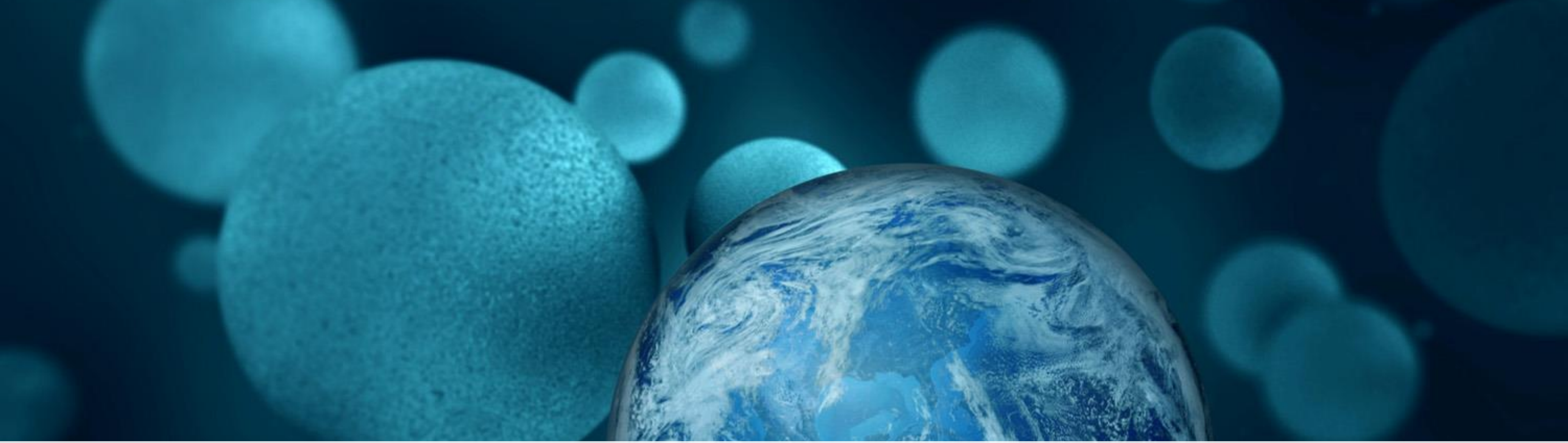


Thermo Fisher SCIENTIFIC

Scios
Gas Injection Systems

Module 5

GIS: Gas Injection System

The GIS or Gas Injection system is what enables the FIB to perform deposition and preferential milling operations.

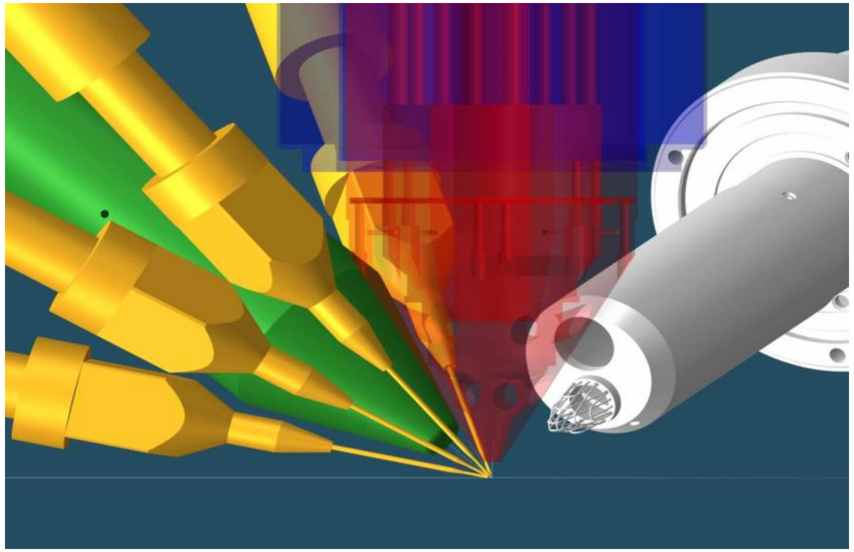
- Deposition chemistries, metal or insulator
- Etching chemistries, normally enhance one or more materials over another to give beneficial effects
- The effects of all chemistries can be further enhanced by adaptive or selective area patterning which is available on all platforms
- There are over 26 chemistries available, but not all are on every tool. The basic set is listed in next slide.

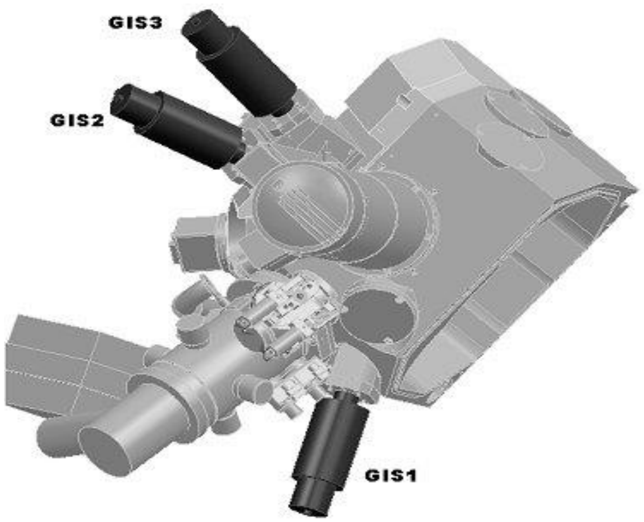
Most used Gases

- **Deposition Gases**
  - Platinum (methyl-cyclopentadienyl) trimethyl platinum)
  - Tungsten (Tungsten Hexa-carbonyl)
  - Carbon (C10H8; naphtalene)
  - Insulator (TEOS=tetraethylorthosilicate)

- **Reactive Gases**
  - Iodine = EE
  - XeF2 = IEE
  - Selective Carbon Milling

GIS alignments point: Eucentric height

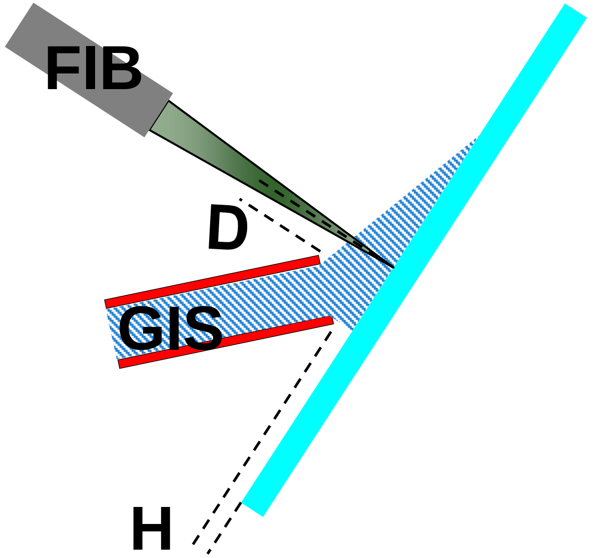




- Multi-needle approach enables rapid switching between gases
- Gas pressure doesn't have to be high when delivered close to sample – gas is concentrated where used
- No pressured gases

- **Deposition parameters:**

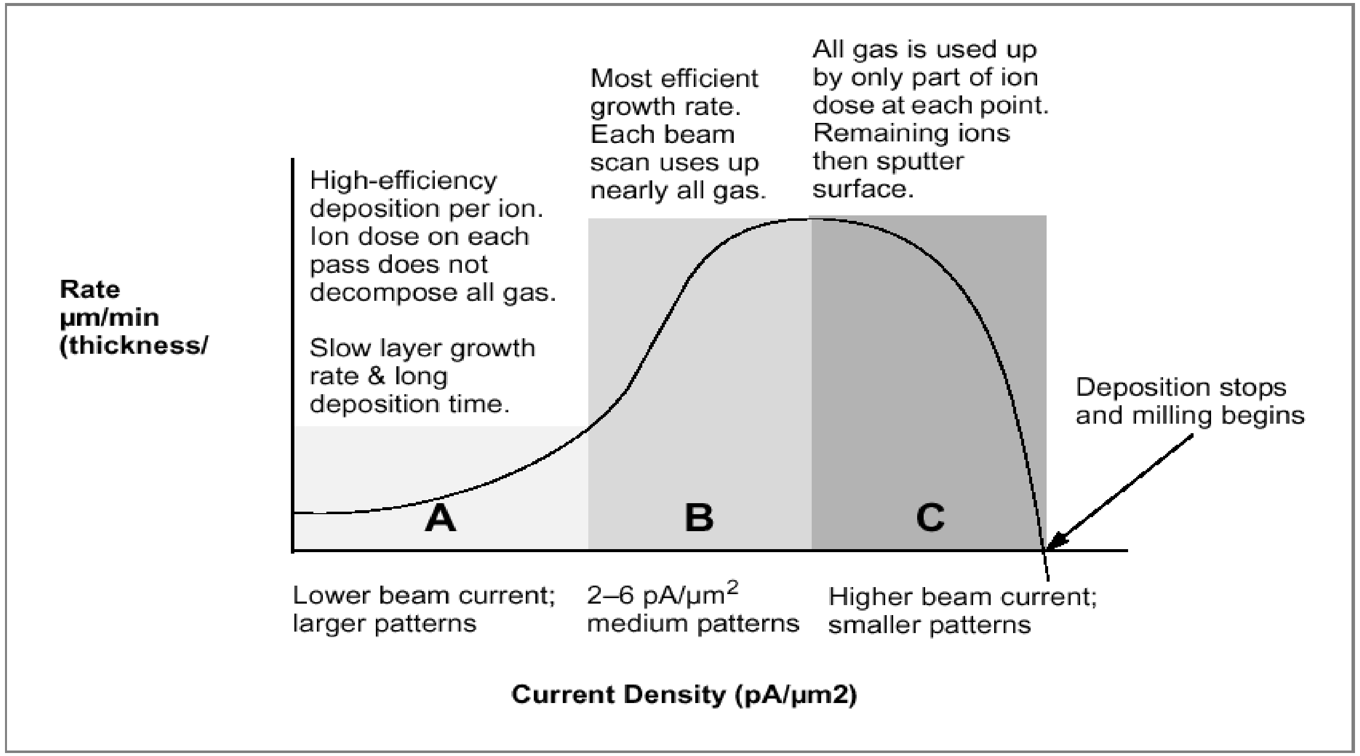
  - needle position (Height-H and Distance-D)
  - needle diameter
  - crucible temperature
  - beam current
  - scanned area and scan speed
    (dwell time and overlap);



- Deposition is a delicate balance between decomposing the adsorbed gas and sputtering the substrate.

GIS: deposition

- Platinum
- Tungsten
- Carbon
- Insulator
- These gases form non-volatile compounds
- Deposition is a delicate balance between decomposing the adsorbed gas and sputtering the substrate.



Pt-deposition rate vs. current density

GIS: beam current density for deposition

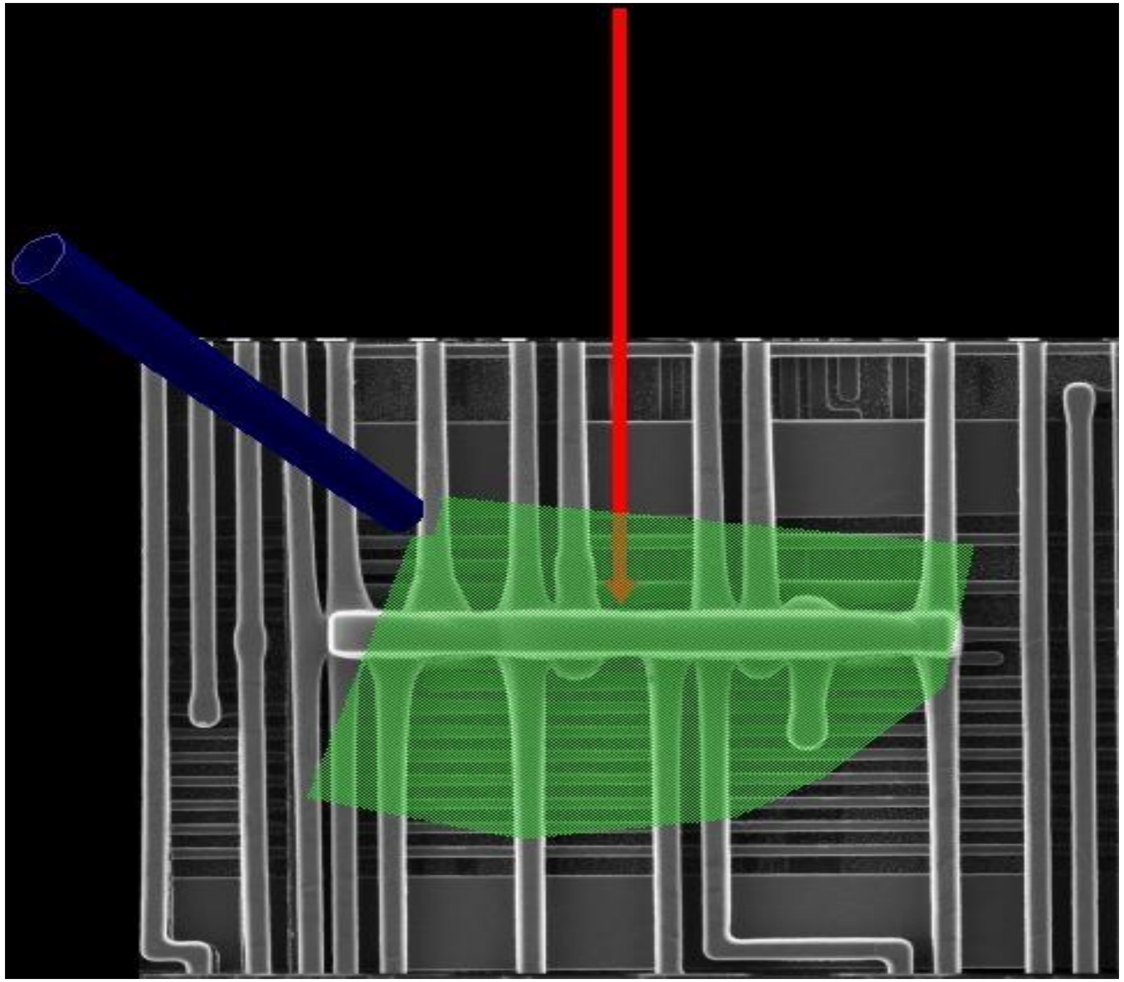
Absorbed gas to produce deposits ⇔ sputtering from the surface

Net deposition rate = deposition rate – sputtering rate

Deposition GIS	Beam current density	Remarks	Note
Pt	2 – 6 pA / μm^2	< 1nA + Z=1μm t = 5min	>1 nA use 2 pA/μm^2
W	70 -150 pA/ μm^2	Appl. File W-dep high + OL 70%	100 pA/μm^2
Carbon	1 -10 pA/ μm^2		
Insulator	1 -10 pA/ μm^2		

Deposition: how does it work?

- Gas absorbs to sample surface
- I-beam or E-beam induce the reactions of the gas
- Low energy particles at the surface decompose the chemical bonds to leave a metal layer on the sample surface.



EBID = Electron Beam Induced Deposition
IBID = Ion Beam Induced Deposition

Comparison of electron and ion beam deposition		
	Electron beam	**Ion beam**
Available deposition material	Pt, W, C, silicon oxide	
Deposition rate	Low	High
Surface damage Sputtering prior to deposition	No	Yes
Ga^{+} implantation	No	Yes
Purity of deposit Higher metal content	Process dependent	High
Conductivity	Less	More
Min feature at HAR/LAR high aspect ratio (pillar) / low aspect ratio (lines)	28 nm / 12 nm	40 nm / 20 nm

<u>EBID deposition</u>:

Low energy particles:
- SE1 and SE2 (0-50eV)
- highest SE yield between 1-3kV

<u>IBID deposition</u>:
More low energy particles:
- SE's (3x e-beam)
- SI's
- Neutrals

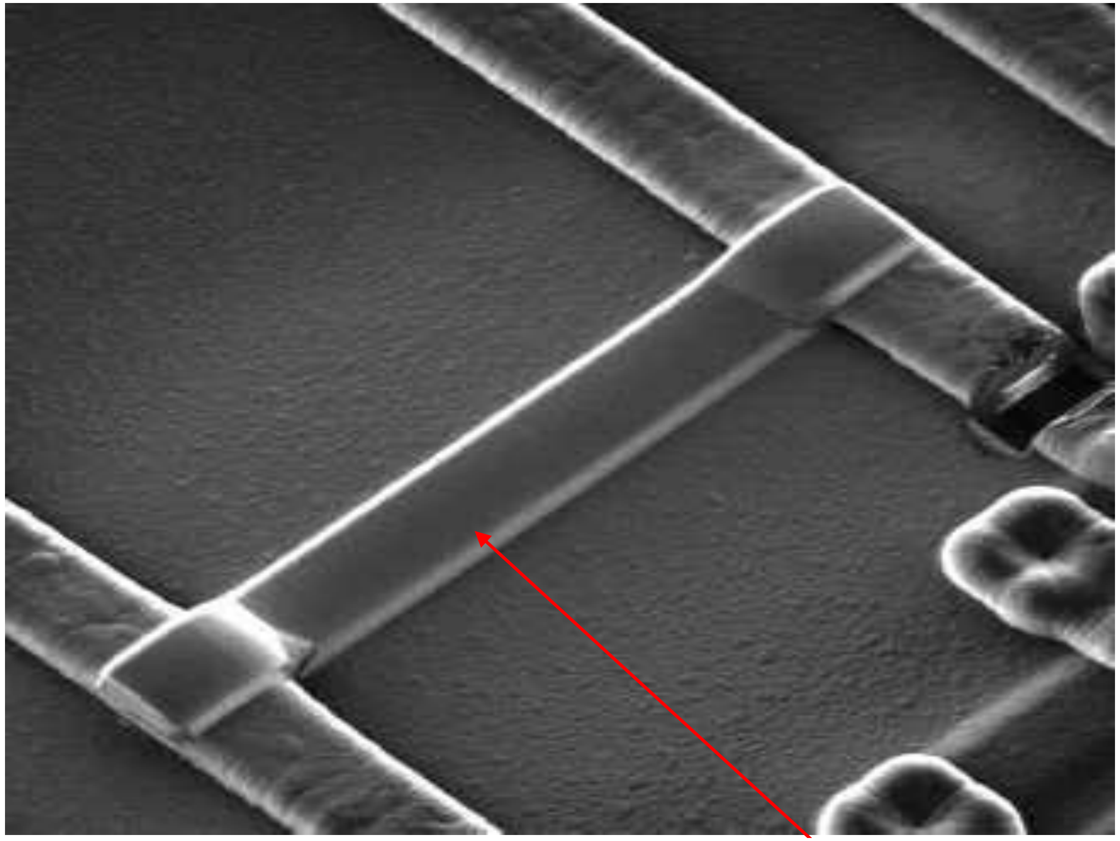
} large, low energy particles

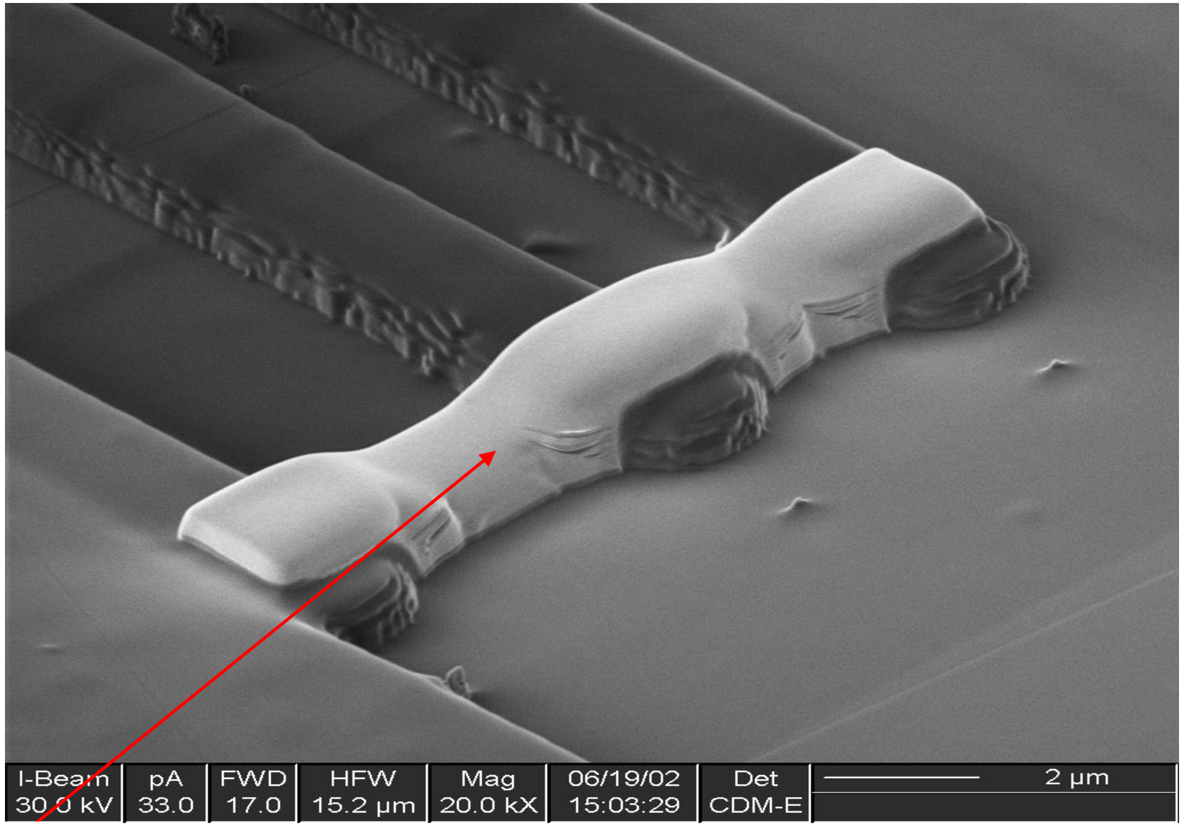
NOTE: $E_{dissociation} = <75eV$

Platinum

- (methyl-cyclopentadienyl) trimethyl platinum
- Solid at room temperature
- Operating Temperature 38-45degrees C.
- About 10 minute warm-up period.
- User refillable (use fume hood)
- Very hard: tougher for probing and thermal cycling.
- Chemically resistant

Platinum IBID

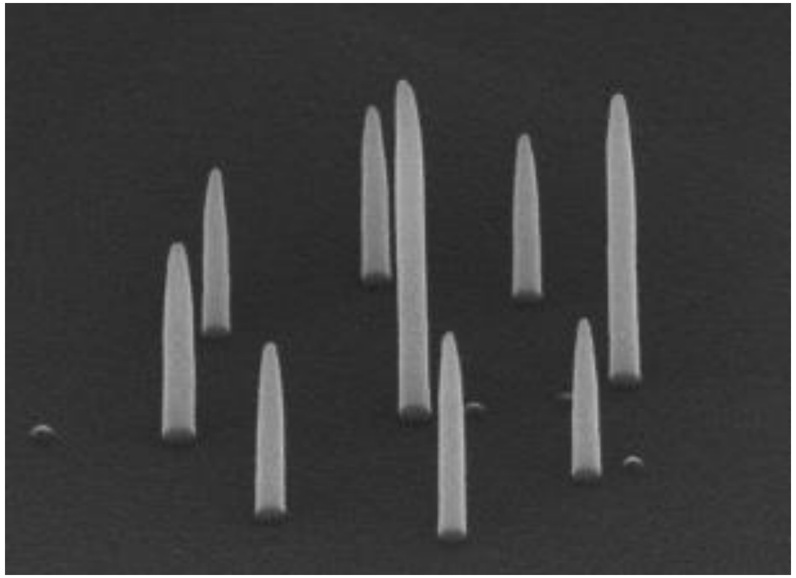


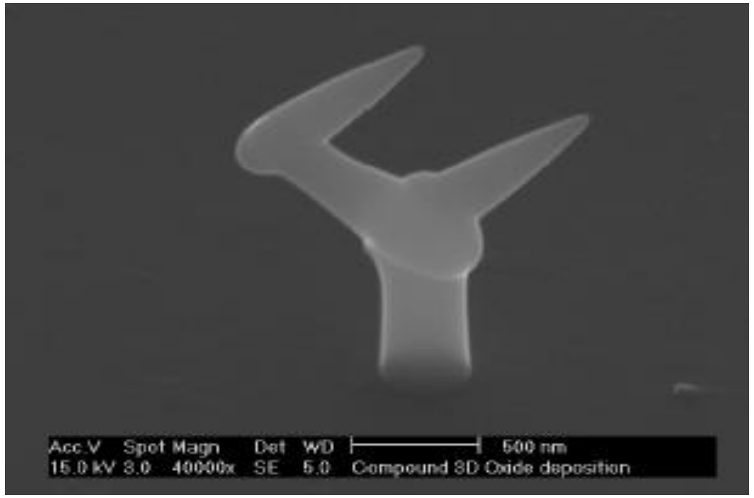


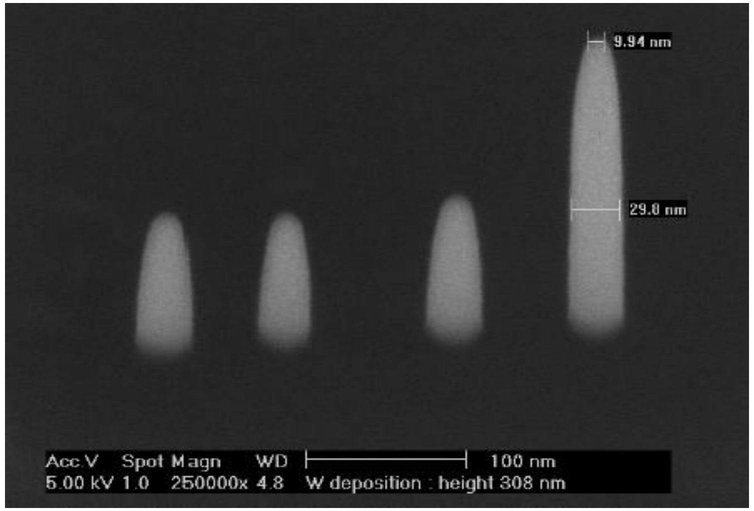
FIB Deposited Pt

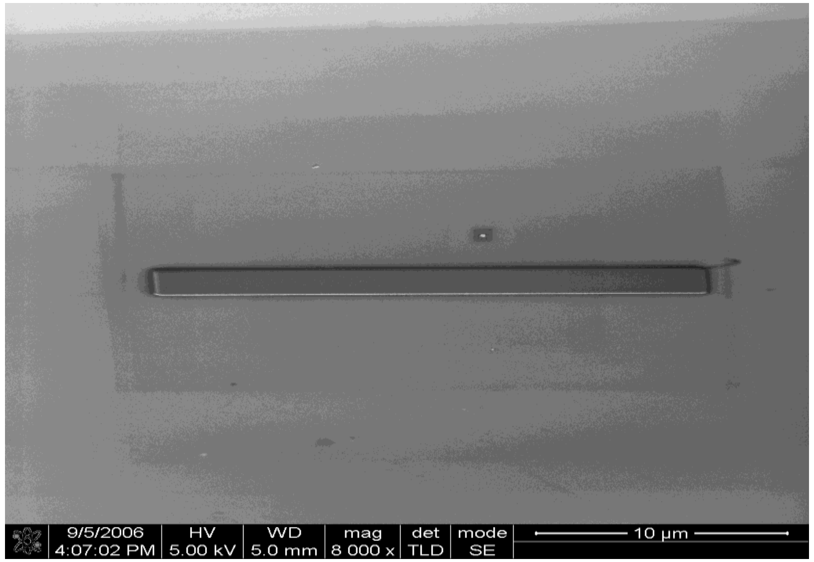
Platinum EBID

Examples of electron beam deposited patterns









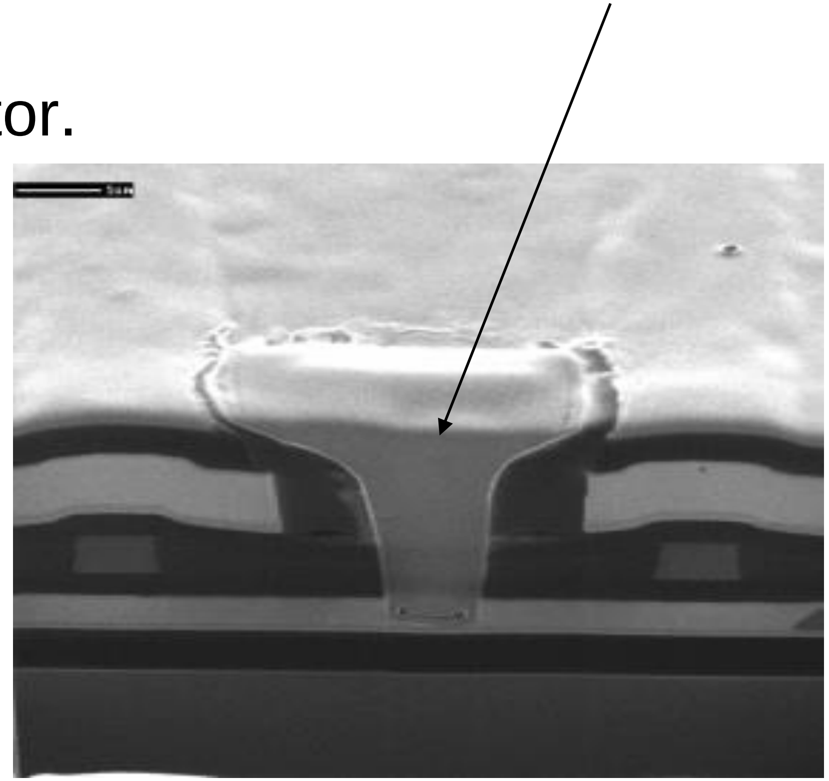
Ebeam deposition for TEM specimen preparation:
Pt deposited for 300 s at 2 kV, BC >> 1nA with t_D= 15 µs and OL = 75%

Tungsten

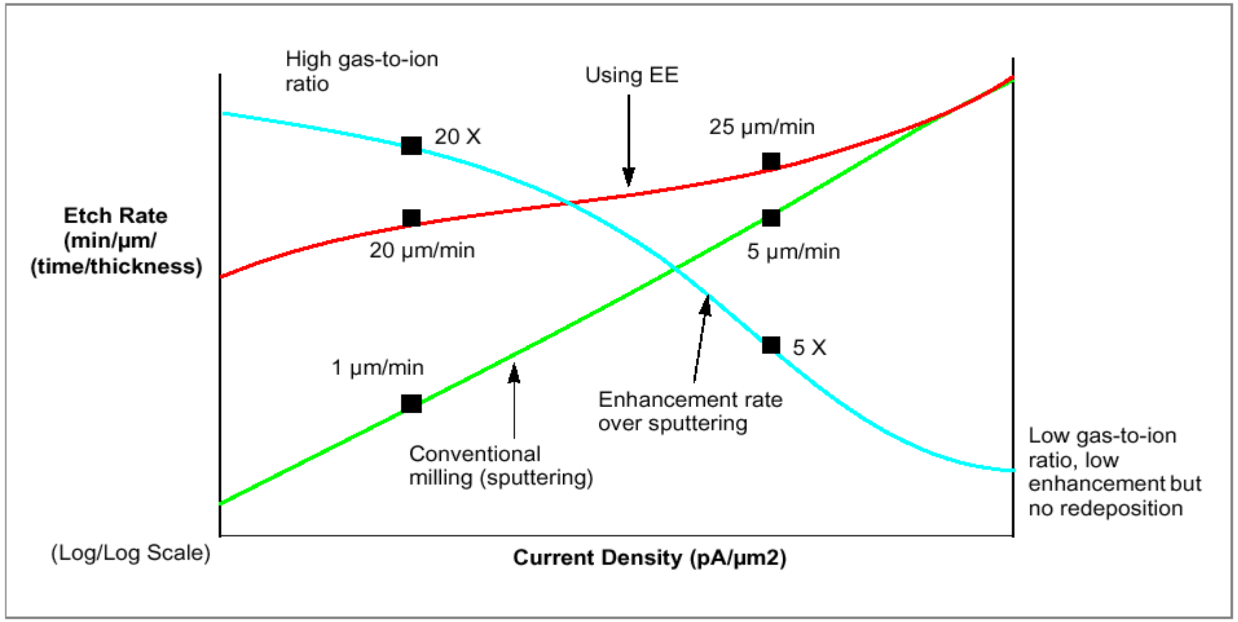
- Tungsten Hexa-carbonyl
- Lower resistivity than Pt (better for Circuit Edit)
- Slower deposition than Pt
- Solid at room temperature
- User refillable
- Operates at 50 degrees C

Insulator Deposition

- Material is TEOS in liquid form at room temperature
- Mixed with H_2O in needle to improve reaction
- Operate at room temperature
- Goes in a standard design crucible and gas injector.
- In via structure, 1 Gohms resistance,
  20 V breakdown
- Deposition rate for coatings is about
  1 micron/20 minutes



Reactive Gases



(Iodine) EE etching

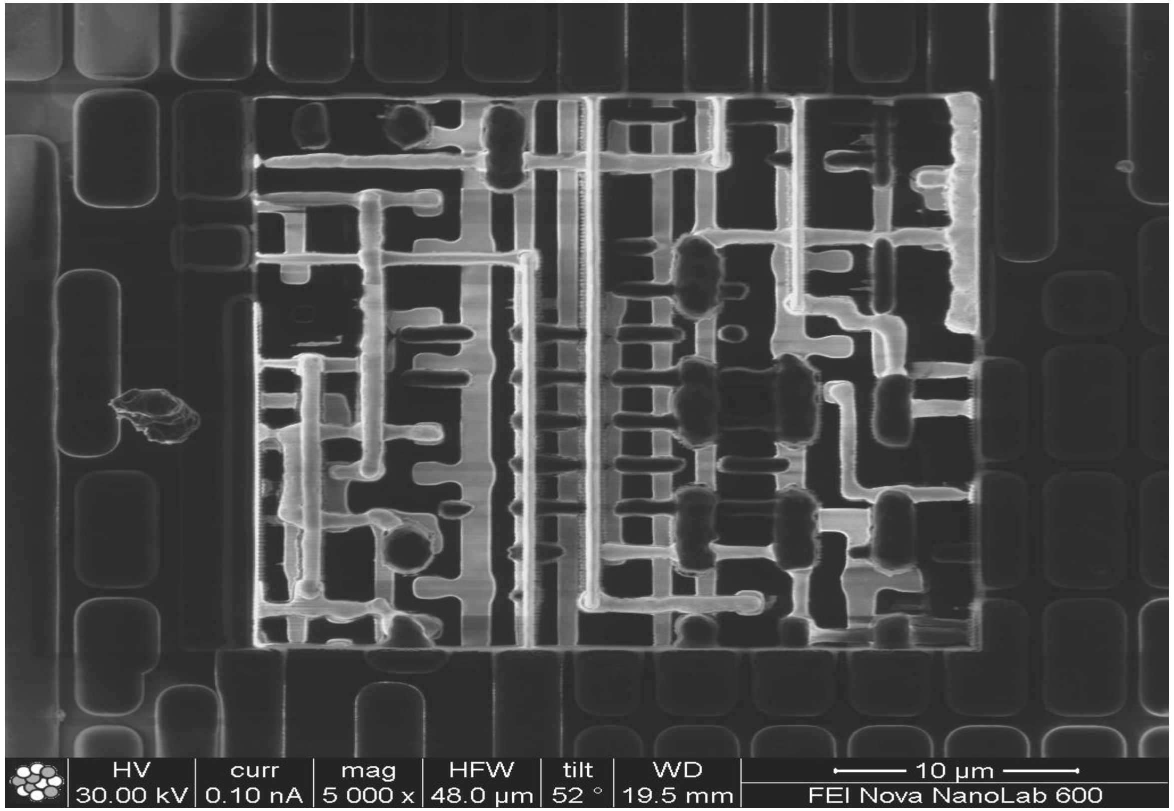
- Advantages:
  - Increased removal rates
  - Higher selectivity between some materials
  - Less redeposited material
- Available:
  - Iodine (low BC, fast DT)
  - XeF2
  - Selective Carbon Milling
  - Delineation Etch
  - (CoppeRx)

    Note; application specific.

Iodine (EE)

- Metal selective etch about 10:1 (over oxide)
- Mills Al about 15x than straight sputtering
- Mills Oxides about 1-3x than straight sputtering
- Solid at room temperature.
- Operate at 32 degrees C.
- Allow 10 minute warm-up period.
- User refillable (use fume hood)

- Insulator Enhanced Etch
- Oxide selective etch ~5:1
- Mills thermal oxide,
  TEOS ~8x than sputtering
- Spontaneously etches silicon, polysilicon
- Solid at room temperature
- Operate at room temperature
- NOT user refillable



Silicon nitride and silicon oxide layers were removed with IEE

Reactive gases: Beam parameters

EE (Iodine):

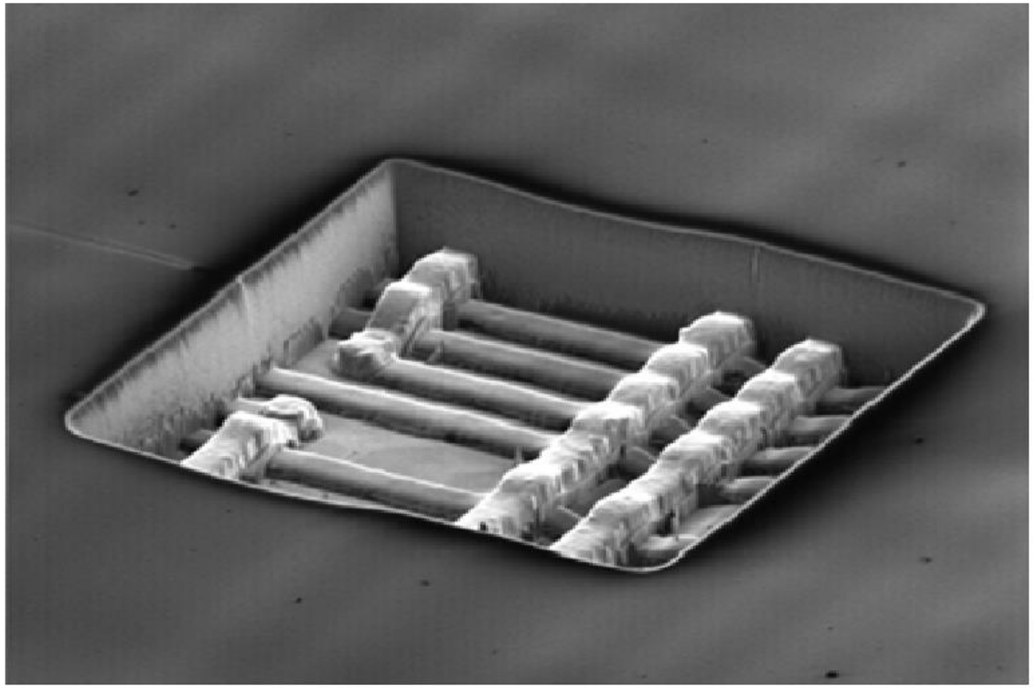
- Large enhancement: Si, Al, GaAs; 20-30x faster
- Low enhancement: Oxides, SiO_2, Al_2O_3 (close to 1);
  Silicon Nitride (Si_3N_4); 5-7x faster
- Scan parameters:
  Overlap: 0%, Dwell: 0.2 – 1 μs,
  large area reduce pixel dwell time: 0.2 μs, small via: 1 μs to 10 μs.

IEE (XeF2):

- SiO_2, Si_3N_4, Si: 20x faster
- Al: 4x faster
- Scan parameter is critical:
  Overlap: 0 to –99%, dwell: 0.1 to 0.5 μs, large area reduce pixel
  to 0.1 μs; small via between 1 to 10 μs.

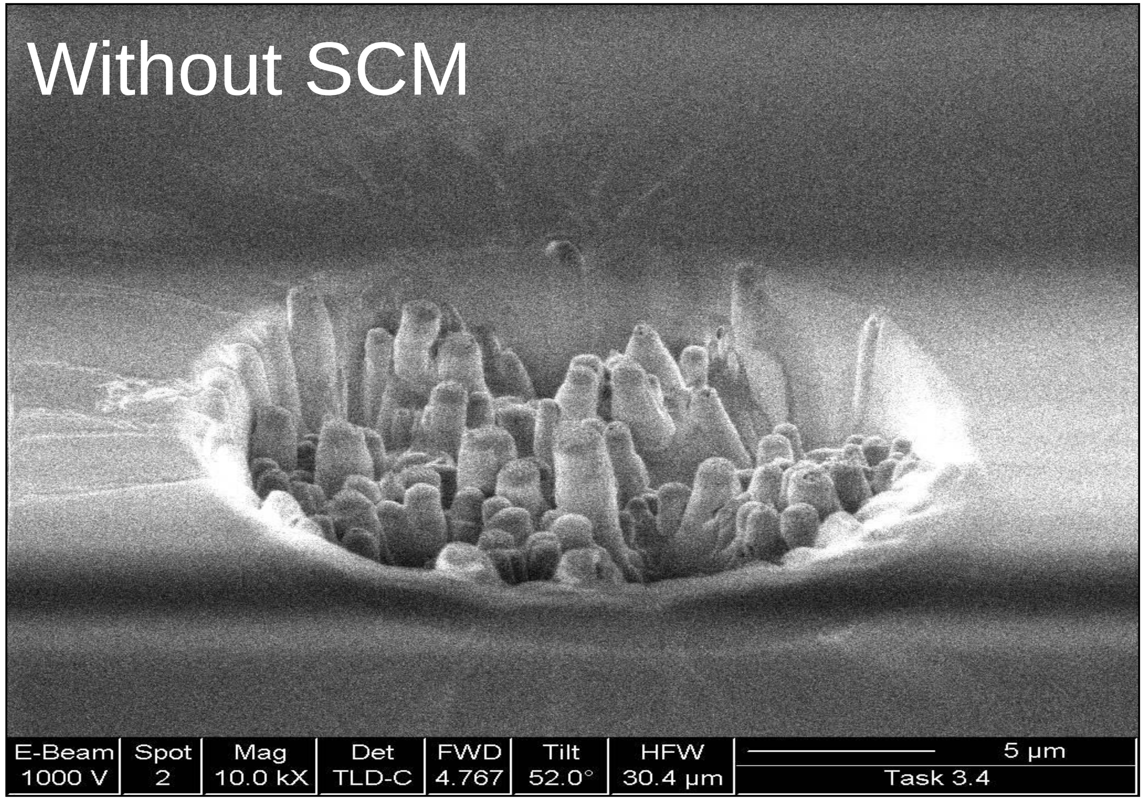
Selective Carbon Mill = SCM/SCE (H_20 Vapor)

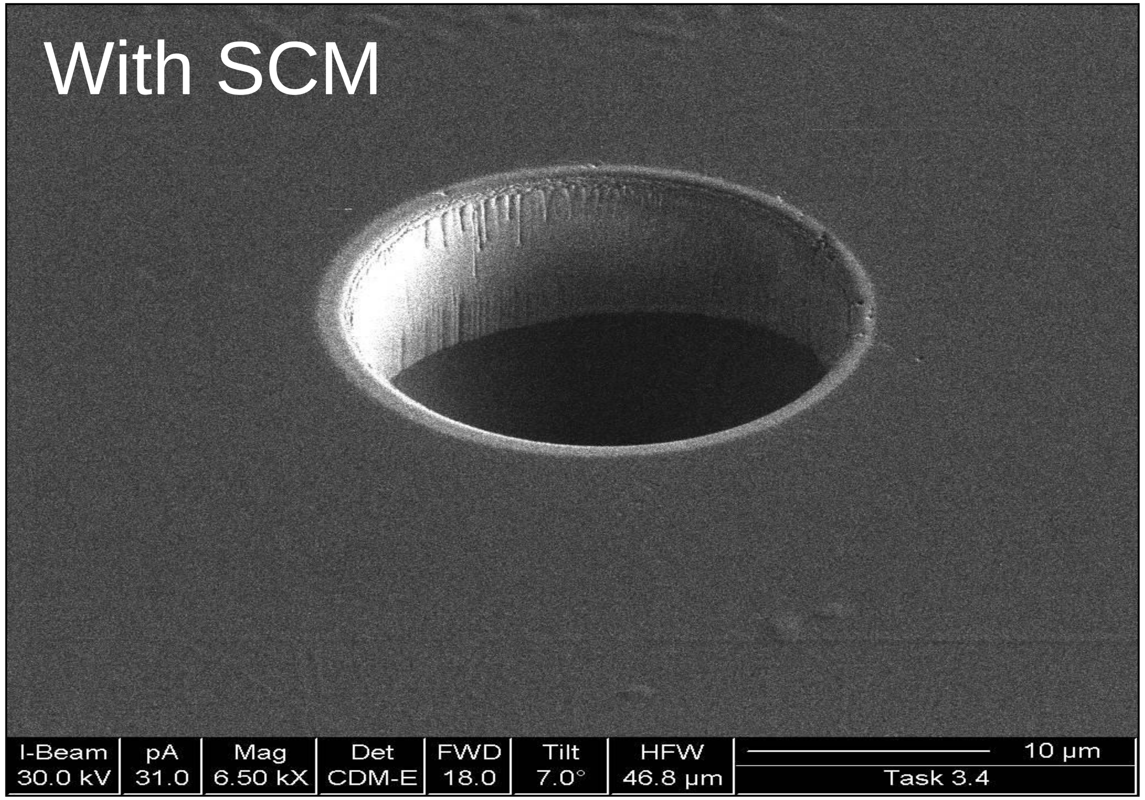
- Magnesium Sulfate Hepta-hydrate (water vapor)
- Mills carbon based species quickly and without damage
- (photo resist and polyimide)
- Acts as an etch stop on silicon
- When combined with high resolution, low voltage imaging, enables measurement of features important for optimizing critical lithography processes (Applications Notes available on Photoresist Milling!)



Very high selectivity of SCM on polyimide
over Al was used to remove polyimide
passivation and dieletric layers from an integrated circuit

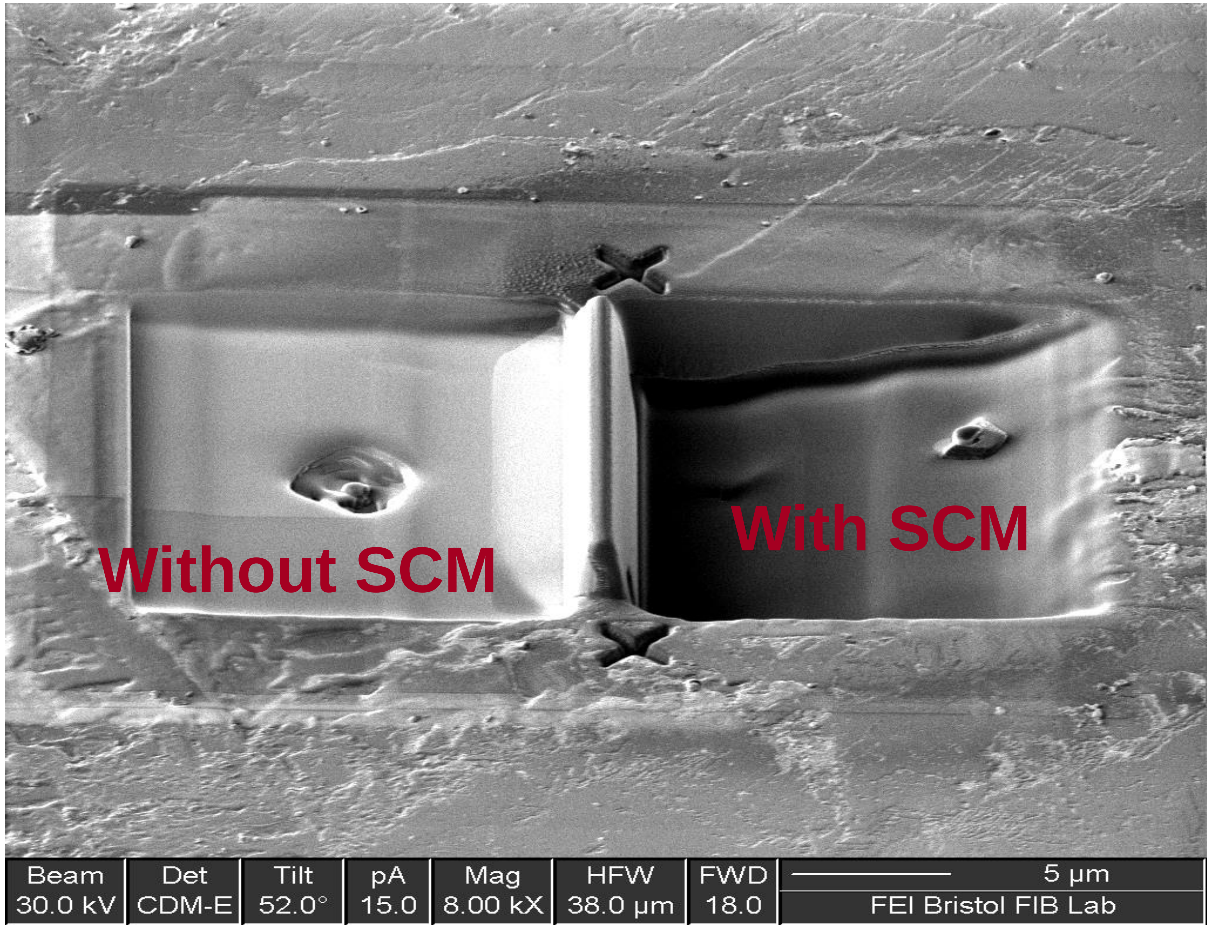
Selective Carbon Mill (SMC)

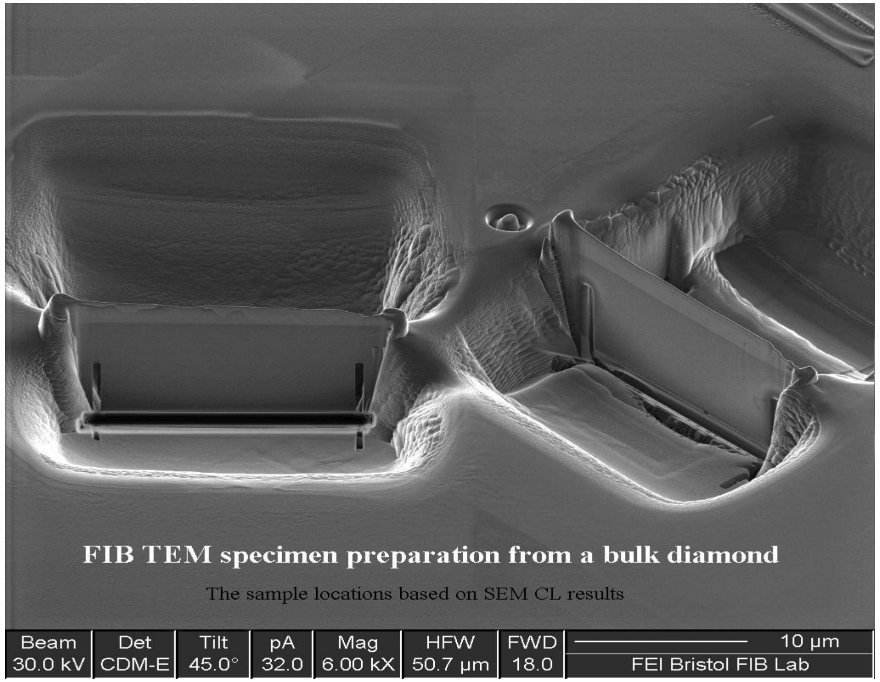




Poly-carbonate (Compact Disc);
SCM reduces charging and re-deposition

Selective Carbon Mill (SMC)





Diamond: TEM specimen