xT Patterning Parameters

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Introduction

The Helios DualBeam systems are equipped with a digital patterning, imaging and acquisition system able to address ~16 million pixels.

The addressable area is greater than 8k X 8k pixels.

The patterning, imaging and acquisition system (PIA) allows the user to control many parameters of the beam; some of which are dwell time, beam overlap/pitch, scan type and scan direction. This overview will explain these parameters.

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Type of Patterns

Line

Box

Outline Box

Circles/Donuts

Polygons

Stream files (beam location and dwell time)

24-bit Bitmap files

Cross-section (5 boxes in parallel)

Cleaning pattern (collection of lines)

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Pattern Edit Functionality in xT

xT 2.0 and up

- Cntl-A – Selects all patterns
- Delete – deletes all patterns
- Left click, drag to enclose patterns – selects the patterns

xT 3.0 and up

- Cntl-C – Copies selected patterns
- Cntl-V – Pastes selected patterns

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Pattern Parameters

Application: sets the material, beam scanning and gas properties

Beam Type: ion or electron

Width, Length and Depth: sets the dimension of the pattern

Rotation: sets the pattern rotation angle in degrees

Gas Type: sets a gas chemistry for the pattern if one is to be used

Pattern Parameters

Volume per Dose: sets the volume of material that is removed per charge

Area: determines the area of the pattern based on the length, width or diameter of the pattern

Fill Style: for box and circular patterns sets whether a solid or frame of the pattern will be milled

Total Time: sets the time for pattern completion

Beam Parameters

Pass: the number of passes that the beam scans over a pattern

Refresh Time: the minimum loop time that must lapse before the next pass can begin

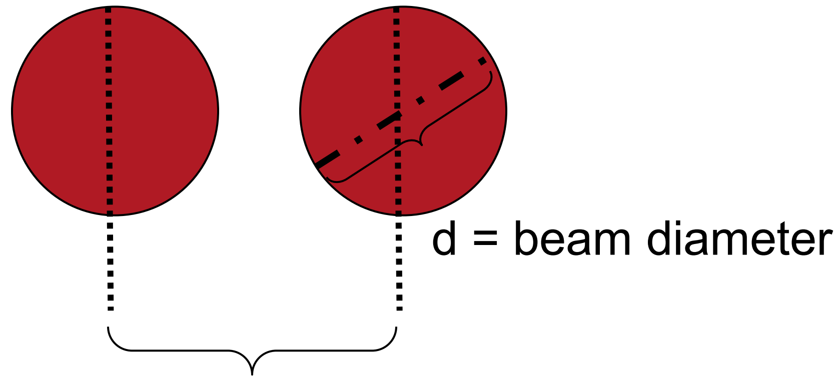
This is very useful for enhanced etching and deposition because it allows for the gas to continue to adsorb onto the surface.

Dwell Time: the time the beam spends on a pixel per pass. The user has a dwell time range of 100 ns to 4.6 ms available in ~120 discrete values.

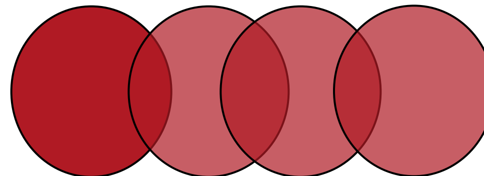
Beam Parameters

Overlap: this parameter sets the overlap of the beam and is given in %

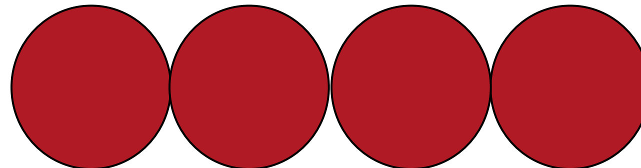
$$OL = \frac{d - s}{d}$$



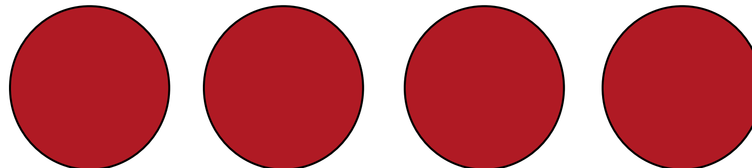
Positive Overlap



No Overlap



Negative Overlap



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Determining Beam Step, Pixel Size and Step Size

Beam Step/Pitch (µm) = d*{100-OL(%)} / 100

Pixel Size (µm) = Horizontal Field Width / ~8000

- Example: using a magnification that corresponds to a horizontal field width (HFW) of 50µm, then the horizontal board resolution is 50 µm / 8000 pixels = 6.3 nm

Step Size (pixels) = integer of (Beam Step / Pixel Size)

- If step size is less than 1, then the UI will show a "-" because pitch is too small

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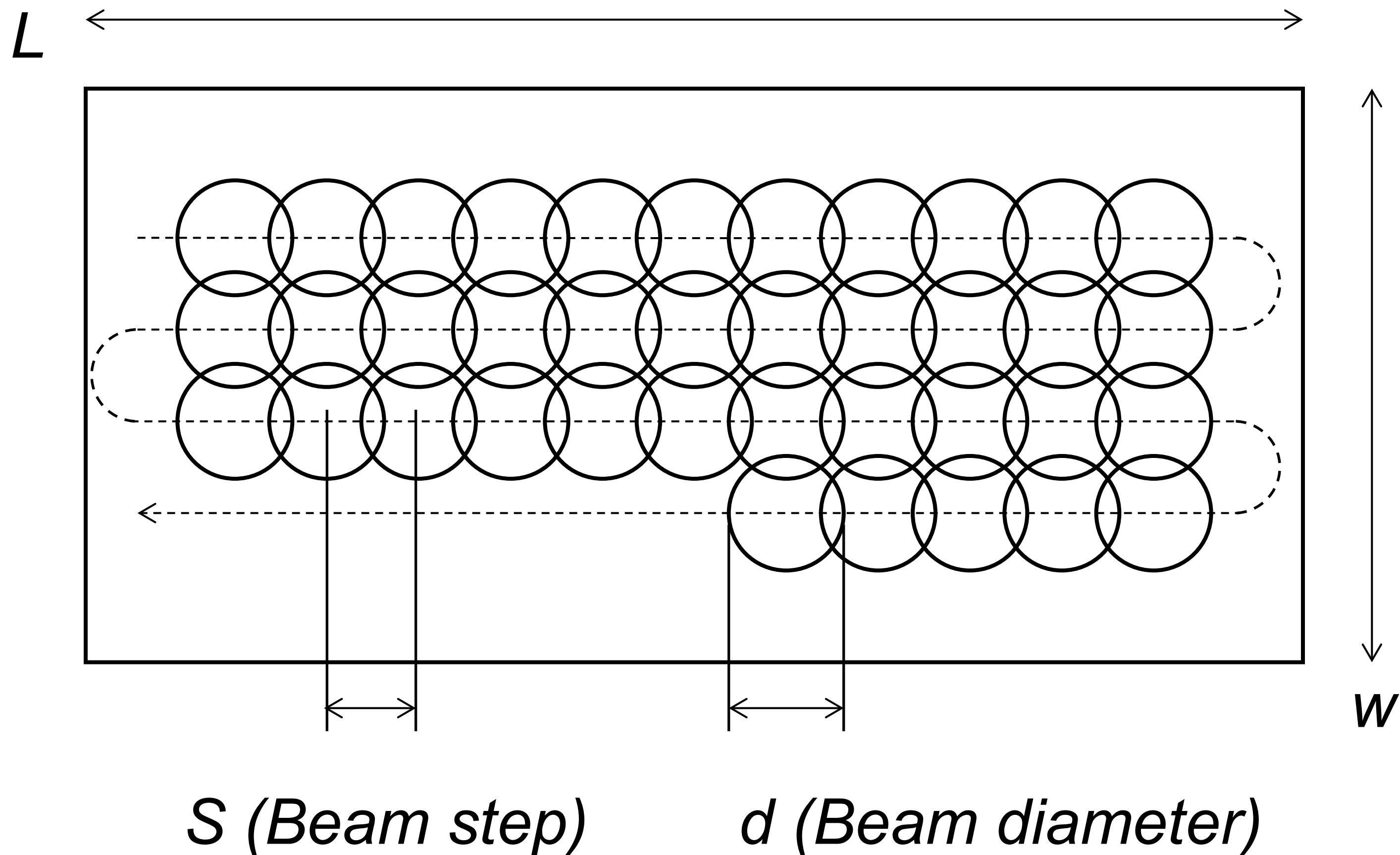
Beam Parameters

Scan Type – The scanning strategy used while patterning.

The user has two options available:

Raster ("type writer" movement) or Serpentine



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Beam Parameters

Pitch: this parameter sets the pitch between spots and is another way of defining the beam overlap (given in distance). Minimum pitch ~ 0.5 nm

Final Edge: determines the final edge of the pattern the beam will scan towards when patterning

The user can set Top to Bottom, Bottom to Top, Left to Right or Right to Left

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Beam Parameters

Defocus: the defocus of the beam (essentially a working distance change) that influences beam diameter and area

Blur: like defocus, but specifies the additional diameter of the blurred spot

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Beam Parameters

- **Interaction Diameter**: this parameter is the diameter for an infinitely small beam and influences the total diameter. It accounts for the beam-solid;beam-gas interaction.
- **Relative Interaction Diameter**: this parameter is the diameter for an infinitely small beam relative to the beam diameter
- **Total Diameter**: the combination of the beam diameter and interaction diameter and influences pitch and overlap

Limitations of Patterning

How many patterns can be loaded?

In principle, hundreds of patterns can be loaded. However, the processing time increases with the number of patterns. In practice 50-100 patterns can be loaded with out long pattern loading times.

What pattern parameters are not currently functional?

Saturation Sputter Rate, Maximum Dose per Area, Saturation Current Density

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Bitmap Milling

In XT an additional pattern has been added that allows you to import bitmaps as a pattern. Bitmap milling enables the user to mill complex shapes such as nano-structures

Each pixel in a bitmap consists of 3 components a red, a green and a blue parameter. The combination of these 3 colors determines the pixel color.

The blue component determines the milling time of a single pixel. If blue is set at 0 the beam will not dwell at this pixel. If blue is set at 255 the UI dwell time as defined in the pattern application file is used. The actual dwell time for the pixels in between these values is linearly interpolated.

The green component determines whether the beam is blanked. Any other value then 0 will unblank the beam.

When drawing a bitmap it is recommended to use black (0,0,0) for none milling points. And blue for milling points.

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Patterning Work Page in xT

File Edit Detectors Scan Beam Patterning Stage Tools Window Help — Pages

350x | 5.0 kV | 0.40 nA | 0.3 µs | 1024x884

Pattern

HIDE

1 -Bitmap 1

Basic | Advanced

Name	Value
Application	Si
File	FeiCompanyInv.
X size	393.83µm
Y size	142.63µm
Z size	1.00µm
DwellTime	1.00µs
ScanDirection	Bottom To Top
Rel. Int. Diam.(%	0%
Beam	Ion

Progress

Total Time : 0:02:15

Overall Progress

CCS Line Progr.

Select All

Omniprobe

Insert Omniprobe

Gas Injection

Overview | Details

In Gas Type	Heat	Flow
SCE	Cold	Closed
IEE	Cold	Closed
C dep	Cold	Closed
Pt dep	Cold	Closed

2

1

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NANOTECH

- Patterning parameters

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How to make a good bitmap and mill it!

Use a photo editing software package to increase the resolution to ~300X300dpi

Grayscale images are best for milling

Save the file as a 24-bit bitmap (*.bmp)

The more values of gray in a file the larger the dwell time should be (e.g. if a black and white photo is to be milled, then a dwell time of 100µs works well)

Use the Si application file or “none” for default milling parameters.

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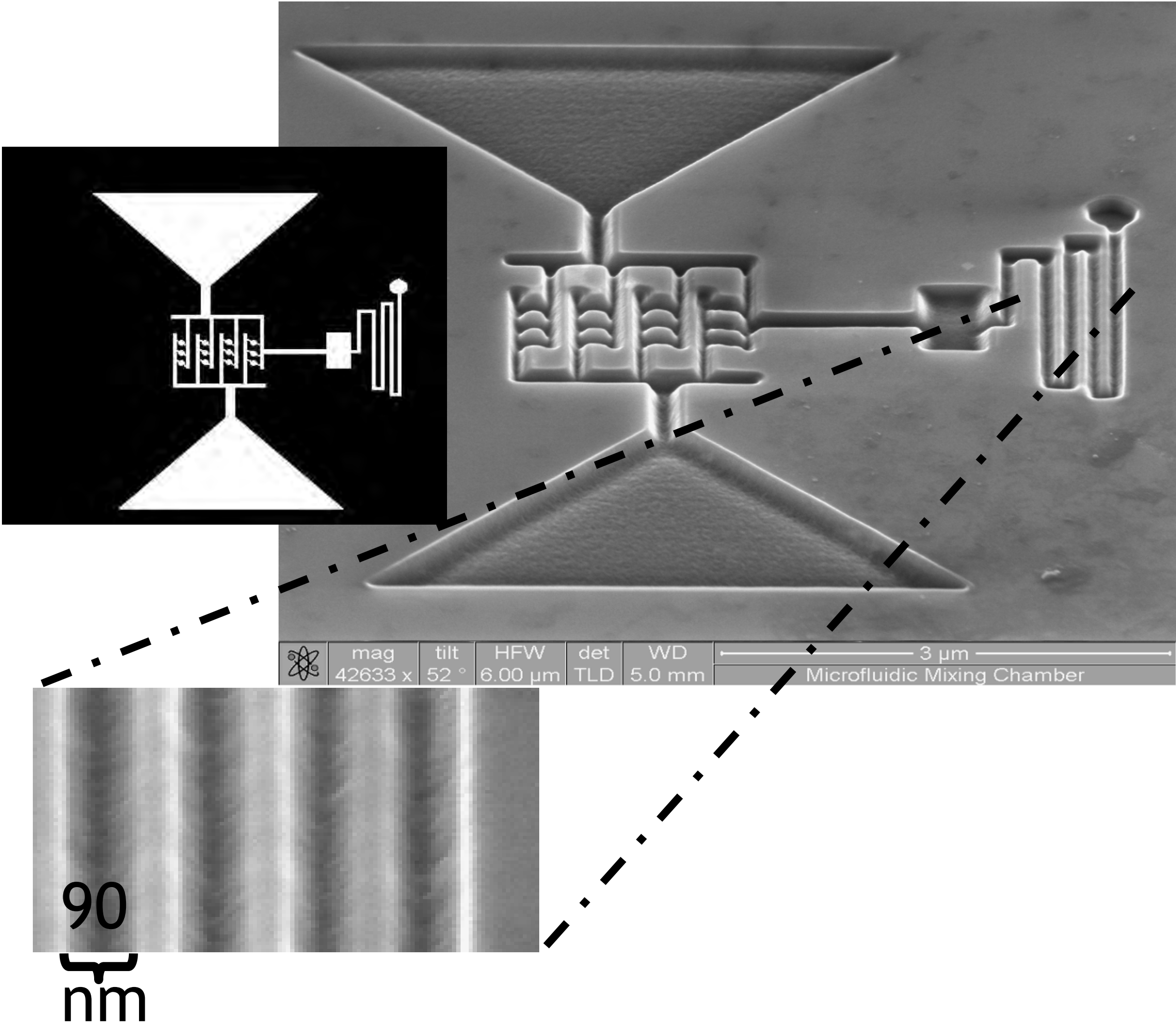
Typical Bitmap and Result



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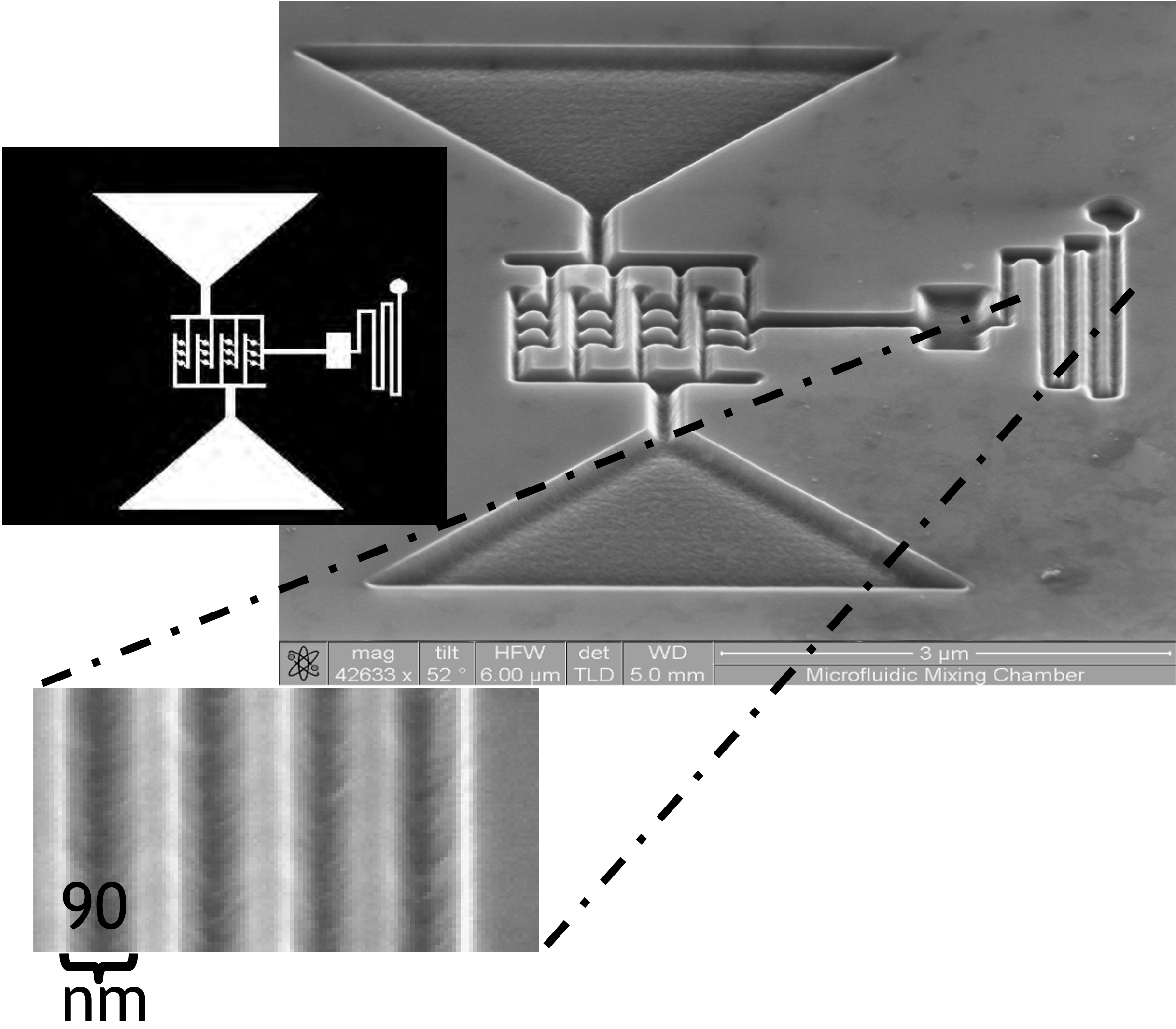
Typical Bitmap and Result



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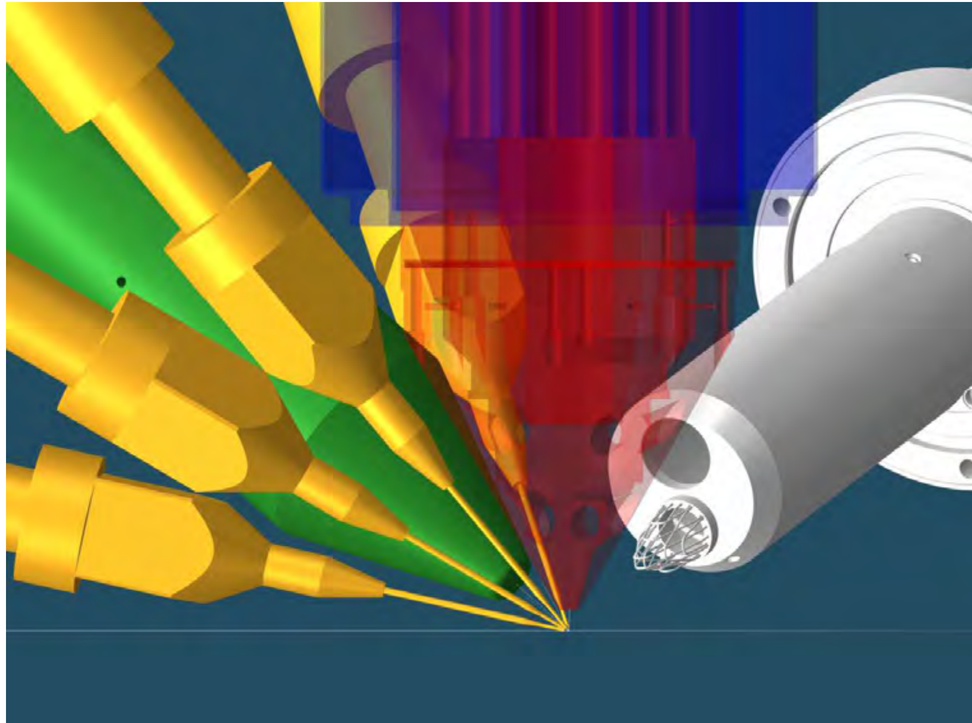
Gas Injection Systems (GIS)



•*Dualbeam chamber with all GIS inserted*

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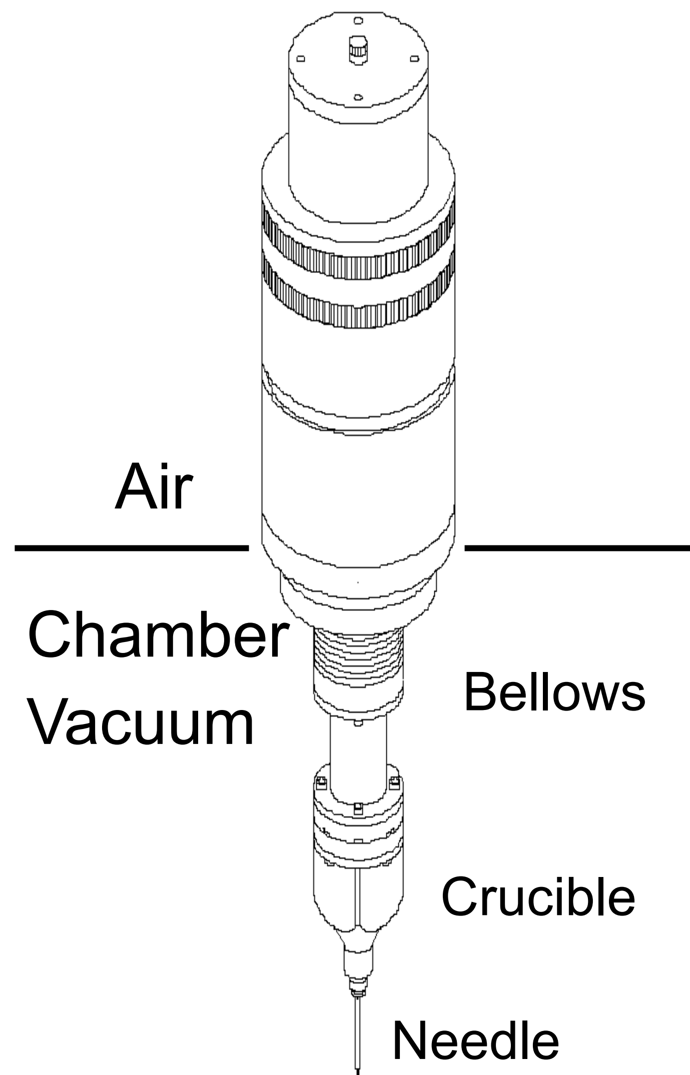
GIS strong points (see Application Note)

- Gas flow control based on accurate temperature setting
- Homogeneous temperature for full gas path – no re-condensation of precursor
- Local gas density fluctuations at sample < 6 % over a width of 100 um
- Double container safety control
- For a wide variety of chemicals and for future nano-technology chemistry
- 100 % free of any cross-contamination
- Extreme ease of use, accurate repositioning and fast operation
- Field proven – more than 1500 units installed



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Depositing/Etching with Gas

Deposition Gases

- Platinum
- Tungsten
- Carbon
- Insulator
- Non-standard Requests, Au

Reactive Gases

- Iodine = EE
- XeF_2 = IEE
- Delineation Etch =DEE
- Selective Carbon Milling = SCM

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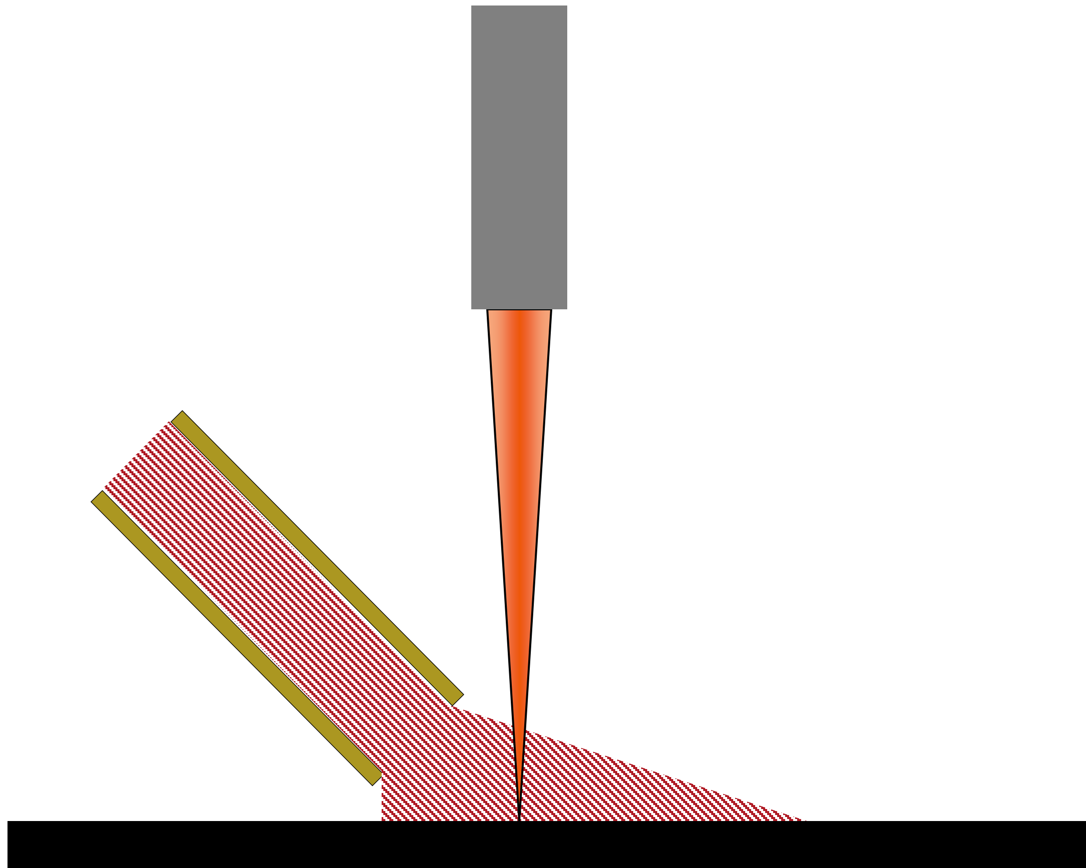
Gas Delivery

Z height, H distance



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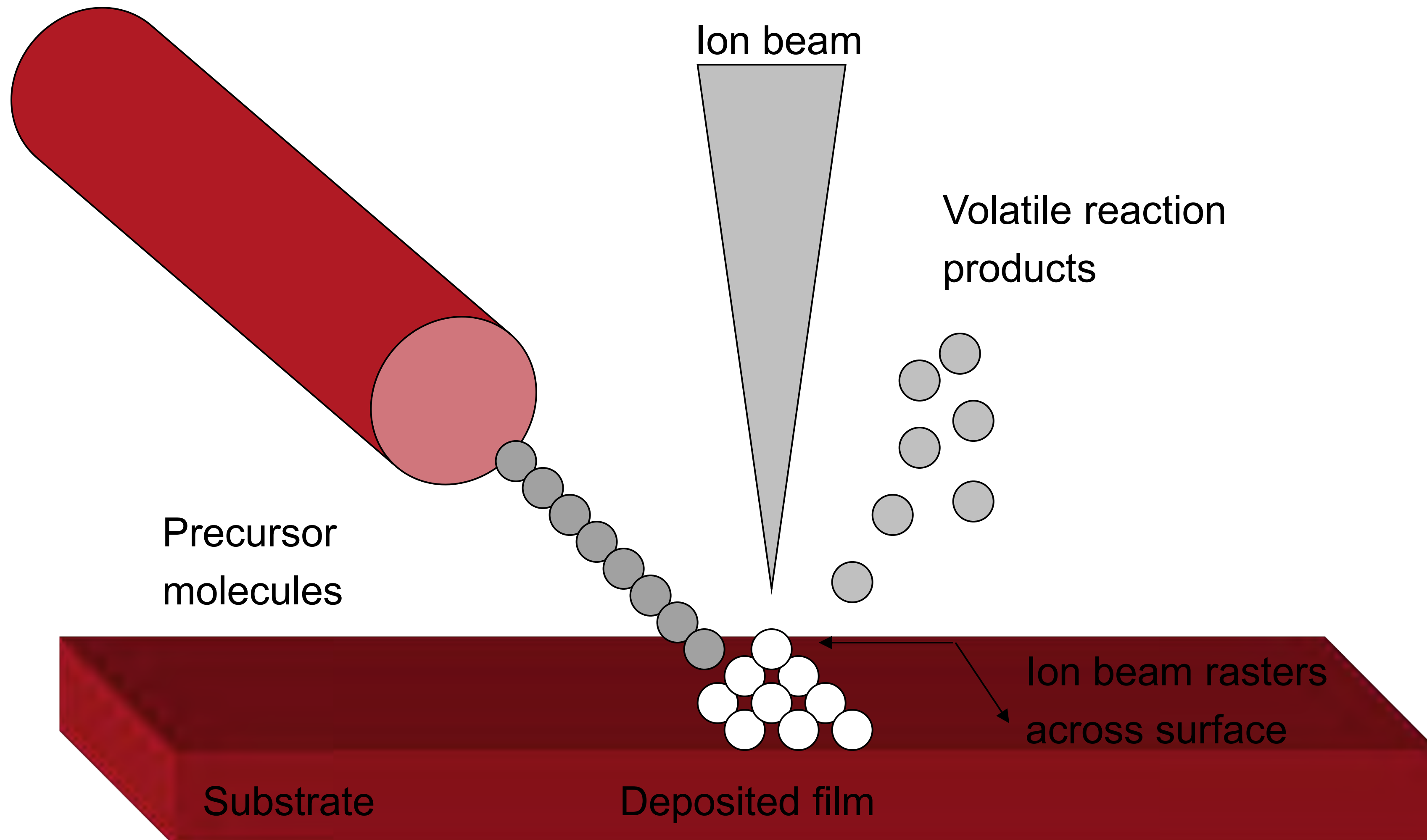
Deposition Process



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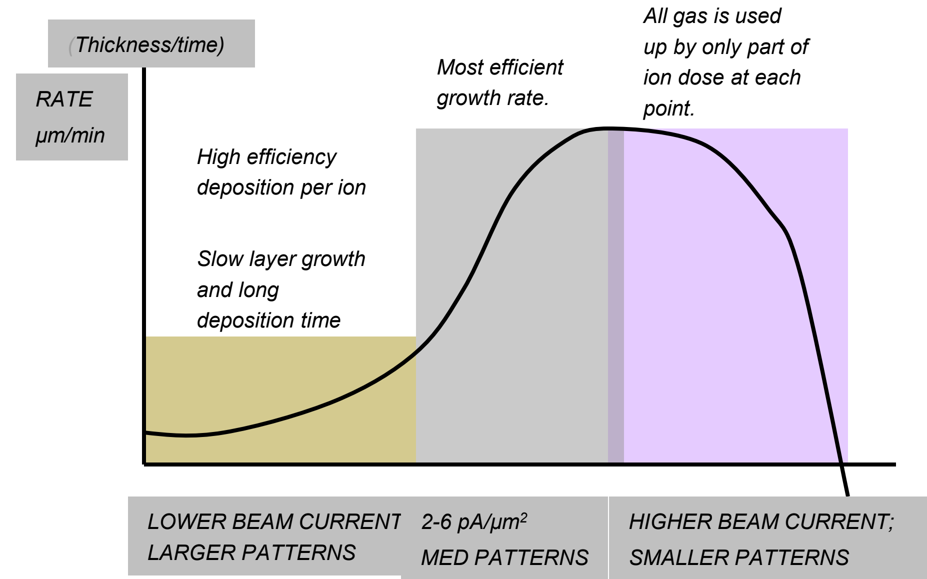
Depositing

These gases form non-volatile compounds

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

Platinum (2-6 pA/µm^2)
Tungsten (70-100 pA/µm^2)
Carbon (1-10 pA/µm^2)
Insulator (1-3 pA/µm^2)



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Platinum Deposition

(methylcyclopentadienyl) trimethyl platinum

Solid at room temperature

Operating Temperature 38-42 degrees C.

About 10 minute warm-up period.

User refillable (use fume hood)

Very hard: tougher for probing and thermal cycling.

Chemically resistant

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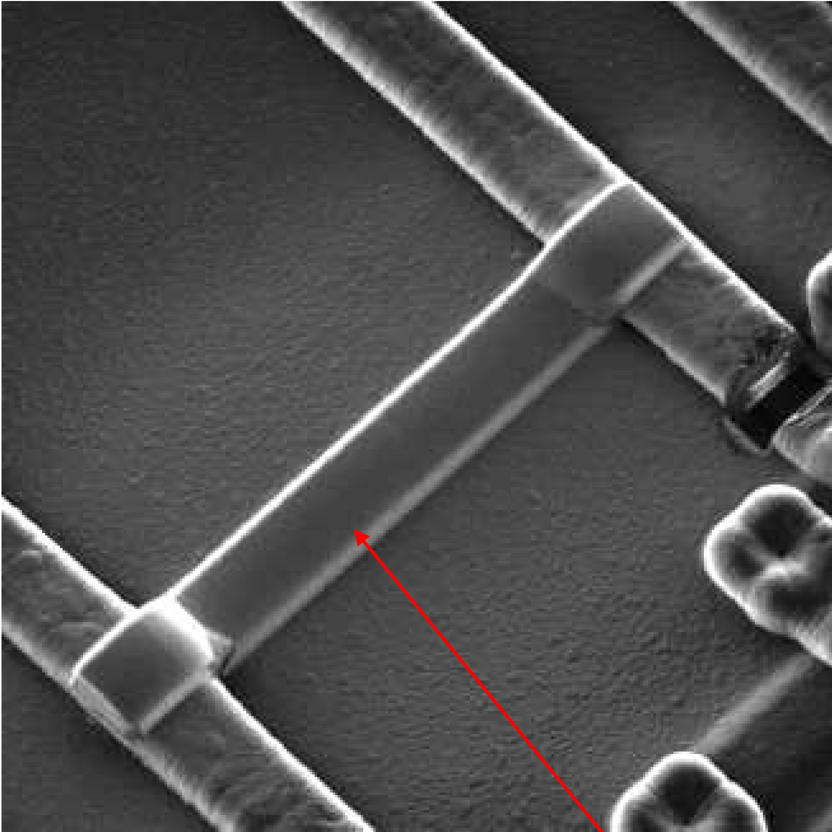
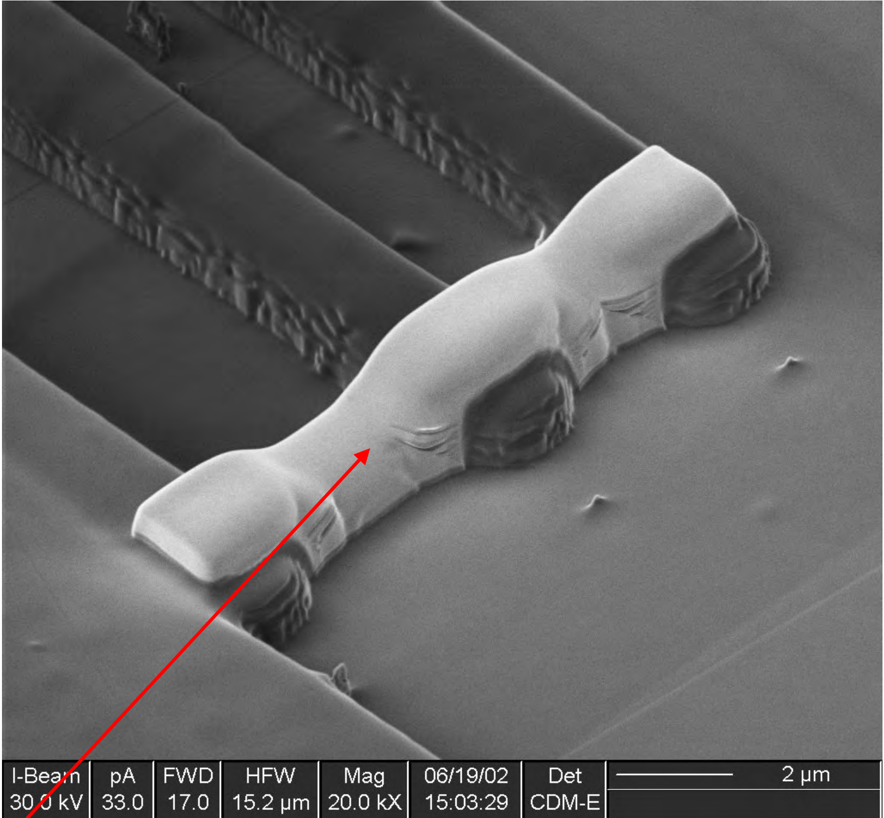
Platinum Deposition





- *FIB Deposited Pt*

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Tungsten Deposition

Tungsten Hexacarbonyl

Lower resistivity than Pt (better for Circuit Edit)

Slower deposition than Pt

Solid at room temperature

User refillable

Operates at 50 degrees C

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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 GΩ resistance, 20 V breakdown

Deposition rate for coatings is about 1 micron/20 minutes

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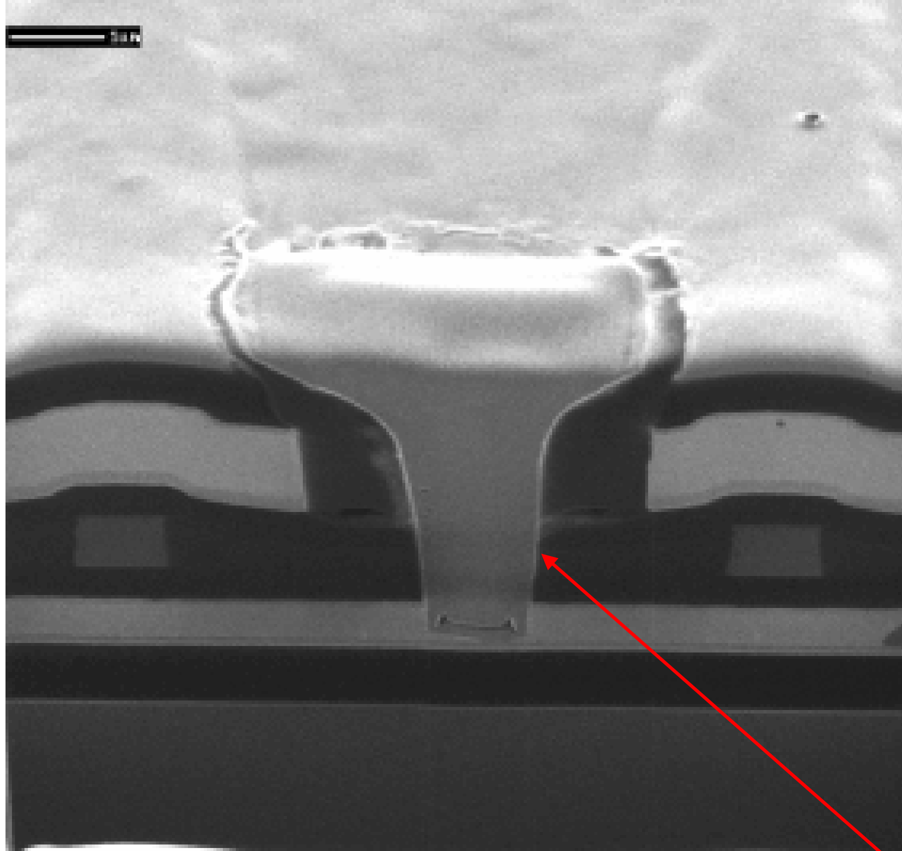
Insulator Deposition



FIB Deposited Insulator

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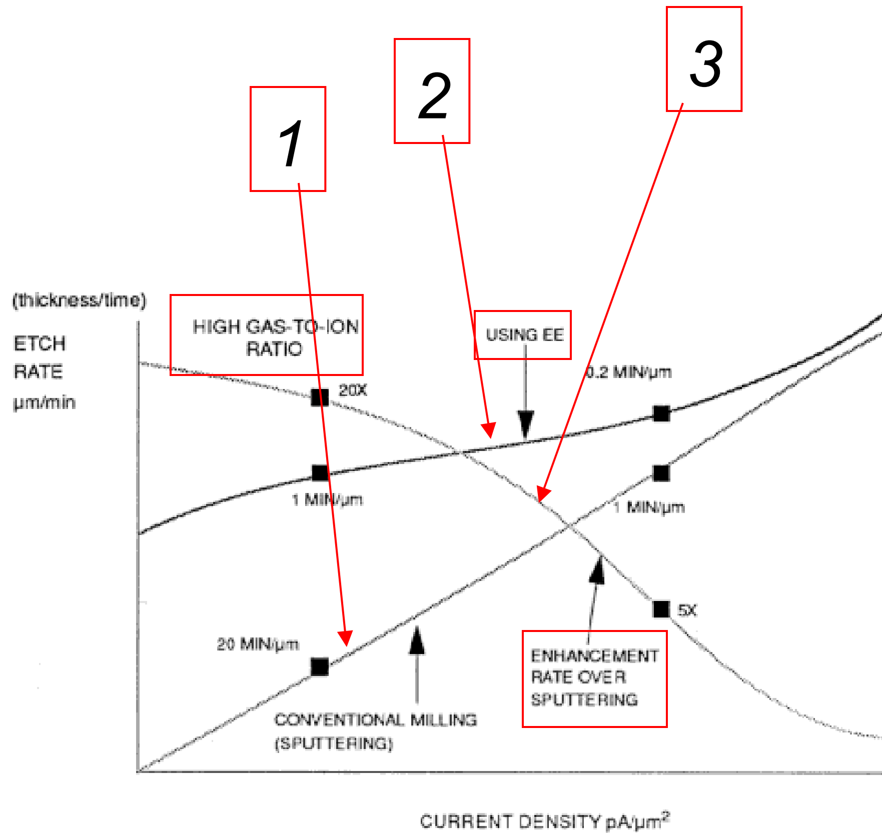
Reactive Gases



This graph is an example for EE etching

Advantages:

- Increased removal rates
- Higher selectivity between some materials
- Less redeposited material

Available:

- Iodine
- XeF2
- Selective Carbon Milling
- Delineation Etch
- CoppeRx

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Iodine Etch (EE)

Solid at room temperature.

Operate at 32 degrees C.

Allow 10 minute warm-up period.

User refillable (use fume hood)

Metal selective etch about 10:1 (over oxide)

Mills Al about 15x than straight sputtering

Mills Oxides about 1-3x than straight sputtering

XeF_2 Etch (IEE)

Solid at room temperature

Operate at room temperature

Oxide selective etch ~5:1

Mills thermal oxide, TEOS ~8x than sputtering

NOT user refillable

Spontaneously etches silicon, polysilicon

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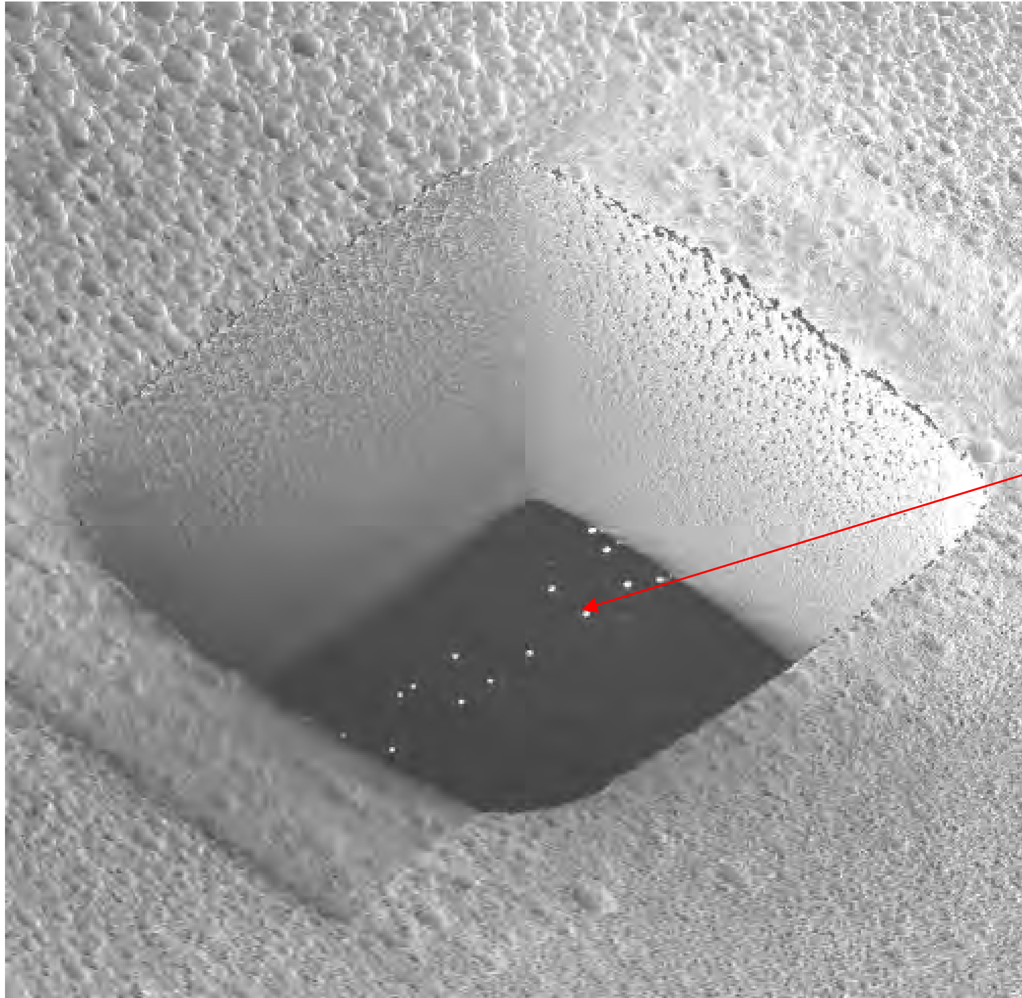
XeF_2 Etch (IEE)



Active region exposed with IEE

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Selective Carbon Mill (H_20 Vapor)

Magnesium Sulfate Hepta-hydrate (water vapor)

Mills carbon based species quickly and without damage (photoresist 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!)

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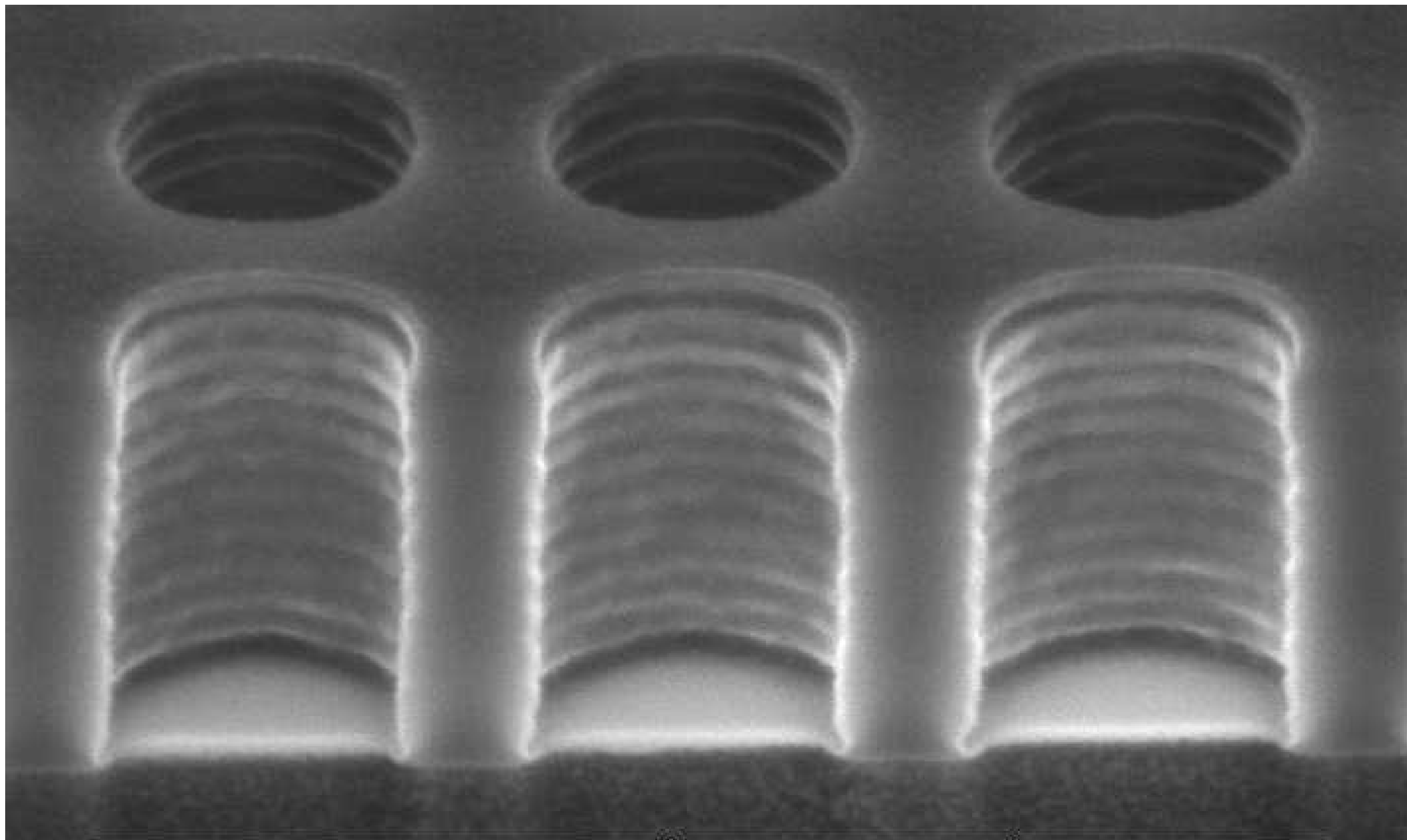
Selective Carbon Mill (H_20 Vapor)



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