SEM Imaging

- Magnification and Deflection System

- Focussing (contamination dots)

- Imaging

Motivation

SEMicroscopy

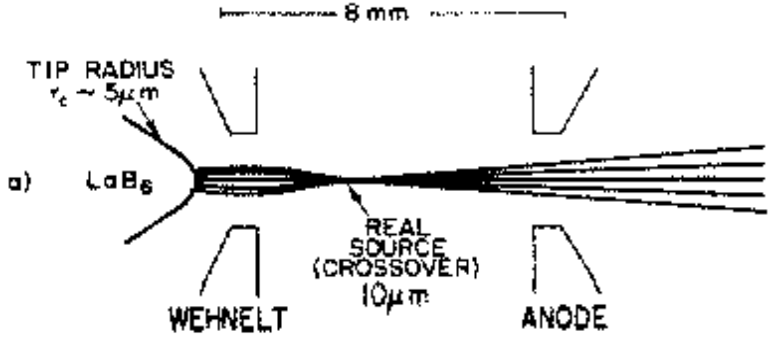
To be good in e-beam lithography

means to be good in SEM imaging.

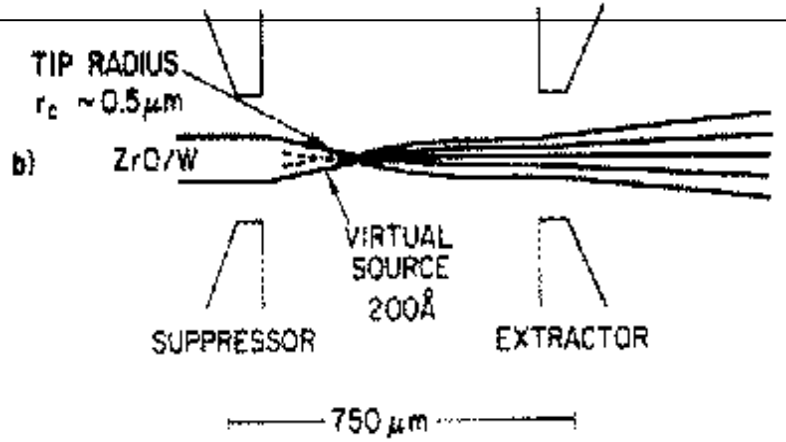
Tip Geometry & Crossover

SEMicroscopy

a) LaB_6 gun



b) thermal field emission



(Gersley, J. Appl. Phys. 65 (3), 914 (1989))

Filament Types

source type	brightness [A/cm²/sr]	source size	energy spread [eV]	vacuum [torr]
tungsten thermionic	~10^5	25µm	2-3	10^{-6}
LaB_6 thermionic	~10^6	10µm	2-3	10^{-8}
thermal FE (Schottky)	~10^8	20nm	0.9	10^{-9}
cold FE	~10^9	5nm	0.22	10^{-10}

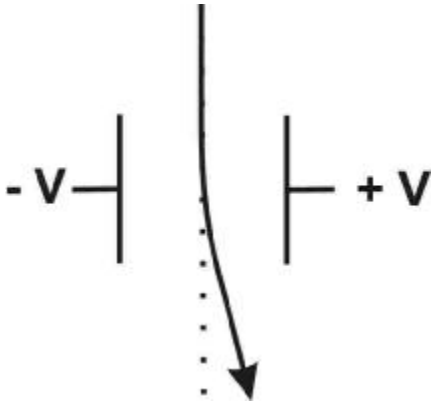
SPIE HANDBOOK OF MICROLITHOGRAPHY, MICROMACHINING AND MICROFABRICATION Volume 1: Microlithography, Chapter 2.2

SEMicroscopy

Beam deflection (E-static/magnetic)

Either magnetic or electrostatic fields can be used to focus electrons just as glass lenses are used to focus rays of light.

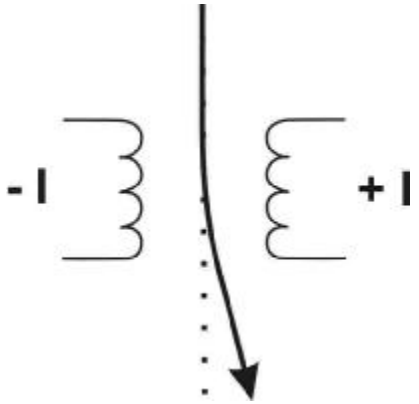
Electro-static



Fast deflection

$$F = q \cdot (E + v \times B)$$

Electro-magnetic



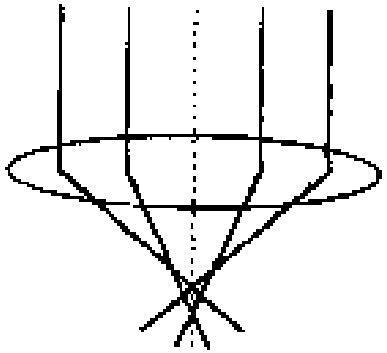
EM lenses more simple

SEMicroscopy

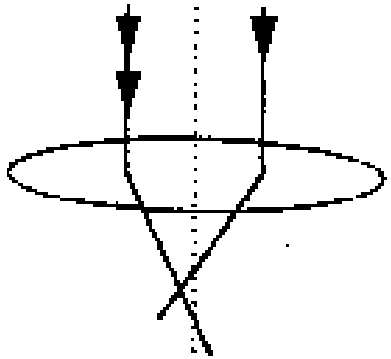
Beam deflection (E-static/magnetic)

Electron lenses have very poor performance (spherical and chromatic aberrations) compared to light lenses; thus electrons must be kept very close to the axis - small a

Spherical aberration



Chromatic aberration



Beam Deflection E-static or B?

SEMicroscopy

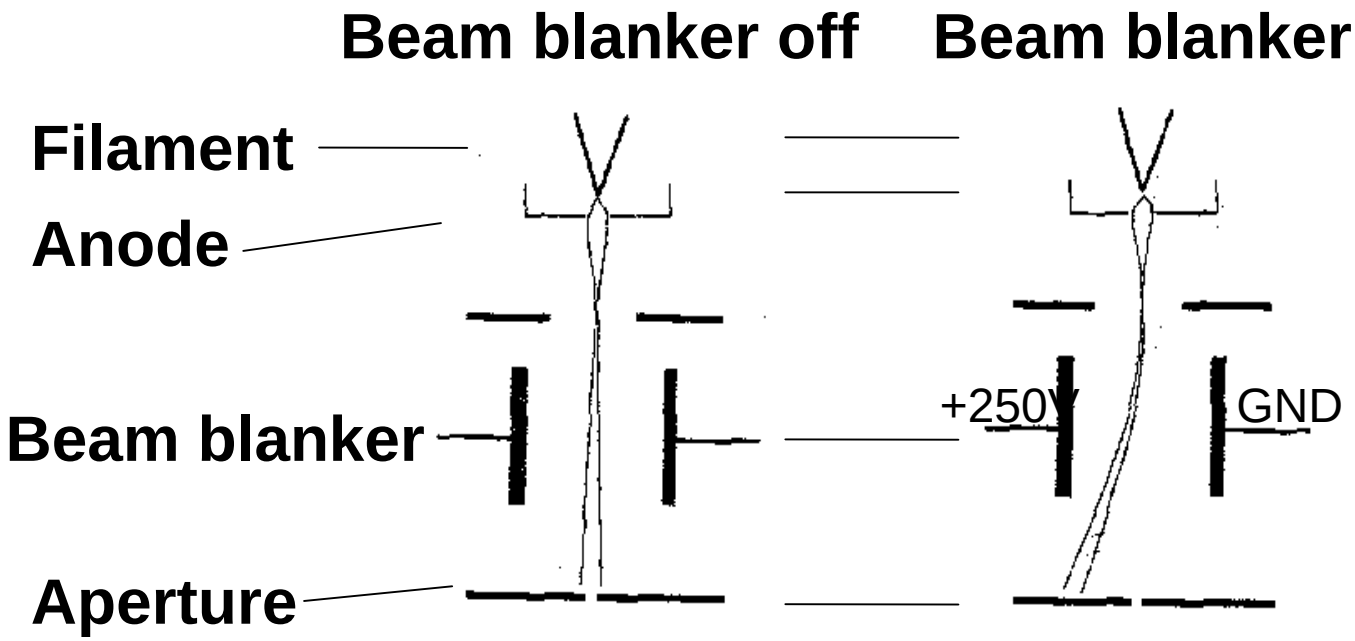
Magnetic deflection

- **lower aberrations (as with electrostatic lenses (= condensor in gun))**
- **but max. frequency is limited by the coil resonances to ~10 MHz.**
- **max. angle limited by off-axis aberrations to about 1 degree**
- **Trade off between resolution and field size**

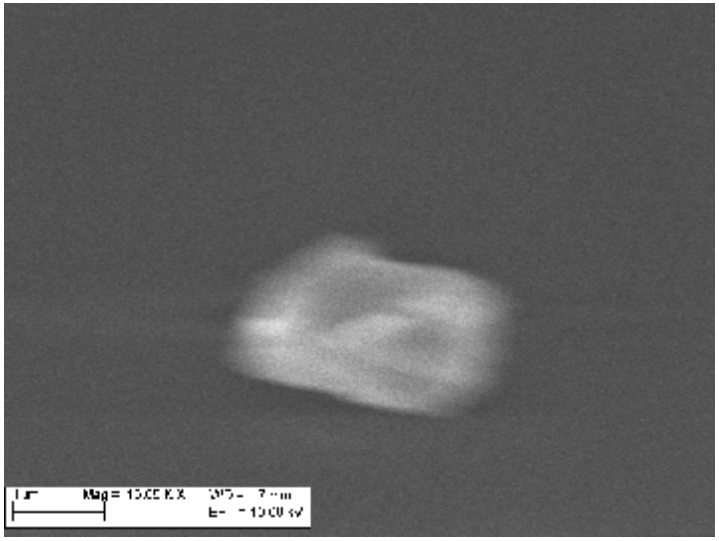
on-axis aberrations increase with increasing working distance Û **deflection angle and thus off-axis aberrations decrease with increasing working distance**

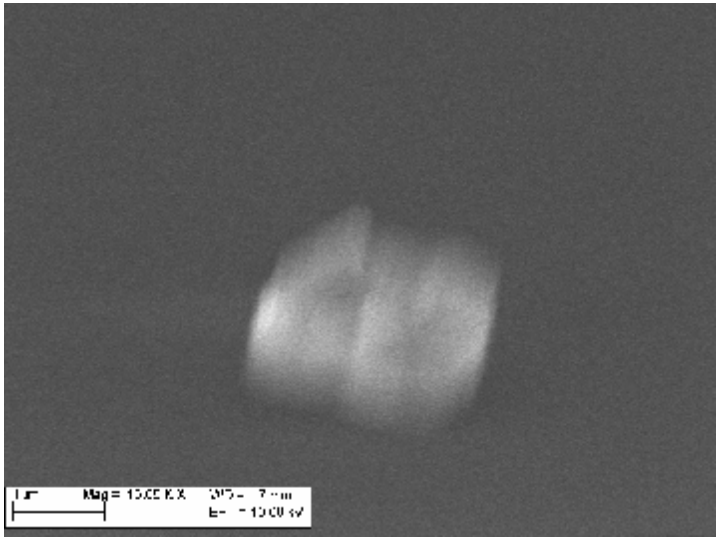
Þ **Compromise field size is much smaller than most chips!**

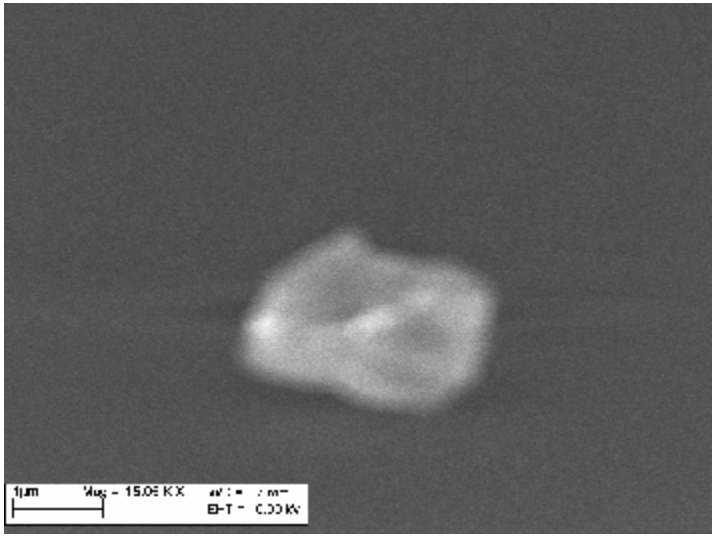
Beam Blanker

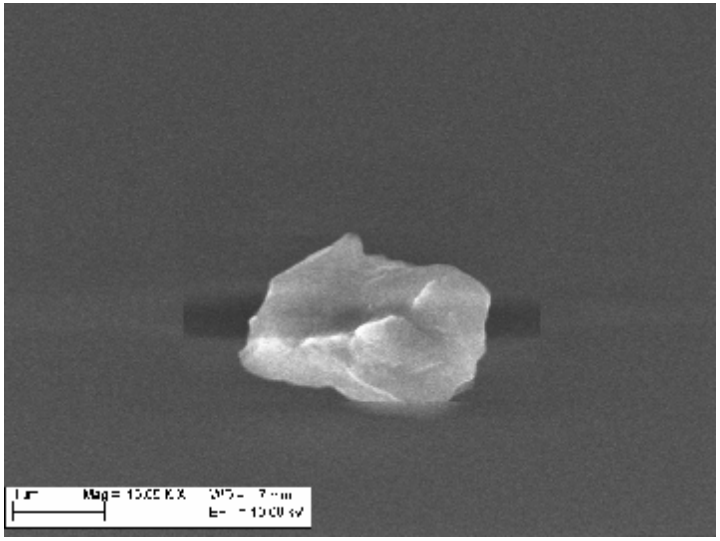


Focus / Stigmation Correction









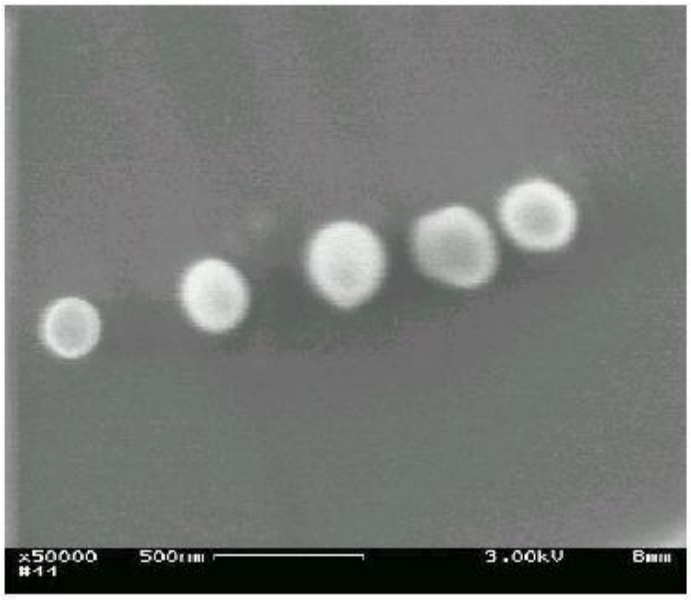
SEMicroscopy

Raith

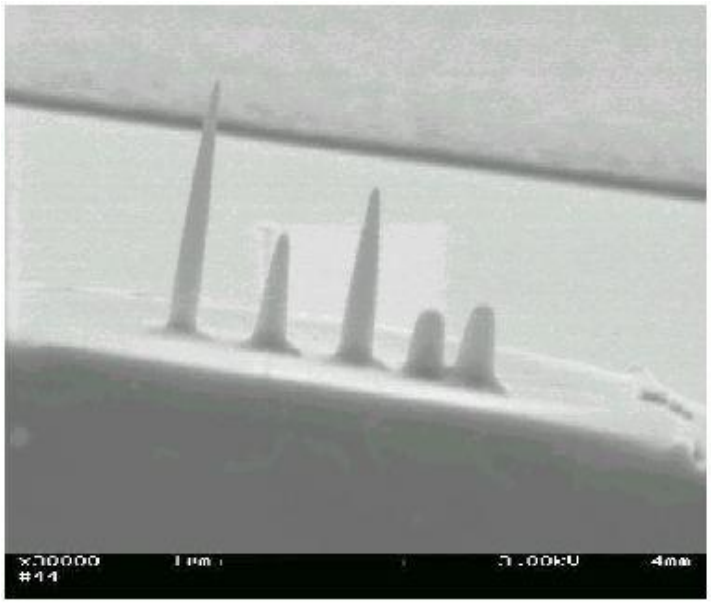
Focussing - Contamination Dots

SEMicroscopy

top view

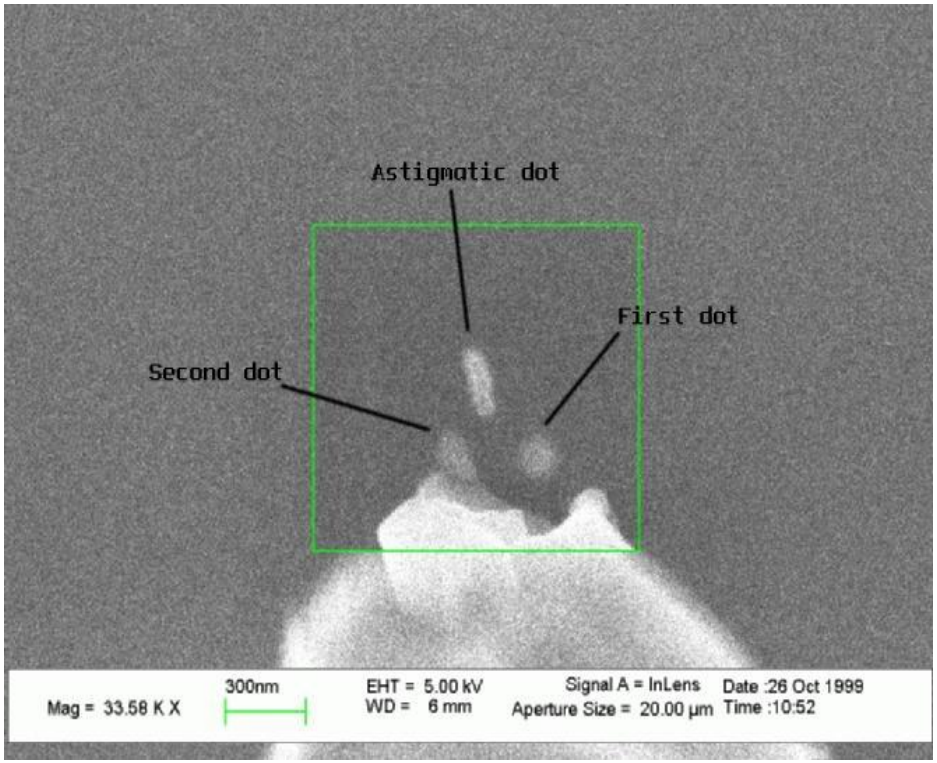


side view



(Images taken during the acceptance test of Raith 200 at the University of Neuchâtel (Switzerland) 4/98)

Focussing = WD and Stigmation



(Image taken at KTH Stockholm (Sweden), see
http://www.nanophys.kth.se/nanophys/facilities/nfl/sem-ebeam.htm)

Influence of Acceleration Voltage

Low (short penetration depth)

+ Clear surface structures
+ Less damage
+ Less charge up
+ Less edge effect
– Lower resolution

High (large penetration depth)

+ Higher resolution
– Unclear surface structures
– More edge effects
– More sample damage (heating)

(A guide to Scanning Microscope Observation, Jeol web page 1999)

Influence of Beam Current-Aperture

Low (small aperture)

+ Higher resolution
+ Less damage (heating)
+ Larger depth of focus
– Grainy image

High (large aperture)

+ Smooth image
+ Good signal-to-noise
– Deteriorated resolution
– More damage (heating)
– Lower resolution
– Smaller depth of focus

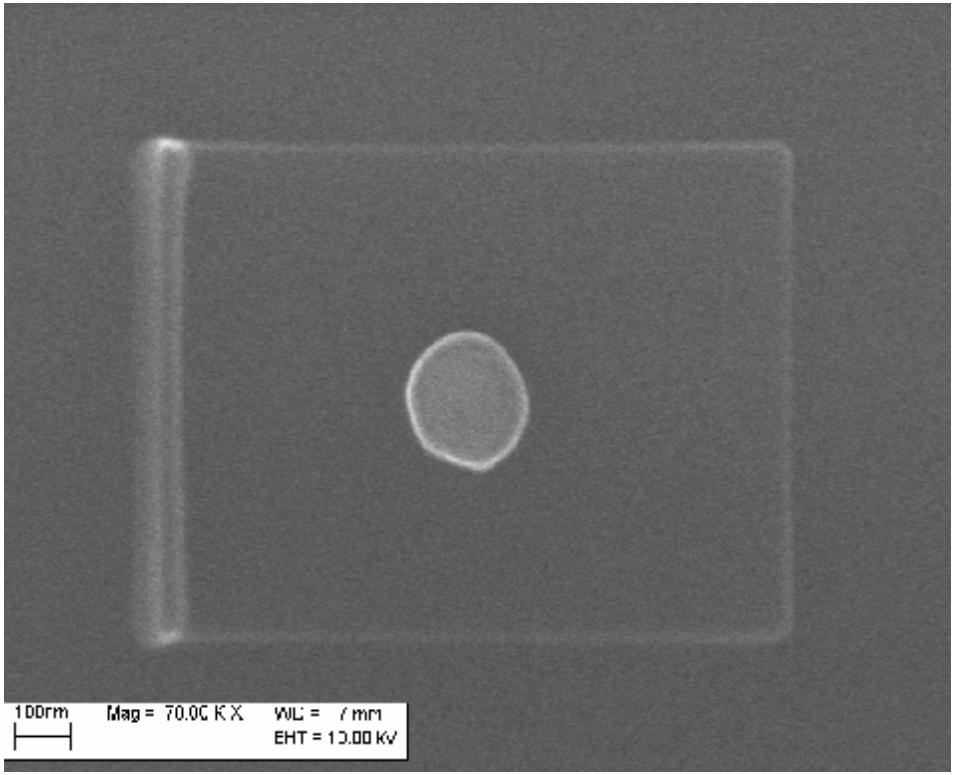
(A guide to Scanning Microscope Observation, Jeol web page 1999)

Influence of Working Distance

Small	Large
+ Higher resolution	+ Larger depth of focus
– Smaller depth of focus	– Lower resolution

(A guide to Scanning Microscope Observation, Jeol web page 1999)

Important rule for SEM imaging



Take always the low magnification images first!!!