Electron Beam Lithography at the Center for Nanotechnology

Electron Beam Lithography

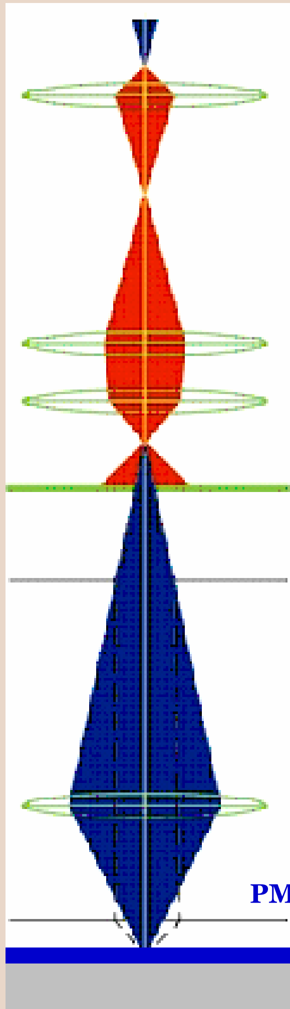
- **Pattern Writing system capable of producing fine linewidths ~ 20nm.**
- **Scanning raster of E beam over resist coated substrate.**
- **First developed in 1960s using existing SEM technology.**

Standard Lithography Uses

- Maskmaking – Chrome on quartz for high resolution optical lithography (1-2μm)
- Direct Writing for fine structure IC design (<1μm)
- Research –
  - Fine structure linewidths
  - Contacts for Nanowires/rods
  - Small feature array patterns

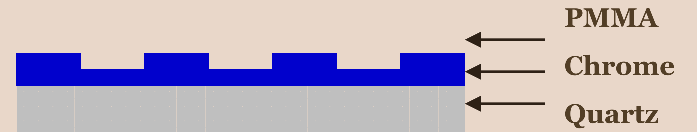
E beam lithography

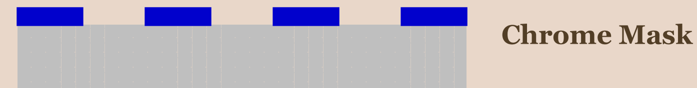
E-Beam



PMMA

Microfabrication



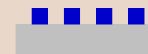


Chrome Mask

> 1 micron

Nanofabrication

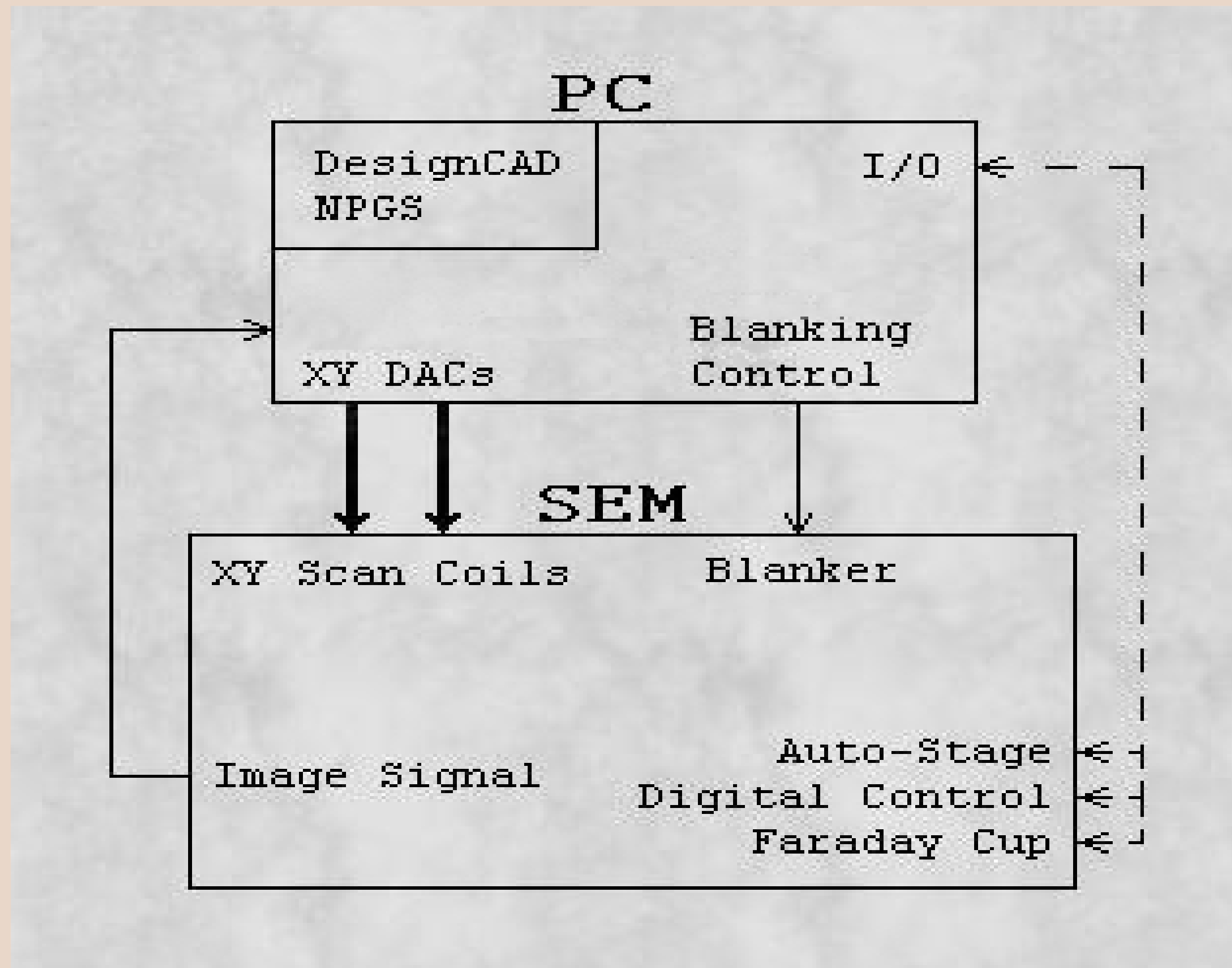
>20 nm



System Interface

- FEI Sirion Schottky Field Emission SEM:
  - Lower saturation current
  - Stable Beam
- DesignCAD vector drawing program
- Beam Blanking System
- Nanometer Pattern Generating System (NPGS)

System Interface

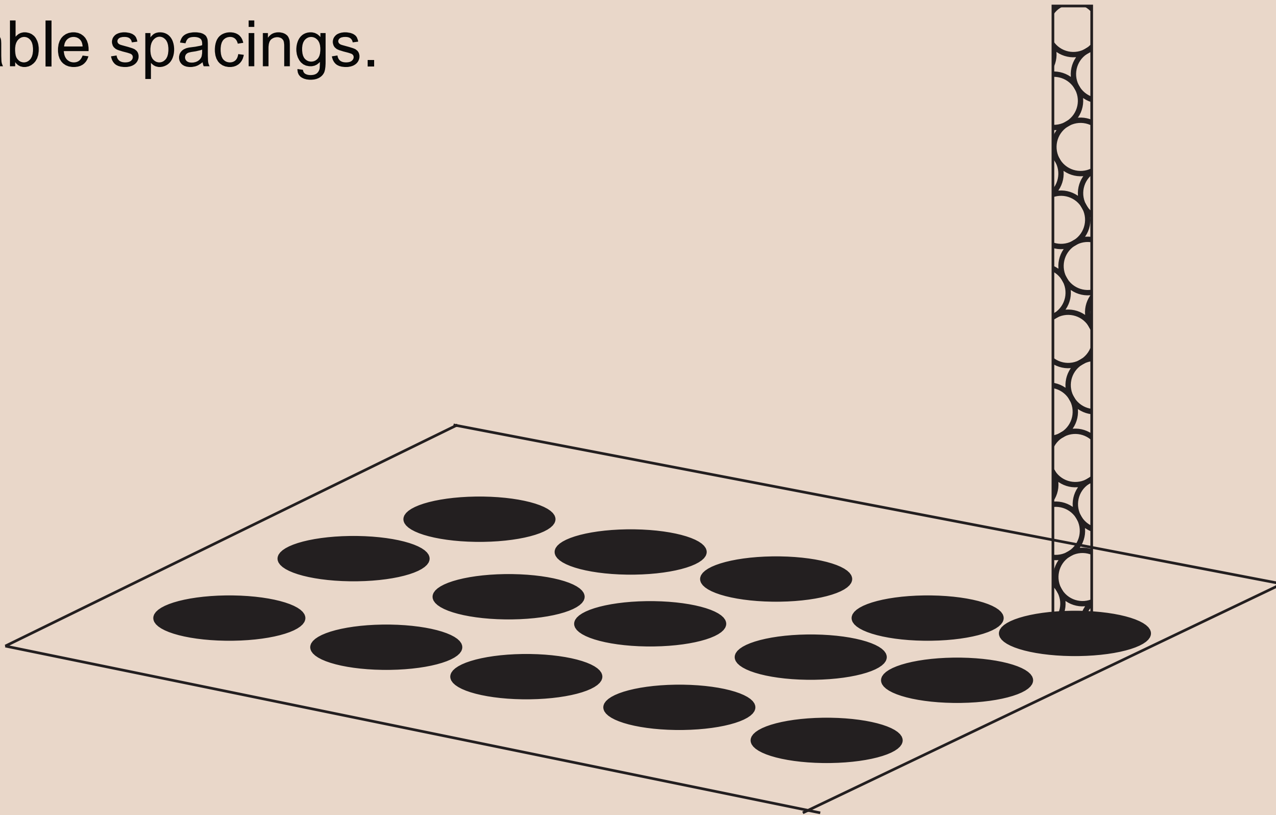


E beam writing breakdown

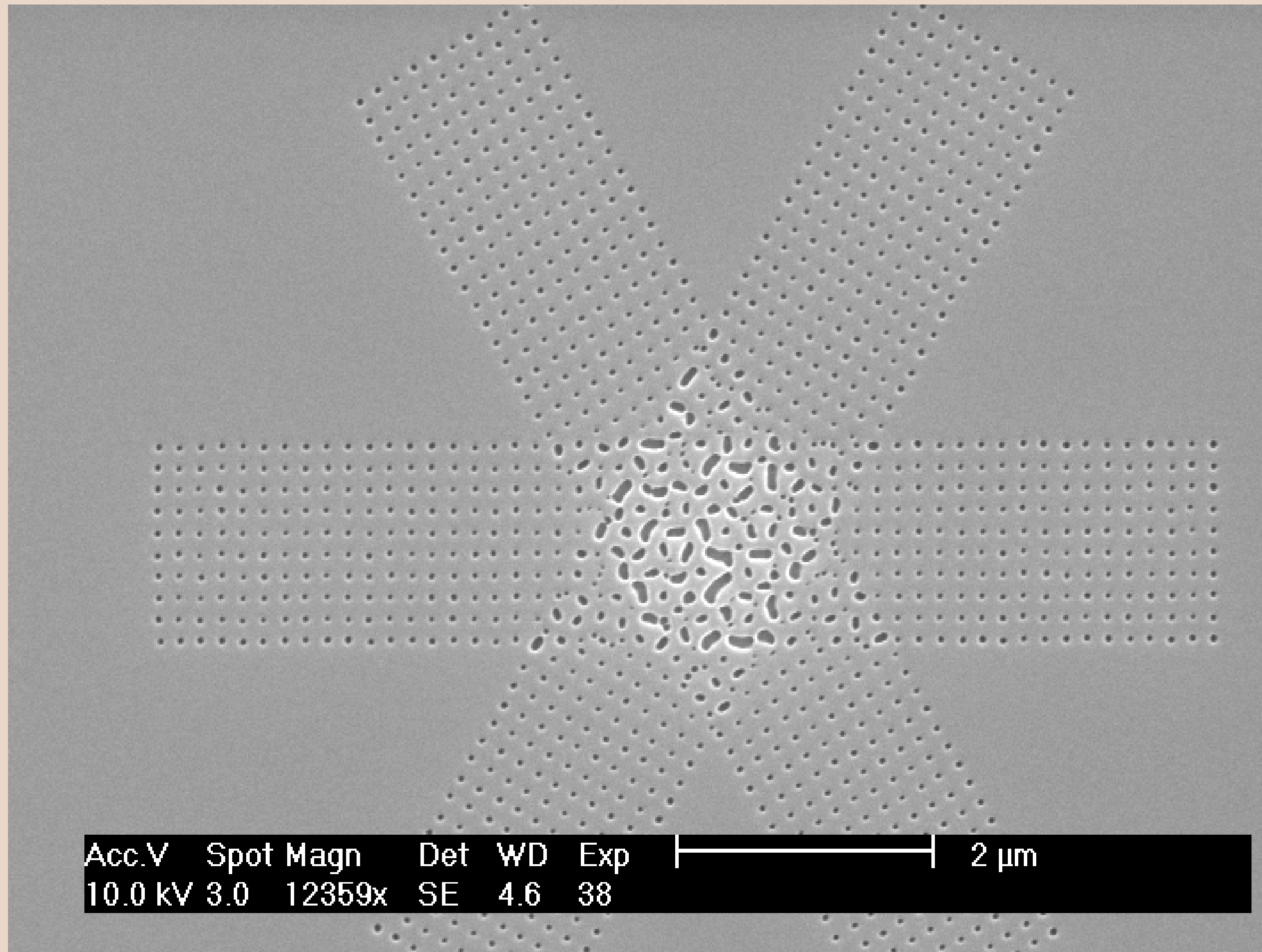
- Series of interconnected points or dots.
- Beam Blanked.
- Distance between dots.
- Exposure Time ~ Energy Dose.

E beam Exposure

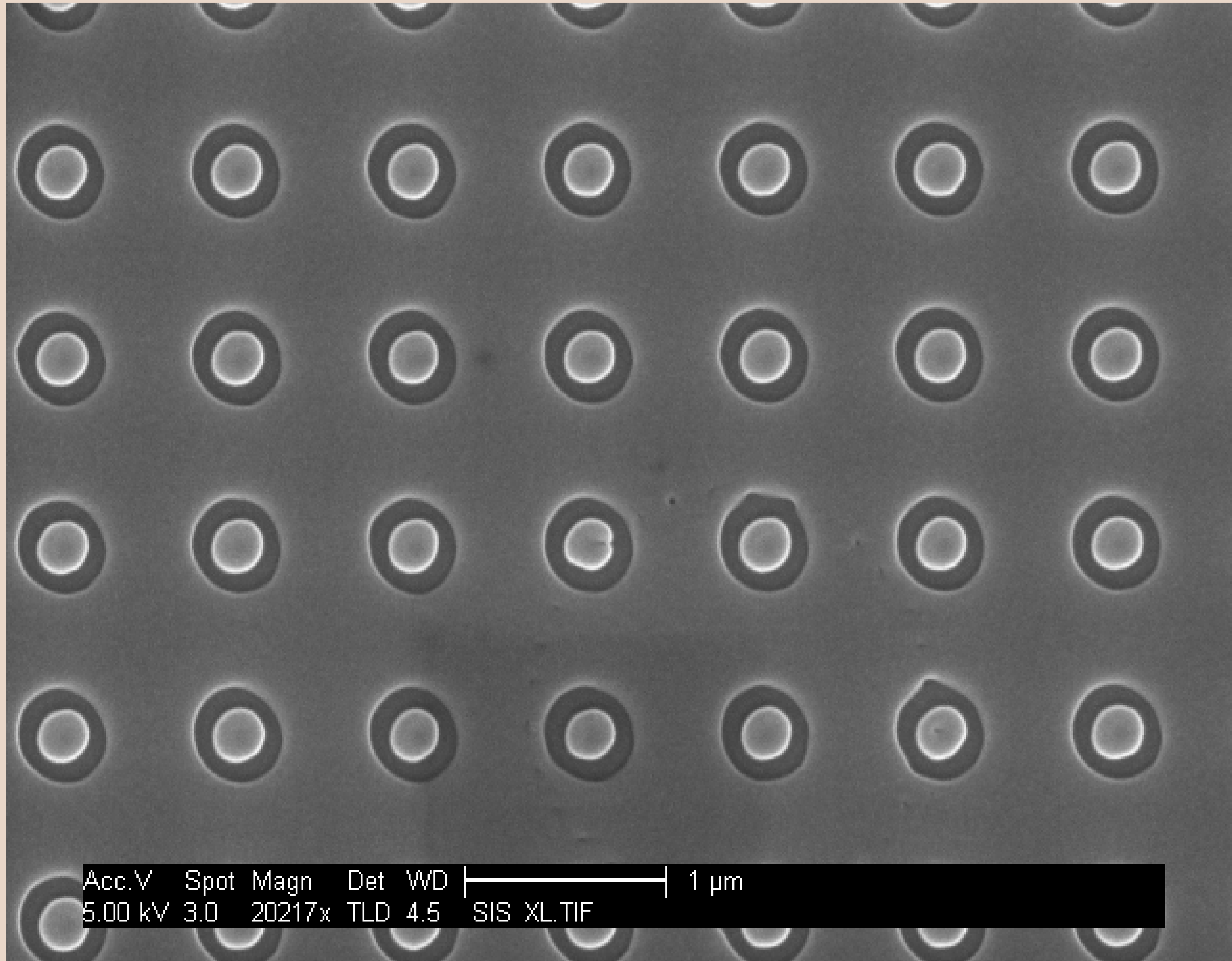
Pattern written as a series of interconnected dots with user adjustable spacings.



Polygon/Array of Dots



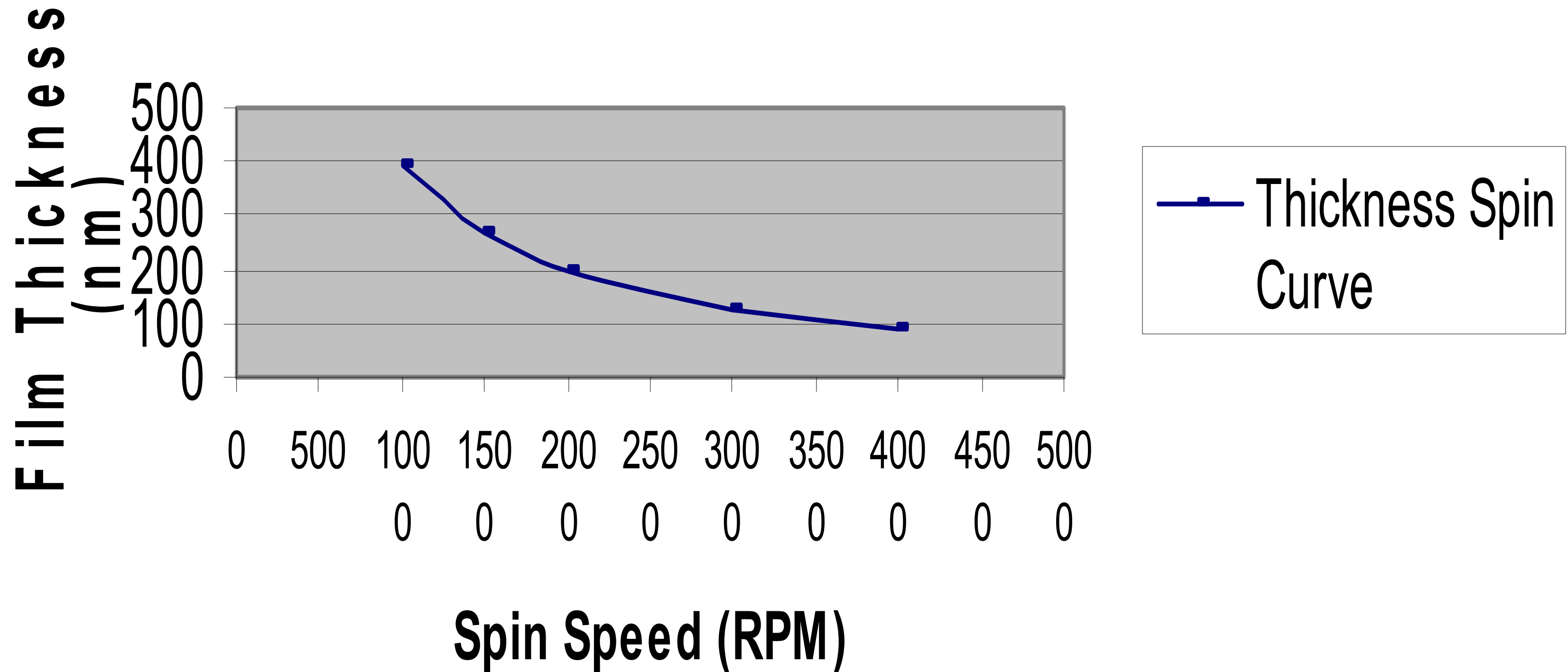
Multiple Pattern Arrays



Electron Beam Resist

- Standard E beam resist at NUF:
  - 950k PMMA (polymethyl methacrylate).
- High resolution (~20nm).
- Thickness dependent on Spin RPM.
- Flexible Aspect Ratios controlled by concentration.

Controllable Film Thickness



Sample Preparation

- NUF houses all necessary equipment for sample preparation and development :
  - 950k PMMA 1%, 3%, 6% in Anisole
  - Spin Coater
  - Pre/Postbake heat sources
  - Developer solution (IPA:MIBK 3:1)
  - Gold sputter coating

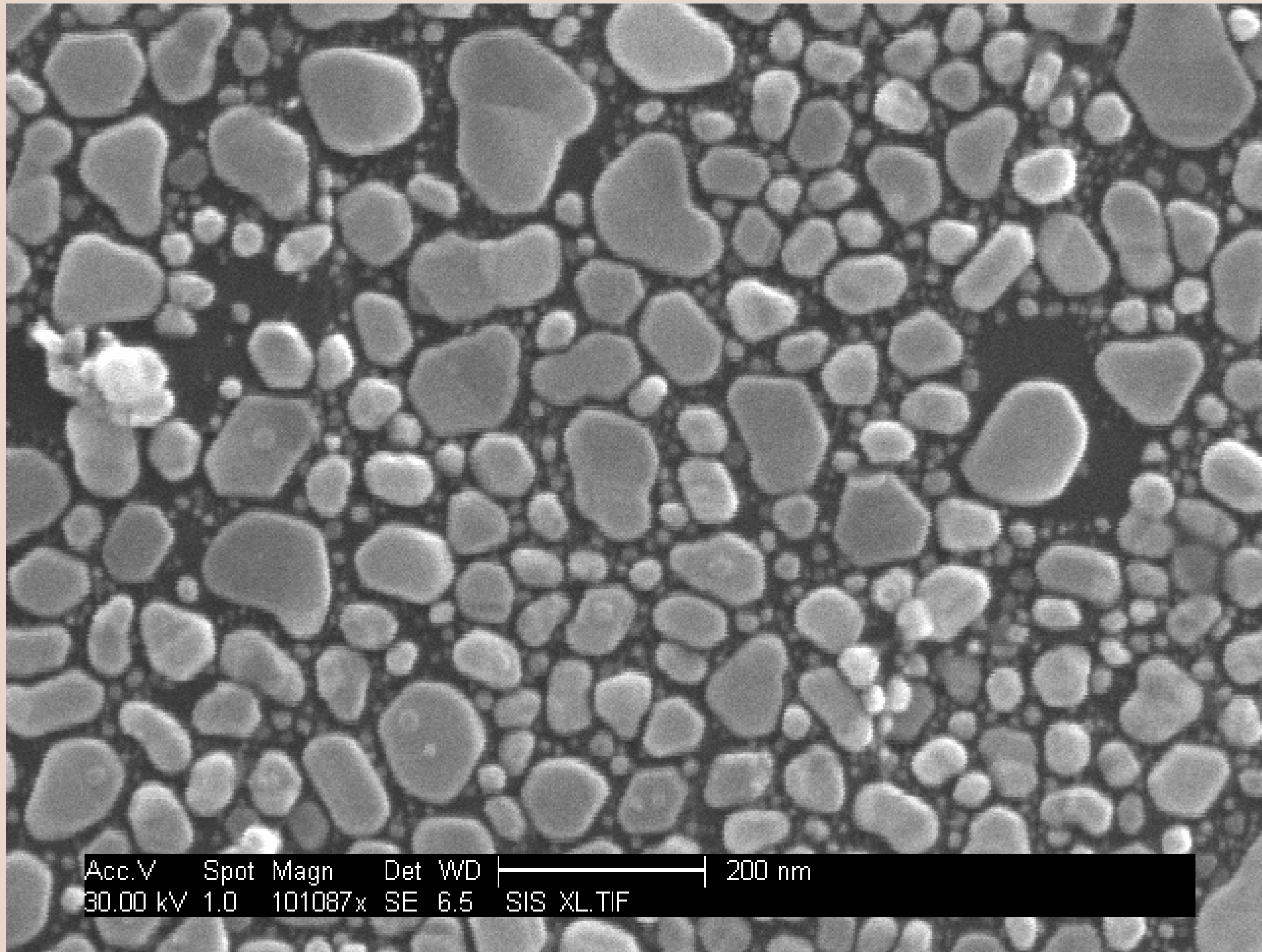
E beam Lithography Fundamentals

- Beam Optimization.
- Users must demonstrate proficiency in high resolution imaging on Au standard.
- E beam lithography system parameters:
  - 30 kV Accelerating Voltage
  - Spot size 1
  - Working Distance = 6.5mm
  - Measured Beam Current ~ 20pA

Beam Optimization

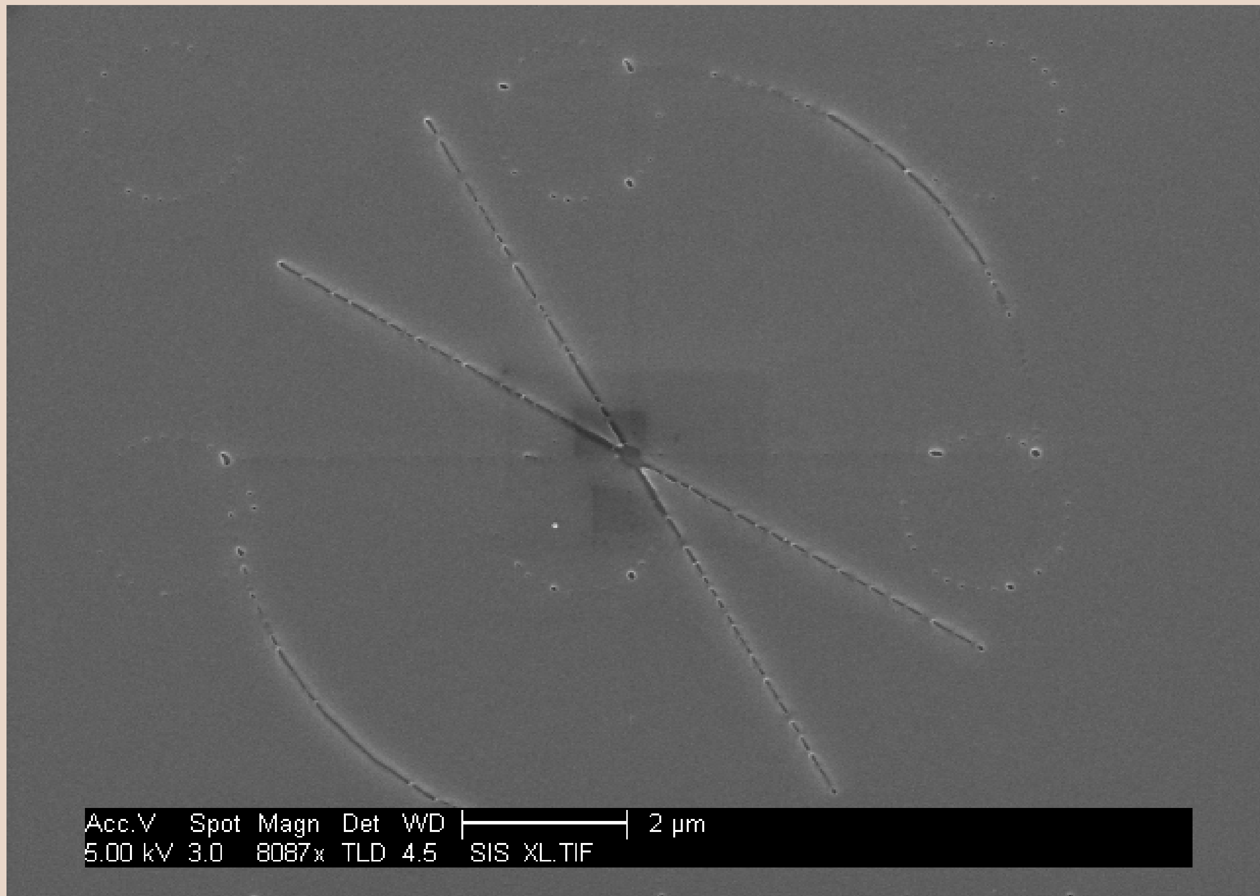
- Demonstrate high resolution imaging (>100000x) on Gold standard sample.
- Beam Optimization:
  - Lens Alignment
  - Stigmation

Gold Standard Sample



Beam Optimized?

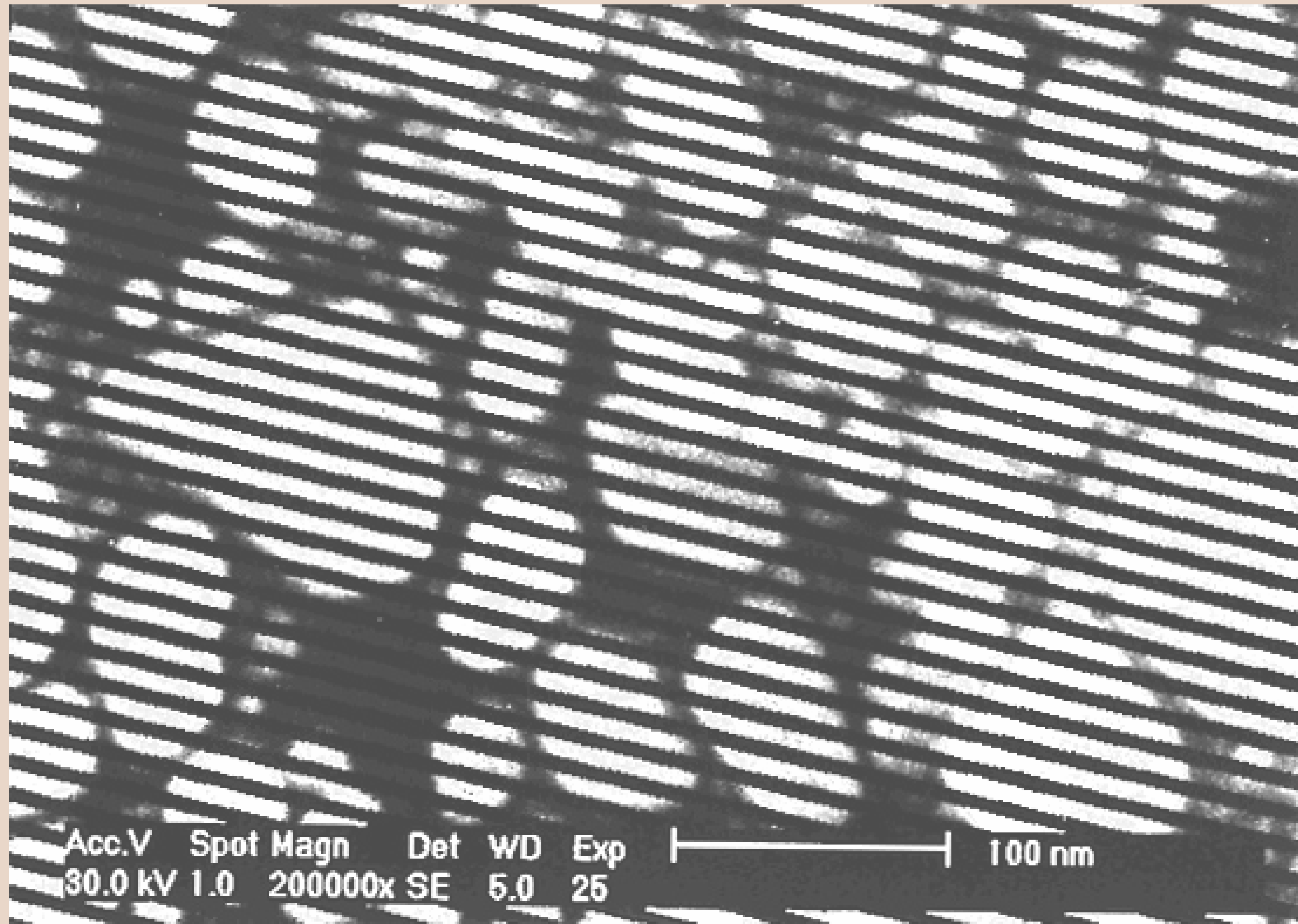
Improper Stigmation Adjustment



Beam Blanker

- 45 V applied to two parallel plates within beam path.
- Deflects beam, forcing the beam off axis.
- Beam position moves according to Center to Center distance as designated by the user.

Beam Blanker



From Design to Writing

- Patterns are created in DesignCAD vector drawing program.
- Patterns may be imported to the DesignCad environment (DWG, DXF, WMF) .
- Interface with SEM using Nanometer Pattern Generating System (NPGS).

NPGS

- Vector Writing Program
- User Specified Sweep Position
- Area Doses for filled Polygons
- Line Doses for high resolution line structures

NPGS Parameters

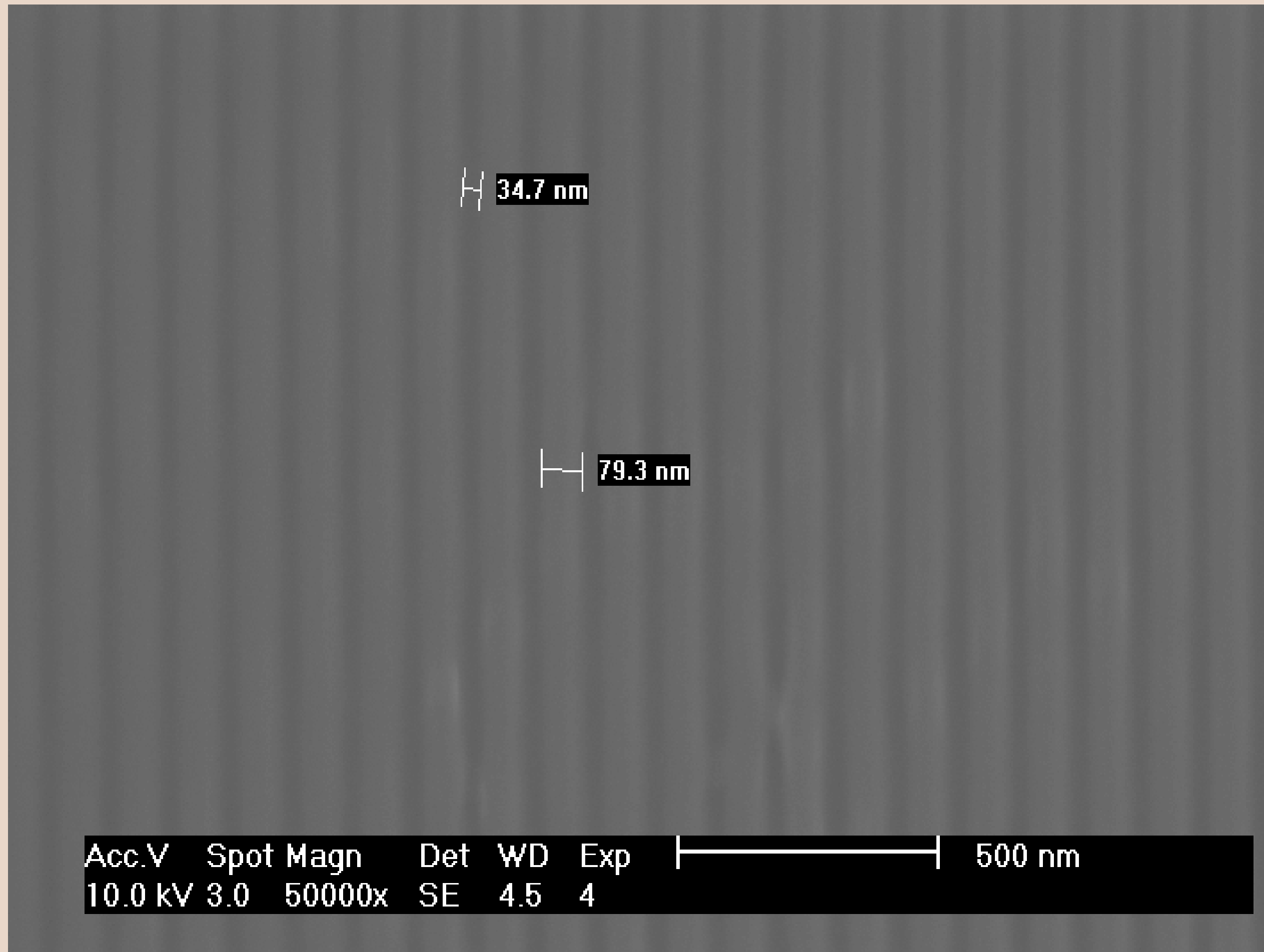
- User defined parameters:
  - Writing field magnification calculated by DesignCAD
  - Center to Center Distance
  - Measured Beam Current
  - Energy of Dose
  - Line Dose vs. Area Dose
    - Controls exposure time

NPGS

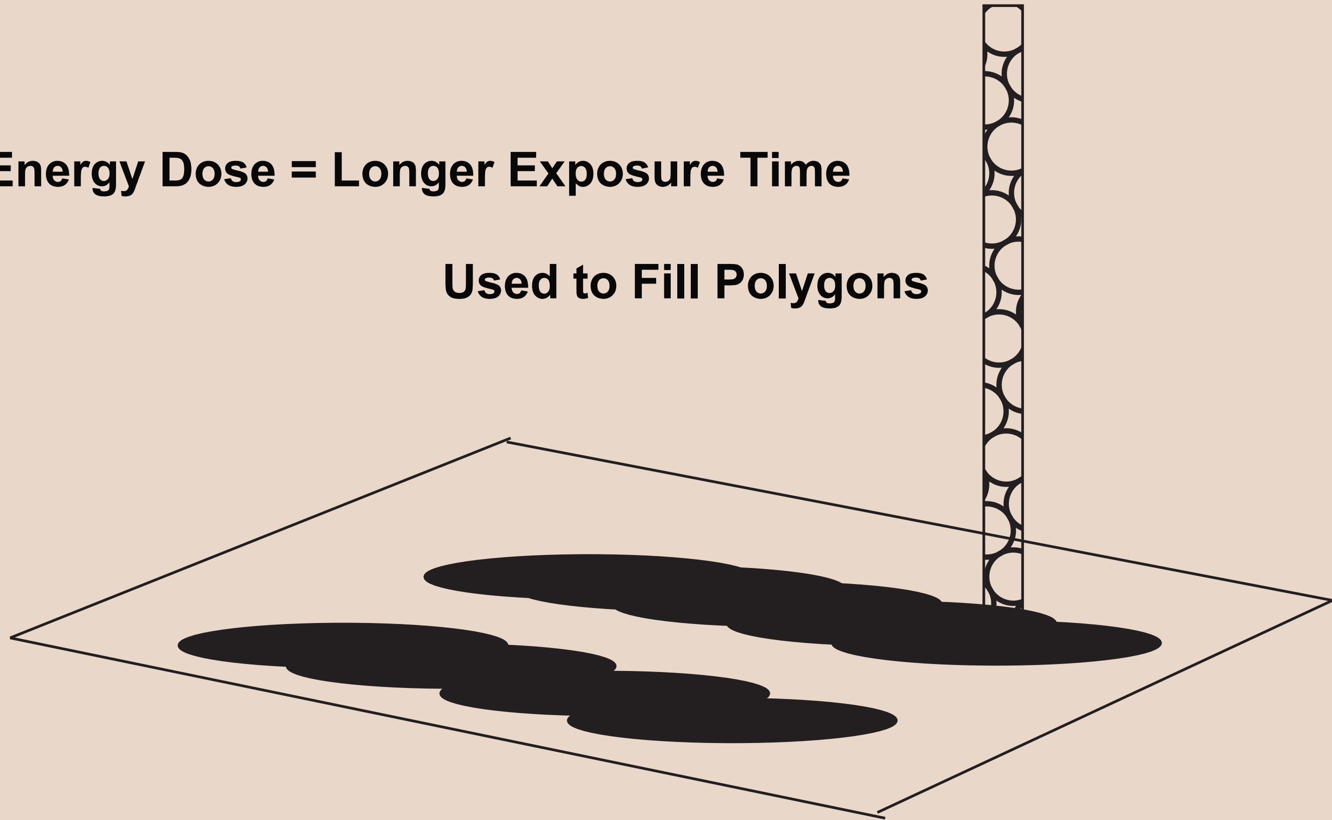
- Line Dose:
  - Use for small scale, fine featured structures
  - C->C spacing close ~100 Angstrom
  - Low Energy Dose ~ 1.5 nC/cm

- Area Dose:
  - Use for writing large scale
  - C->C spacing close ~ 100 Angstrom
  - High Energy Dose ~ 250 $\mu C/cm^2$

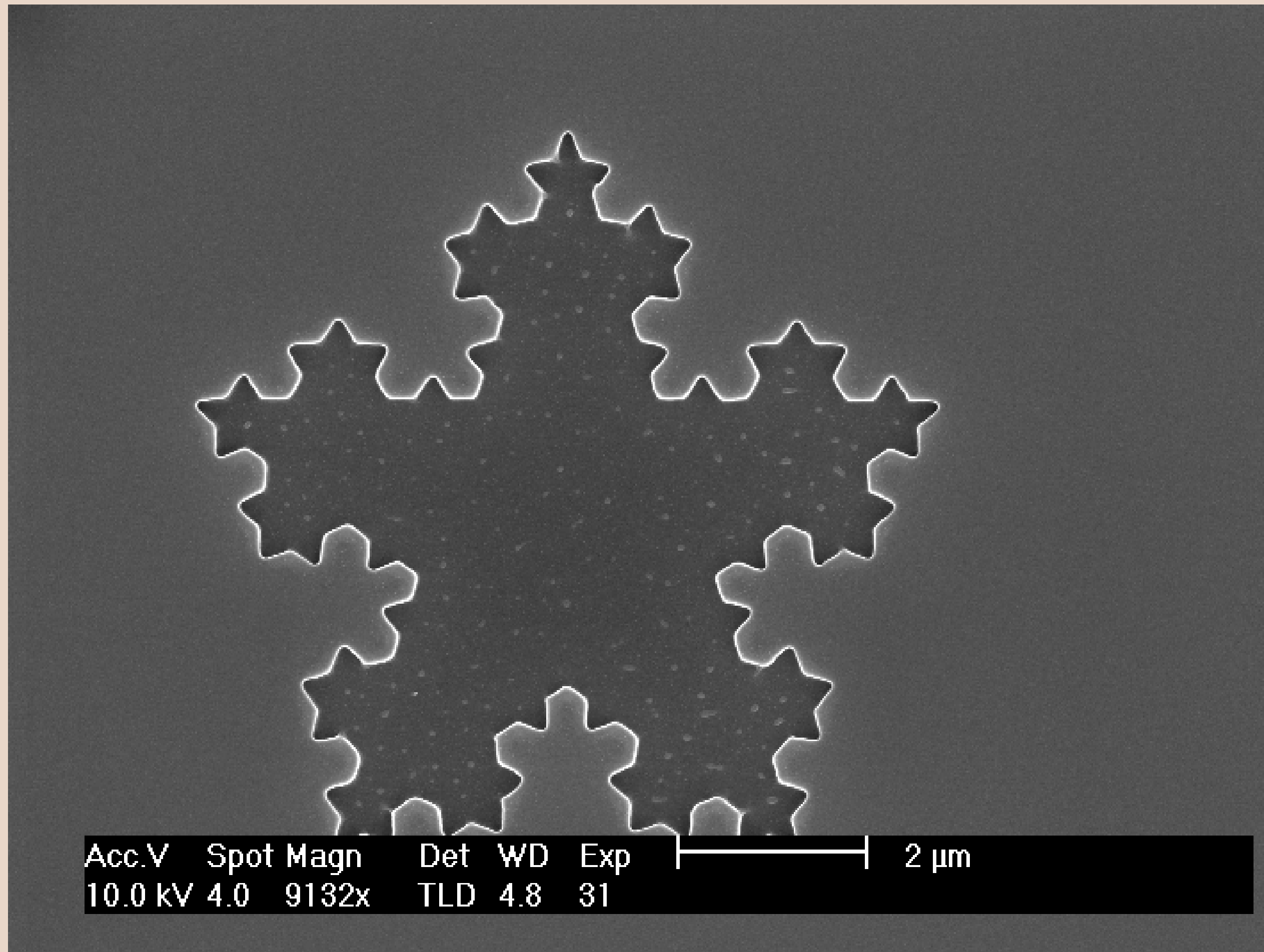
Fine Line Structure



Area Dose



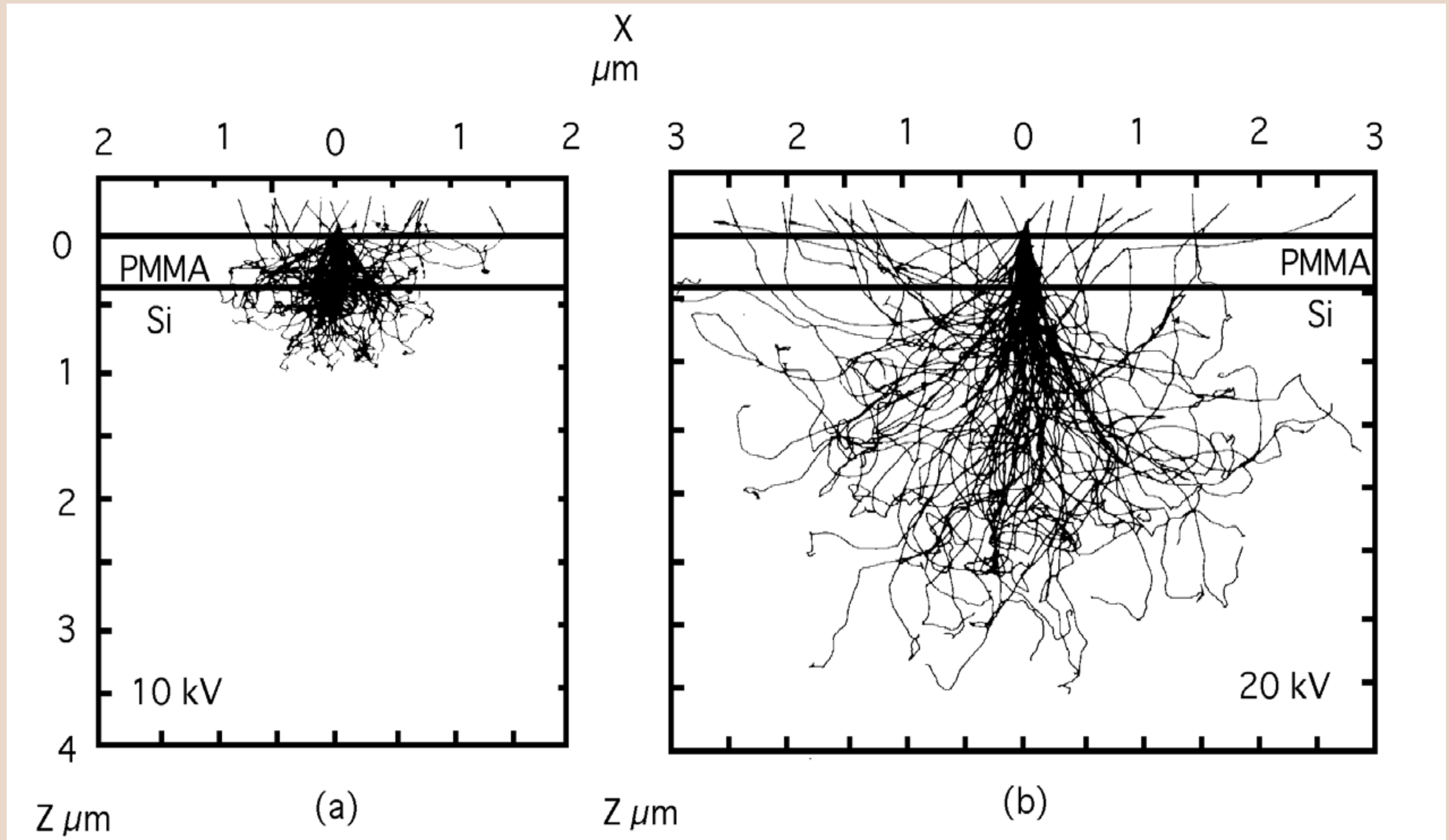
Filled Polygons



Resolution

- Contribution from Electron – Substrate Collisions
  - Forward Scattering
    - Collisions off resist
  - Backward Scattering
    - Collisions off substrate
    - Proximity Effect
  - Secondary Electrons
    - Dispersion of primary beam electrons
    - Main contribution to exposed resist

Resolution



Contributing electrons at different Beam Accelerating Voltages.

Proper Beam Optimization