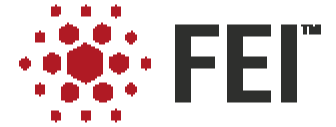

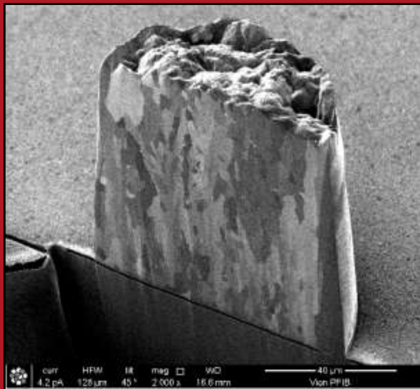

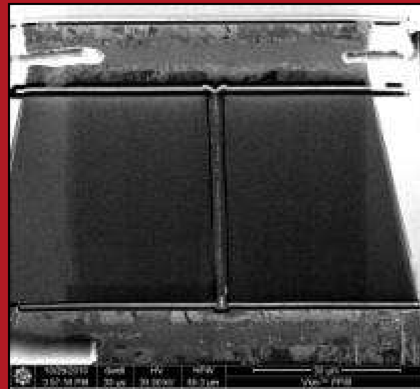

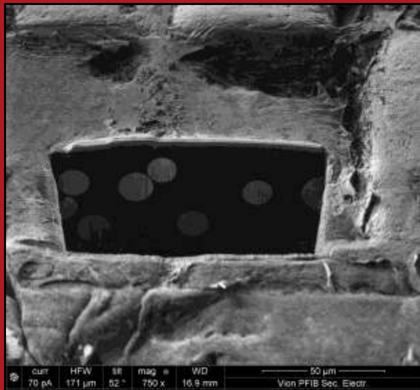

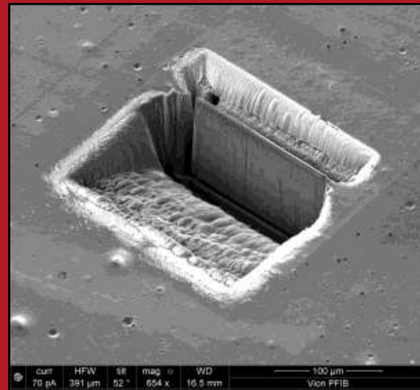

Site-specific Physical Failure Analysis of 3D Systems using “Plasma” FIB

Remco Geurts, P.D. Carleson, R.J. Young, R. Routh, C. Rue, G. Franz, and L.F.Tz. Kwakman

FEI Company

EFUG 2011

Monday 3rd October, 2011

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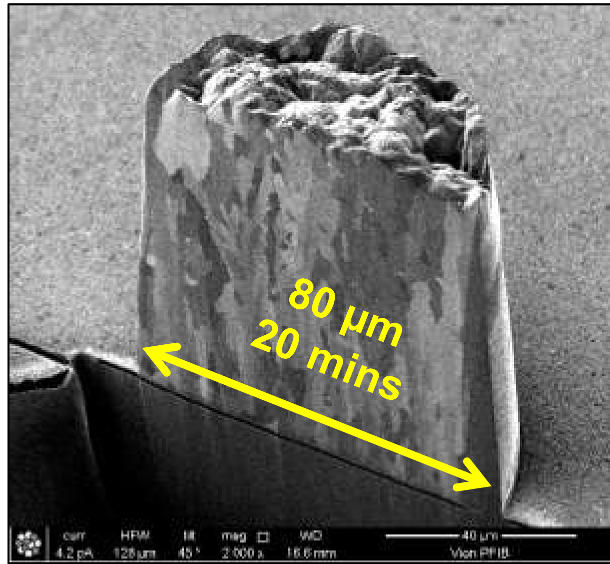
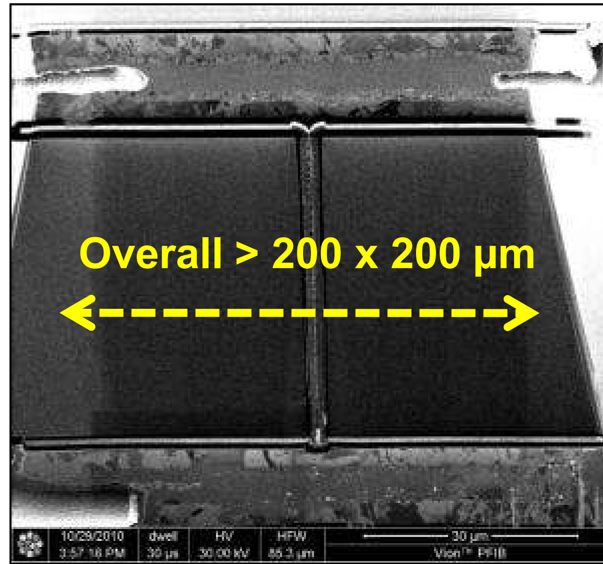
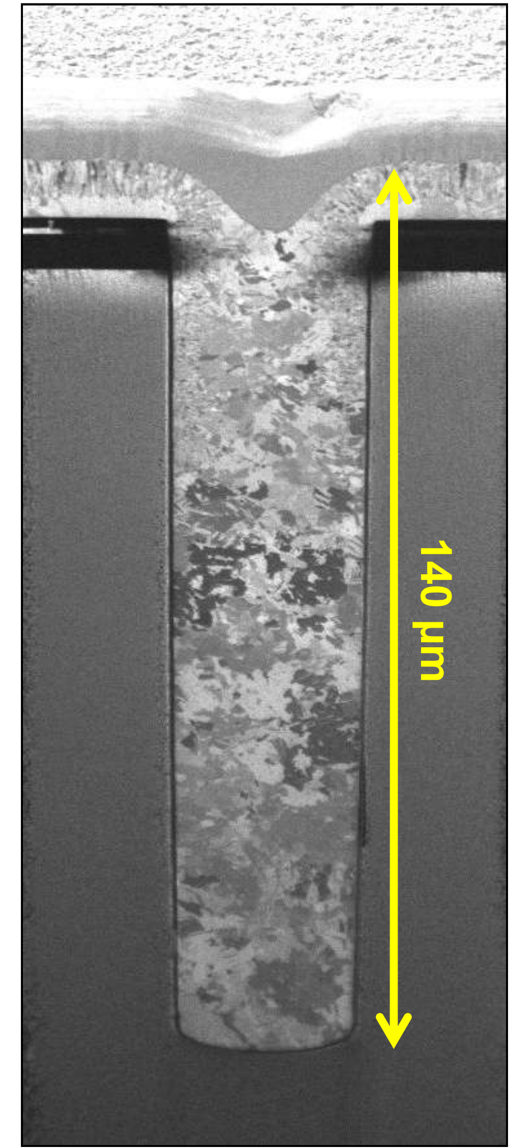
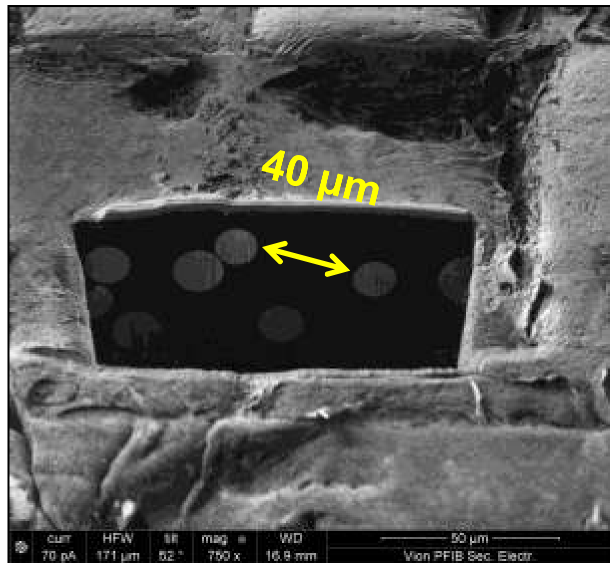
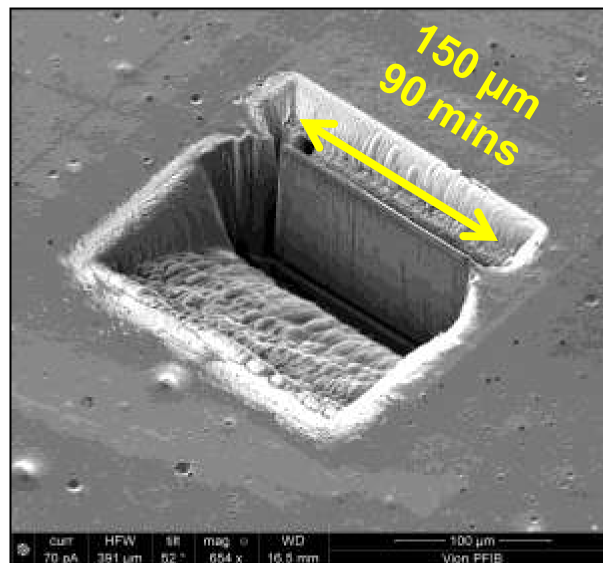
Plasma FIB Technology and Applications











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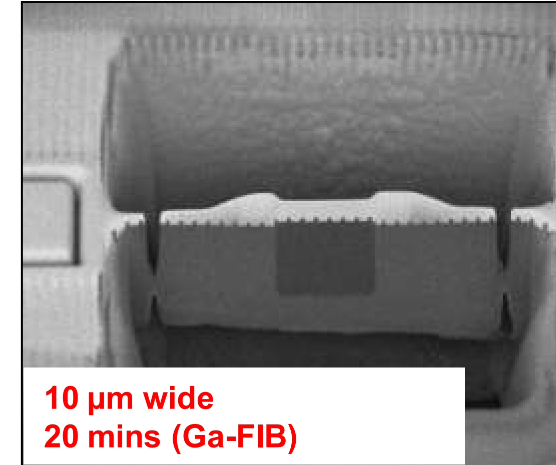
Focused ion beam sample preparation

Excellent for site-specific sample preparation

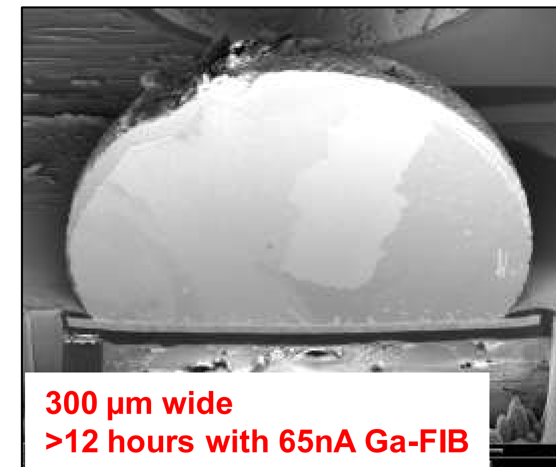
- Localized – positioning to nm level
  - Leave rest of device intact
  - Multiple locations on single device
- Any orientation
- No mechanical shock or tearing/smearing


10 µm wide
20 mins (Ga-FIB)

Generally uses gallium liquid metal ion source (LMIS)

Typical beam current range 1 pA to 20-65 nA

- ~10^3 μm^3/min for silicon at 60 nA
- Short prep times for sections a few 10s of µm on a side
- 3D IC technology/packaging sections often > 100 µm
- Therefore, require new techniques focused on throughput and efficiency


300 µm wide
>12 hours with 65nA Ga-FIB

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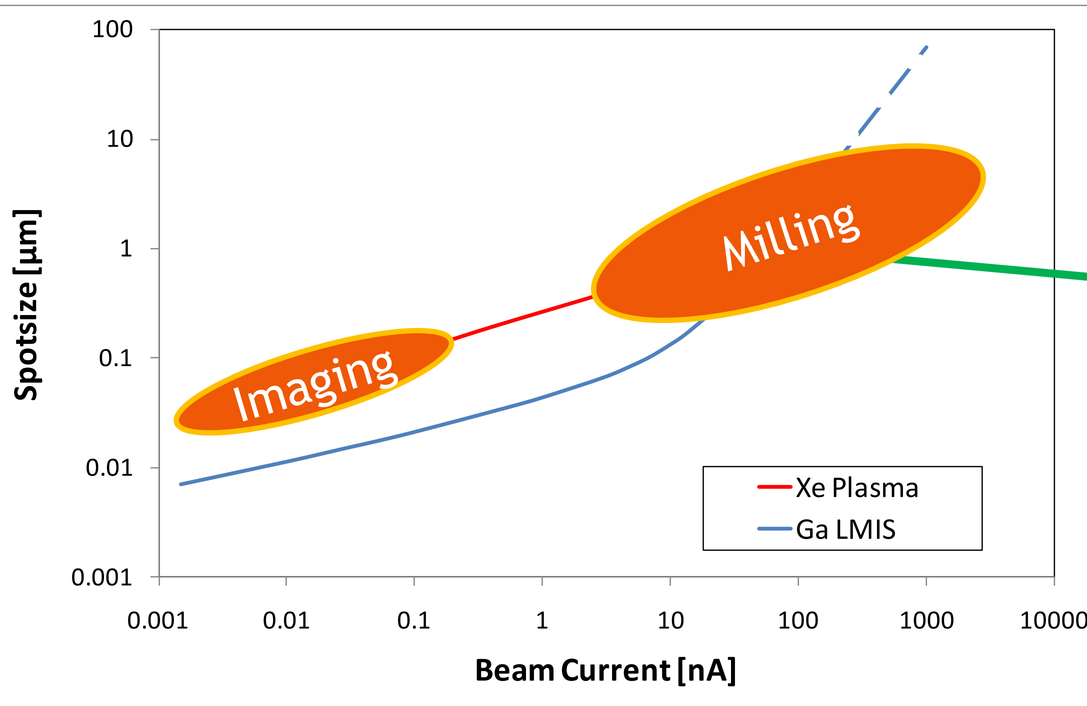
Why *Plasma* FIB: 20x faster than current FIBs

A system that provides unique and fast ion milling capabilities for rapid cross sectioning of features from 50 to 1000 microns.



- ✓ High volume milling / high beam current
- ✓ Ga-FIB loses size advantage to plasma source as beam current goes above 50-60 nA
- ✓ Xe has high sputter yield, high brightness, and low energy spread
- ✓ No Ga contamination

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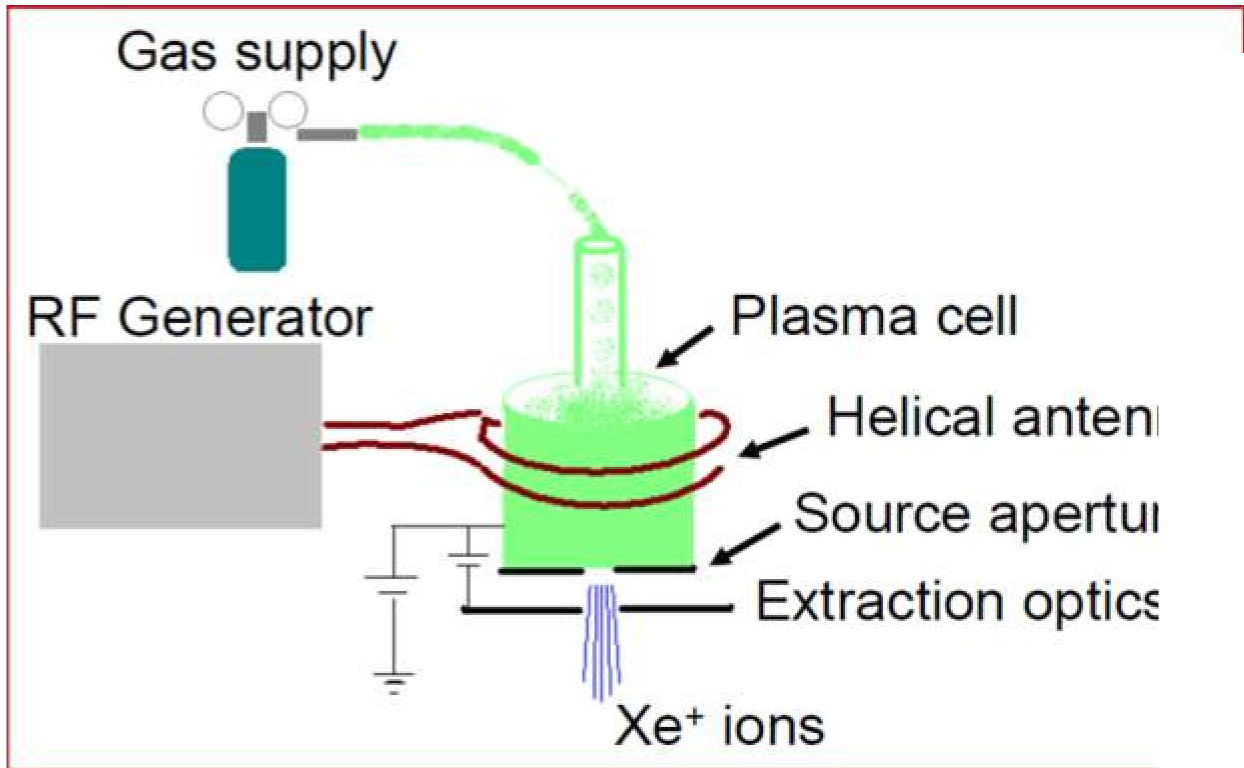
Inductively coupled plasma (ICP) ion source



- Gas flows into plasma cell
- Helical antenna couples energy into plasma cell
- Electrons removed from atoms to form Xe^+ ions
- Extraction optics accelerate ions into FIB column

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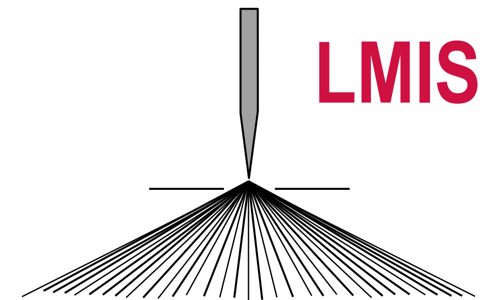
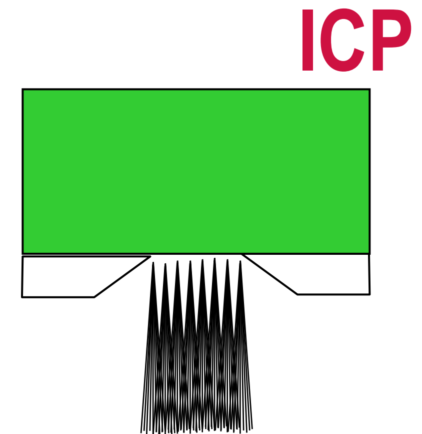
Comparison of FIB sources

	Liquid Metal Ion Source (LMIS)	Inductively Coupled Plasma (ICP) Source
Descriptive Phrase	"Point source with low angular intensity"	"Broad source with high angular intensity
Angular Intensity [mA sr^{-1}]	0.02	50
Virtual Source Diameter [nm]	50	15,000
Normalized Brightness [A sr^{-1} m^{-2} V^{-1}]	10^6	10^4
Optical Challenge	Above about 10 nA, spherical aberrations degrade FIB performance	Extreme demagnification required for small probe sizes (< 50 nm)



Conical emission pattern



Collimated emission pattern

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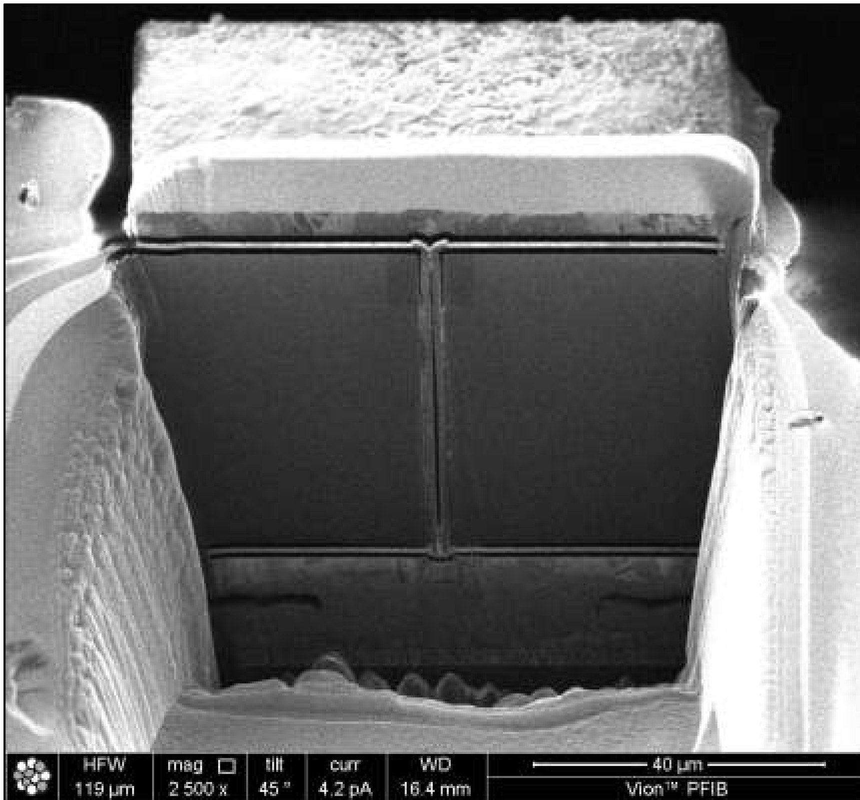
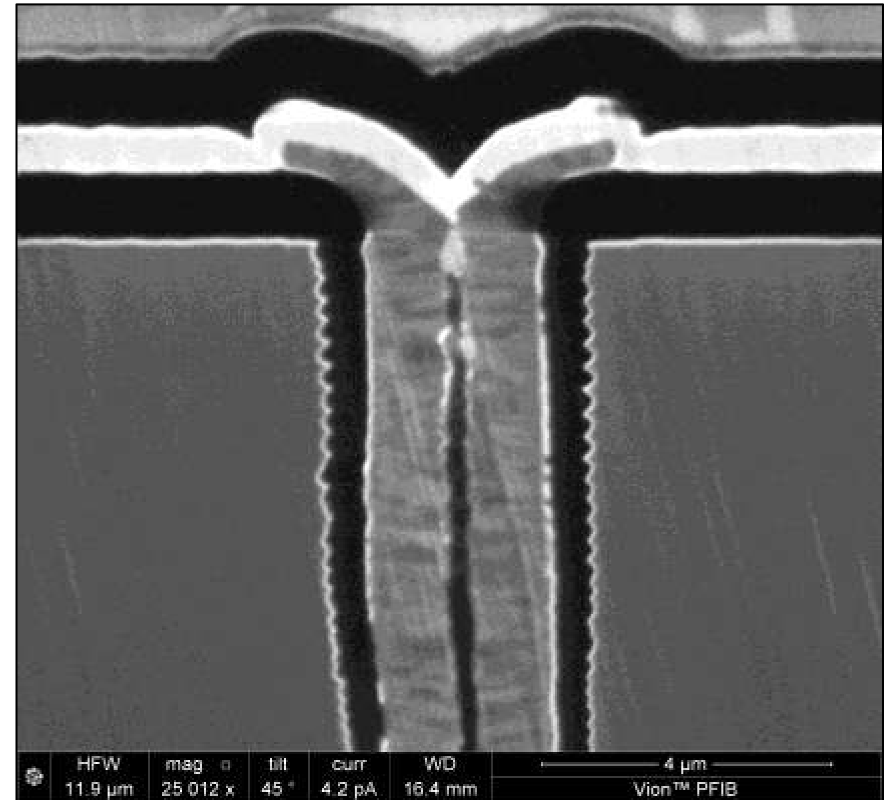
TSV– full section (depo, bulk, polish) in 20 mins





PFIB imaging provides the similar contrast mechanisms as standard Ga-FIB:

- Topographic contrast
- Materials contrast
- Passive voltage contrast
- Ion channeling contrast

- Smallest useful HFW: 10-15 µm
- Limited sputtering/image at low current (compared to using HFW of 2-3 µm with Ga)

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Sample courtesy of Fraunhofer, Munich
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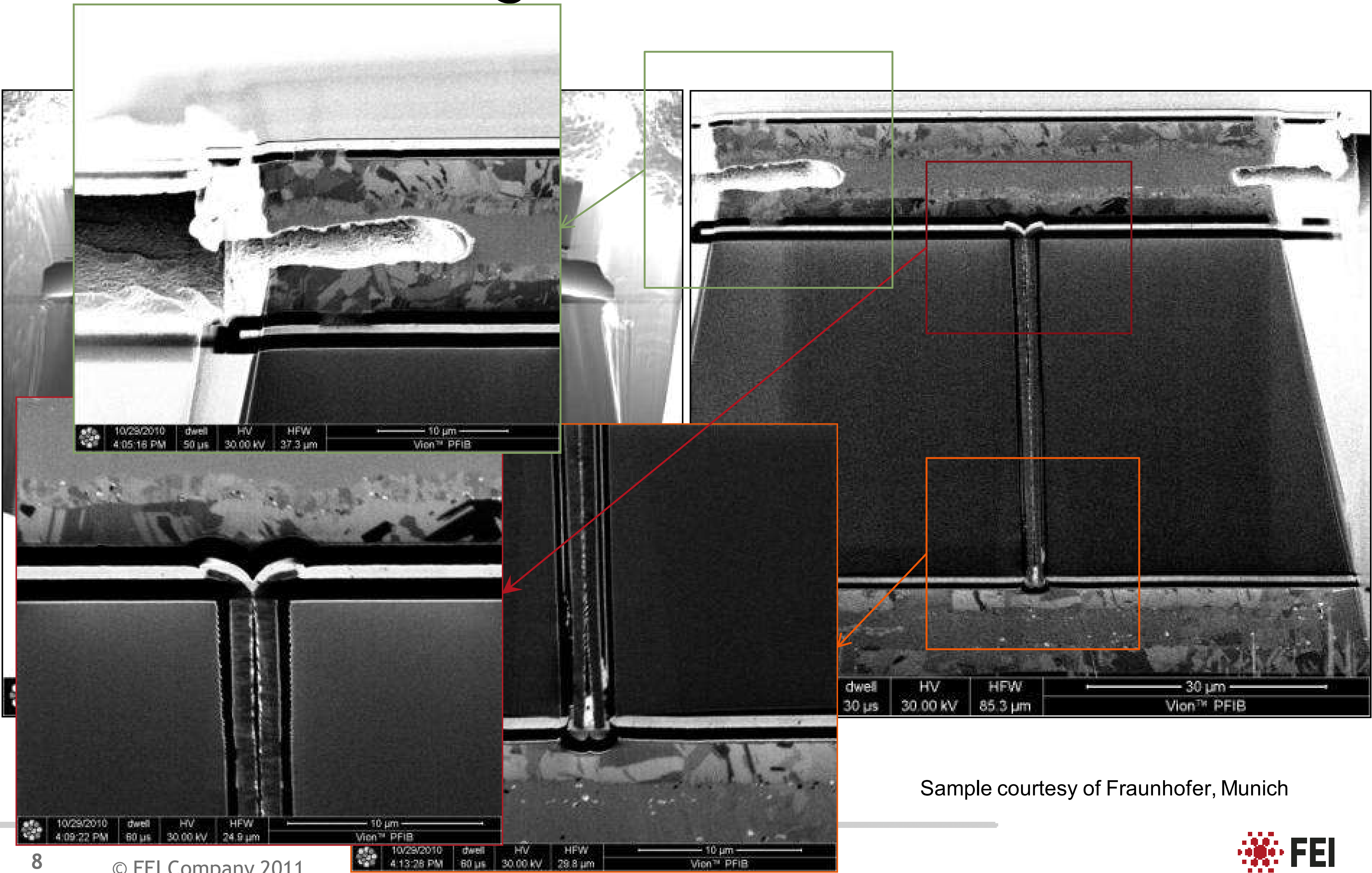
Cross sectioning three-die stack



Sample courtesy of Fraunhofer, Munich

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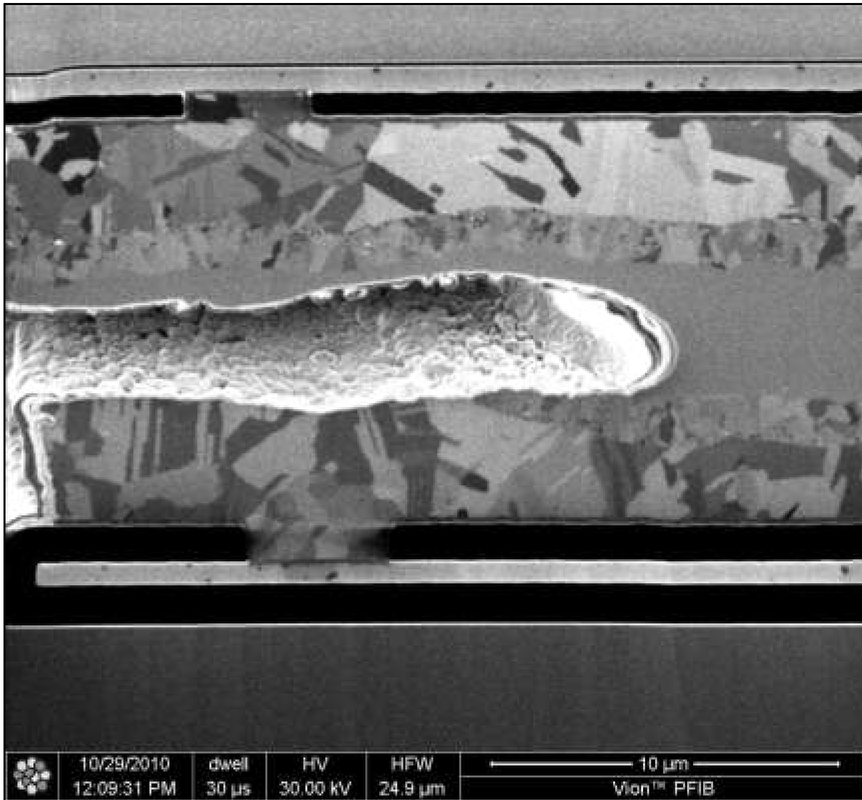
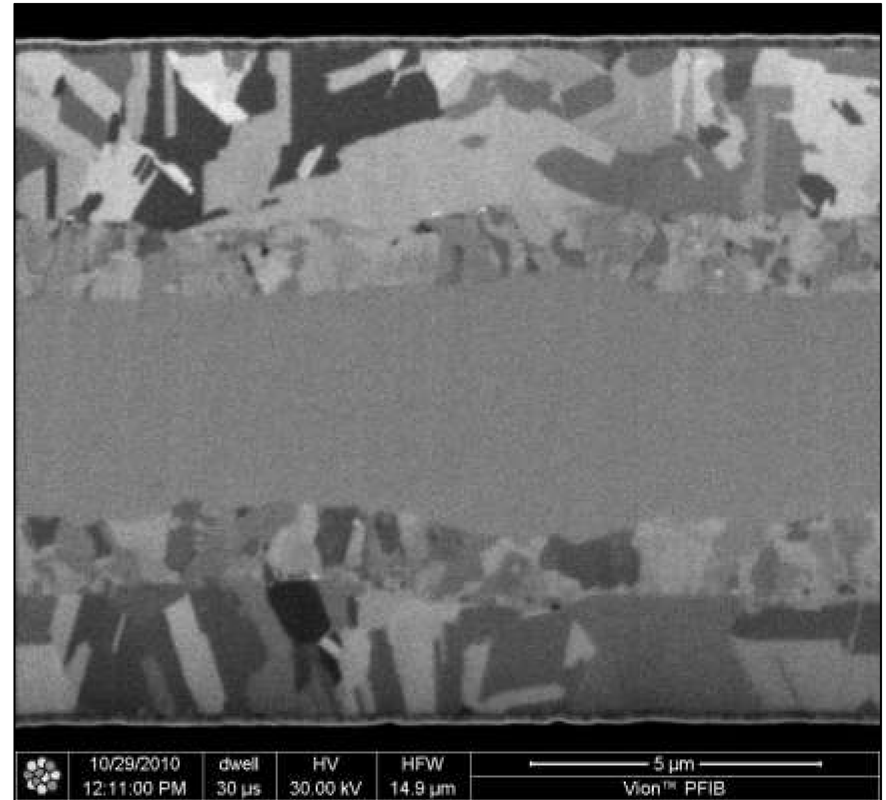
Details of SLID metallurgy (Cu-Sn-Cu)





SLID bonding solid liquid interdiffusion

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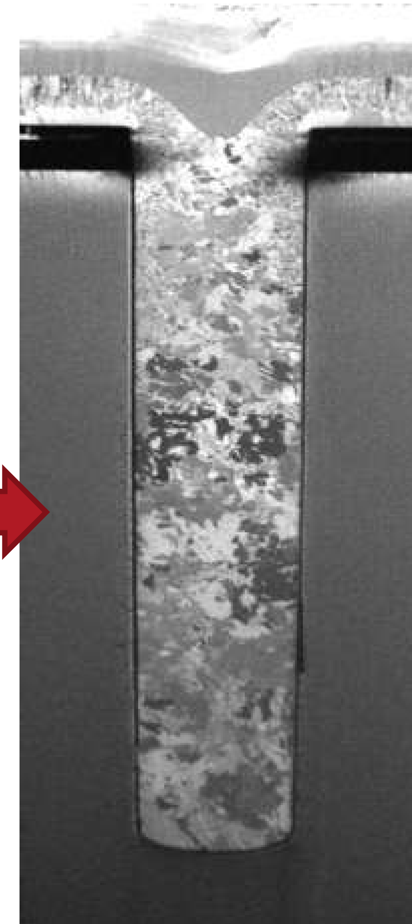
Reducing curtaining

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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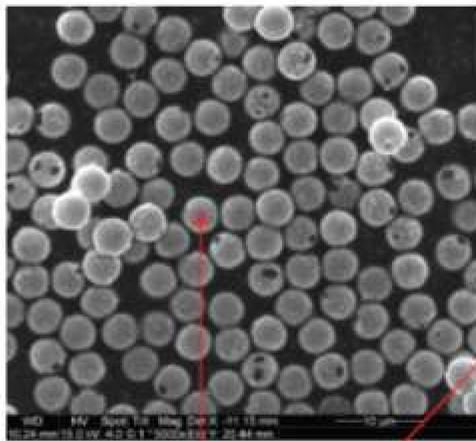
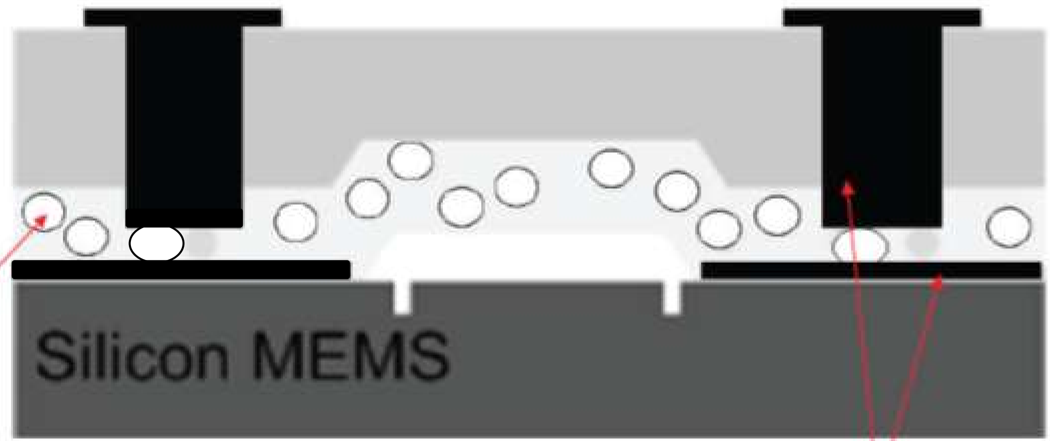
Anisotropic conductive adhesive (ACA) for Wafer-to-Wafer (W2W) bonding





Metal coated polymer spheres (4 µm diameter)

Electrical contacts

Ref: M.M.V. Taklo, T. Bakke, H.R. Tofteberg, L.G.W. Tvedt and H. Kristiansen, Proc. IMAPS Device Packaging Conf., Scottsdale, Arizona, 2011

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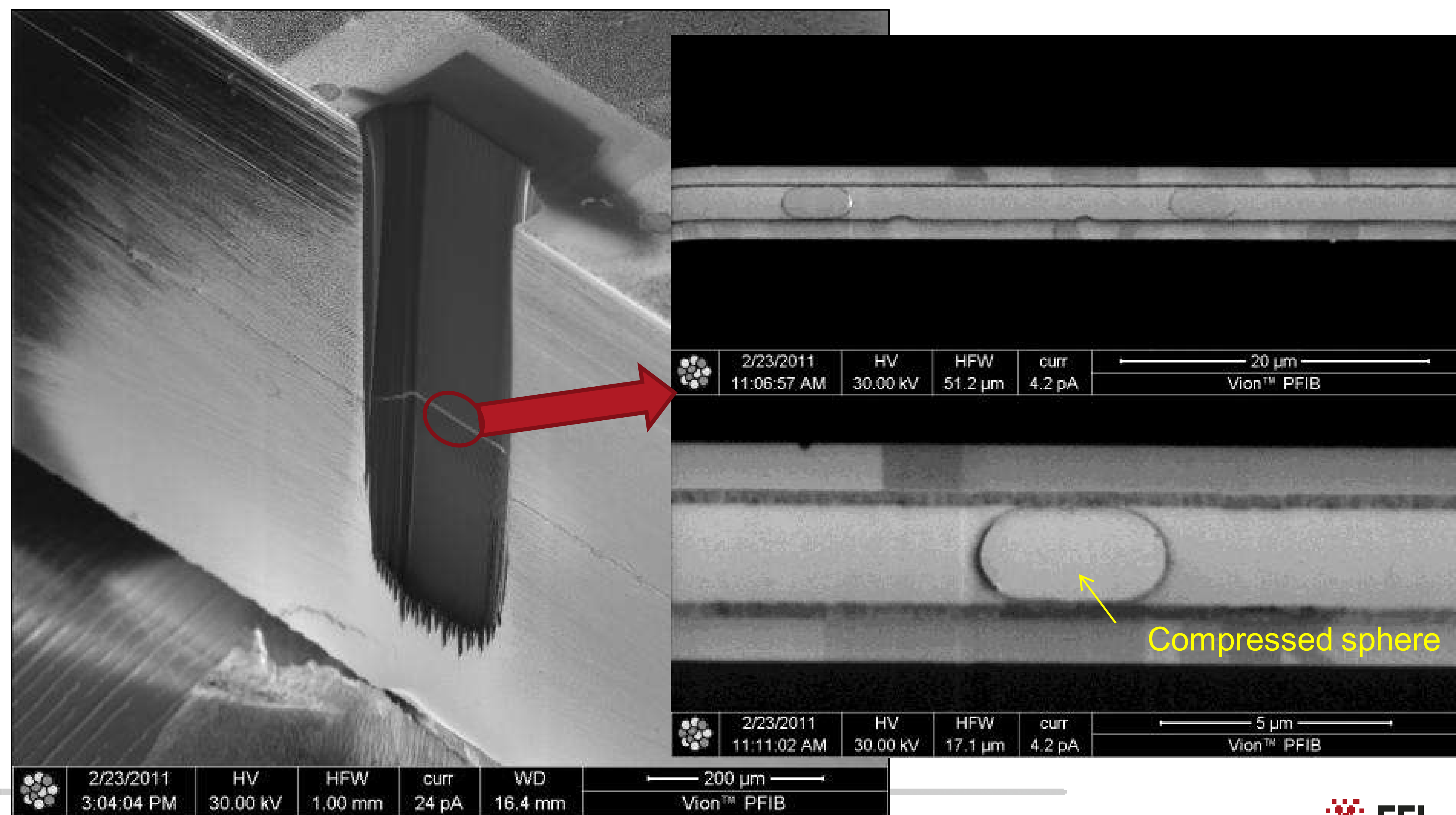
Anisotropic conductive adhesive (ACA) for W2W bonding



Sample courtesy of SINTEF, Norway

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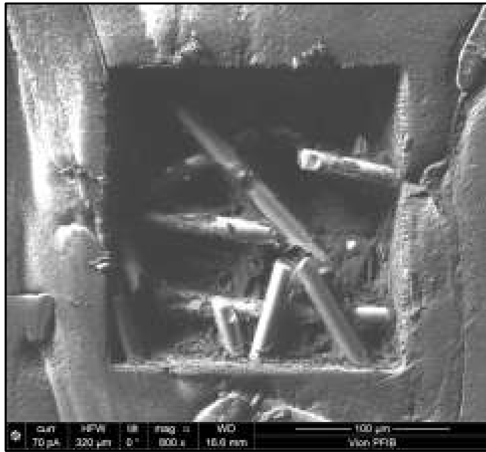
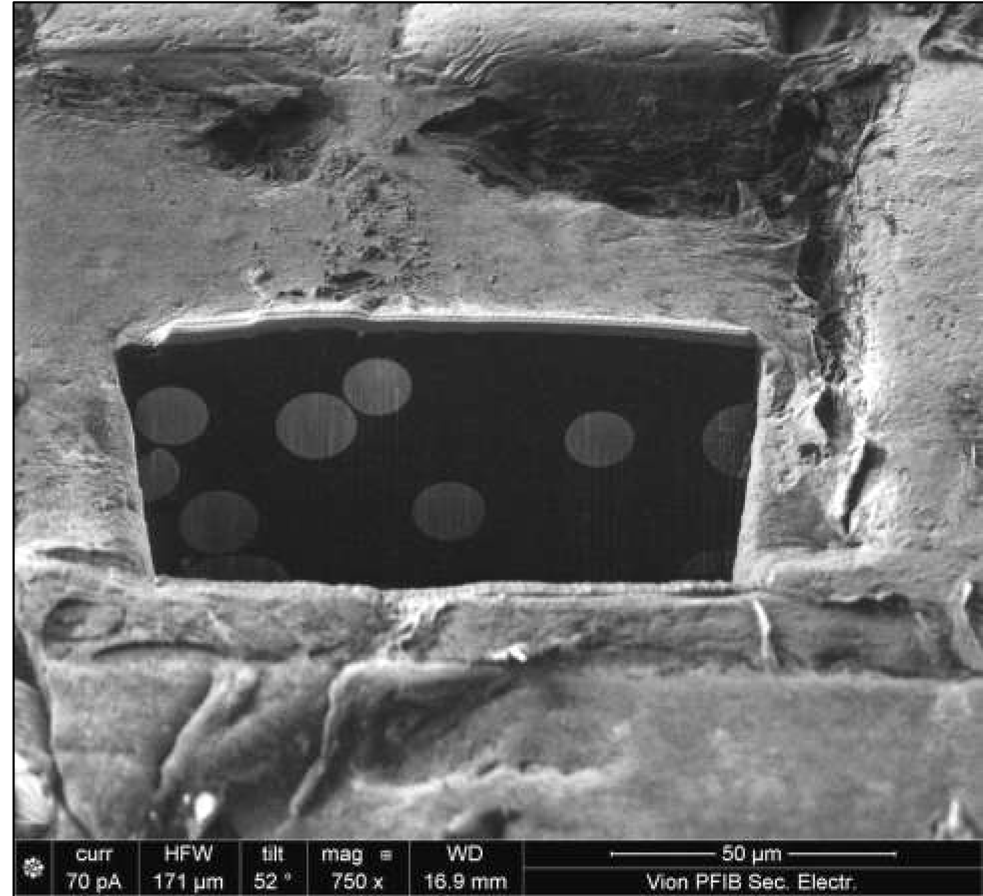
Fiber reinforced polymer bar used for tensile testing





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Summary

3D IC technology needs metrology and root cause analysis down to the sub-micron level for development and failure analysis

- But it takes too long with traditional Ga-FIB

Plasma FIB technology brings site specific advantages of Ga FIB to chip/package scaled problems

- More than 20x faster than traditional FIB
- Capable of high-precision final cuts and high-resolution (sub-30 nm) imaging
- Provides faster development feedback and failure analysis

• Non-semiconductor applications

- Many possible applications – just starting to scratch the surface
- There are many interesting beam-sample and beam-chemistry interactions to discover
- Ga has a 20-year head start, but PFIB learning curve on new samples is rapid!!

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