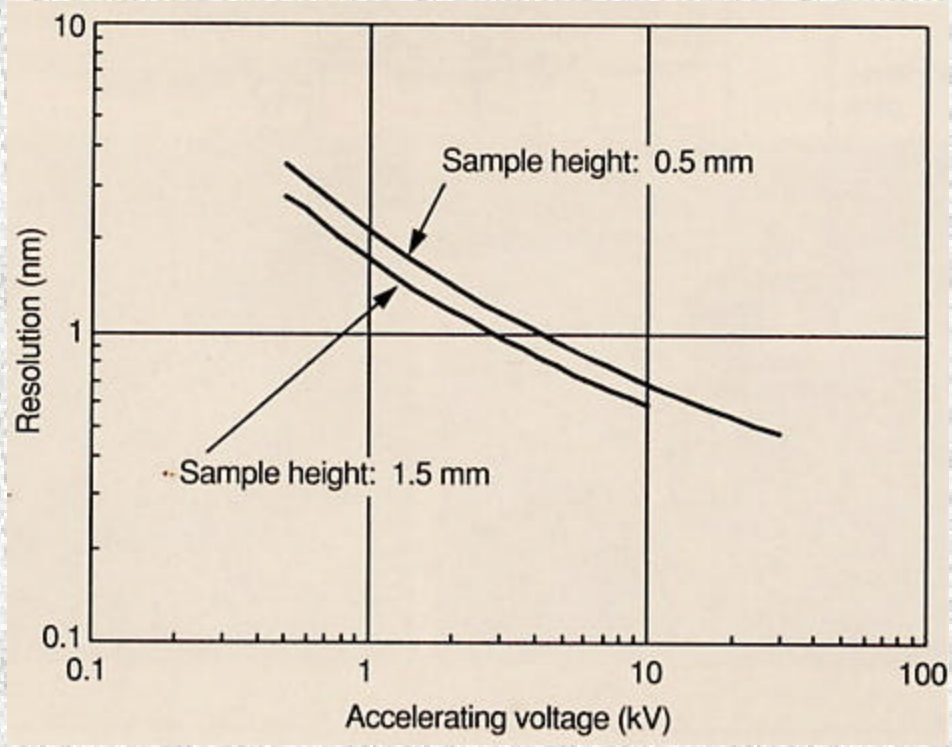
Resolution ~ Final Probe size



Key Points of S-5200

THEORY:

Resolution ~ Final Probe size



Resolution of S-5200 as function of accelerating voltage

Key Points of S-5200

S-5200

THEORY:

Resolution ~ Final Probe size

"REAL LIFE":

Resolution ~ Final Probe size

+ f_1(vibration) + f_2(stability) + f_3(contamination)+ f_4(detection)

S-5200 COUNTERMEASURES:

- *New column frame*
- *New dampers*
- *Sample in vibration center*

- *Side-entry hiper stage*

- *Electrostatic beam blanker*
- *optional 2nd TMP*

Advanced ExB Filter with optional 2. Upper SED for low kV BSE imaging

Allowable Vibration

S-5200

Frequency	S-5200
1 Hz	10 um p-p
1.5 Hz	5 um p-p
2 Hz	6 um p-p
3 Hz	8 um p-p
5 Hz	10 um p-p
10 Hz	10 um p-p

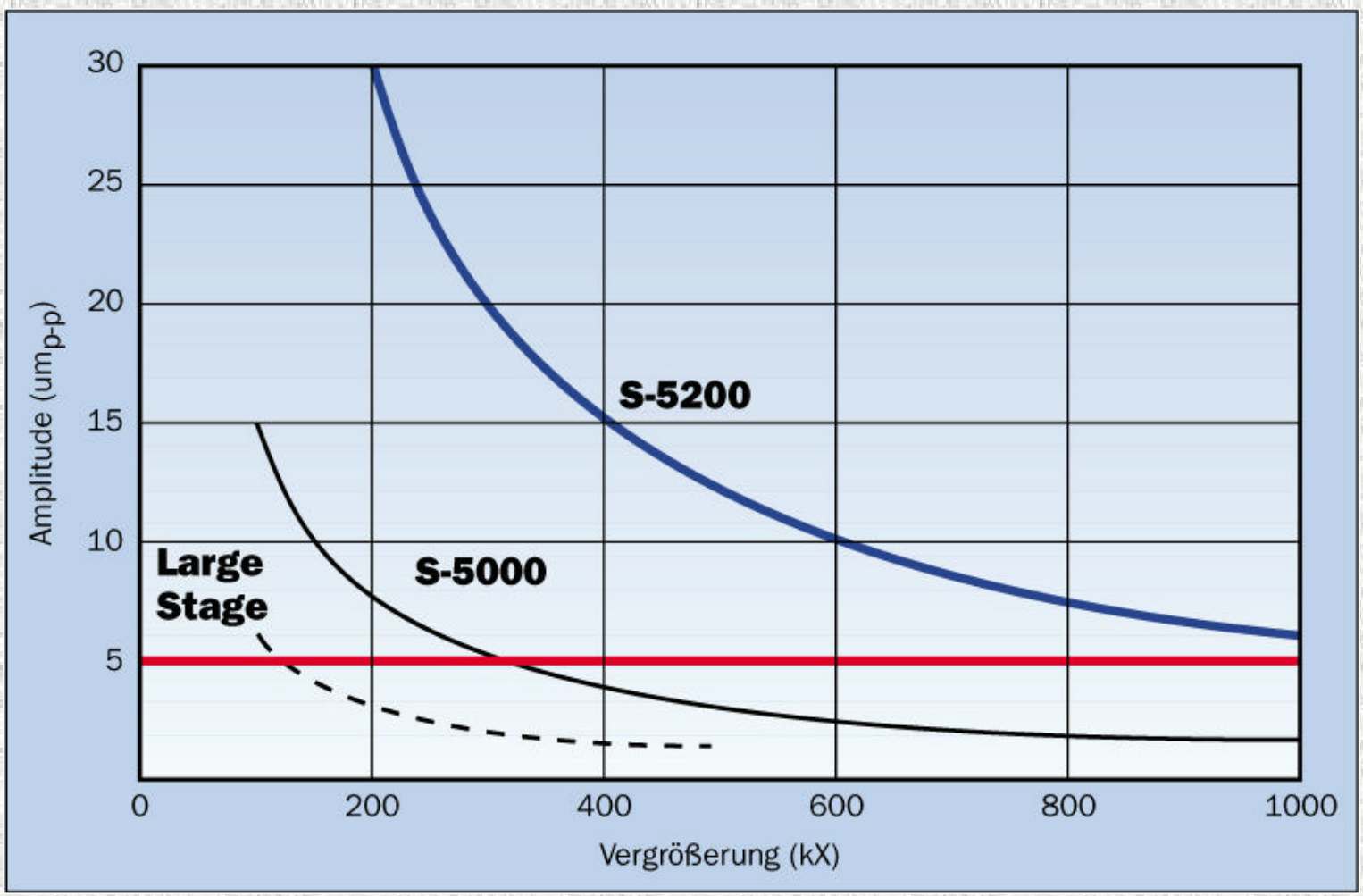
Improvement of frame strength

Improvement of rubber mounts

Move stage to vibration center

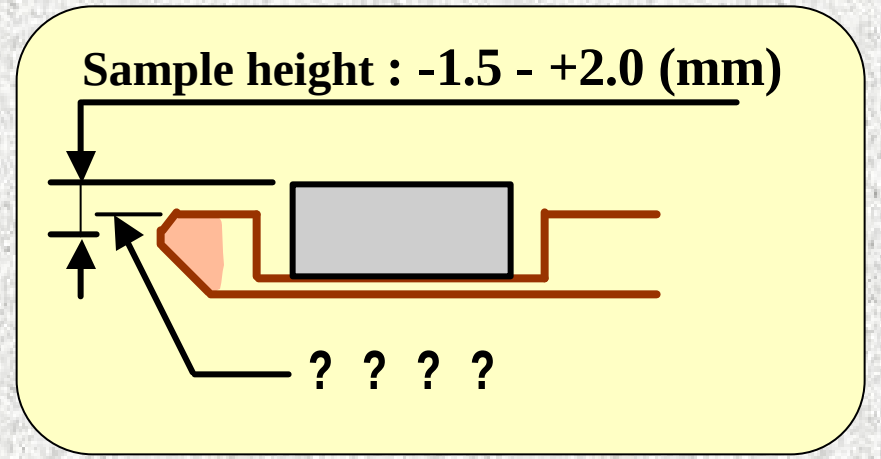
Allowable Vibration at 5Hz

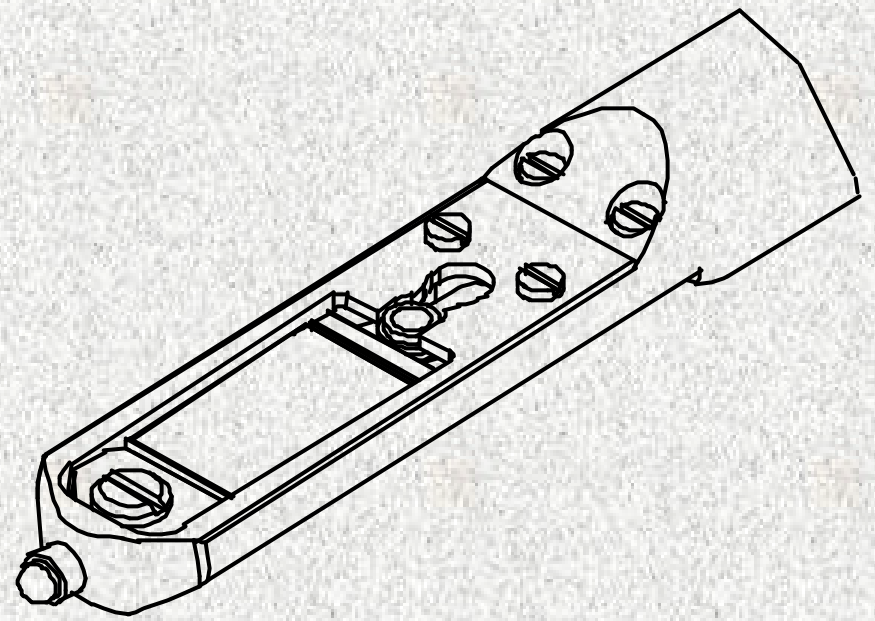
S-5200

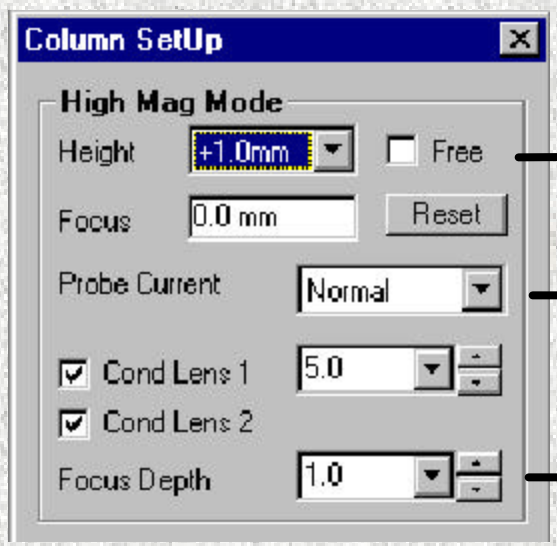


Shorter focal length

S-5200





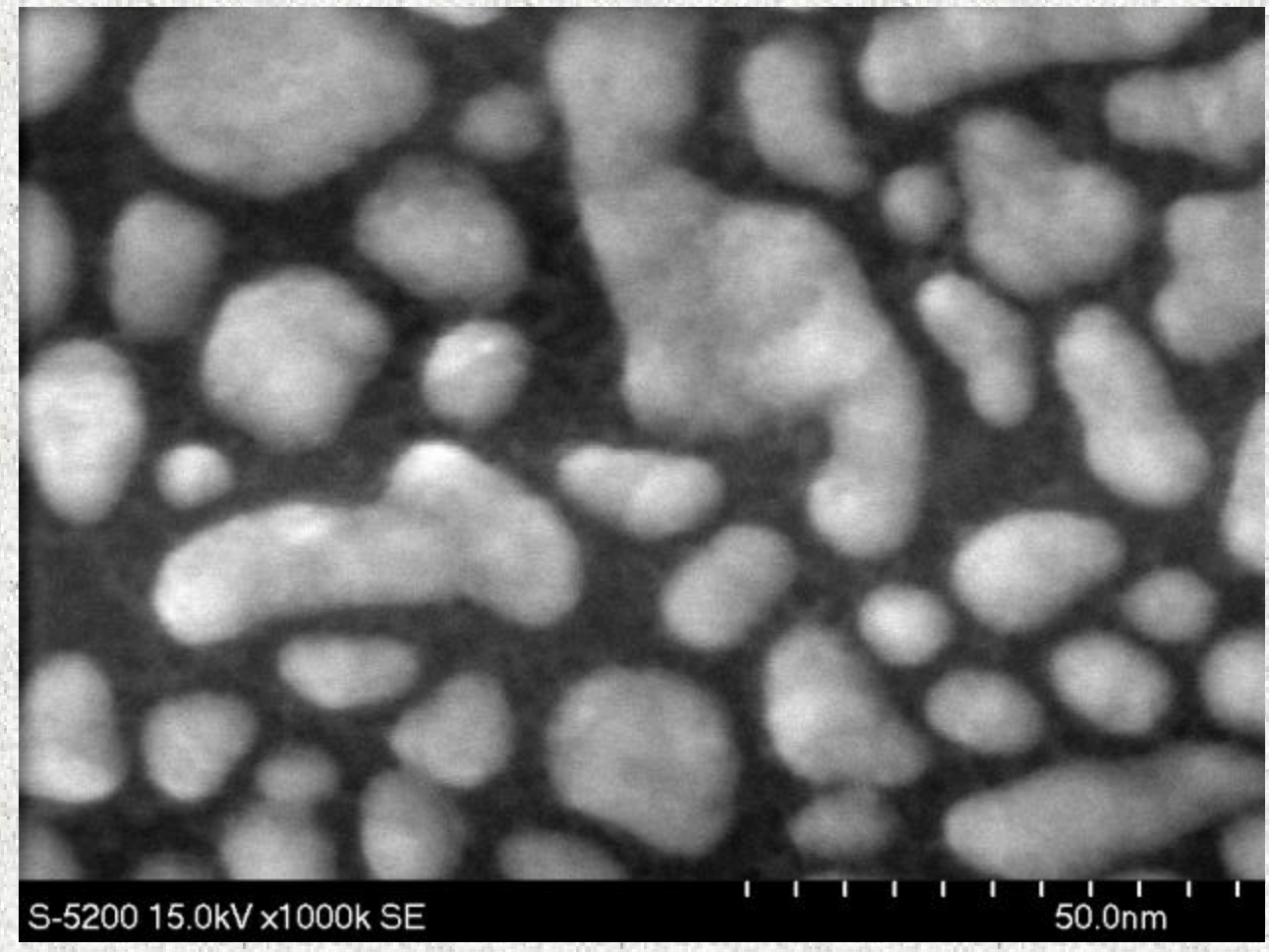


Sample height setting

Normal/Analysis

Focus depth parameter

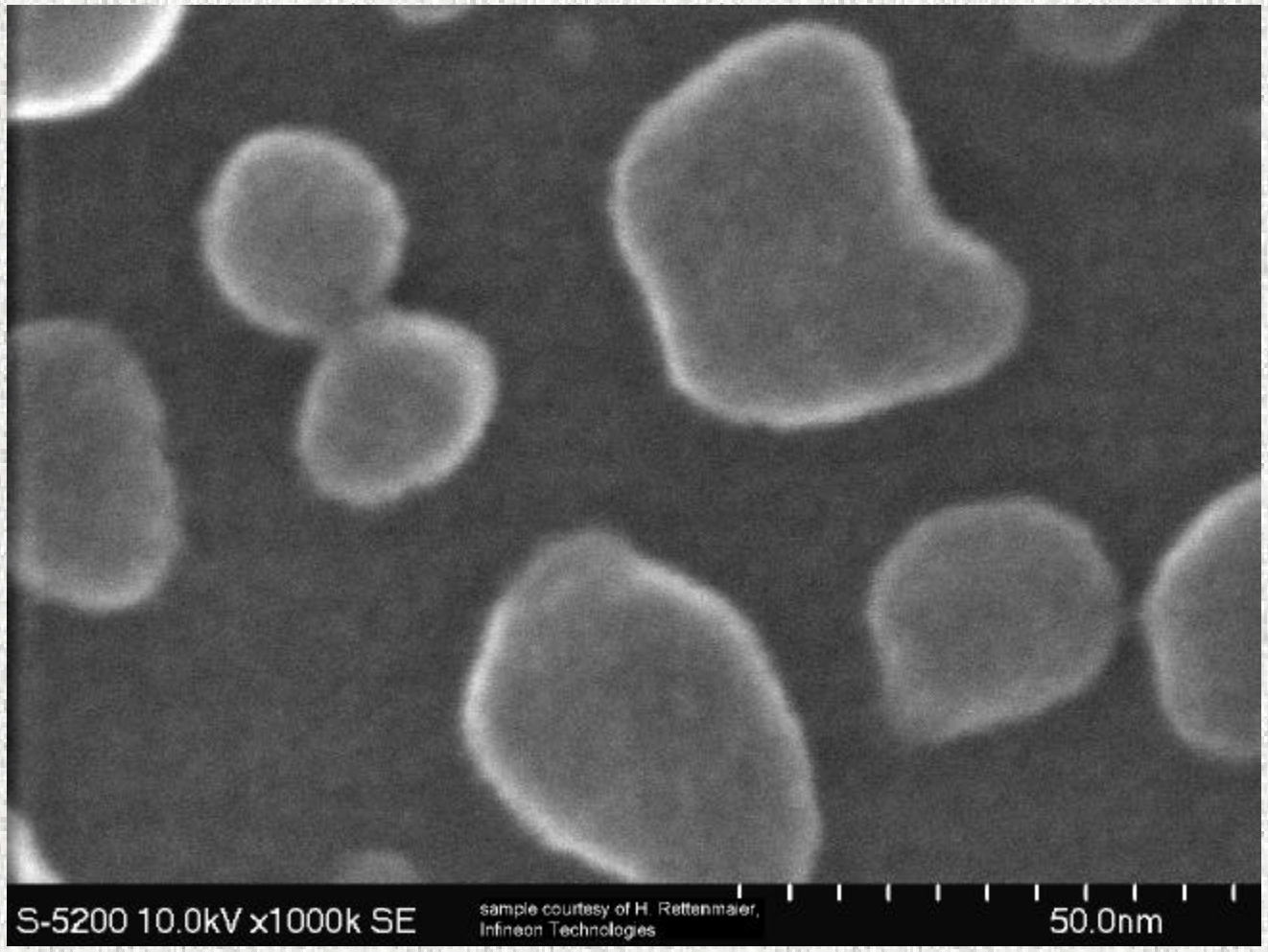
S-5200



U_{acc}: : 15.0 kV
Mag : 1000 kx

Hemispherical Silicon Grains (HSG)

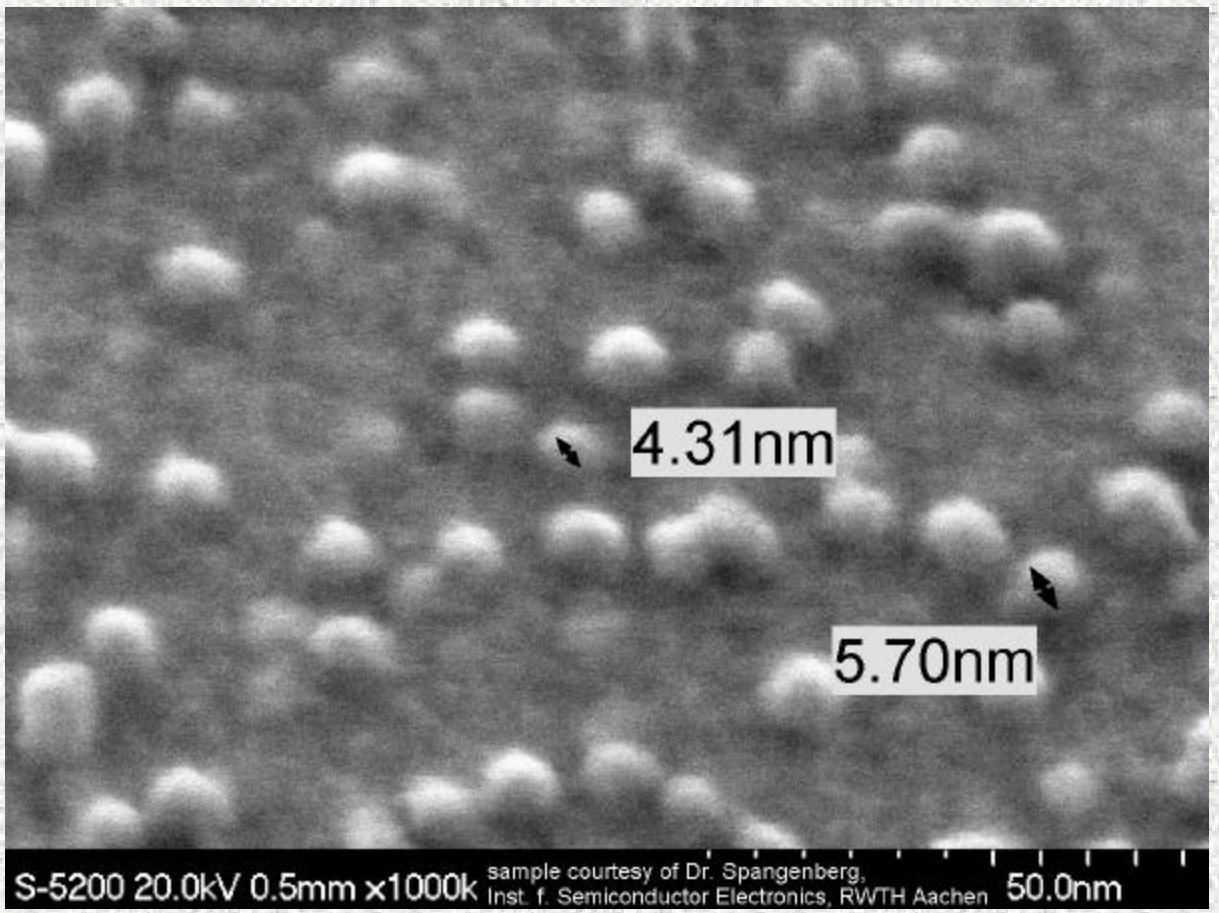
S-5200



U_{acc}: 10kV
Mag: 1000k

SiO2 dots on Si

S-5200



U_{acc}: 20kV
Mag: 1000k

Key Points of S-5200

S-5200

THEORY:

Resolution ~ Final Probe size

"REAL LIFE":

Resolution ~ Final Probe size

+ f_1(vibration) + f_2(stability) + f_3(contamination)+ f_4(detection)

S-5200 COUNTERMEASURES:

- *New column frame*
- *New dampers*
- *Sample in vibration center*

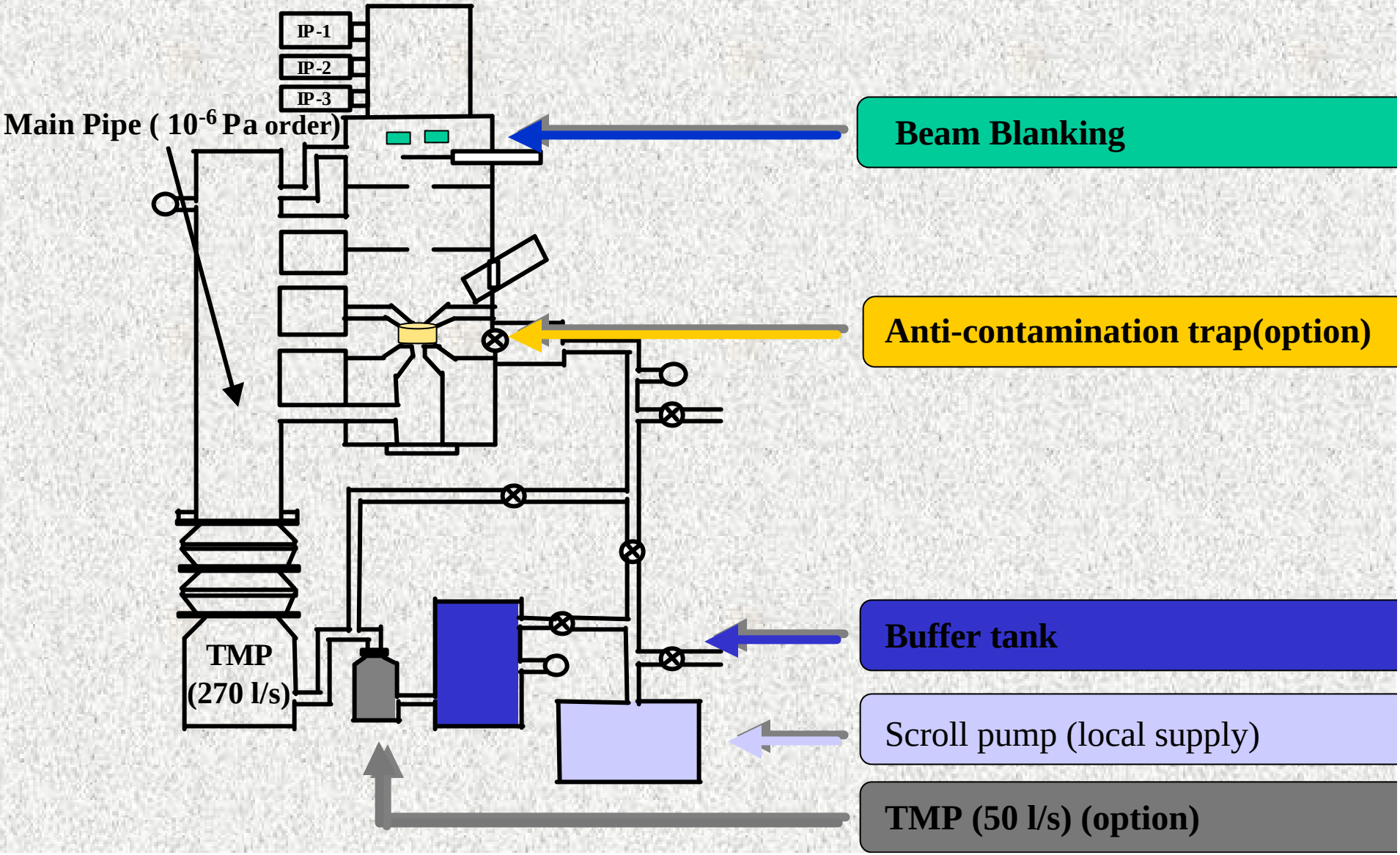
- *Side-entry hiper stage*

- *Electrostatic beam blanker*
- *optional 2nd TMP*

Advanced ExB Filter with optional 2. Upper SED for low kV BSE imaging

S-5200 Evacuation system

S-5200



Key Points of S-5200

S-5200

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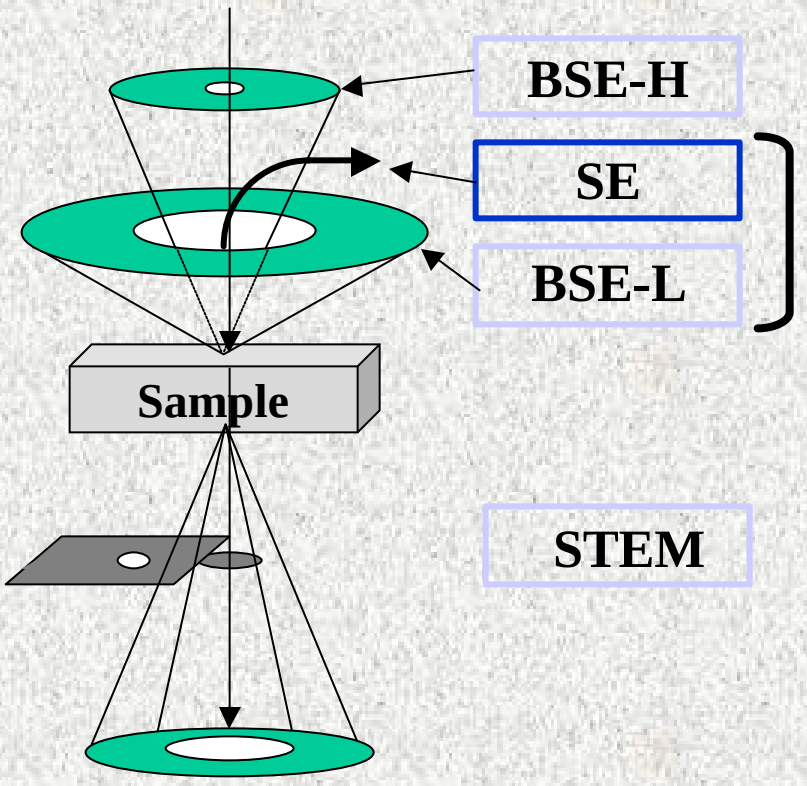
Advanced ExB Filter with optional 2. Upper SED for low kV BSE imaging

Flexible signal detection

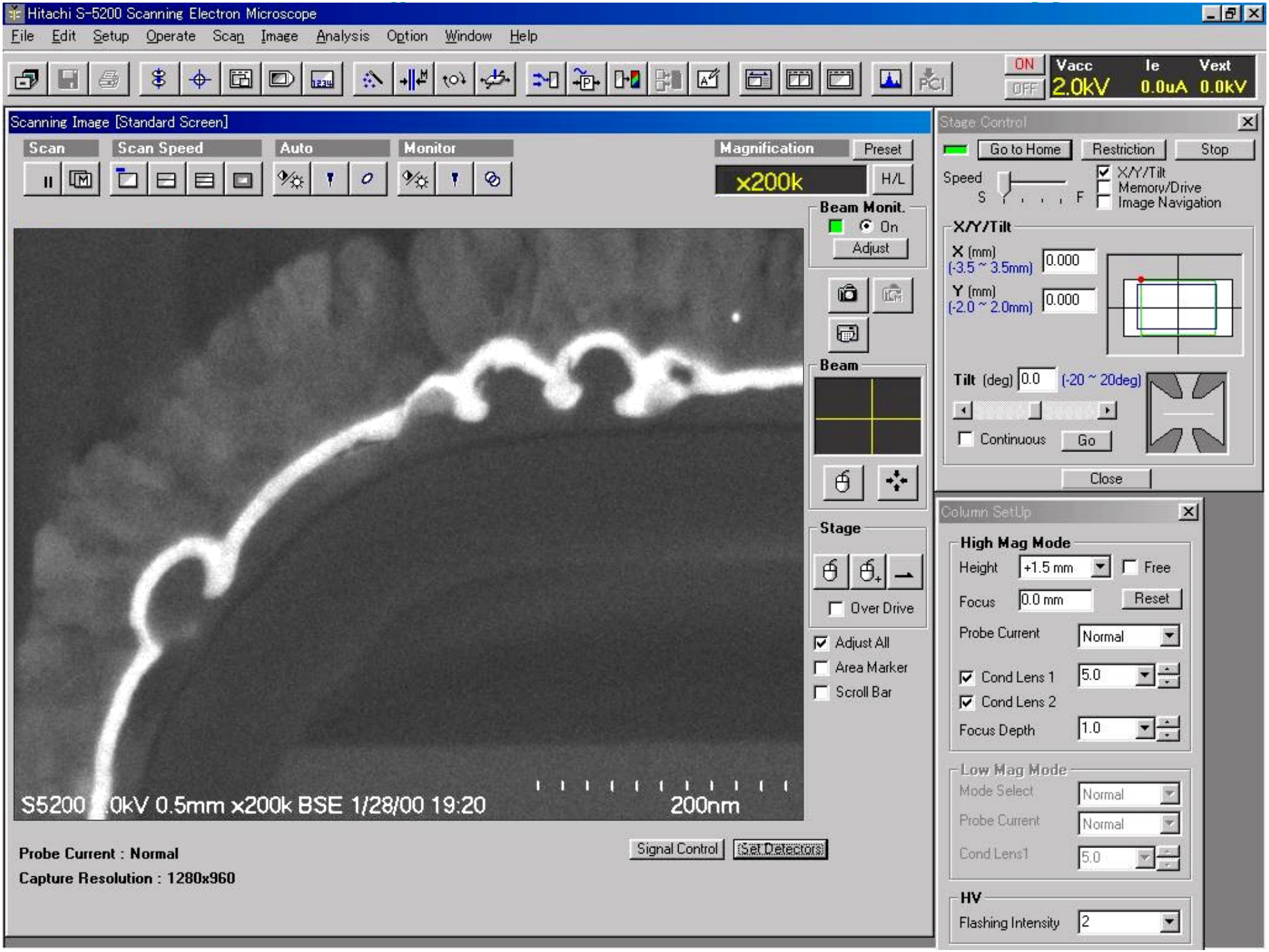
S-5200



YAG BSE/SED(option)

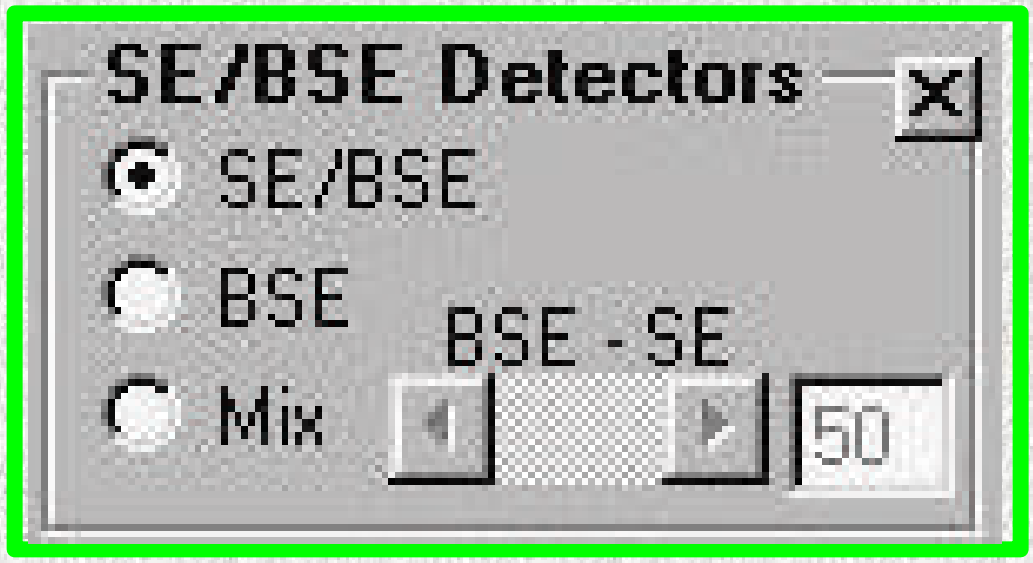
Standard SED
(Controllable)

Bright/Dark Field (option)


Hitachi S-5200 Scanning Electron Microscope
File Edit Setup Operate Scan Image Analysis Option Window Help
ON
OFF
Vacc
2.0kV
Ie
0.0uA
Vext
0.0kV
Scanning Image [Standard Screen]
Scan
Scan Speed
Auto
Monitor
Magnification
Preset
x200k
H/L
Beam Monit.
On
Adjust
Beam
Stage
Over Drive
Adjust All
Area Marker
Scroll Bar
S5200 0kV 0.5mm x200k BSE 1/28/00 19:20
200nm
Probe Current : Normal
Capture Resolution : 1280x960
Signal Control
Set Detectors
Stage Control
Go to Home
Restriction
Stop
Speed
S
F
X/Y/Tilt
Memory/Drive
Image Navigation
X/Y/Tilt
X (mm)
(-3.5 ~ 3.5mm)
0.000
Y (mm)
(-2.0 ~ 2.0mm)
0.000
Tilt (deg)
0.0
(-20 ~ 20deg)
Continuous
Go
Close
Column SetUp
High Mag Mode
Height
+1.5 mm
Free
Focus
0.0 mm
Reset
Probe Current
Normal
Cond Lens 1
5.0
Cond Lens 2
Focus Depth
1.0
Low Mag Mode
Mode Select
Normal
Probe Current
Normal
Cond Lens1
5.0
HV
Flashing Intensity
2

Signal Detector Selection

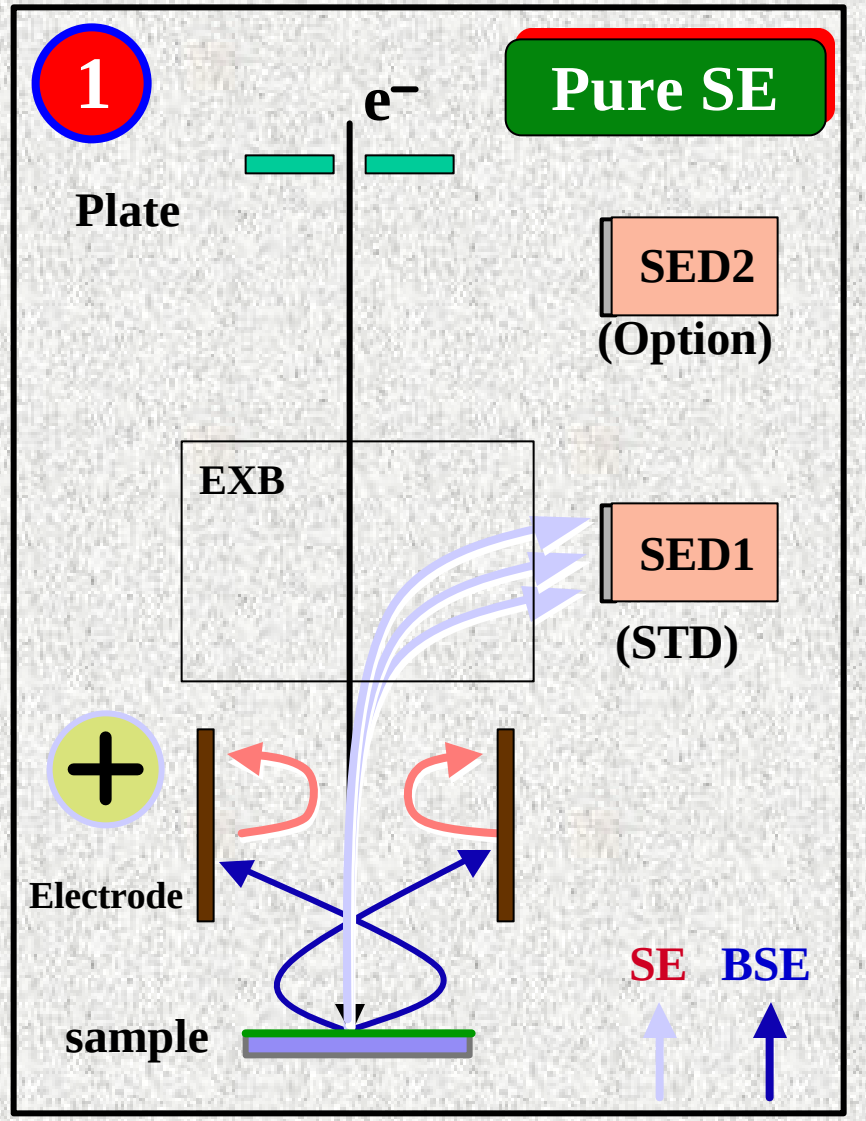
S-5200

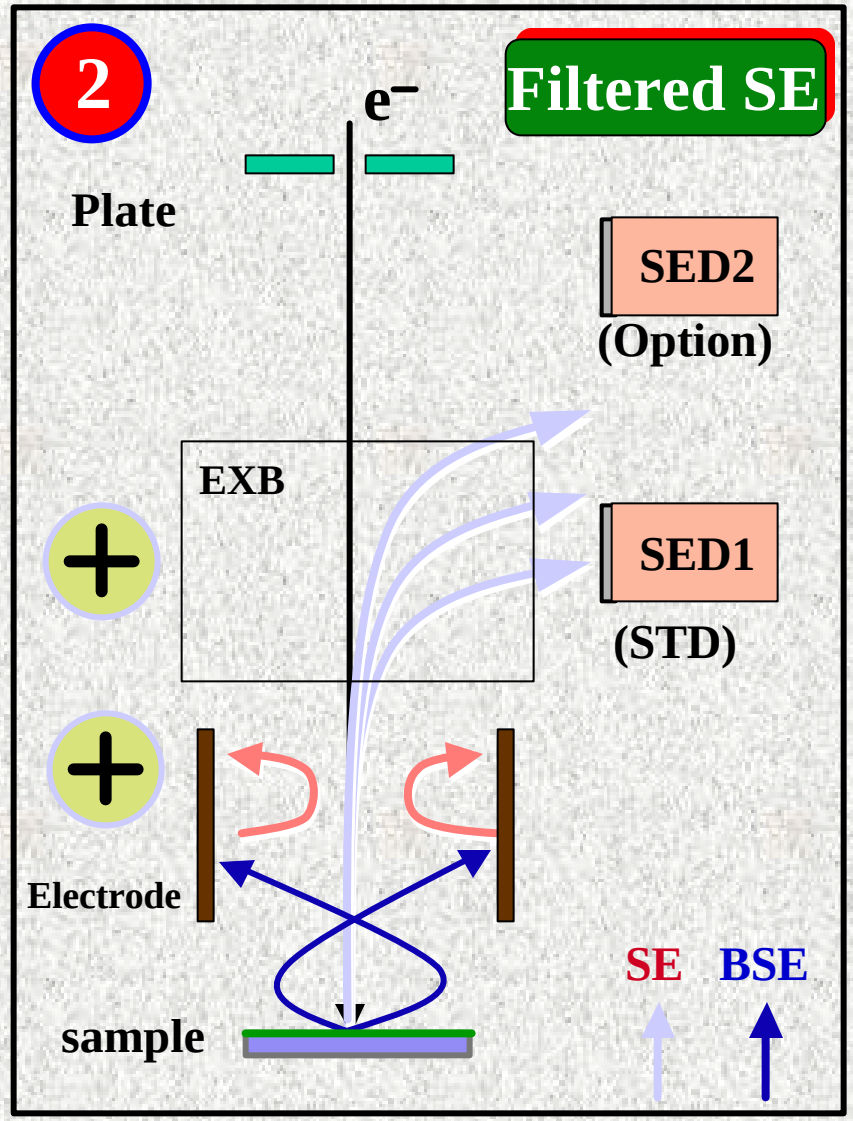


- **Standard**
- **BSE (option)**
- **Mixing (option)**

Signal Detector Selection

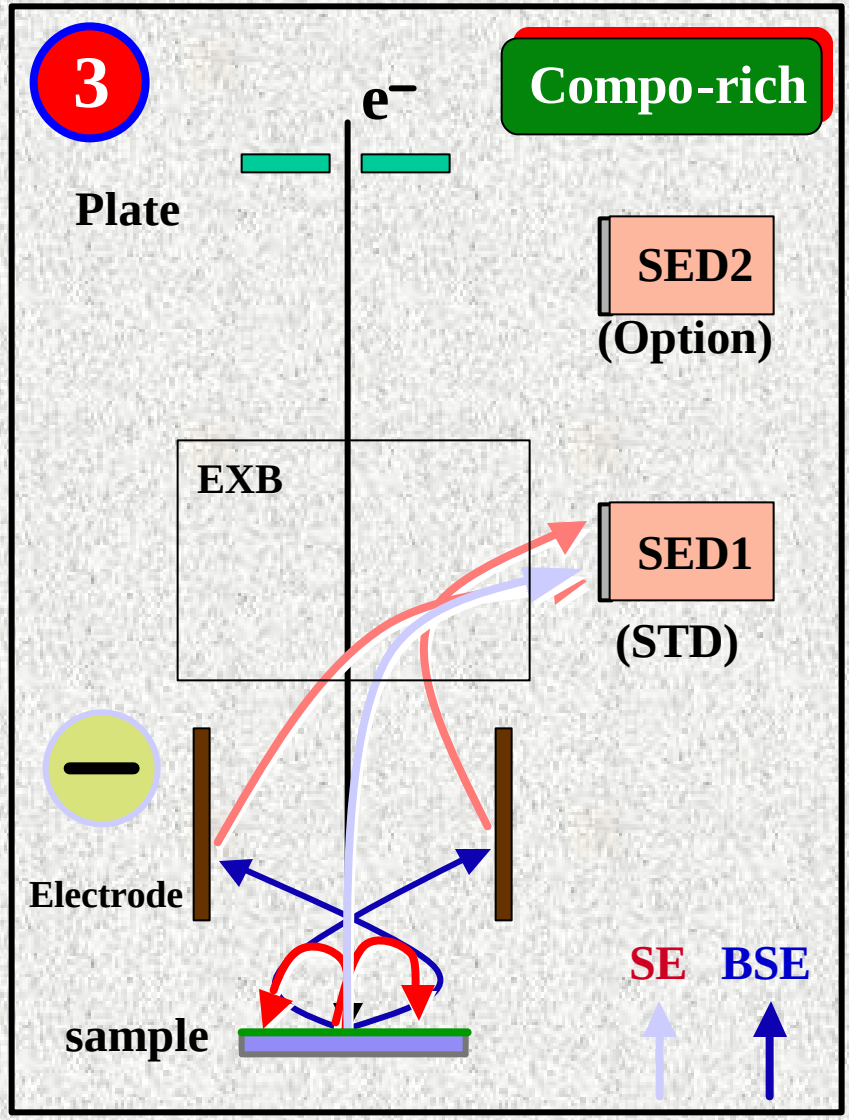
S-5200

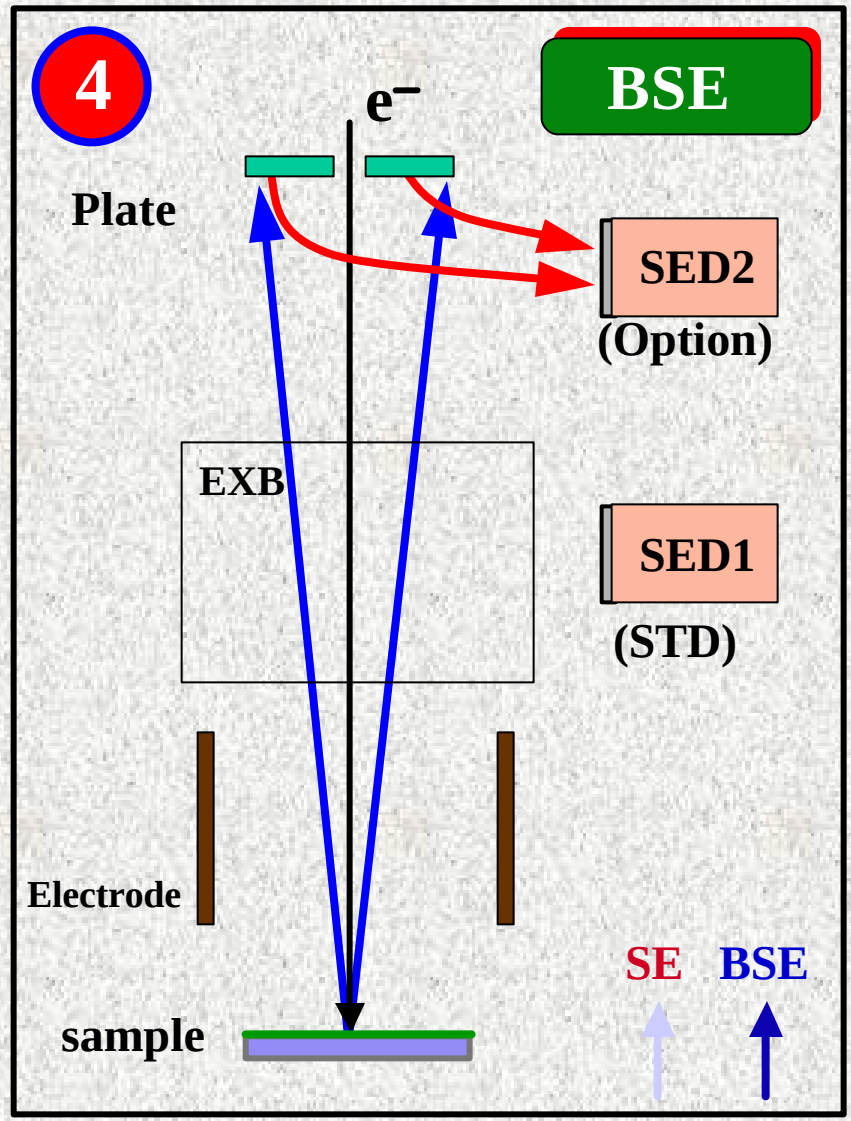




Signal Detector Selection

S-5200





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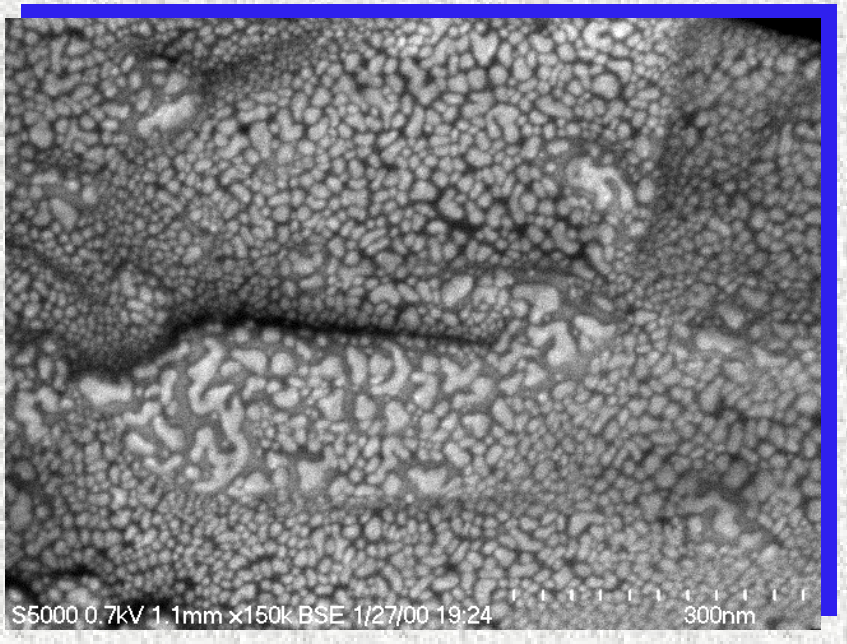
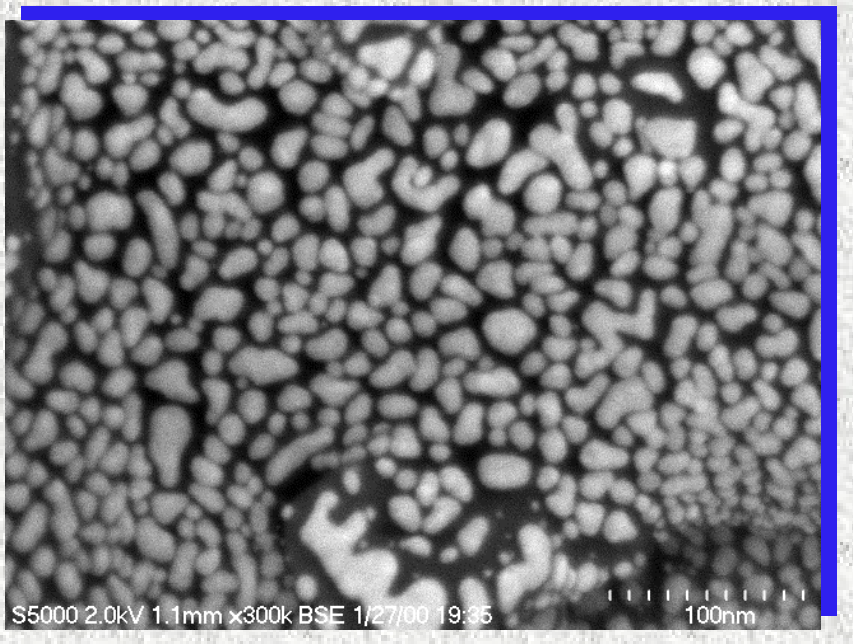
Low Energy BSE Image

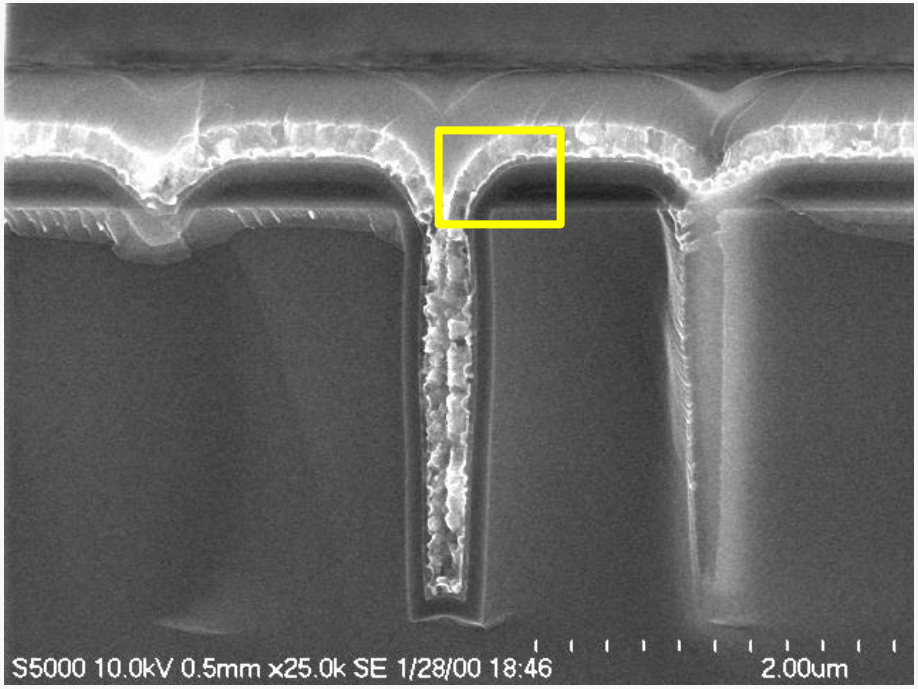
S-5200

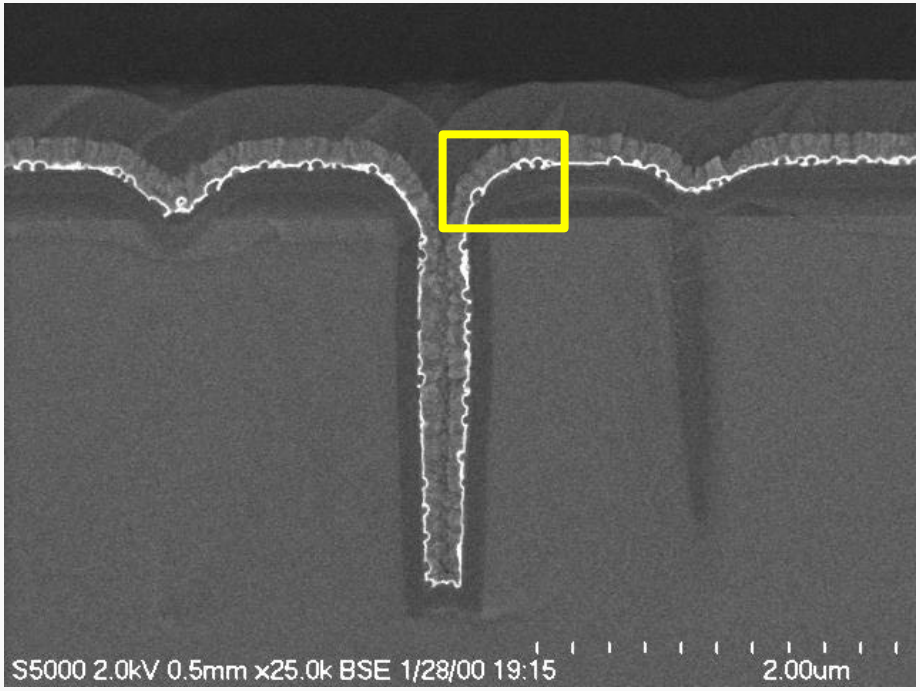


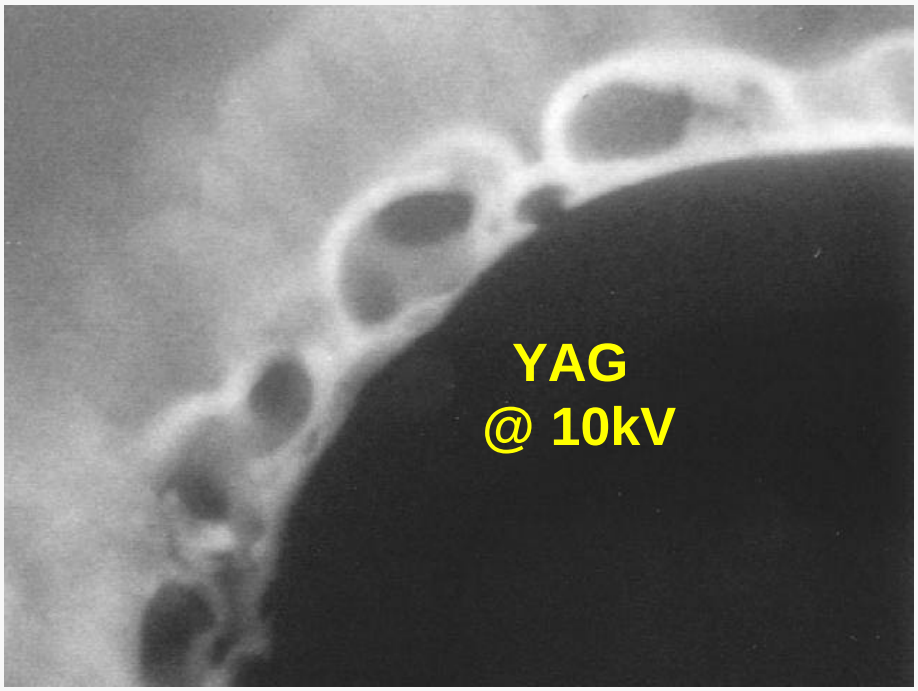


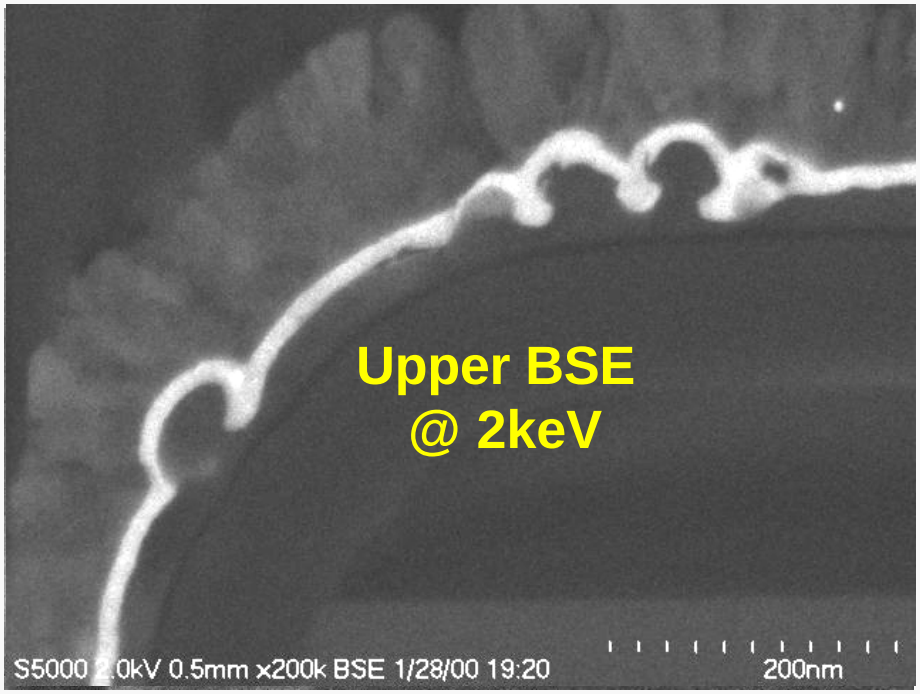
Sample : Au Particle
Vacc : 0.7 kV
Mag : 150 kX

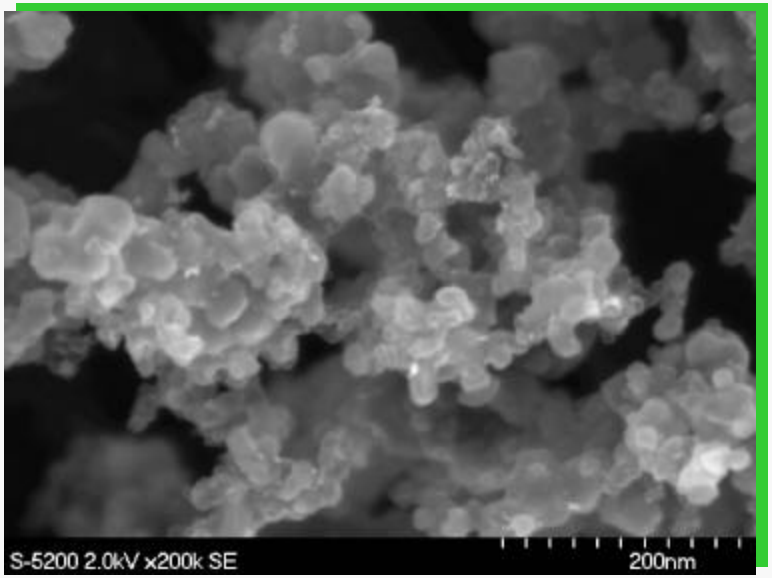
Sample : Au Particle
Vacc : 2.0 kV
Mag : 300 kX

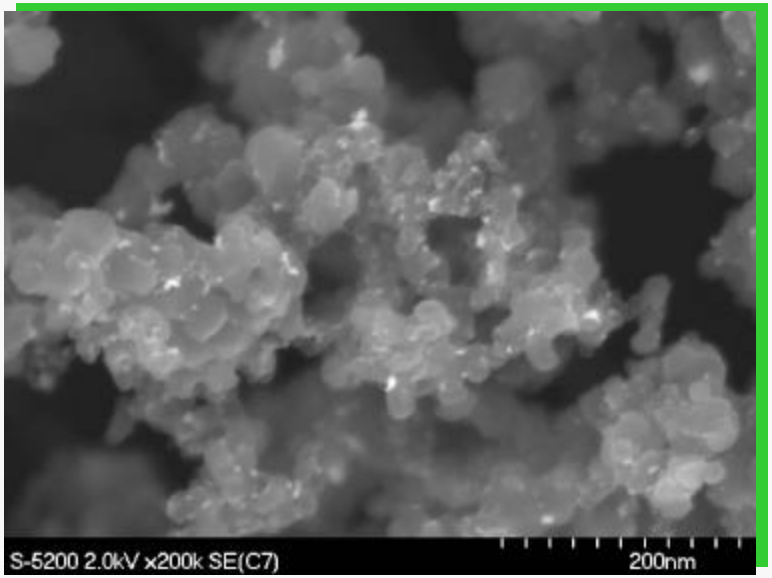

S5000 10.0kV 0.5mm x25.0k SE 1/28/00 18:46
2.00um

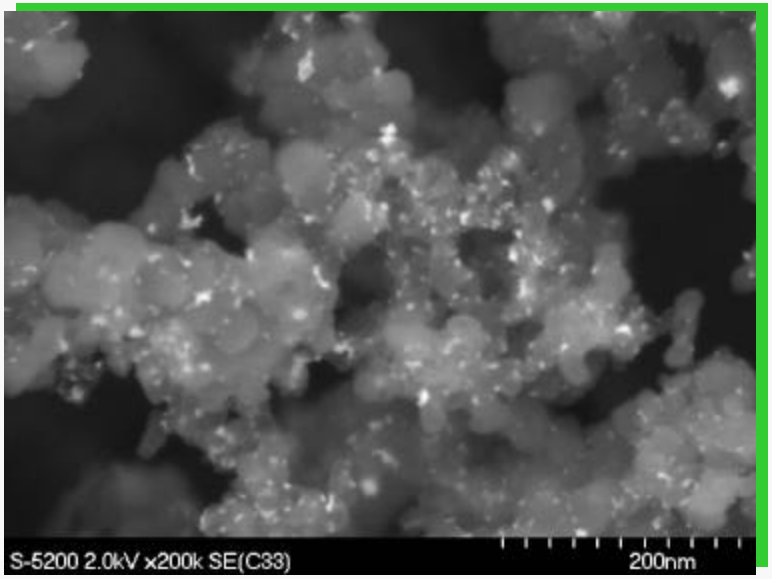

S5000 2.0kV 0.5mm x25.0k BSE 1/28/00 19:15
2.00um


YAG
@ 10kV


Upper BSE
@ 2keV
S5000 2.0kV 0.5mm x200k BSE 1/28/00 19:20
200nm



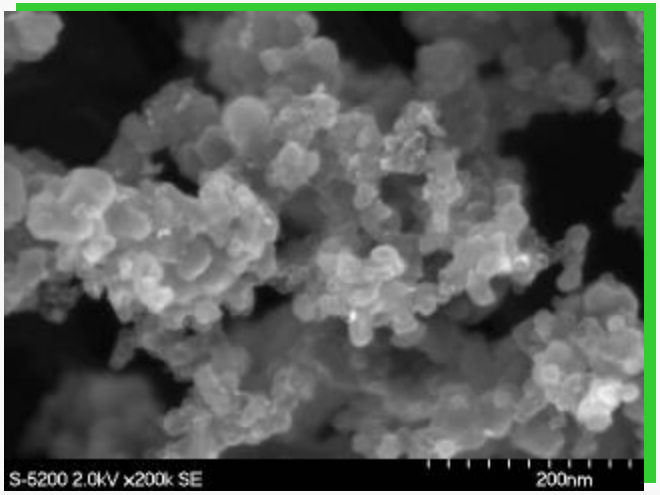




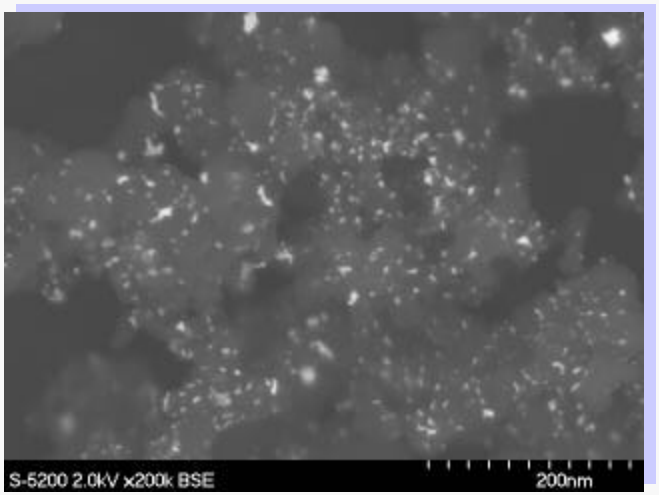
SE	-10V
-50V	

Sample : Catalysis
U_{acc} : 2.0 kV
Mag : 200 kX

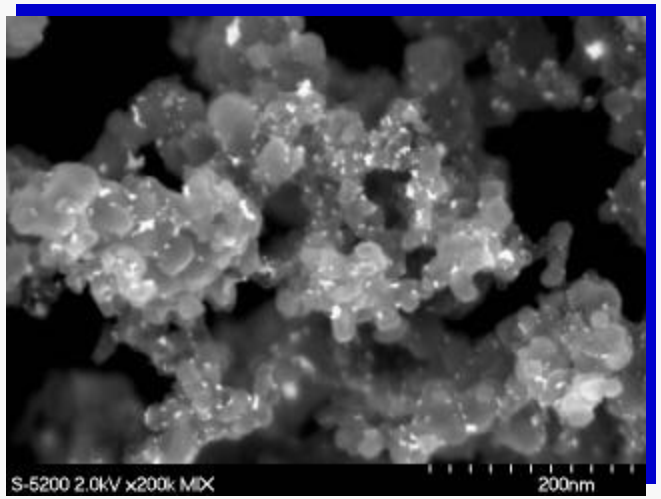
Compo-Rich Effect



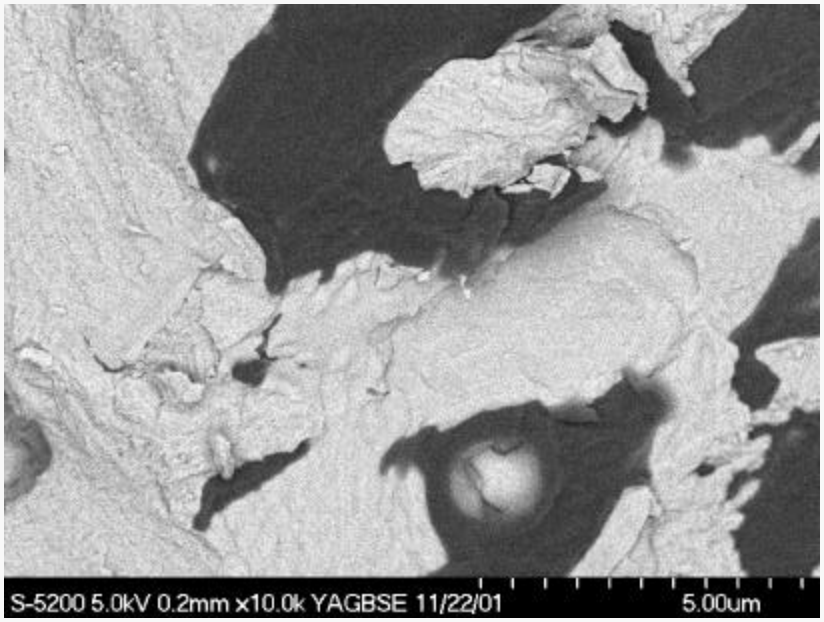
Pure SE Image

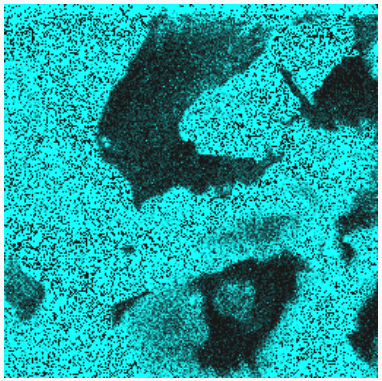


BSE Image

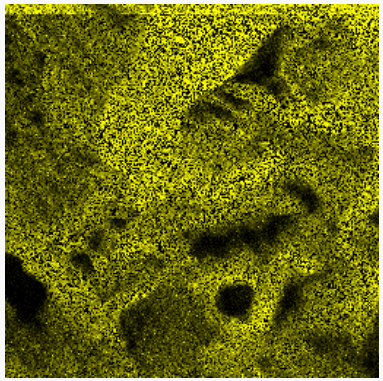


Mixed Image (SE+BSE)

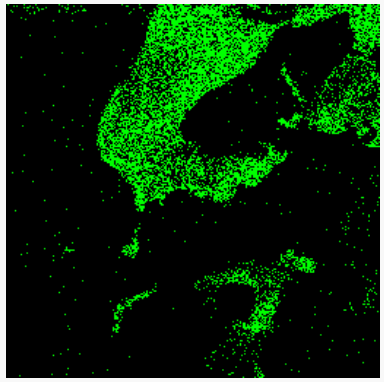




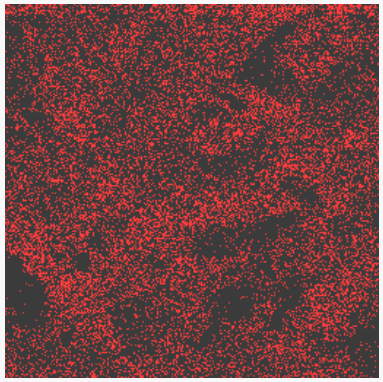
Zr-L



O-K



Mg-K

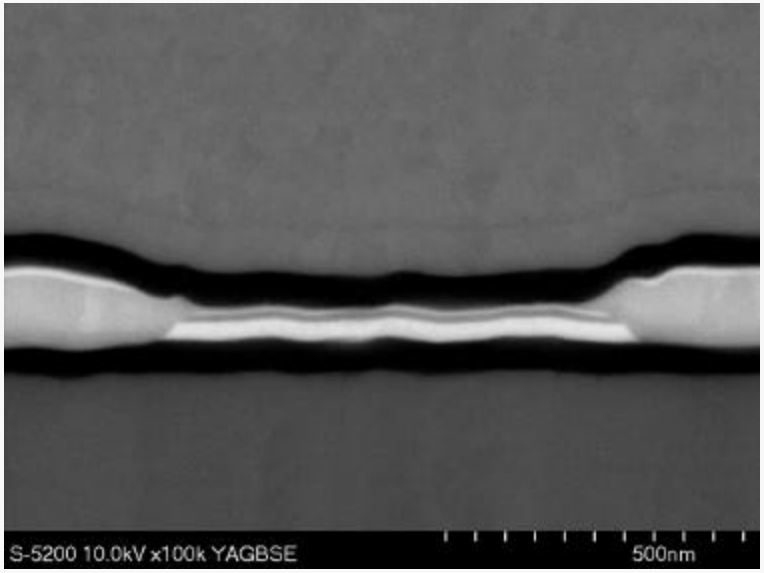


B-K

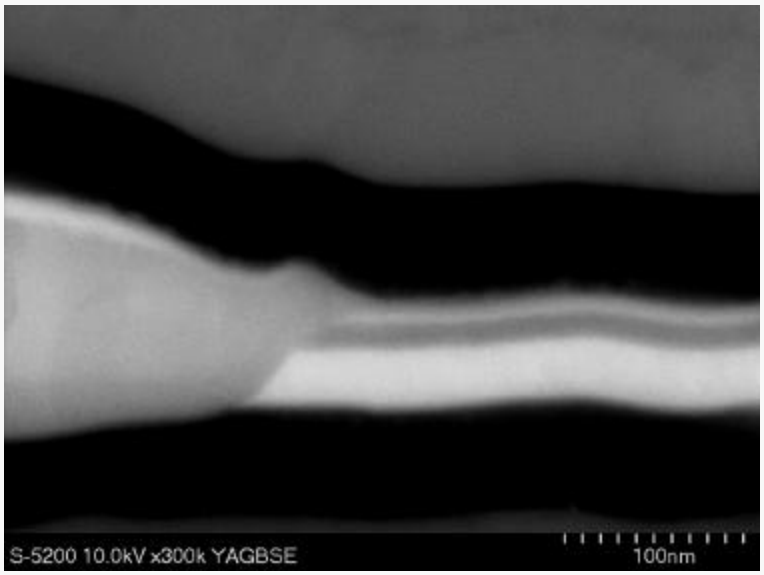
Mapping of ZrO at 5kV (15min.)

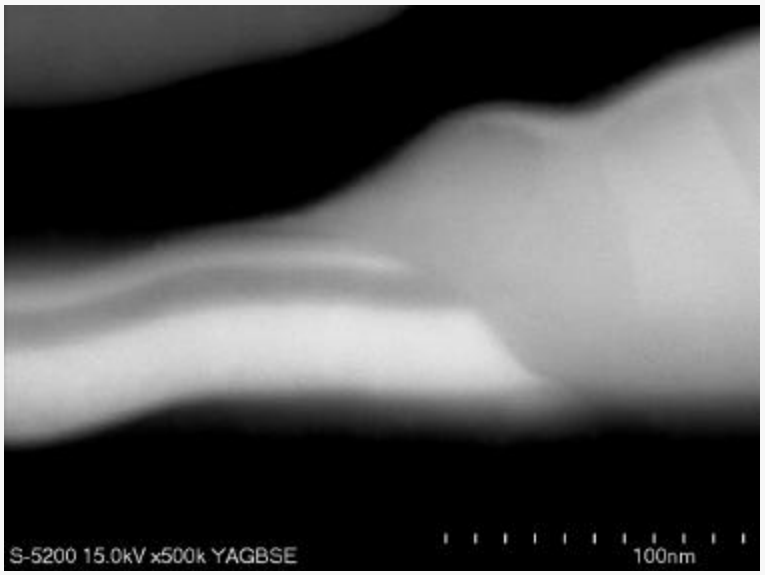
Materials science applications

Sample: GMR Film



Mode : YAGBSE
(BSE-H)
Vacc. : 10kV
Mag. : x100k, 300k, 500k





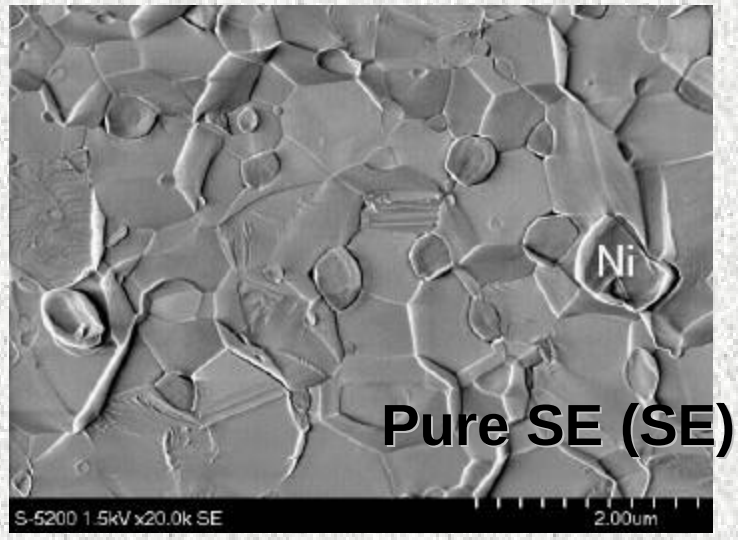
Low kV Backscattered Electron Imaging

S-5200

Ta barrier under Cu Seed

Signal Control (SE / BSE-L /BSE-H)

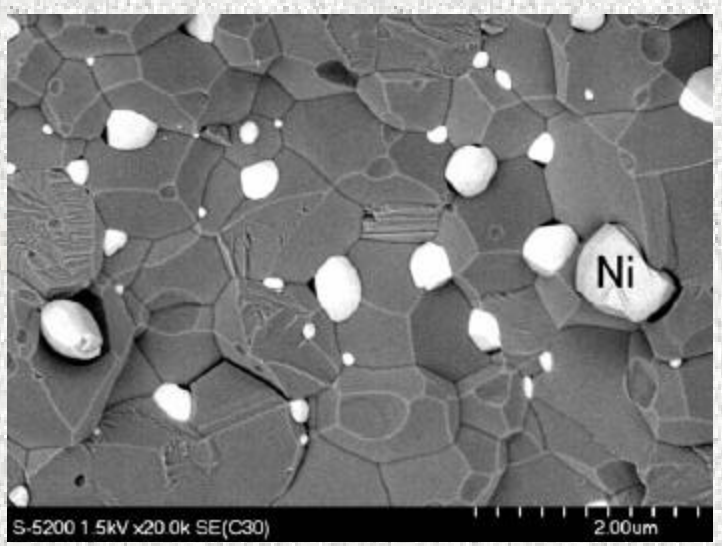
S-5200



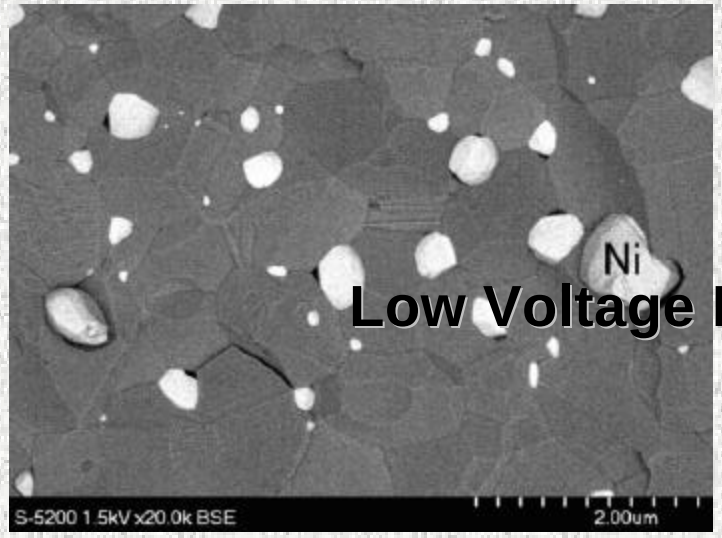
Pure SE (SE)

Alumina / Nickel Composite

Vacc. : 1.5kV Mag. : x20k

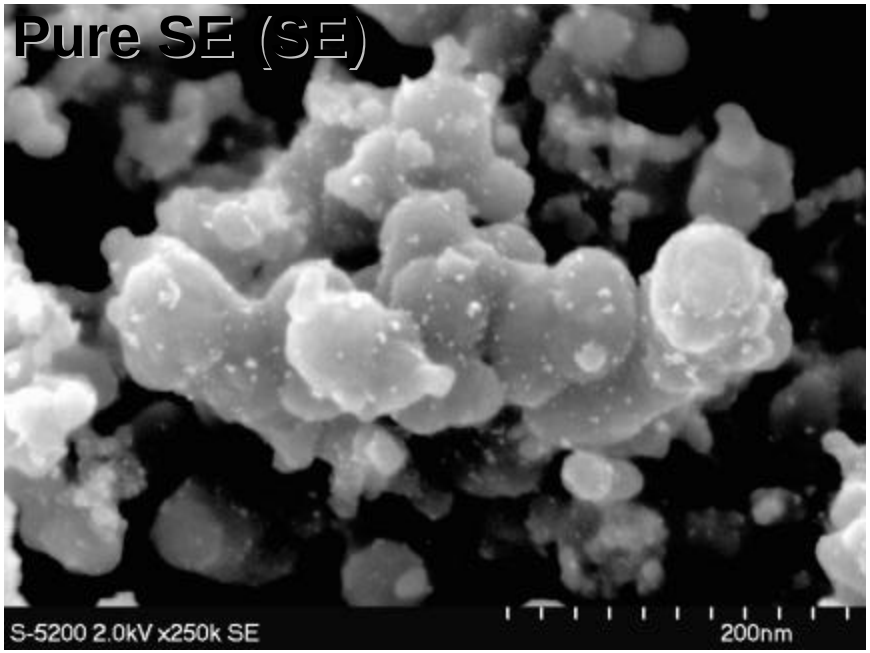


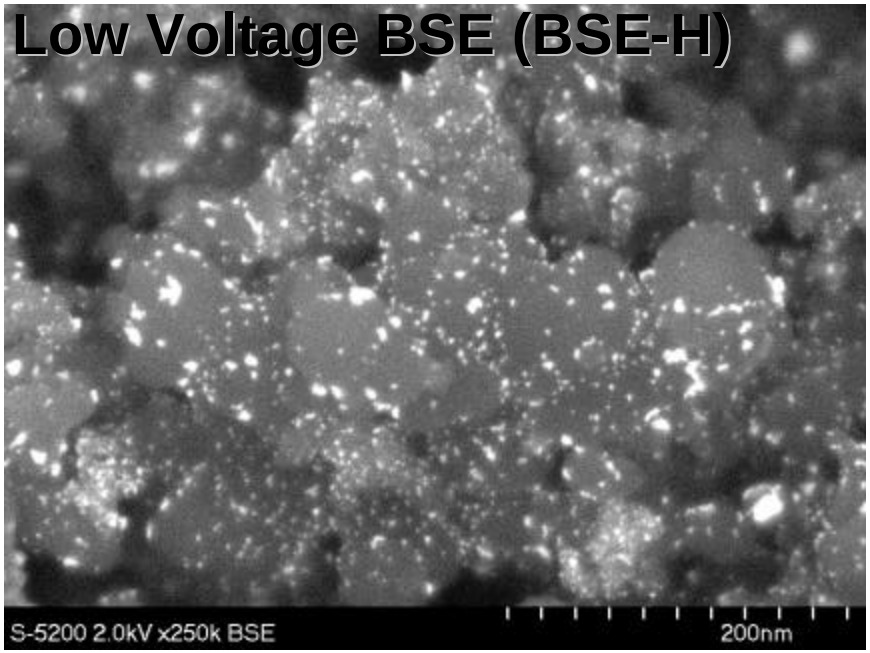
Composite Rich (SE+BSE-L)

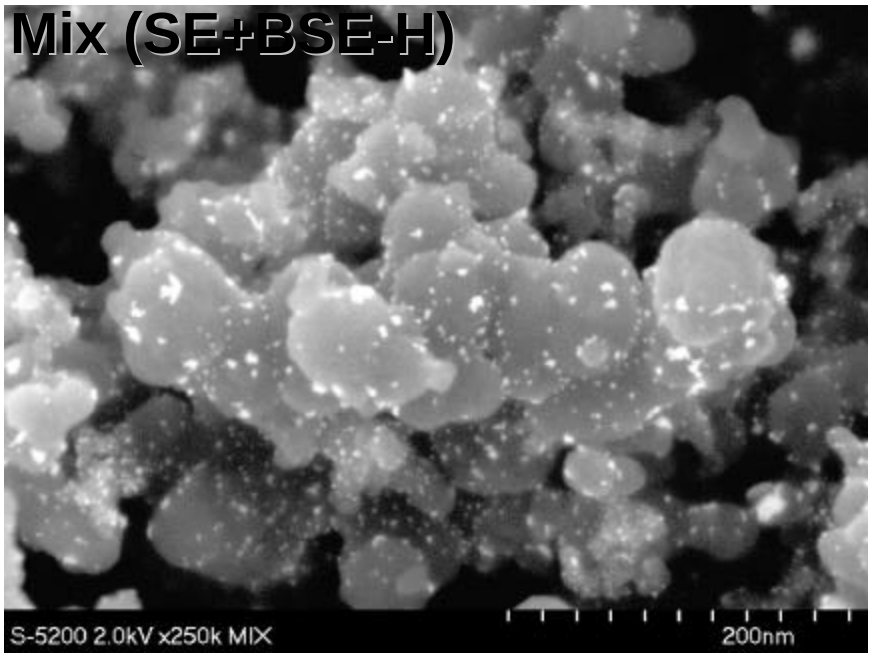


Low Voltage BSE (BSE-H)

Sample courtesy of Associate Prof.. T. Sekino,
ISIR, Osaka Univ.







Catalyzer

Vacc. : 2kV
Mag. : x250k

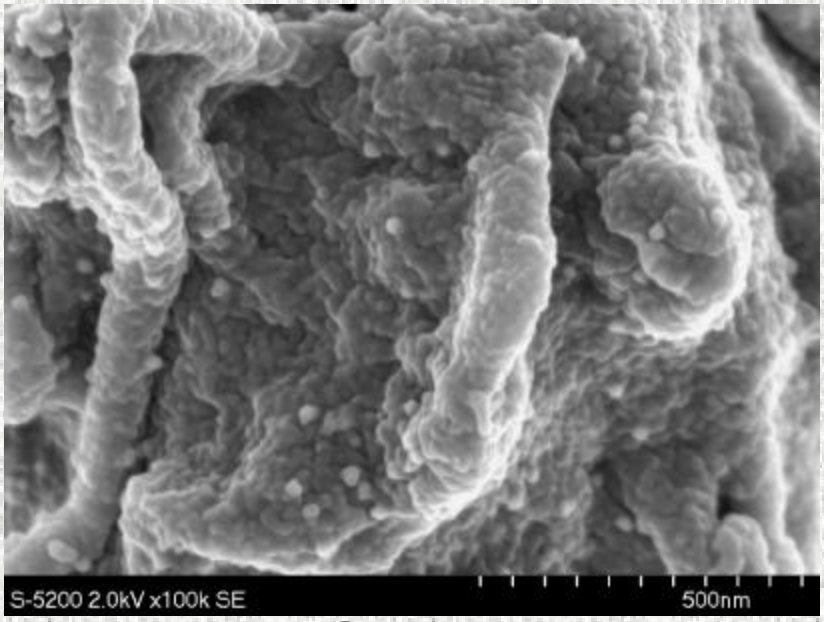
Life Science Applications

S-5200

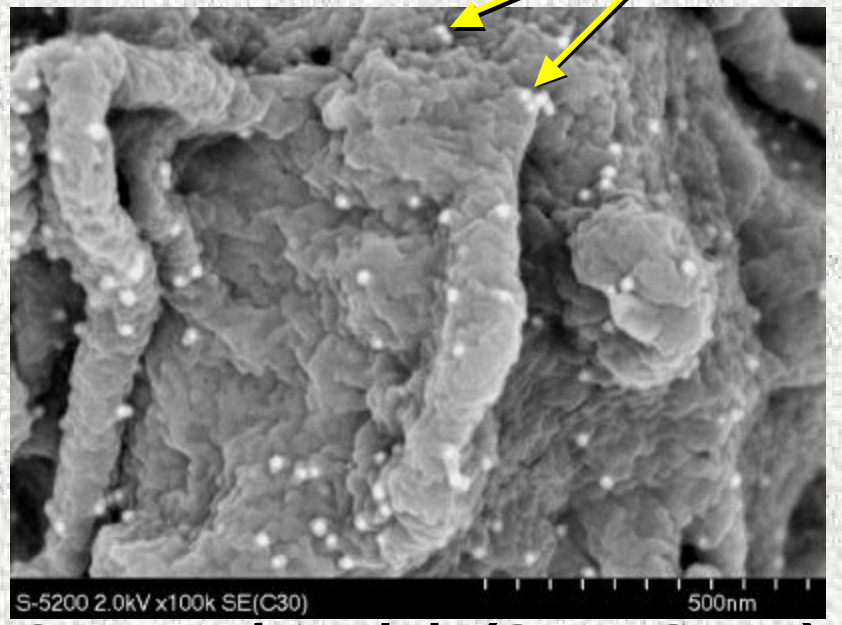
Human Blood Platelet
(activated and labeled)

Vacc. : 2kV Mag. : x20k, 100k

10nm
Colloidal Gold



Pure SE



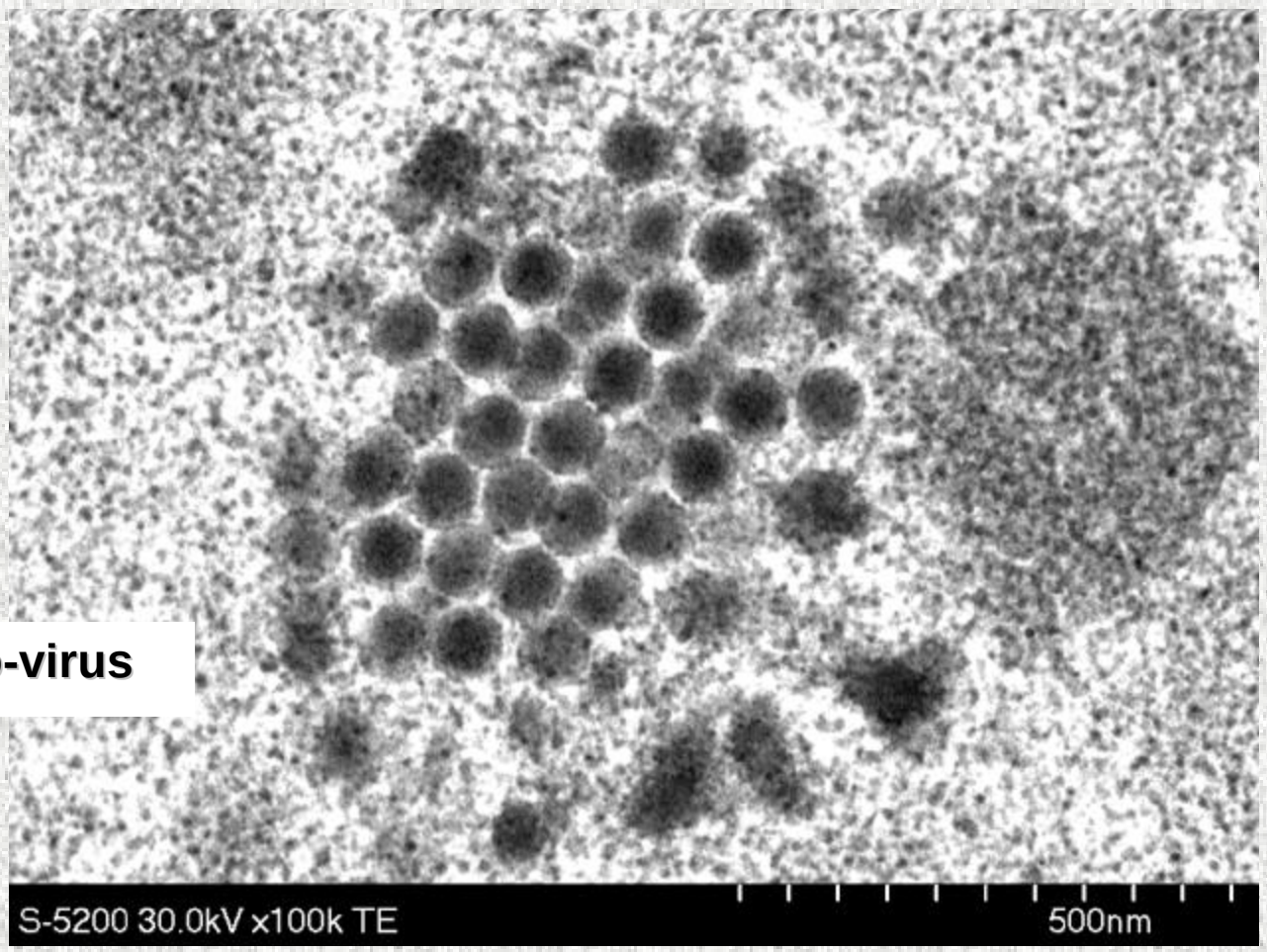
Composite Rich (SE+BSE-L)

Courtesy of Dr. H. Suzuki, Tokyo Met. Inst. Med. Sci.

Life Science Applications

S-5200

Adeno-virus



Mode : STEM(BF) Vacc. : 30kV Mag. : 100k

Courtesy of Dr. S. Fukuda, Faculty of Medicine, Univ. of Tokyo

Hitachi S-5200 features:

S-5200

- **worldbest resolution performance**
  - 0.5nm @ 30kV and 1.8nm at 1kV
- **magnification up to 2.000.000x**
  - Due to the excellent mechanical stability, allowing 5Hz floor vibrations of 10µmp-p
- **Unique Through-The-Lens (TTL) detection system**
  - With ExB filter for SE and flexible control of Z-contrast
- **Chem. Analysis of nanostructures**
  - With EDX and 2nm @ 2kV resolution of TTL BSE detector
- **Complementary information of TEM samples**
  - With optional bright and dark field STEM detector