Non-Gallium Applications for Circuit Edit and Failure Analysis

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Gaeta, Italy

Contents

- Non-gallium technologies
- Xe^+ plasma FIB
    - Cross sectioning
        - Reducing curtaining
    - Si trenching
    - Metal deposition

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Non-Gallium Technologies

- Plasma Source
  - Xe^{+}, Ar^{+}, O^{+}
- SEM
- Light ion microscopes
  - He^{+}, Ne^{+}
- Mass-filtered alloy source FIBs

Non-Gallium Technologies

- **Plasma Source**
  - **Xe^+, Ar^+, O^+**
- SEM
- Light ion microscopes
  - He^+, Ne^+
- Mass-filtered alloy source FIBs

- Long source lifetime
- High current
- Different ions are possible
- Deposition yields higher than Ga^+

- Lower resolution than Ga^+
- Metal depositions (electrical)

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Other Technologies

- Plasma Source
  - Xe^+, Ar^+, O^+
- **SEM**
- Light ion microscopes
  - He^+, Ne^+
- Mass-filtered alloy

source FIBs

- High resolution
- No mechanical damage
- Extreme chemical selectivity

- Extreme chemical selectivity
- Electrical invasiveness

Other Technologies

- Plasma Source
  - Xe^{+}, Ar^{+}, O^{+}
- SEM
- **Light ion microscopes**
  - **He^{+}, Ne^{+}**
- Mass-filtered alloy source FIBs

- High resolution
- Very low mechanical damage
- High milling/deposition precision

- Very low current
- Source stability
- Bubbles

- Metal deposition (electrical)?
- Electrical invasiveness?

Other Technologies

- Plasma Source
  - Xe^+, Ar^+, O^+
- SEM
- Light ion microscopes
  - He^+, Ne^+
- **Mass-filtered alloy source FIBs**

- Easy switching between ions

- Source lifetime
- Lower resolution than Ga^+

- Metal deposition (electrical)?
- Electrical invasiveness?

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Comparing Ga with Other Technologies

Task	Ga	Plasma FIB	SEM	Light Ion Microscope	Alloy Source FIB
Cross Sectioning					?
Si Trenching					?
Metal Deposition (electrical)				?	?
Metal Deposition (protective)				?	?
Copper cutting				?	?
Nanomachining					?

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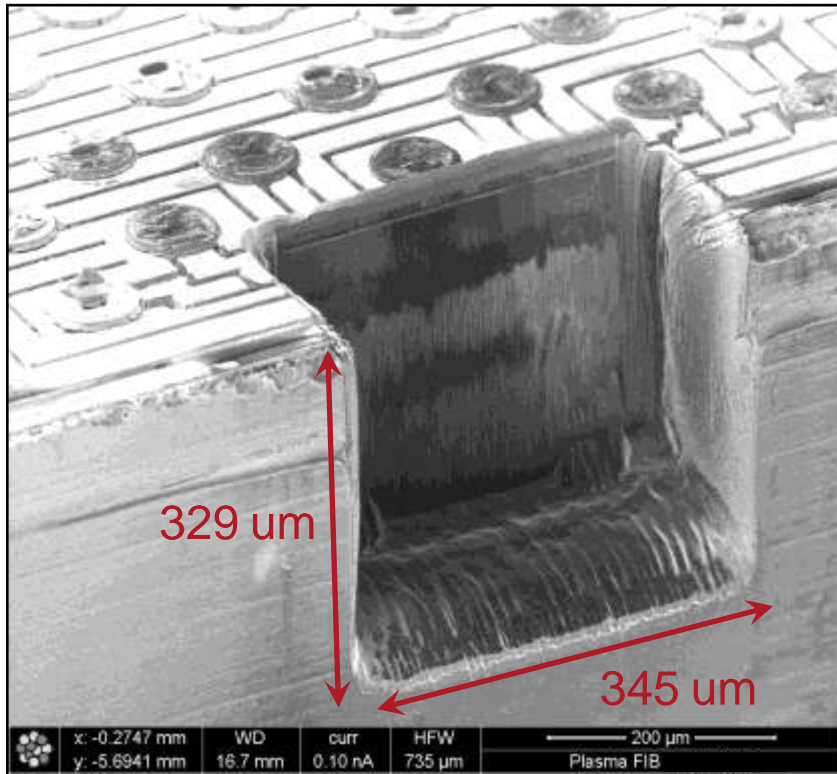
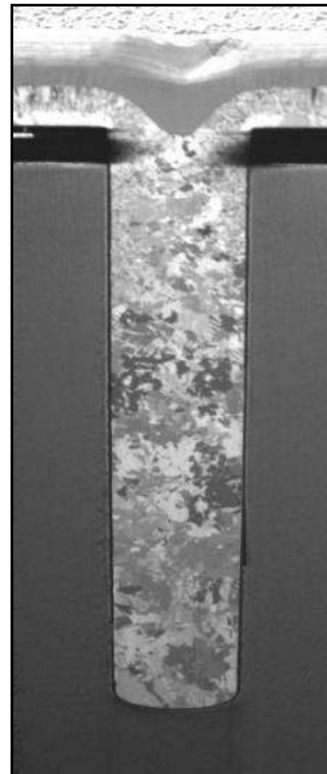
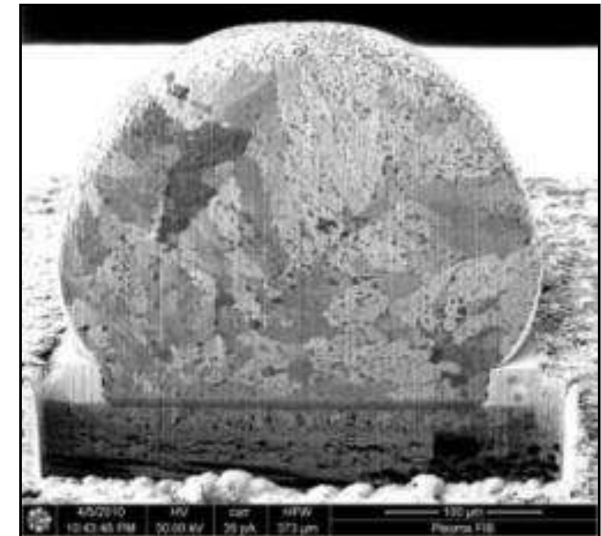
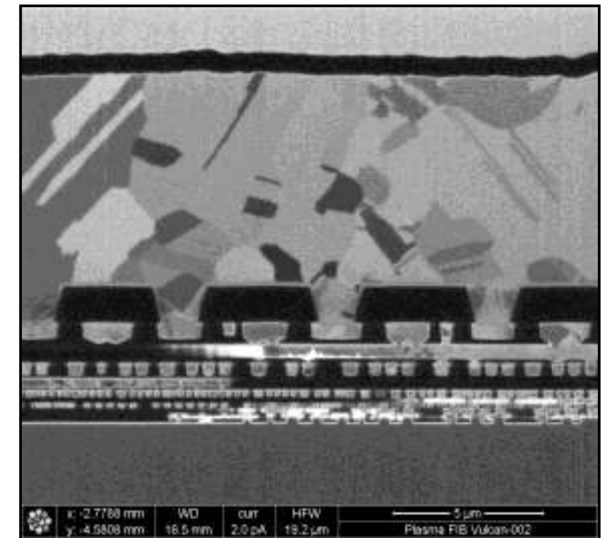
Plasma FIB Applications









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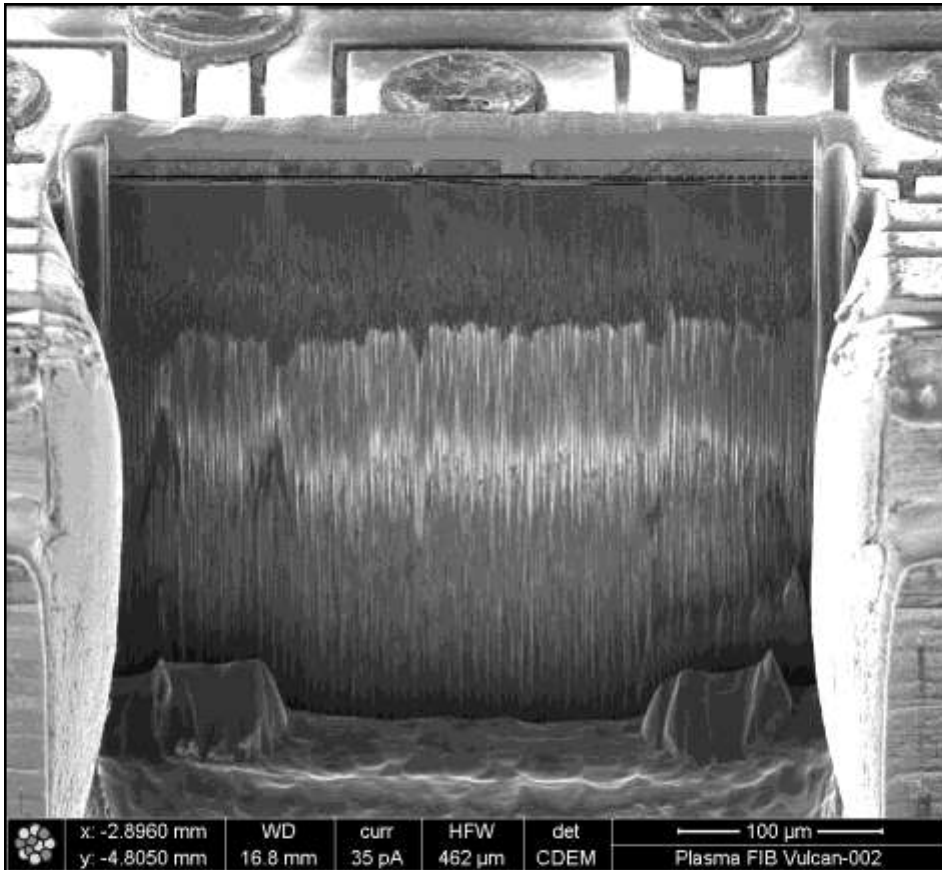
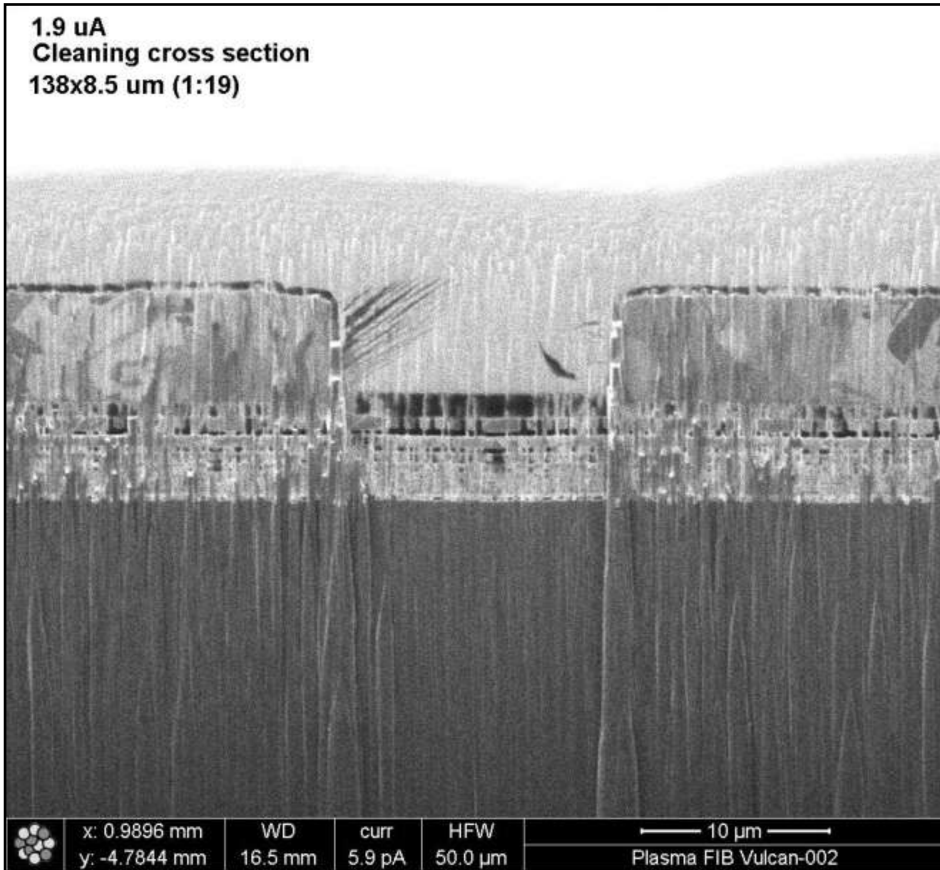
How to Reduce Curtaining on Large X-Sections?





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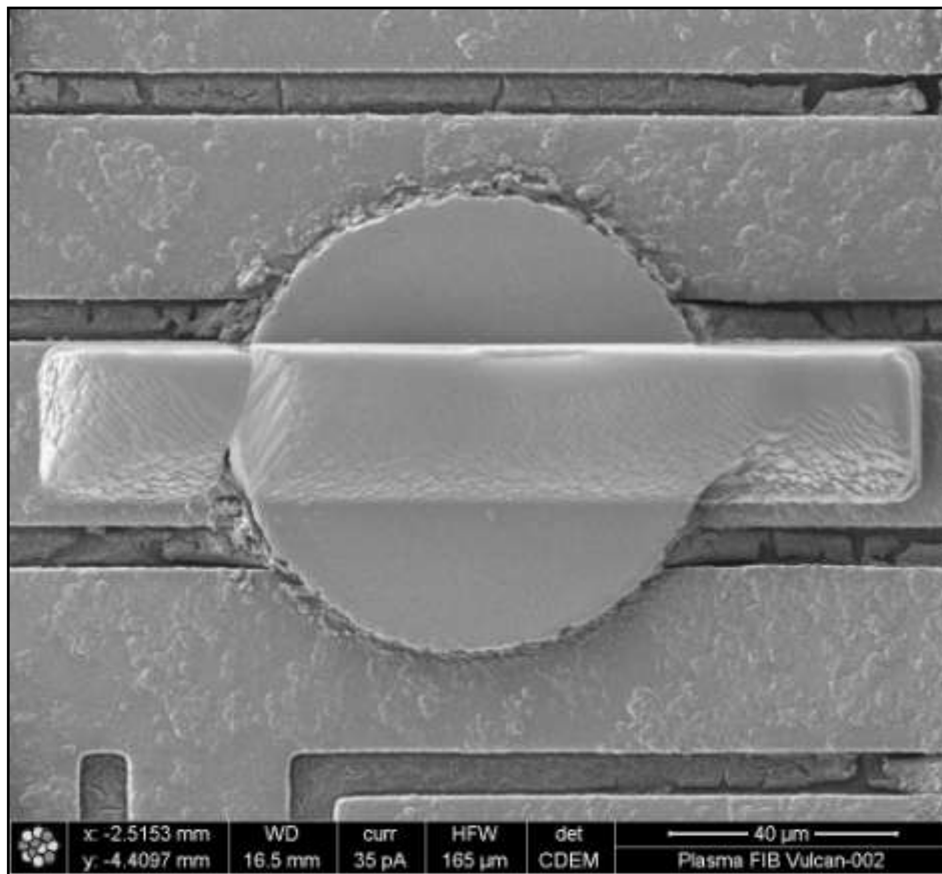

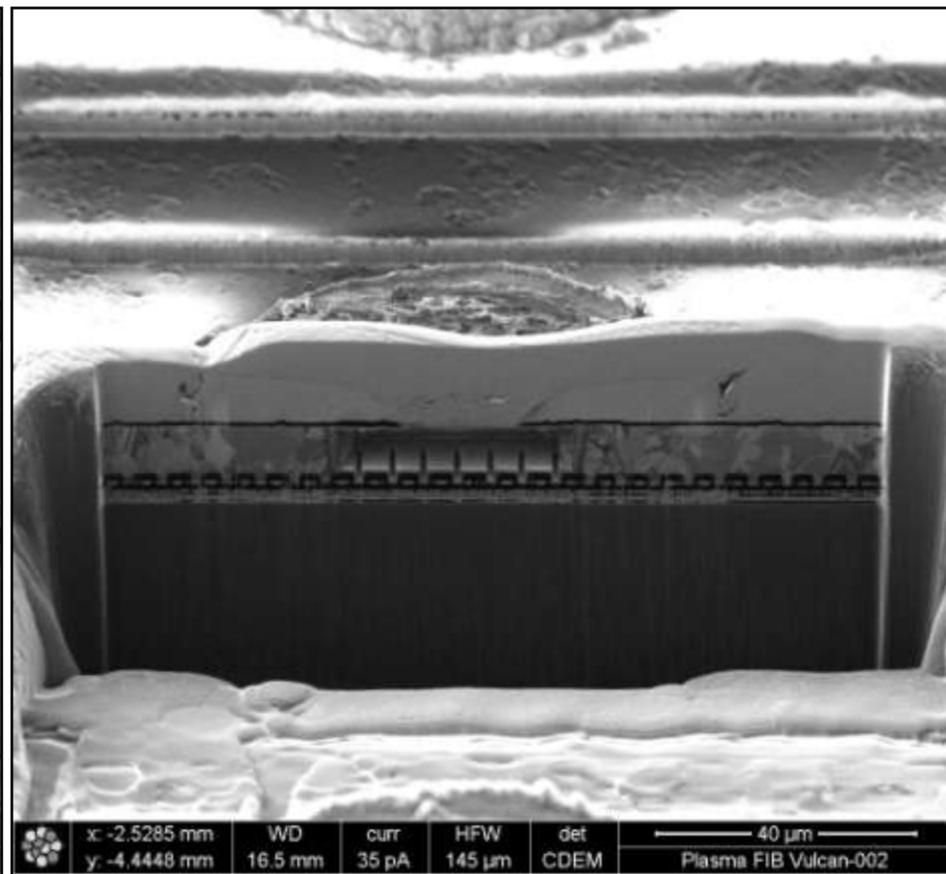

Sacrificial metal deposition

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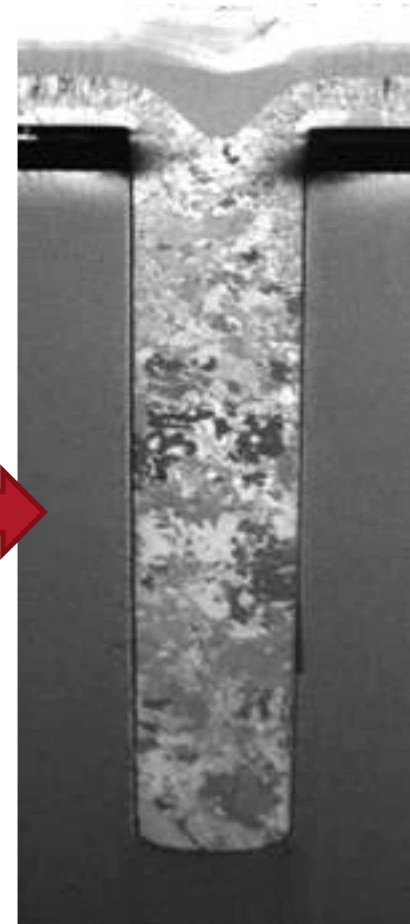
Reducing Curtaining

Typical curtaining on a TSV

Dynamic Focus OFF

WD	curr	HFW	det	tilt	50 µm
16.4 mm	35 pA	136 µm	CDEM	55 °	Plasma FIB Vulcan-002



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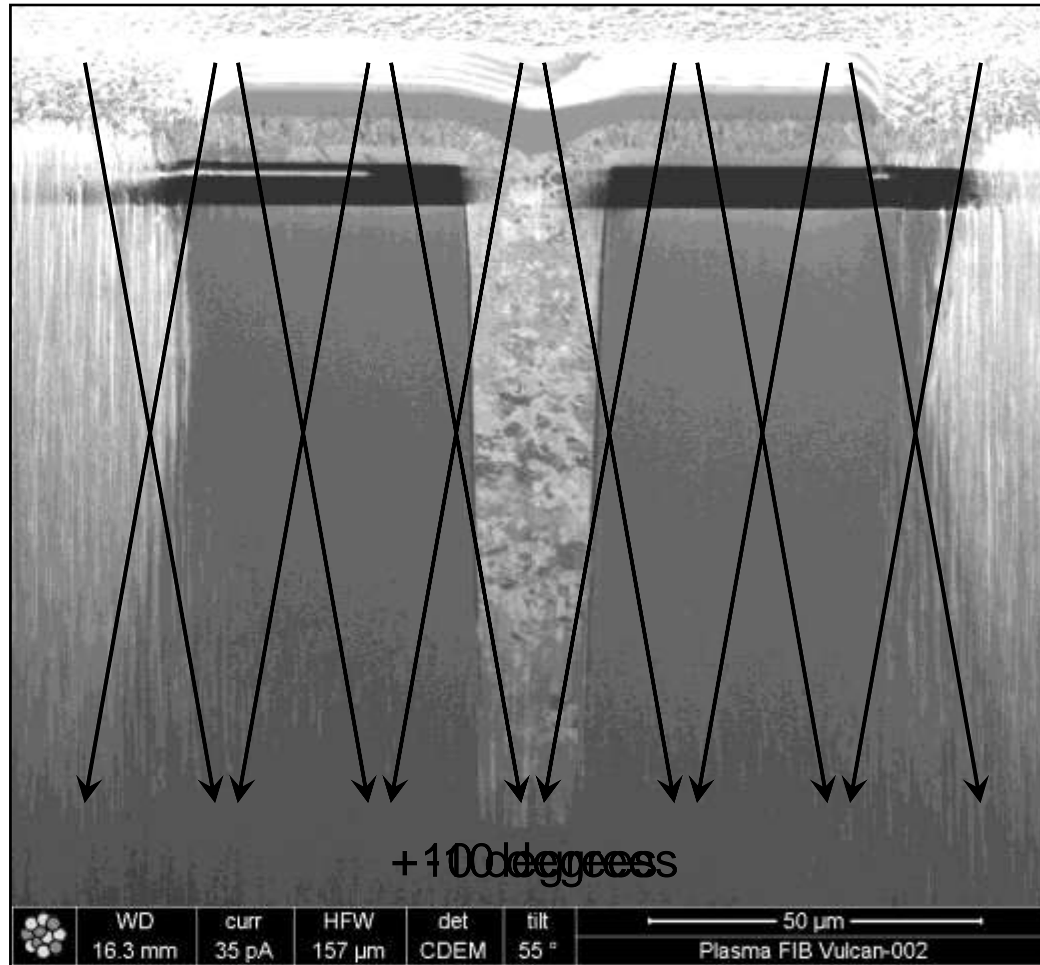
Reducing Curtaining with Tilted Milling



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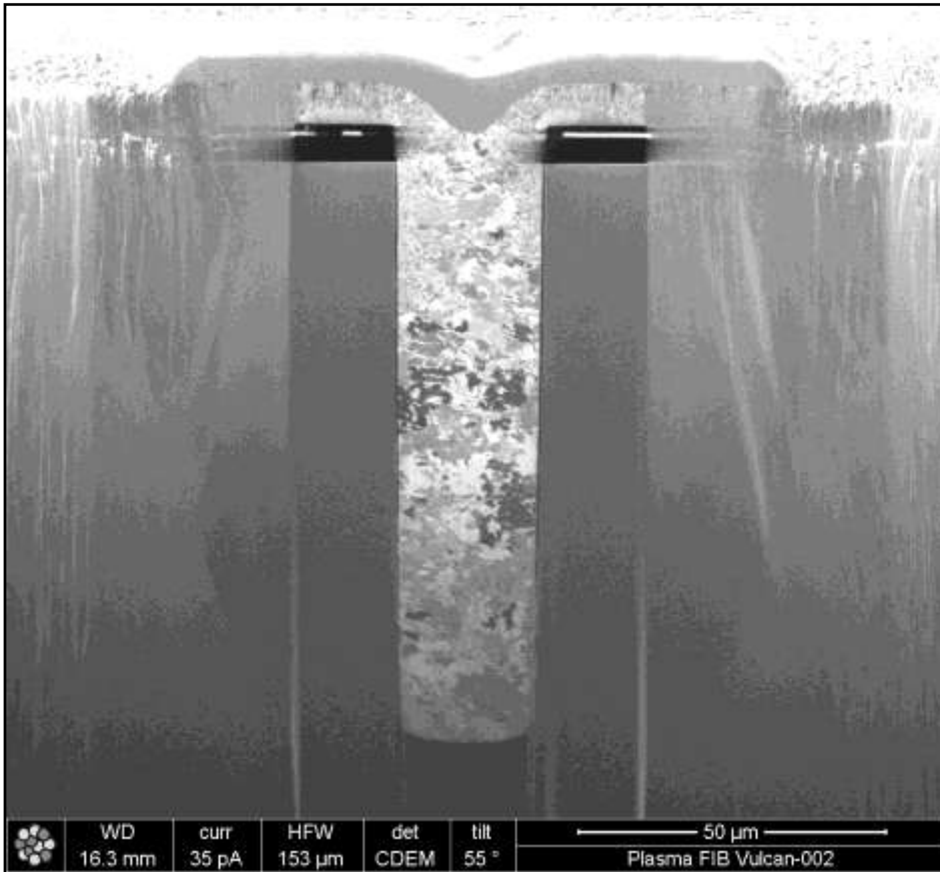
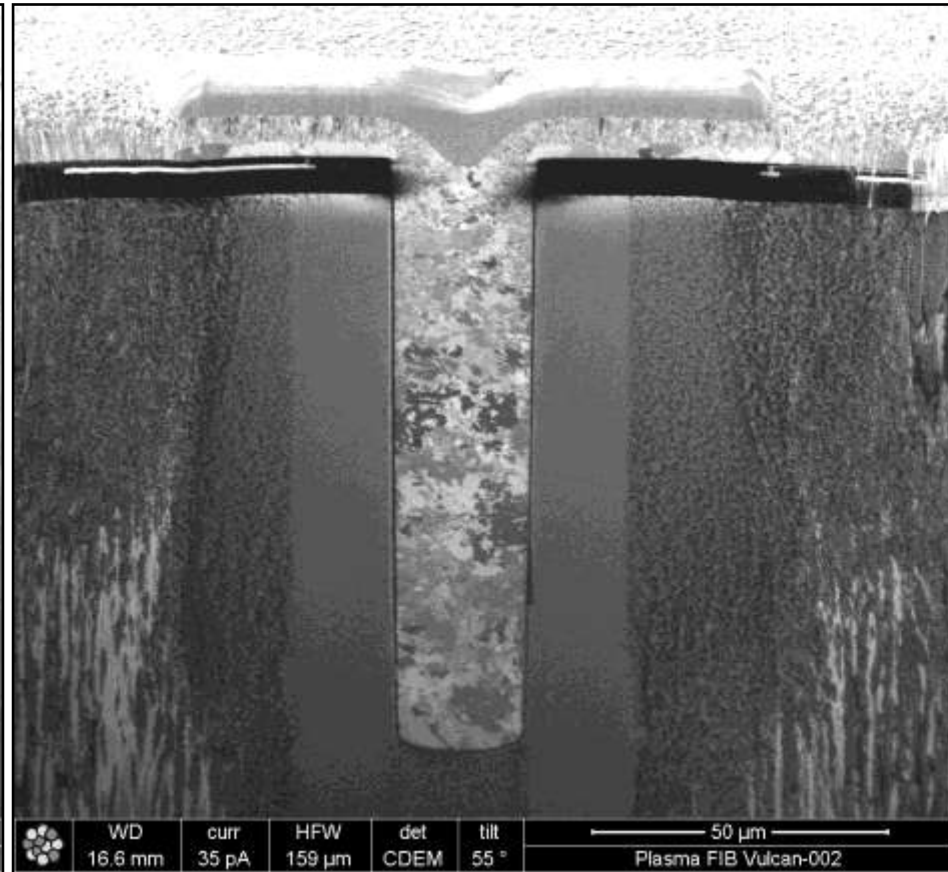


Tilted milling complete…



…and after a splash of XeF_2

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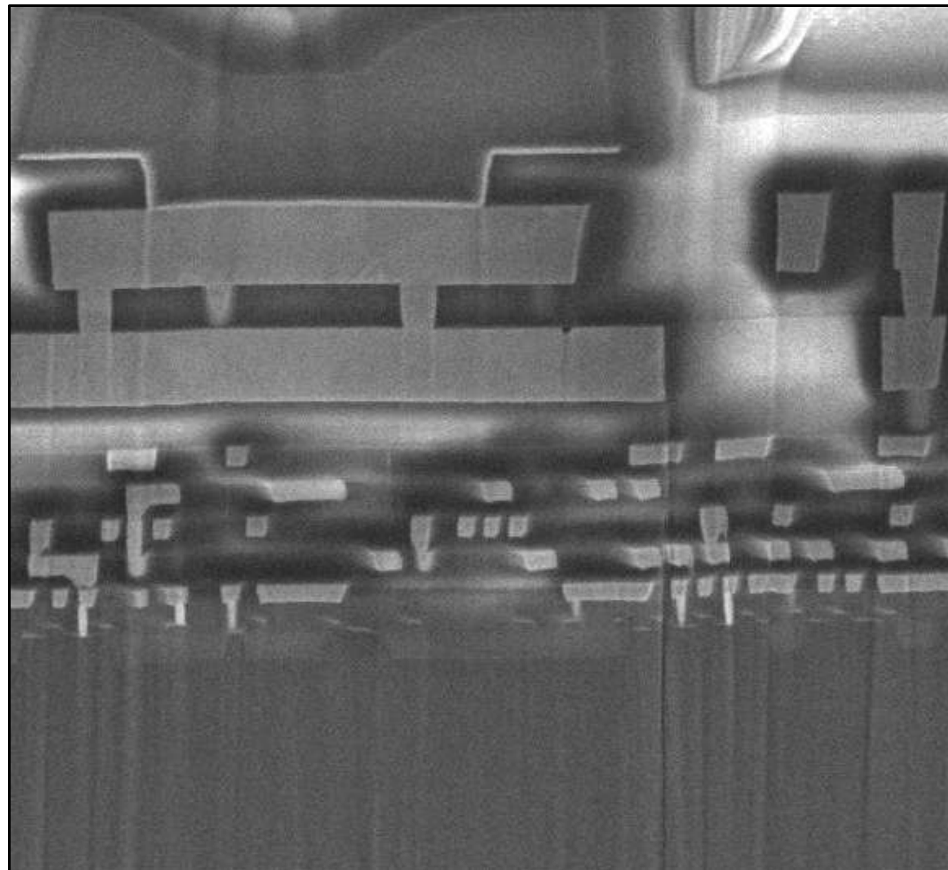
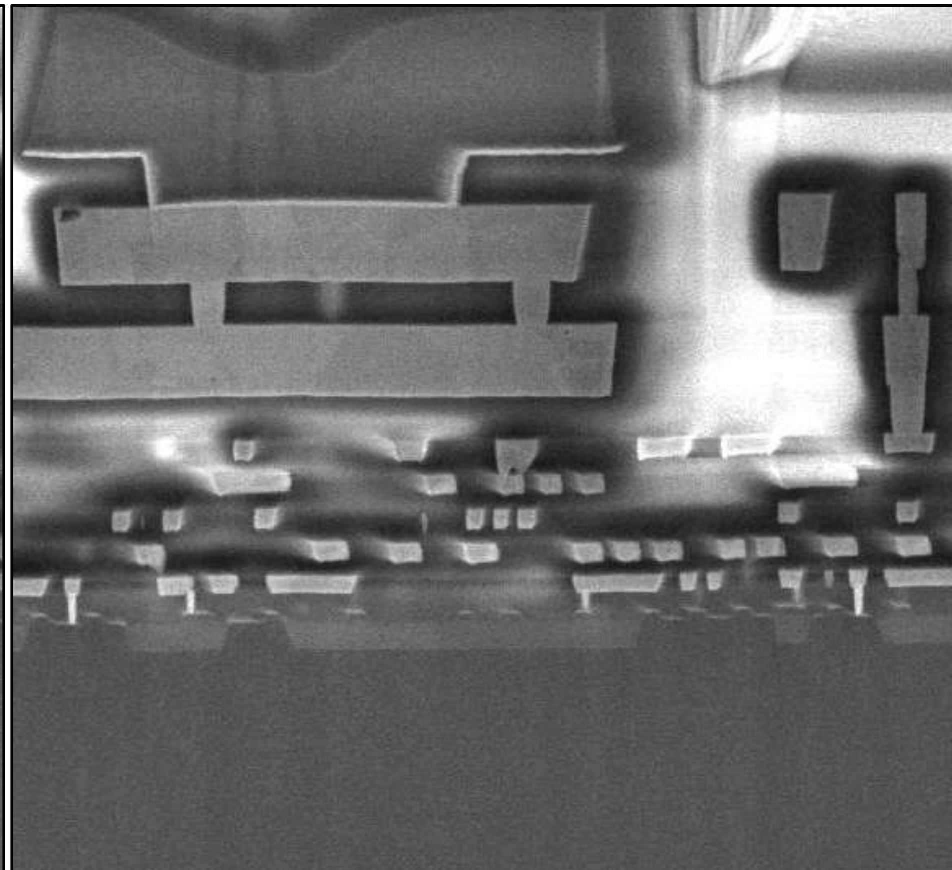
Reducing Curtaining with Tilted Milling



After typical cleaning cross section



After tilted milling process

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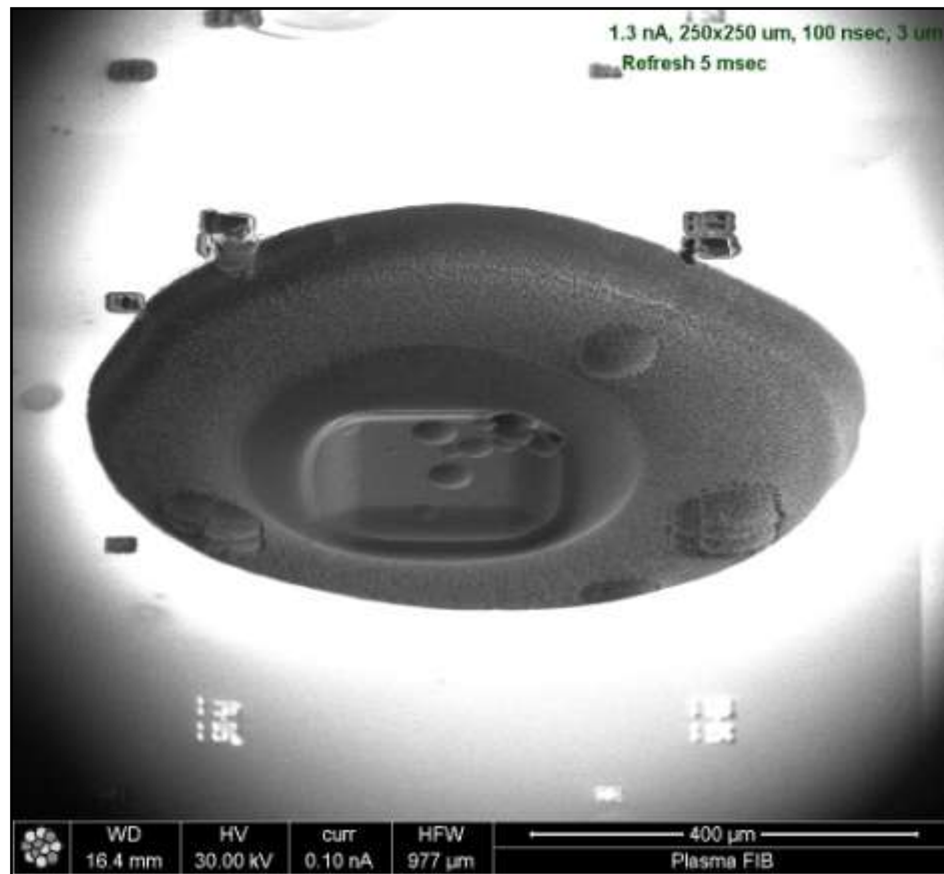
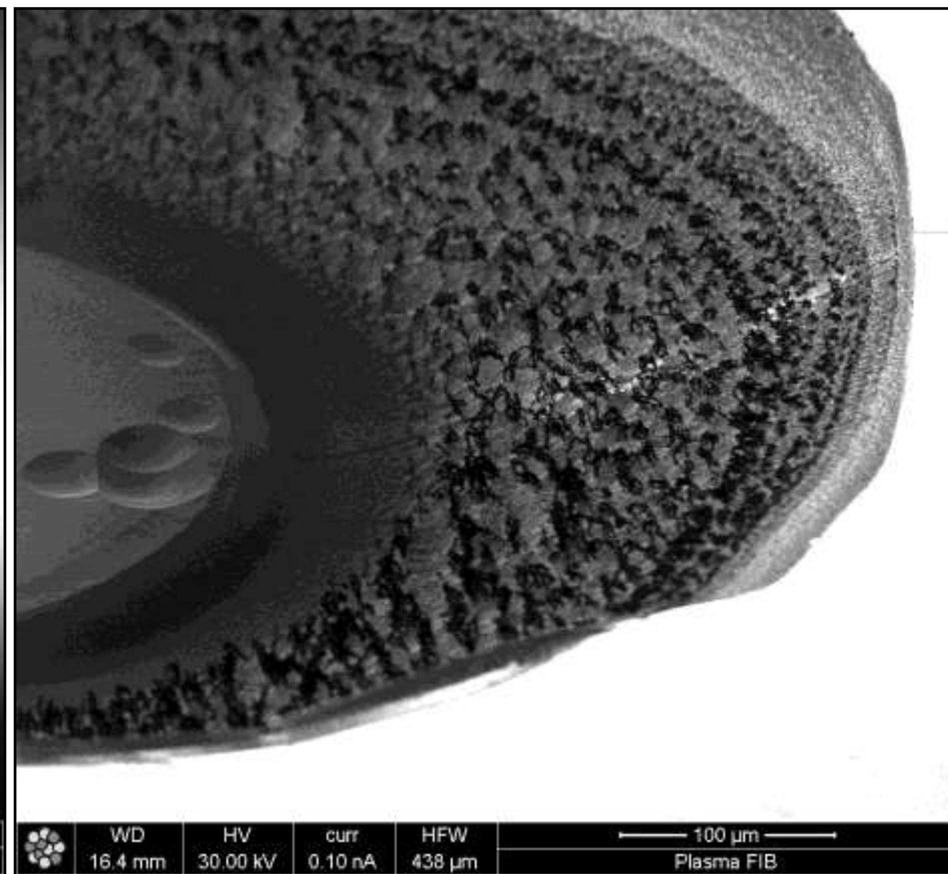
XeF_2-Assisted Si Trenching





Gas depletion effects can be severe if the parameters are not optimized

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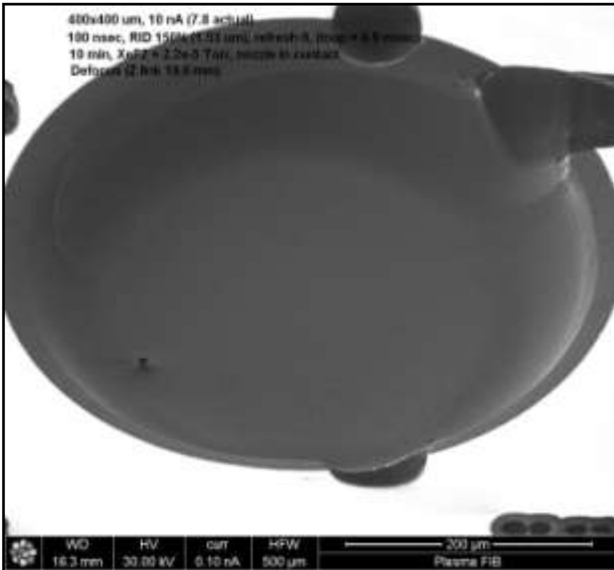
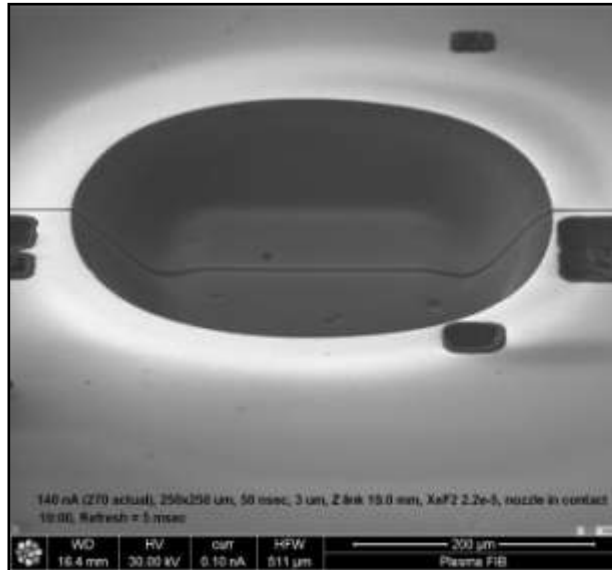
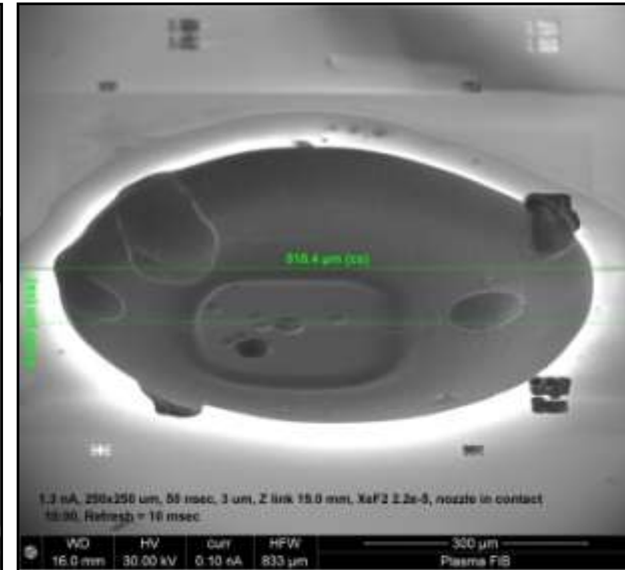
Gas Depletion Effects







Gas enhanced Gas depleted

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XeF_2-Assisted Si Trenching

Successful trenching:

•Short dwell time (100 nsec)

•Large pixel spacing (-150%)

•Defocus

•High gas flux (2e-5 Torr w/ coax nozzle)

Best results so far:

•Enhancement factor = 45

•Milling speed = 1.42×10^6 μm^3/min = 2.37×10^4 μm^3/sec

•Estimated time to mill full thickness sample (780 μm):

- •250x250 (4.9x107 μm3) $\approx$ 34 min
- •400x400 (1.25×10^8 μm^3) $\approx$ 89 min

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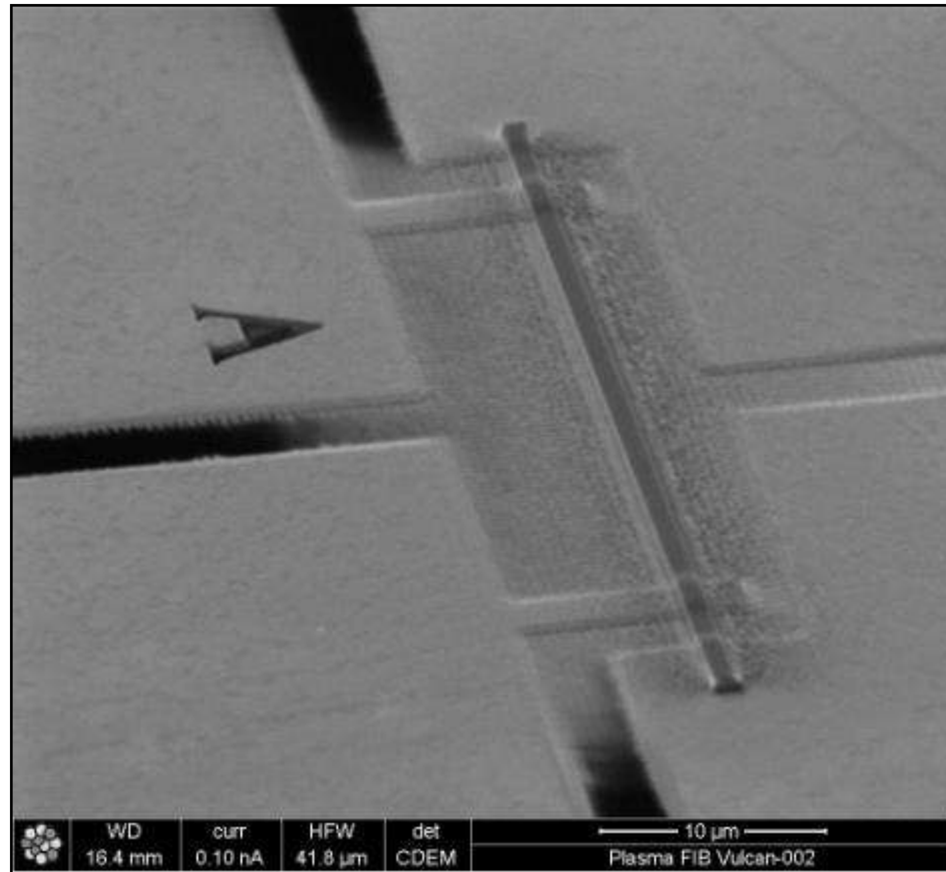
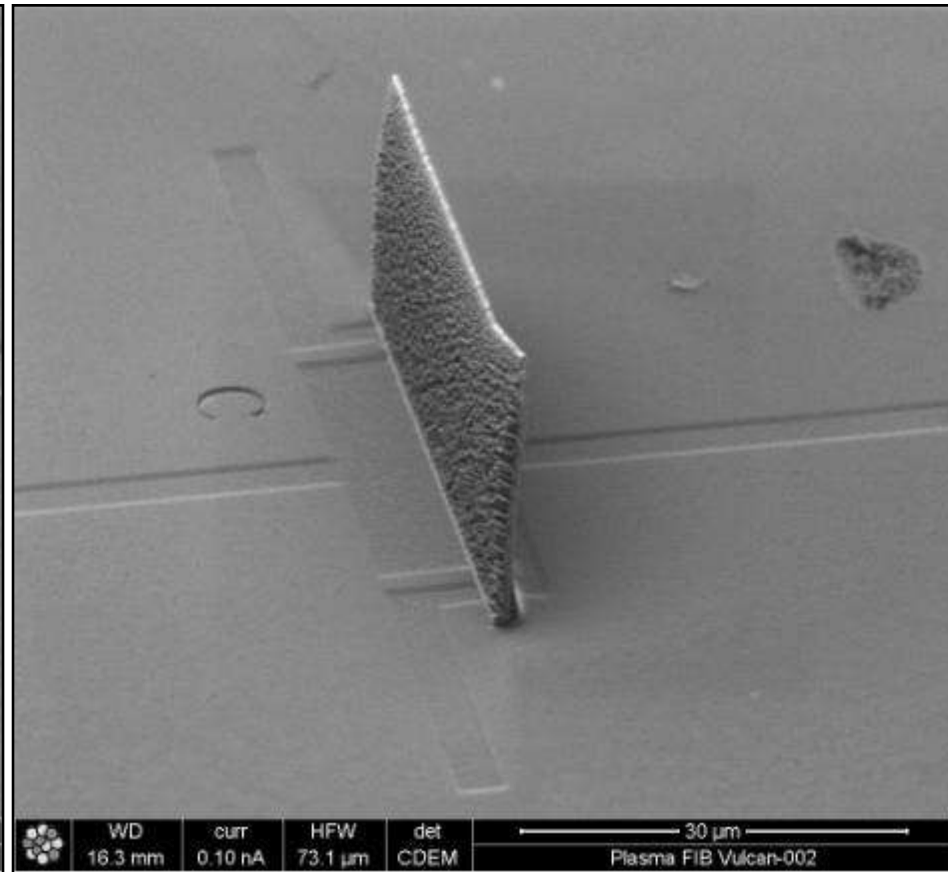
Metal Deposition Yields



W Deposition,
dose of 2



Pt Deposition,
dose of 2

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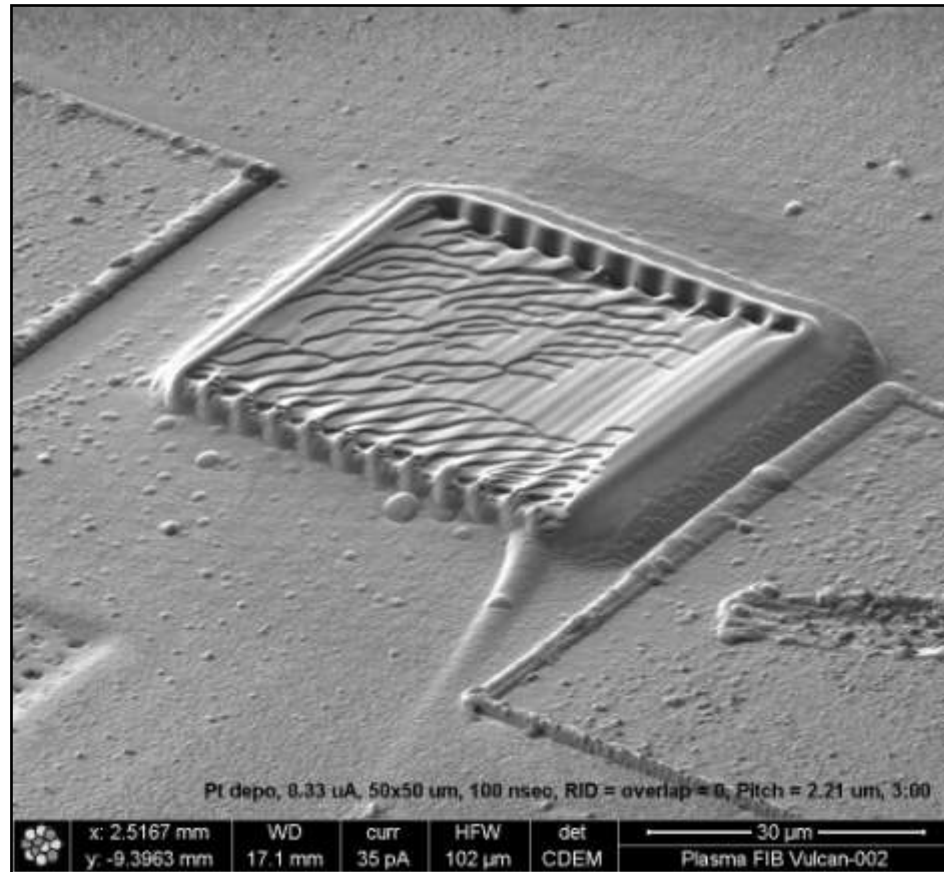
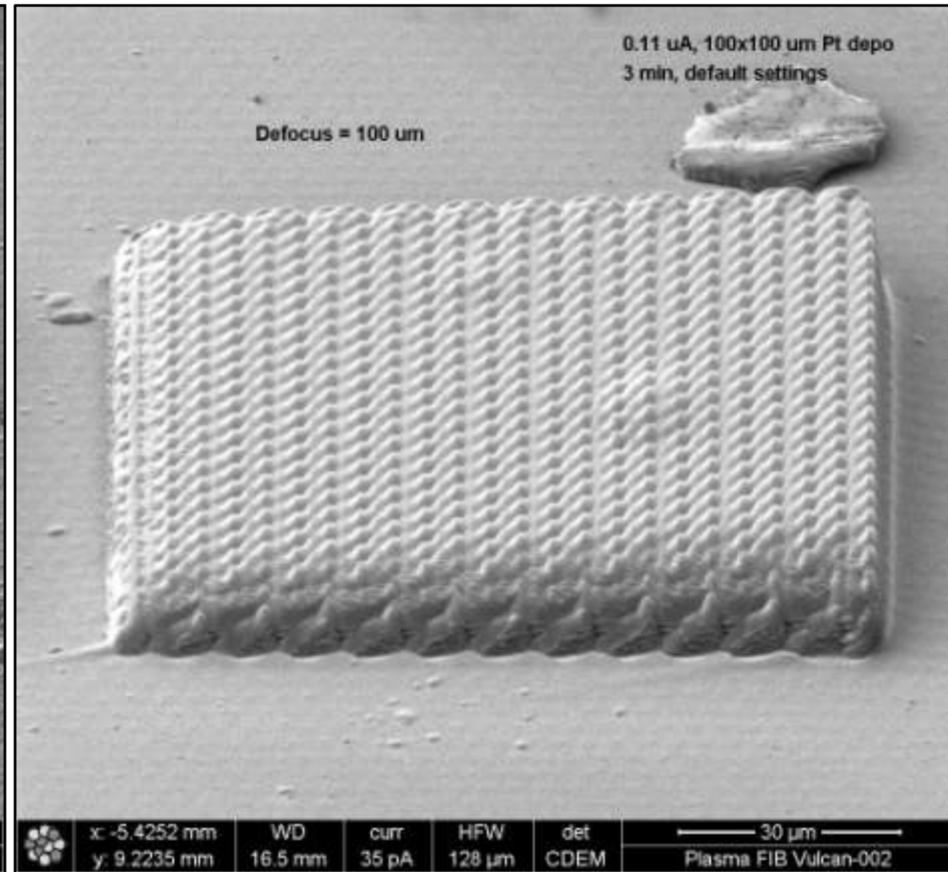
Sacrificial Pt Depositions





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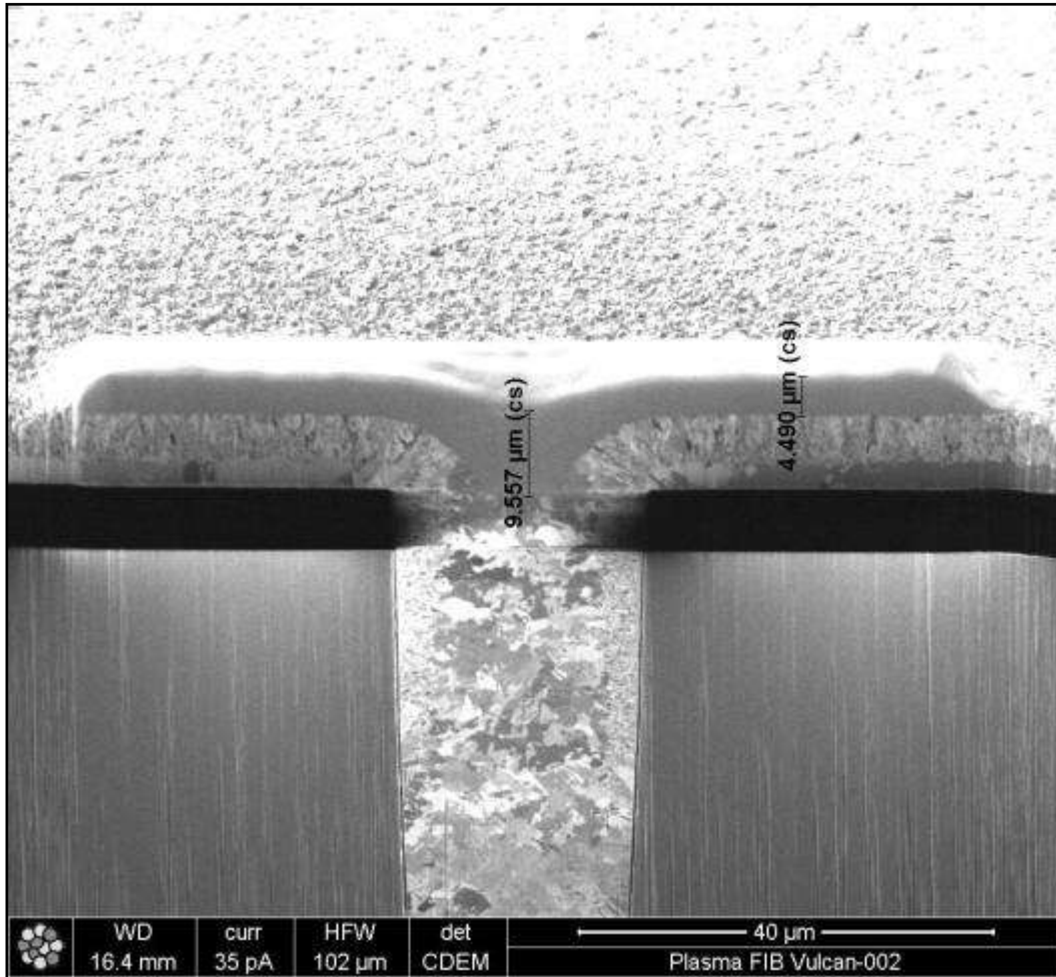
Sacrificial Pt Depositions



- 150x25x7.5 um in 3 min (62 nA)
- 156 um^3/sec
- 2.52 um^3/nC*

* Ga ~0.67 um^3/nC

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Conclusions

- Many existing and emerging technologies, but… Ga is tough to beat
- Xe^{+} plasma FIB results:
  - Titled milling can reduce curtaining
  - Si trenching requires careful balance
  - Metal deposition is very fast
    - Good for sacrificial caps
    - Poor electrical performance

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