Approaches and Challenges for Analysis of 3D Packages

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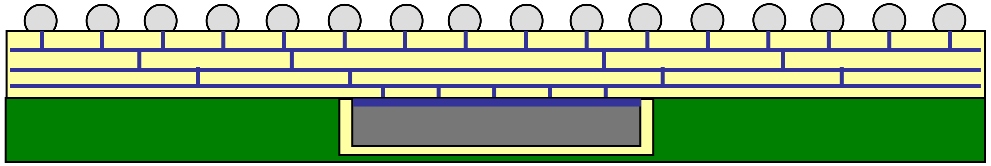
Overview

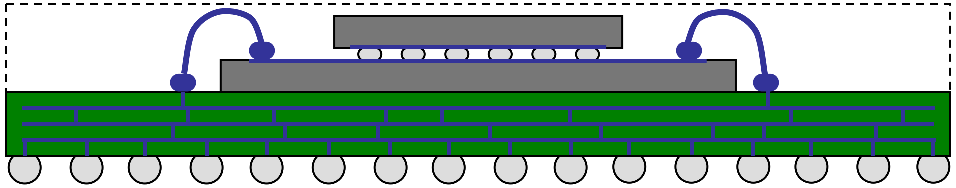
- 3D-The Analysis Challenge in the 2nd decade of the century
- Present Solution Approaches and Methods
- What else do we need ?
- Outlook

Problem: Failure Localisations in SiP's (System in Package)



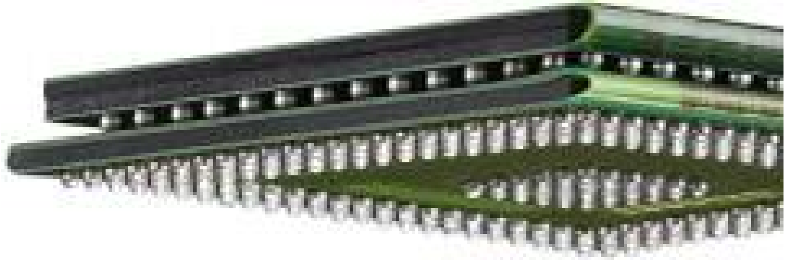
Bumpless Buildup Layer (BBUL)

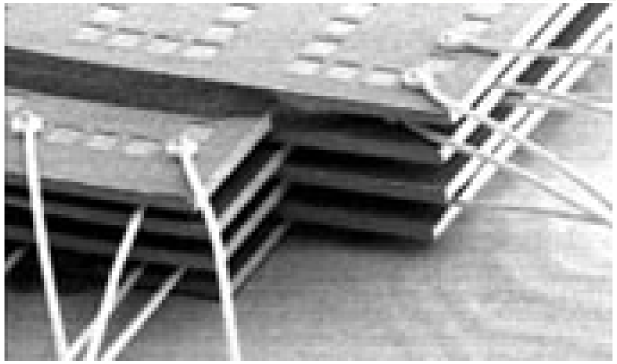
Chip directly contacted in package



“Stacked” Chips in MCMs (MultiChipModule)

Several chips are stacked within a common encapsulation





Courtesy of Neocera

3D FA Applications

- Stacked Semiconductor Devices like MCM‘s etc.
- COB, CSP and other advanced packaging
- MEMS/ MOEMS
- Capacitor FA
- MicroCoil Short FA, for example in RFIDs

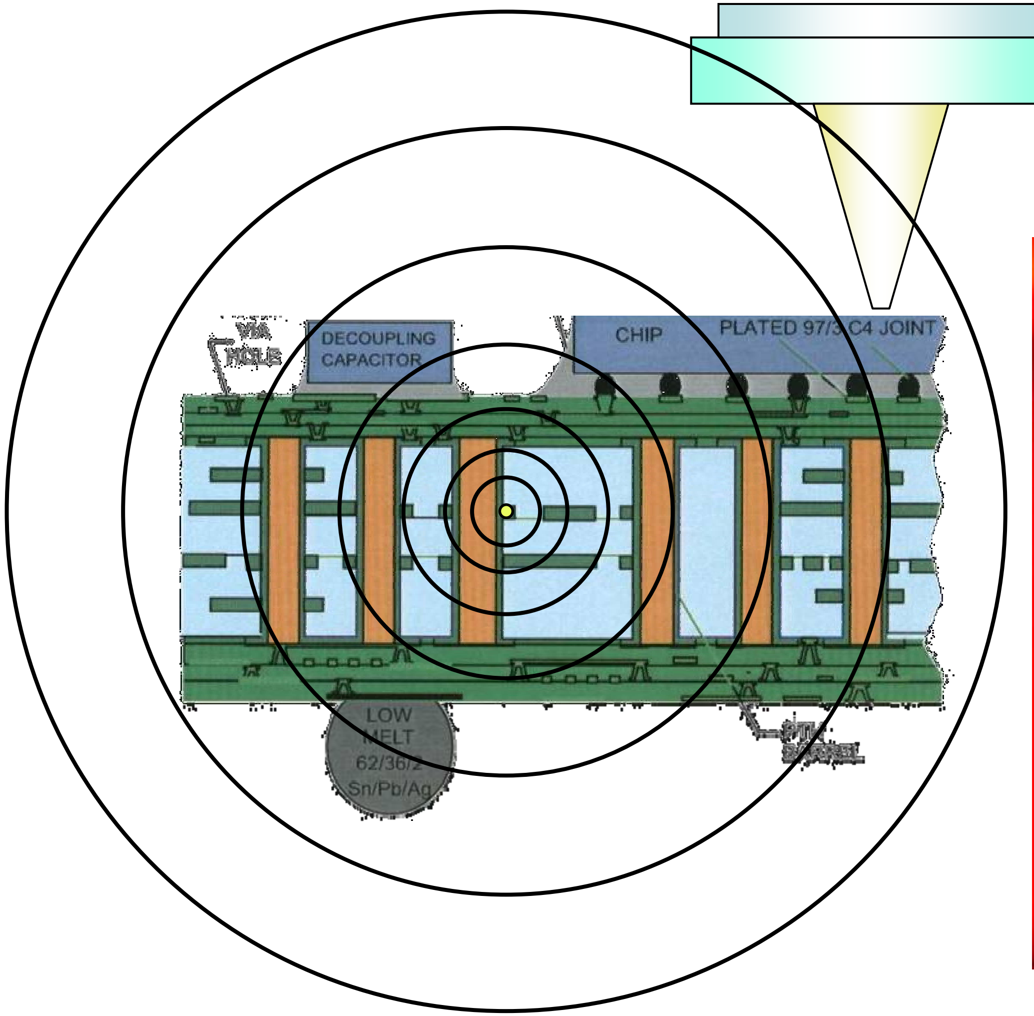
3D FA Challenges

- Electrical signal path analysis
- High-resolution tomography
- Physical in-stack access for analysis
- Inertial device testability

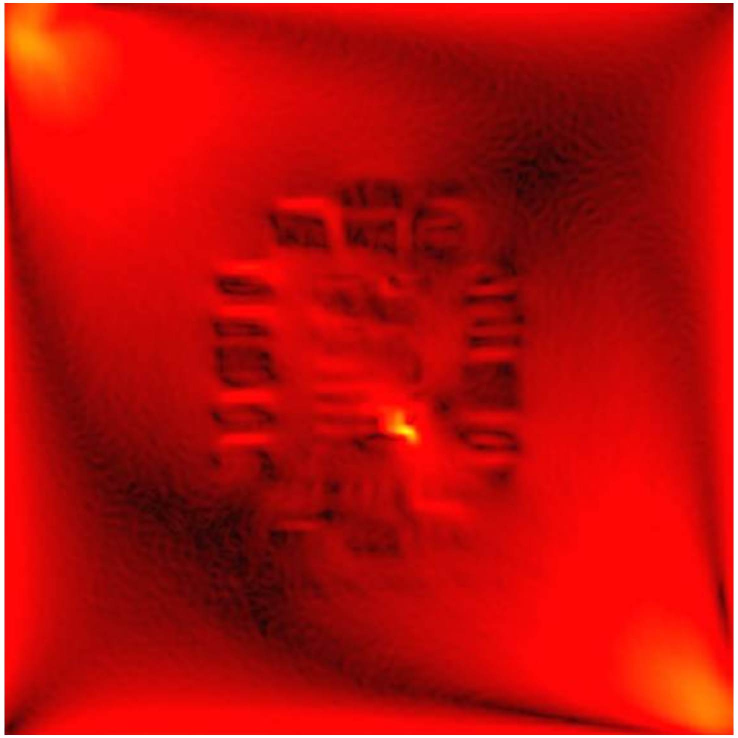
Present Approaches

- **Magnetic microscopy**
- UV Laser ablation
- Infrared Thermography
- **X-Ray Tomography**
- Backside FIB-access
- **Xenon-Beam FIB**
- **3D-TEM**

Basic Principle of MCI

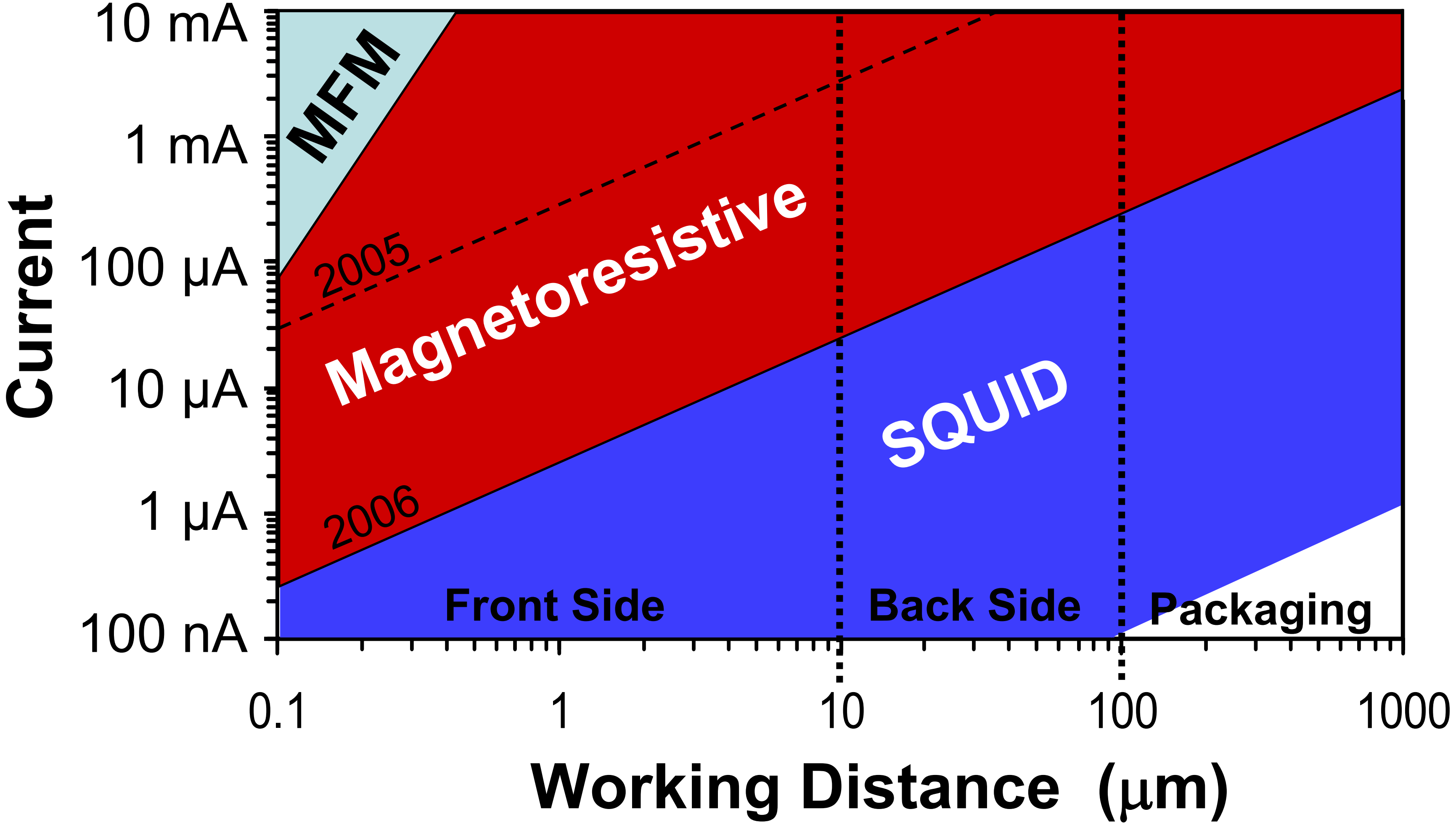


MCI generates a current density image by scanning the sample



Courtesy of Neocera

Magnetic Sensor Comparison



MFM= Magnetic Force Microscopy, an AFM-Derivate, Development work at Duisburg University (Germany)

Pin Short in 3-Chip-MCM

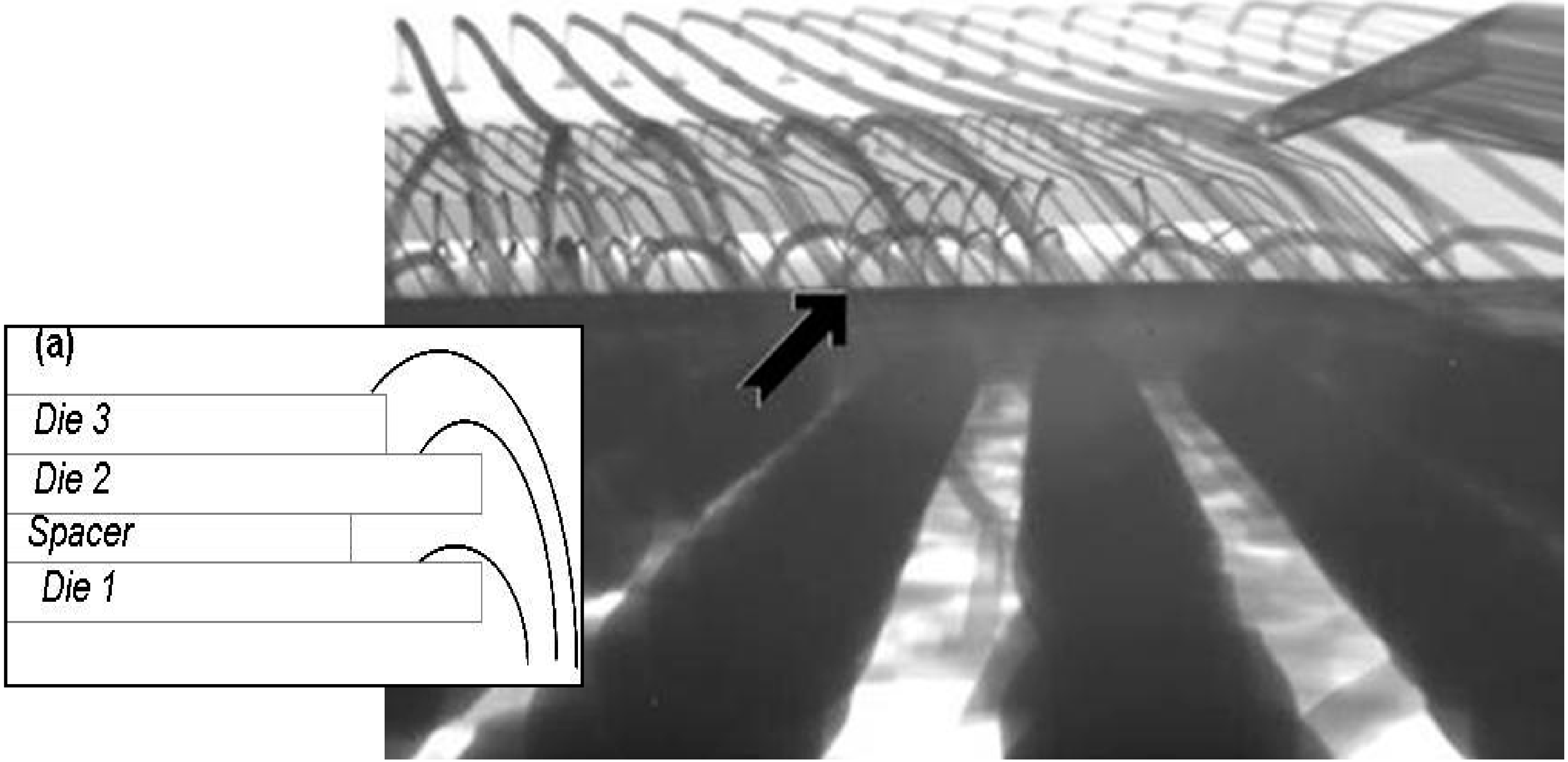
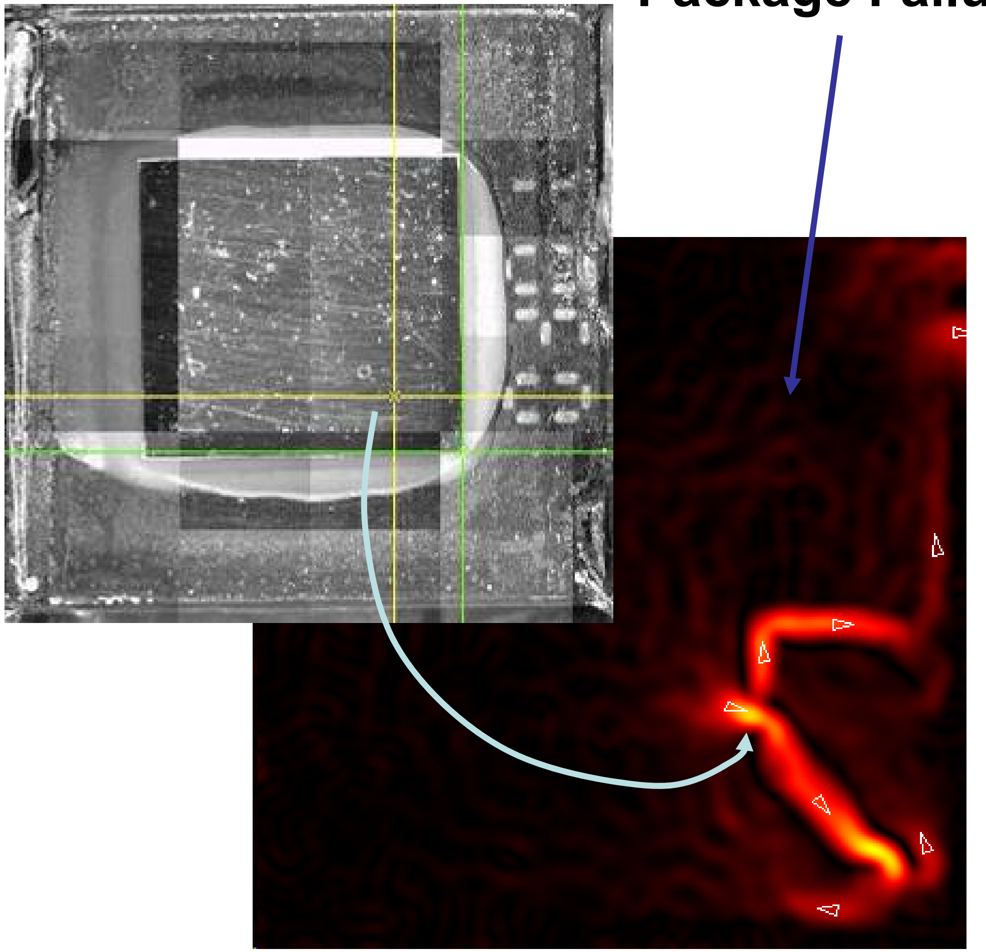
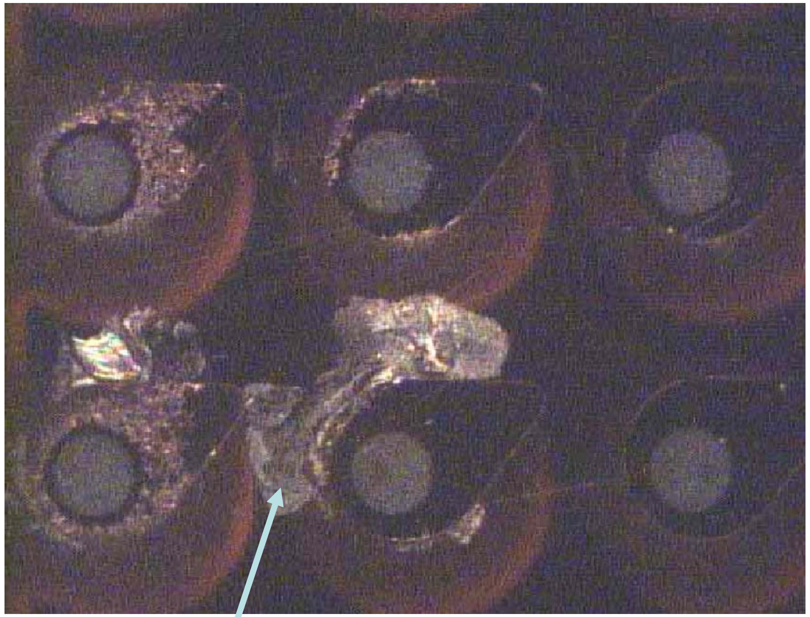


Image: Pacheco, Intel, ISTFA 2004

Short at the “Clock”-Pin of a Die-Scale-Package (DSP)



Package Failure in 750µm depth



Via lands shorted with lead

Courtesy of K. Scott Wills, TI and Neocera

Magnetic Microscopy Experiences

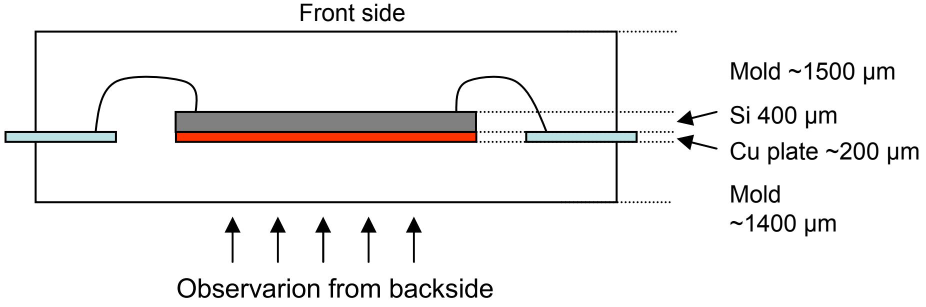
- Allows interesting Current imaging, even if the current flow is rather deep
- 3D imaging possible
- Needs rather low working distance
- Limitations in Resolution
- Long sample scanning time

→ Excellent for PCB and package related failure current detection, limitations, yet, for semiconductor-chip-internal analysis

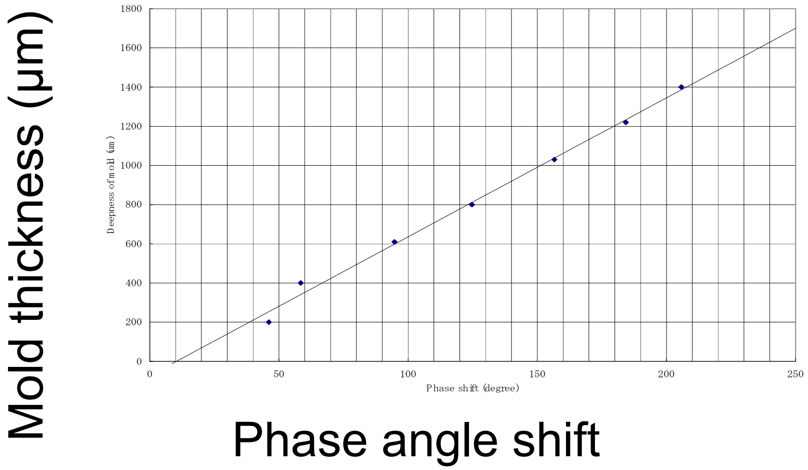
3D-IR-Thermography

Use of the phase angle shift to determine the failure depth

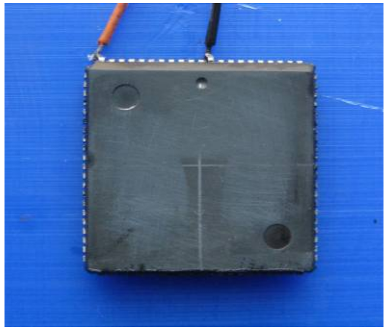
1. Device structure



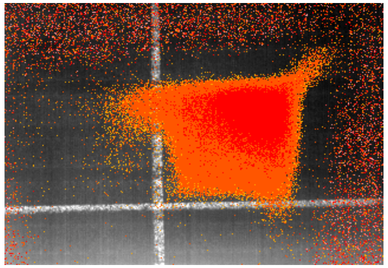
2. Result: About 150°/1000µm phase shift



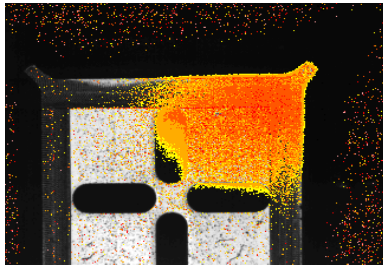
Courtesy of Hamamatsu Photonics Germany



Thermal images



Mold thickness ca. 800 µm



Mold thickness ca. 0 µm (Cu plate)

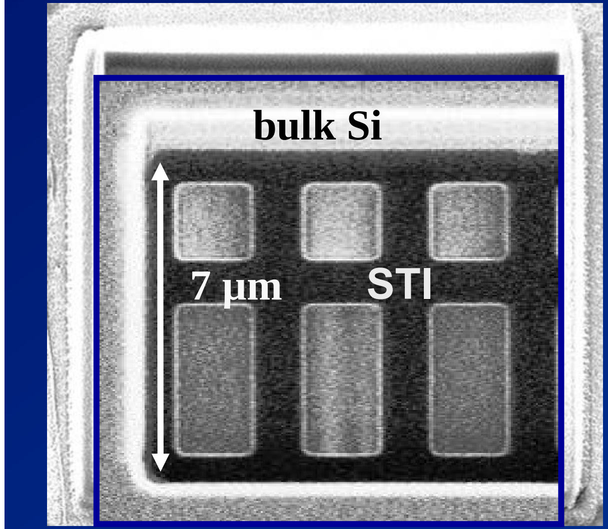
FIB for Backside Circuit Editing (CE)

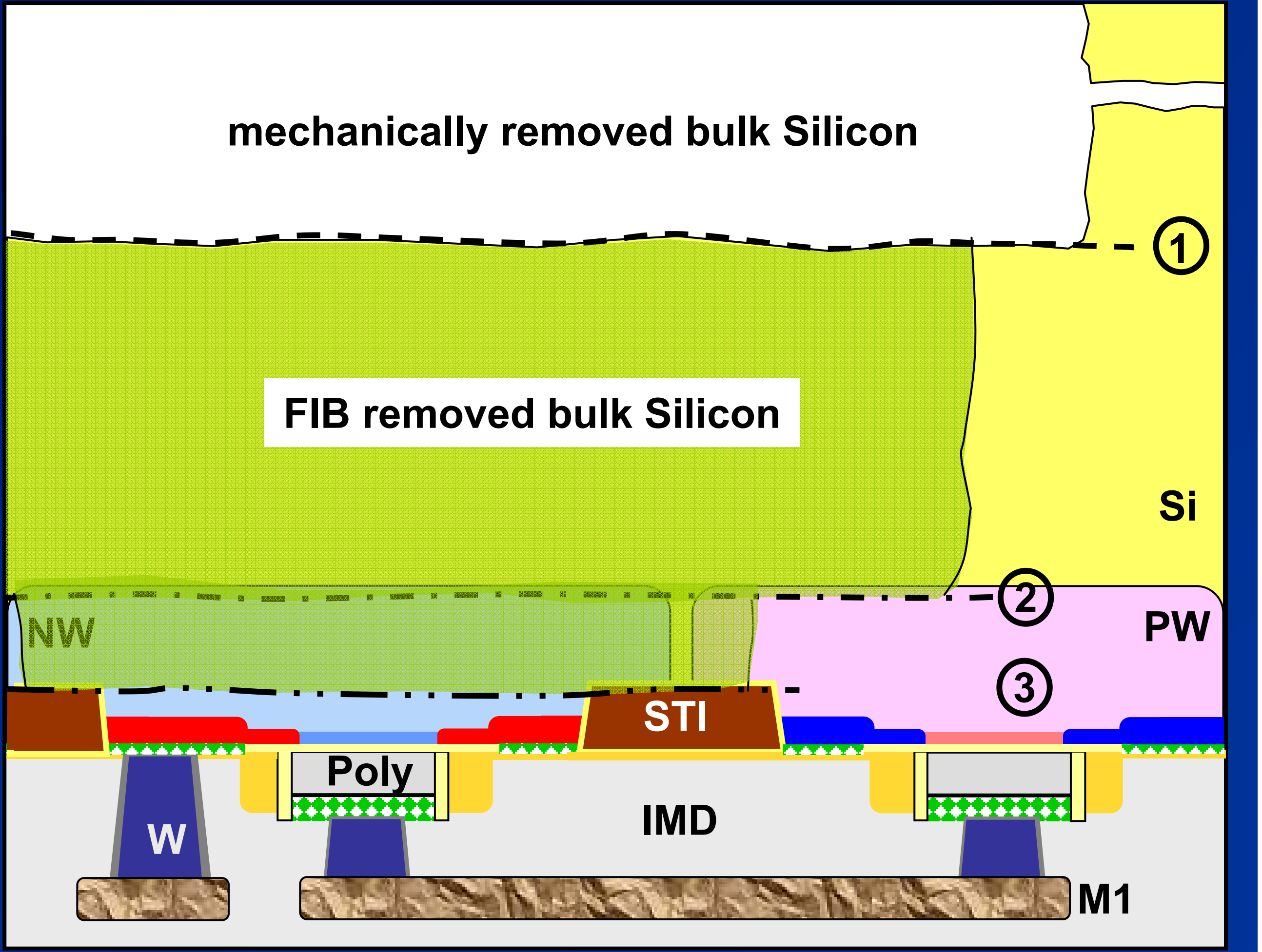
Process Flow:

① Mechanical thinning to 10 - 40µm (locally or full die)

② FIB - trench to n-well (100 - 600 µm²)

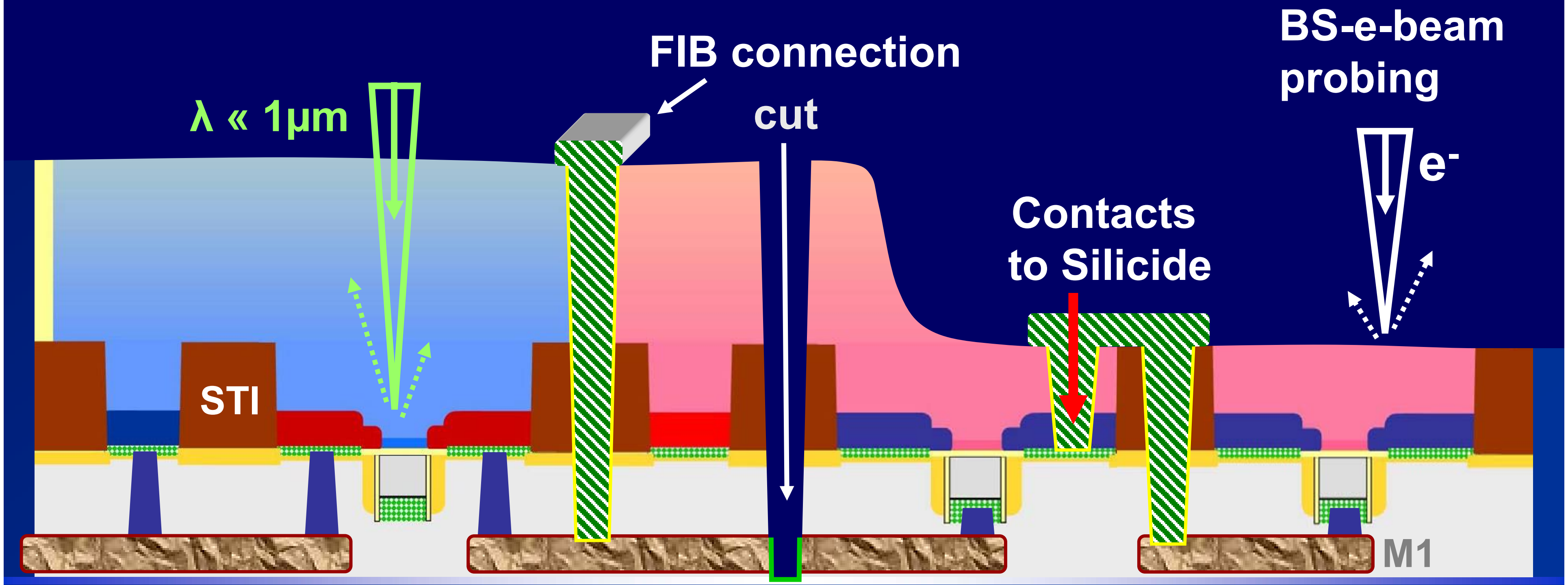
③ FIB - trench to Shallow Trench Isolation (STI) (4 - 50 µm²)



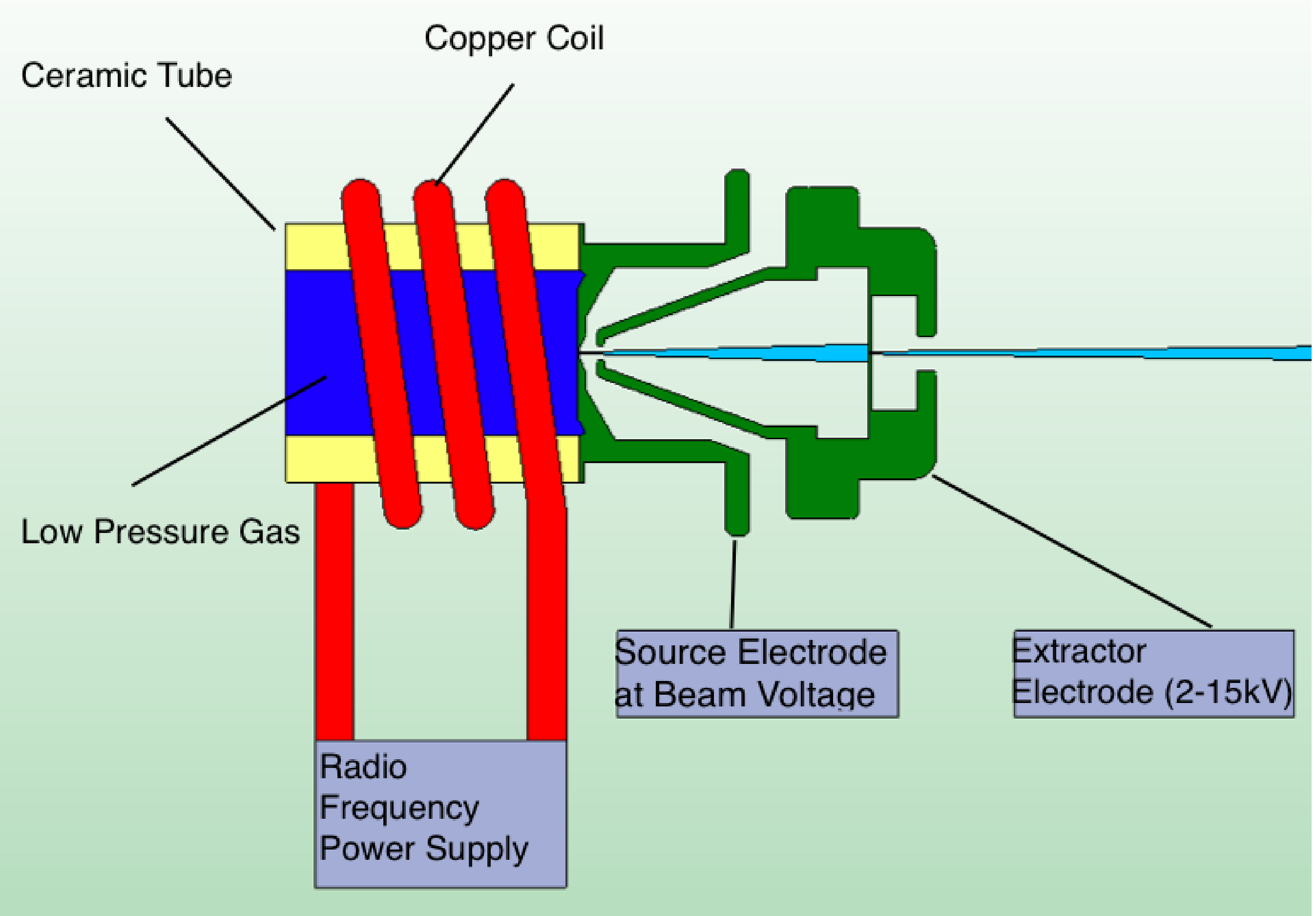


Backside (BS) CE and more…

- CE with better access to lower metal layers
  - no CMP fill shapes, no cap layers, no charging of IMD….
- CE on device level
  - further reduced via resistance, access to any signal on chip…
- high resolution Circuit Analysis

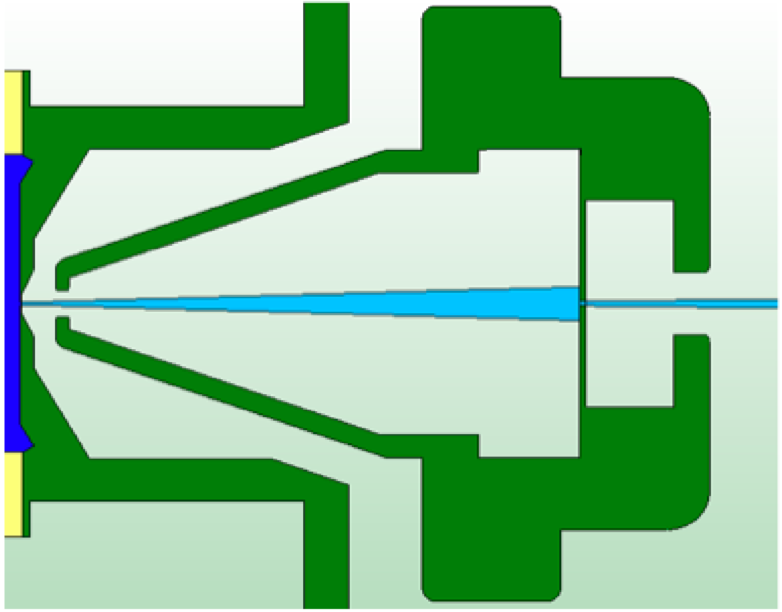


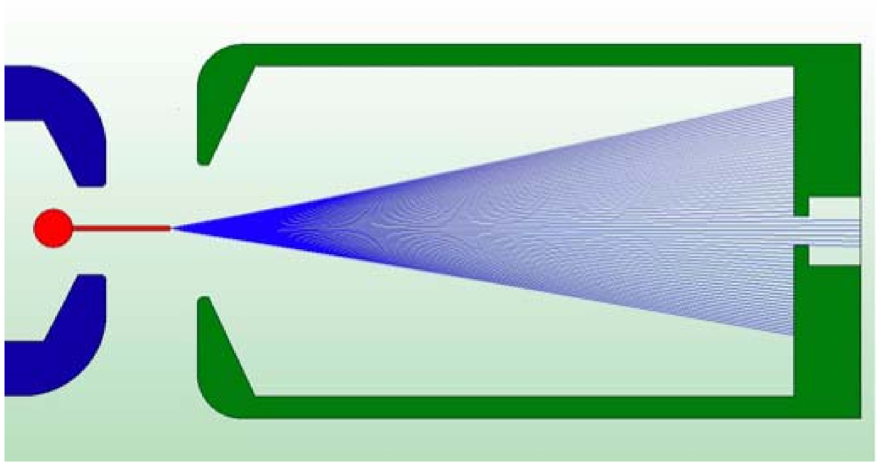
Xe-FIB: Inductively Coupled Plasma (ICP) Ion Source



Courtesy of Oregon Physics

ICP Ga Ion Source and Ga-LMIS comparison





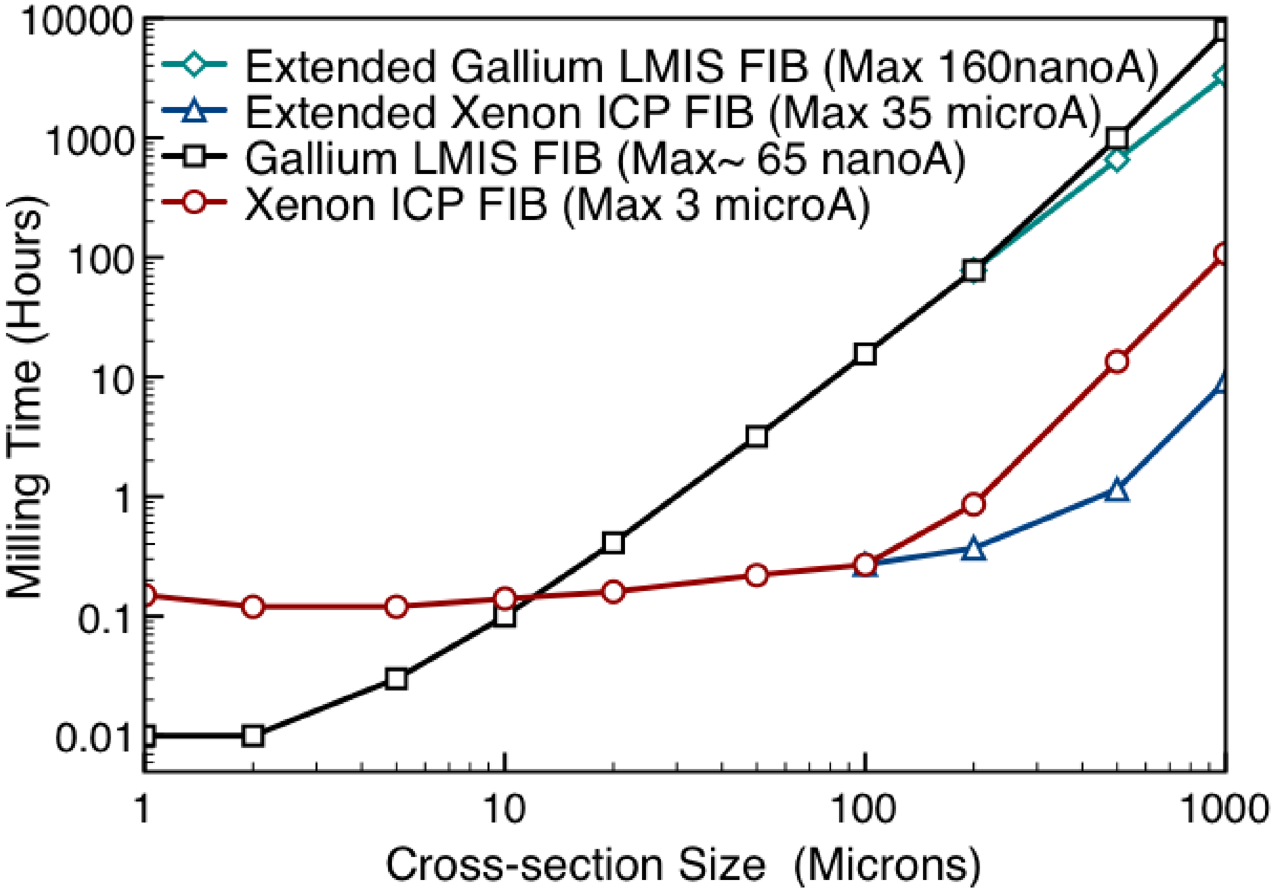
- ICP-IS: ~25 µA emitted into narrow angle
- LIMS: 1-2 µA emitted into wide angle

Courtesy of Oregon Physics

FIB Performance Comparison

- **At 30 kV the sputter rate of Xenon is 60% higher than Gallium (0.43 vs 0.27 cubic microns/nanocoulomb)**
- **Xenon does not react with the sample or deposit a conductive layer**
- **Ga LMIS FIBs are severely limited at high current due to spherical aberrations from their low angular intensity**

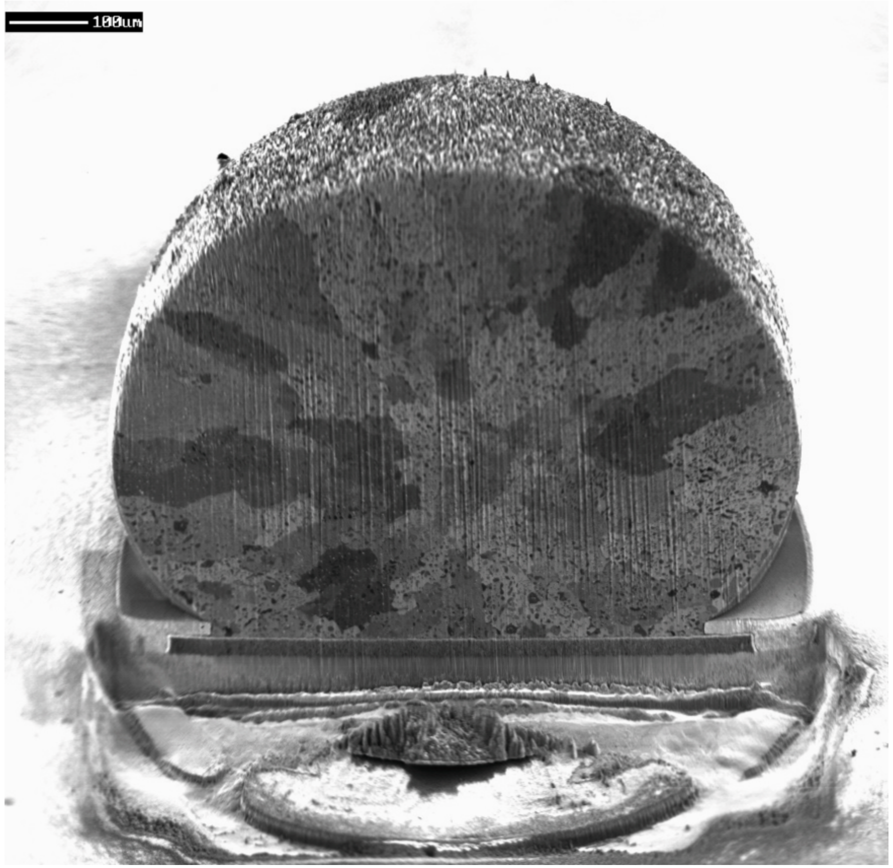
Cross-sectioning Performance Comparison on 30kV Columns

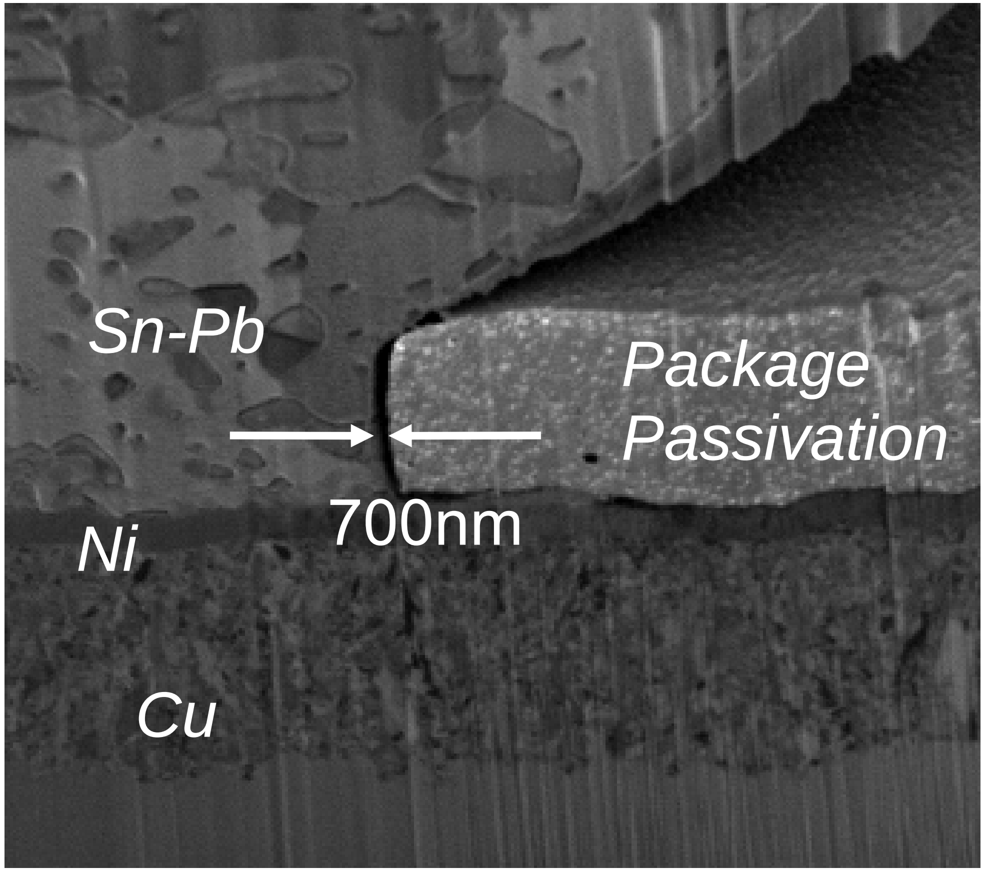


- **Assumptions:**
  - **Beam size is 1/40th of the cross-section size**
  - **Different sputter rate is taken into account**

Courtesy of Oregon Physics

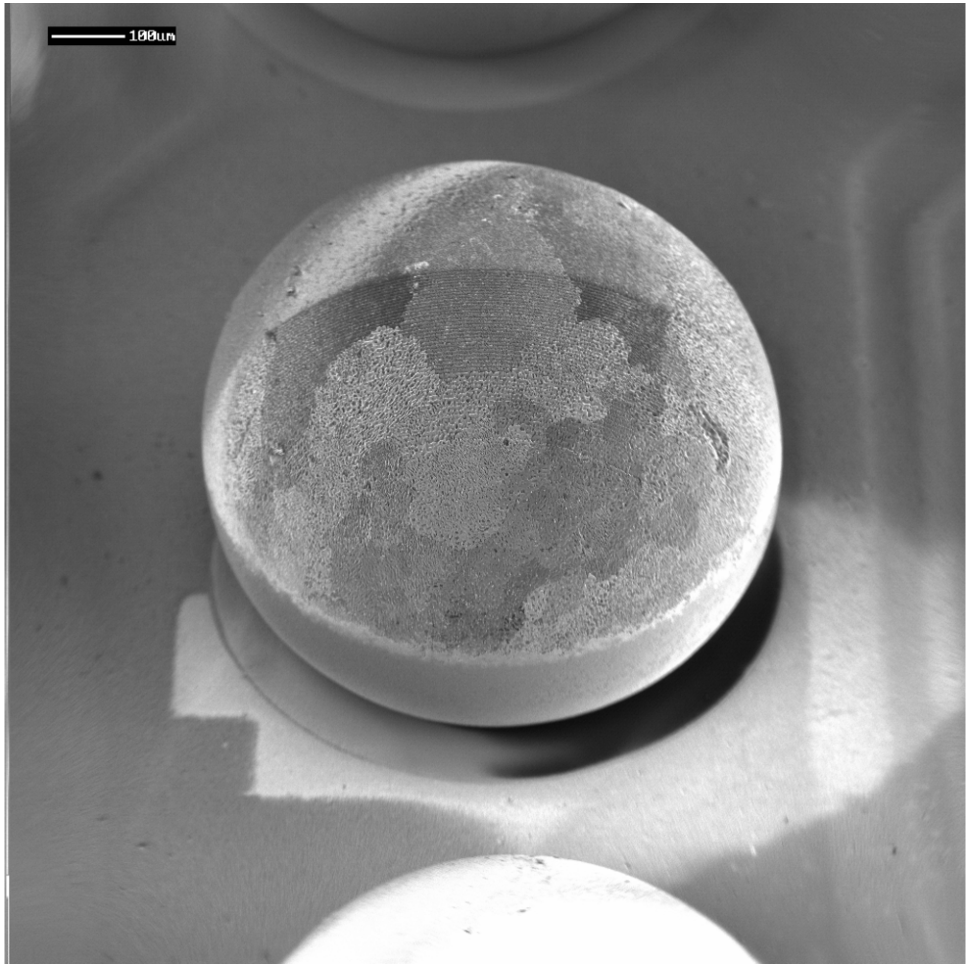
Xe-ICP FIB Applications: 750 micron solder ball





Courtesy of Oregon Physics

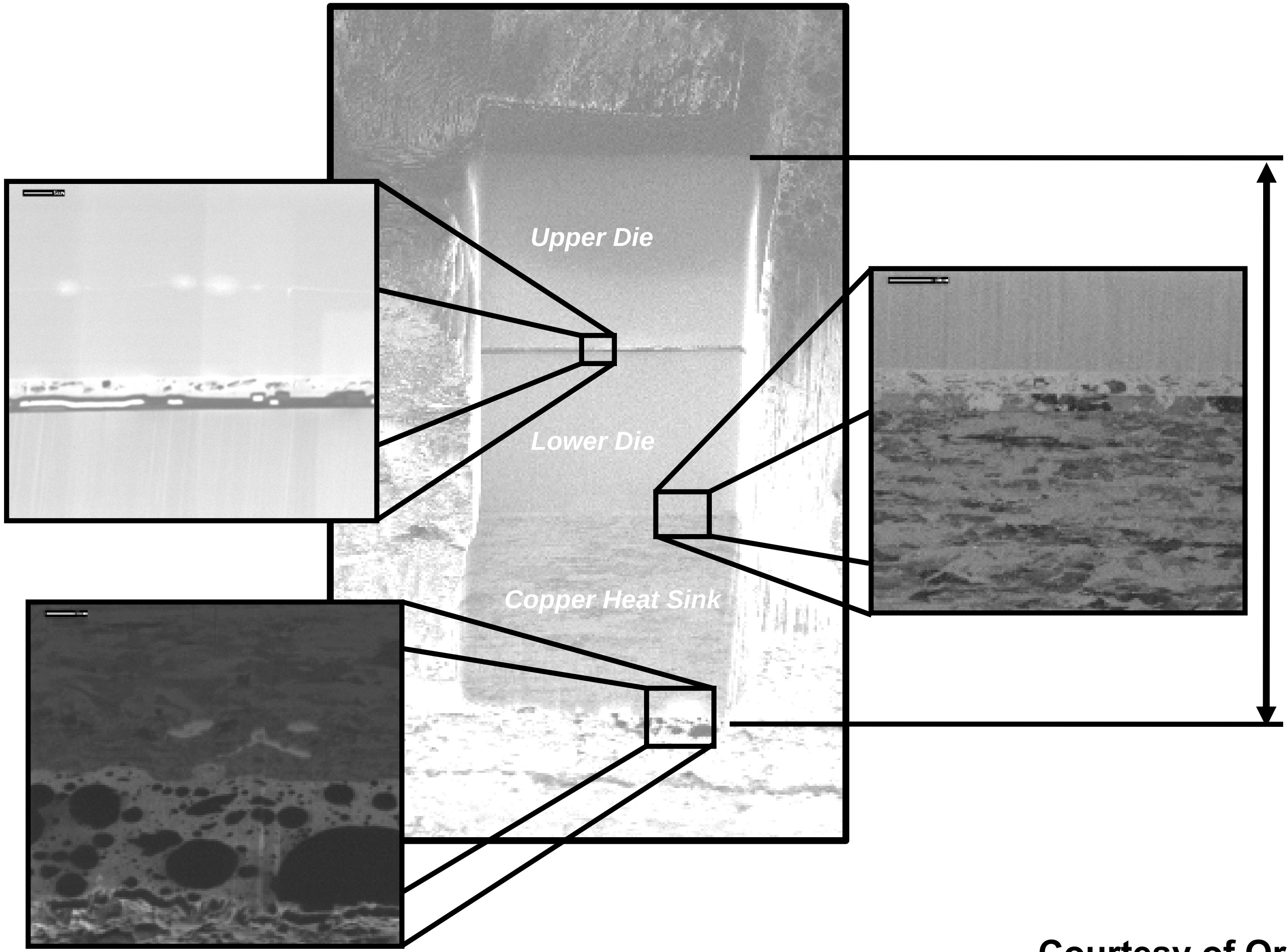
Ga LMIS Comparison: 750 micron solder ball



The ball was just slightly „surface-cleaned“ within the same operation time on a conventional Ga-LIMS FIB

Courtesy of Oregon Physics

ICP Fib Applications: 3D-IC stacked wafer



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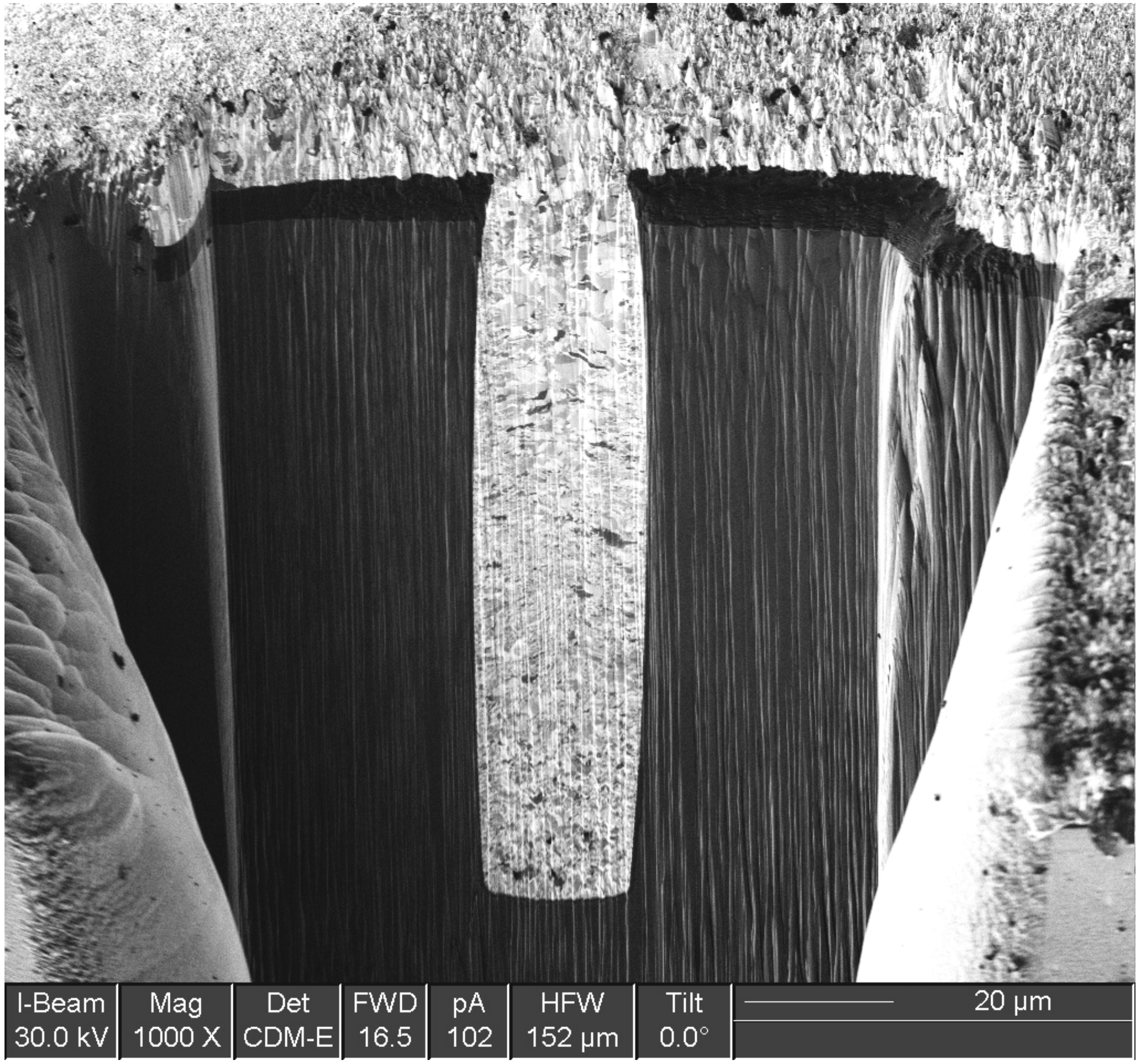
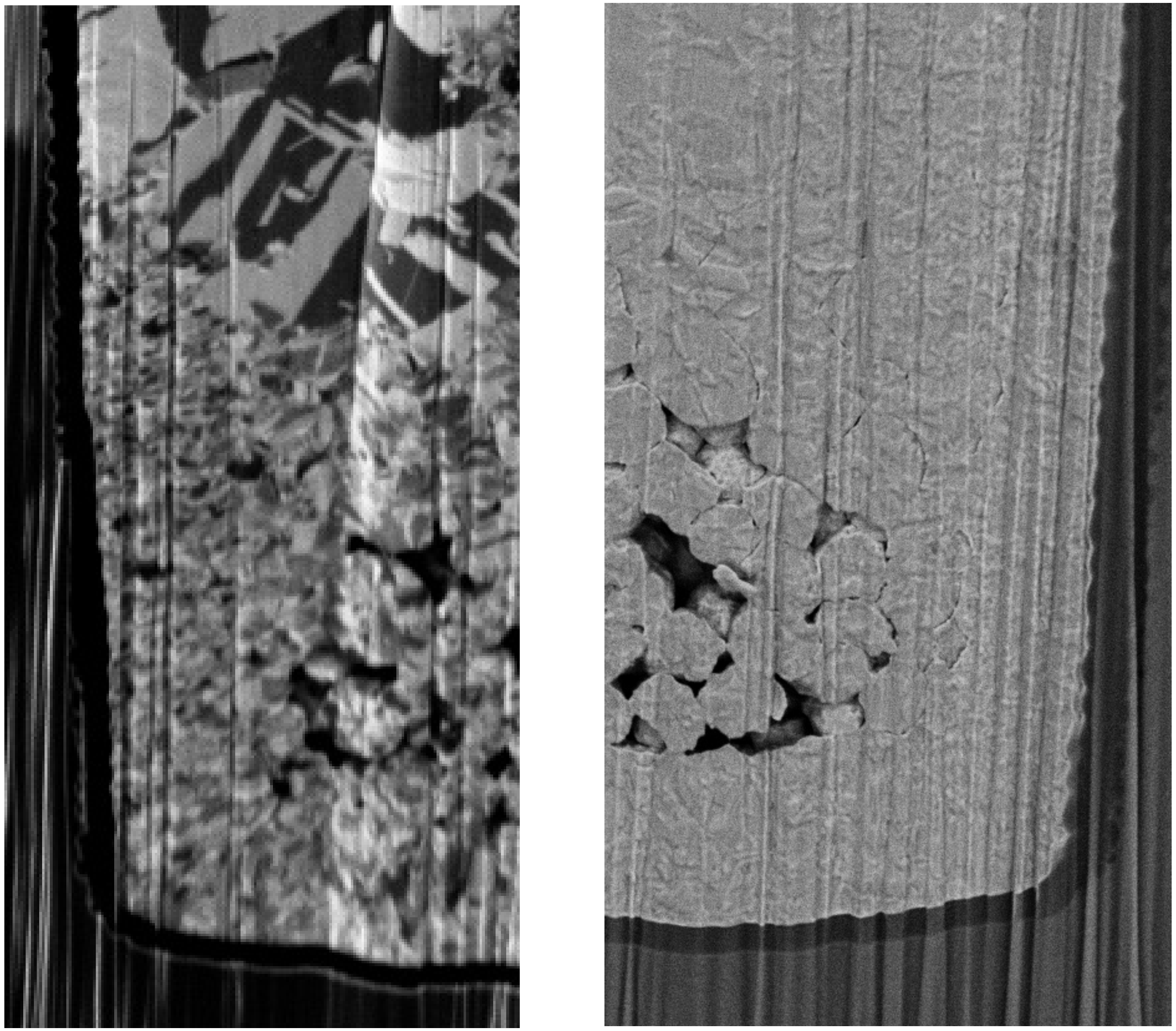
ICP FIB Applications: Through Silicon Via



Horizontal Field Width =152 microns

Courtesy of Oregon Physics

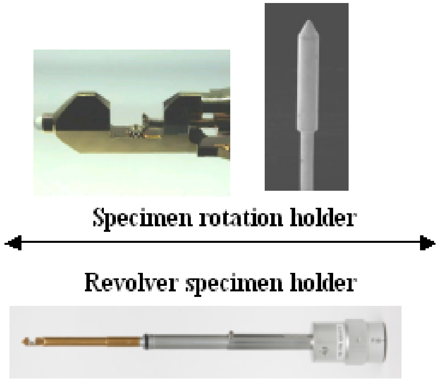
ICP FIB Applications: Through Silicon Via



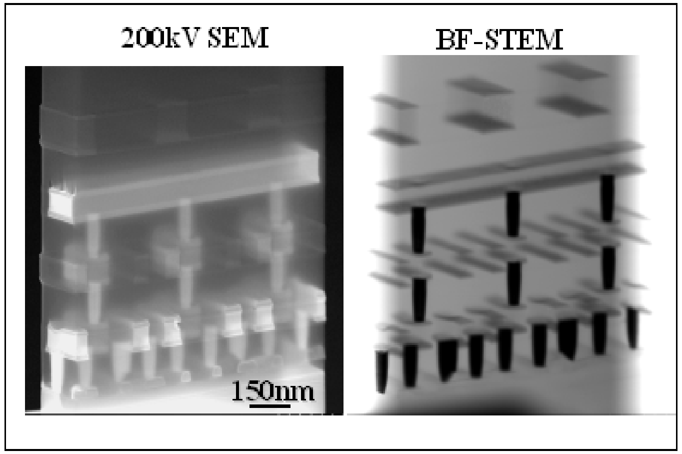
Courtesy of Oregon Physics

FIB-TEM Combination Tool

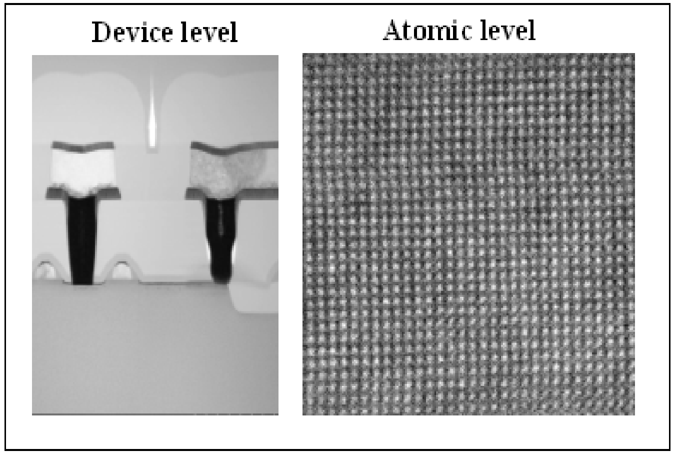
NB5000
Focused Ion & Electron Beam System



HD/HF/H-XX00 series
STEM/TEM



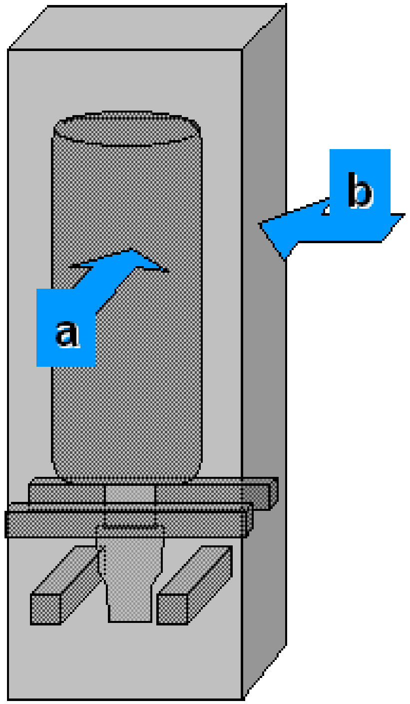
3D observation of thick specimen

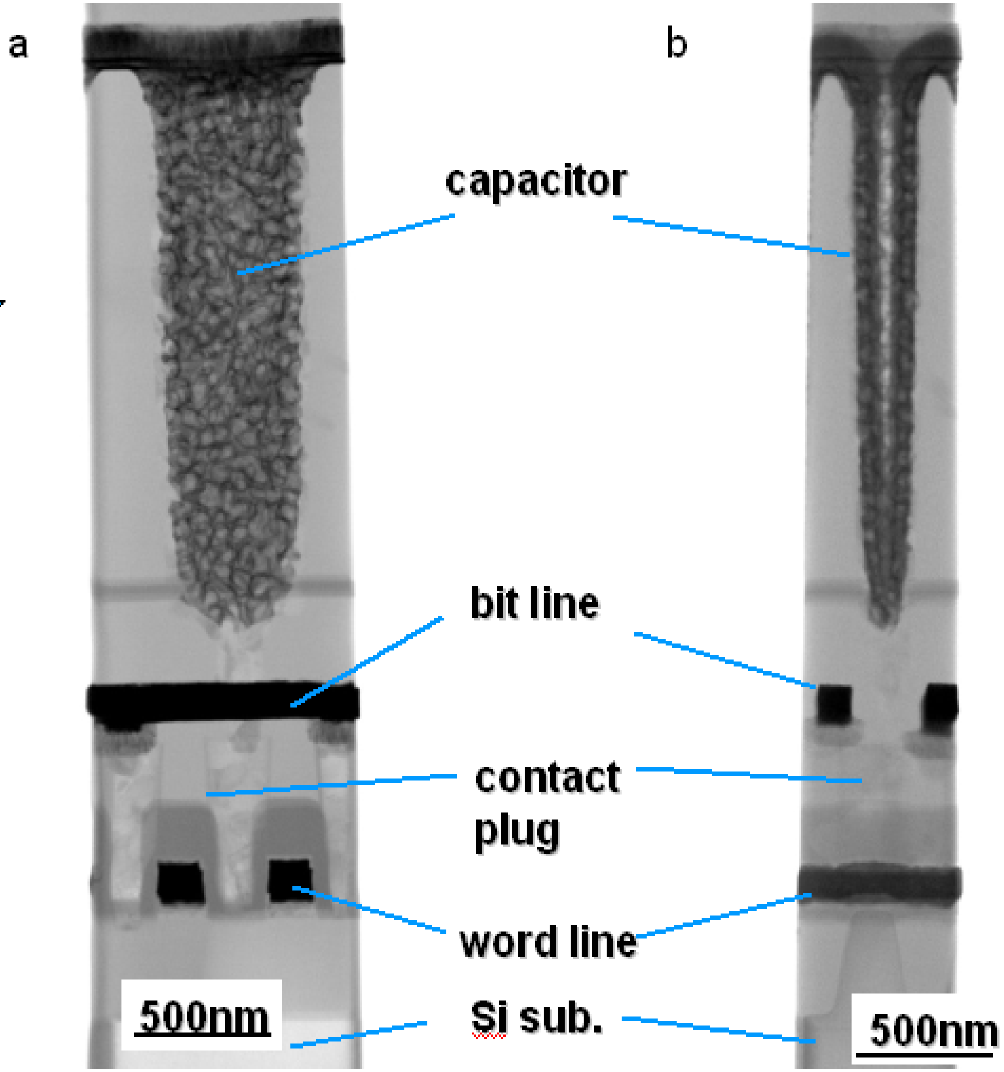


High resolution observation

Courtesy of Hitachi High Technologies

STEM observation of a single HSG capacitor





capacitor

bit line

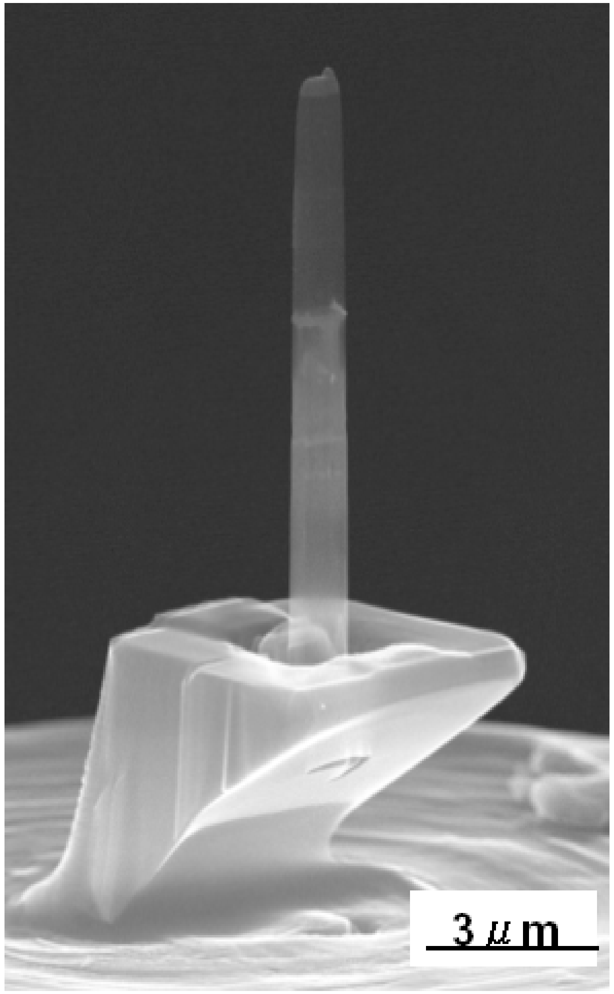
contact
plug

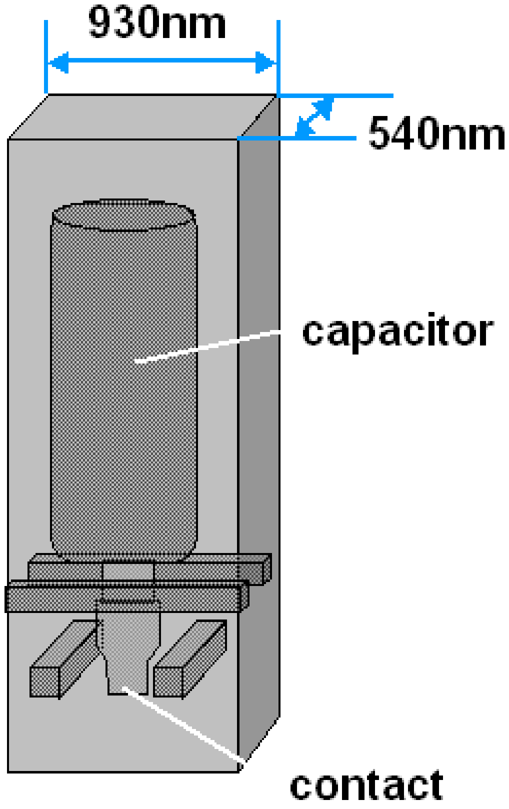
word line

Si sub.

Courtesy of Hitachi High
Technologies

Micro-pillar sampling for observation of a single HSG capacitor





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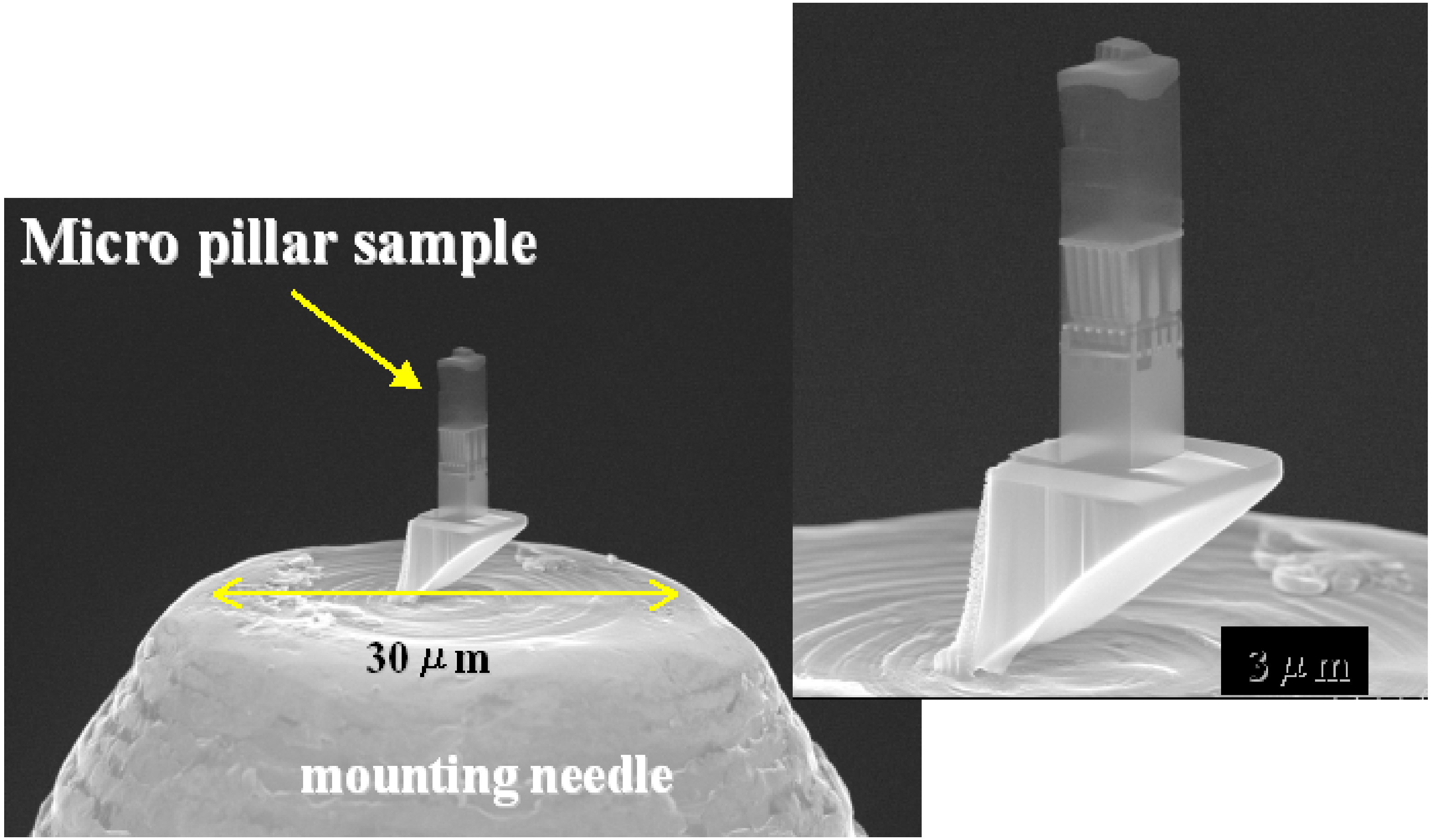

Courtesy of Hitachi High Technologies

What do we need for 3D analysis?

- Fast cross sectioning tools with FIB-comparable precision and resolution

  solution approaches: Xe-FIB, picosec-UV-Laserablation
- High resolution Tomography

  solution approaches: X-ray tomography

  ultrasonic-based methods

  TEM (in microscale)
- 3D Current flow/ defect detection/ localisation

  solution approaches: magnetic microscopy

  3D IR Thermography ?

  Reflective RF-waves-based methods?