OREGON PHYSICS
High Brightness Ion Beams

FIB Milling Applications for the New Hyperion™ Ion Source

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OREGON PHYSICS

- Primary mission is to develop and manufacture charged particle optics equipment.
- First product now available see www.oregon-physics.com.
- FIB service lab now online for *VERY* high throughput FIB applications.

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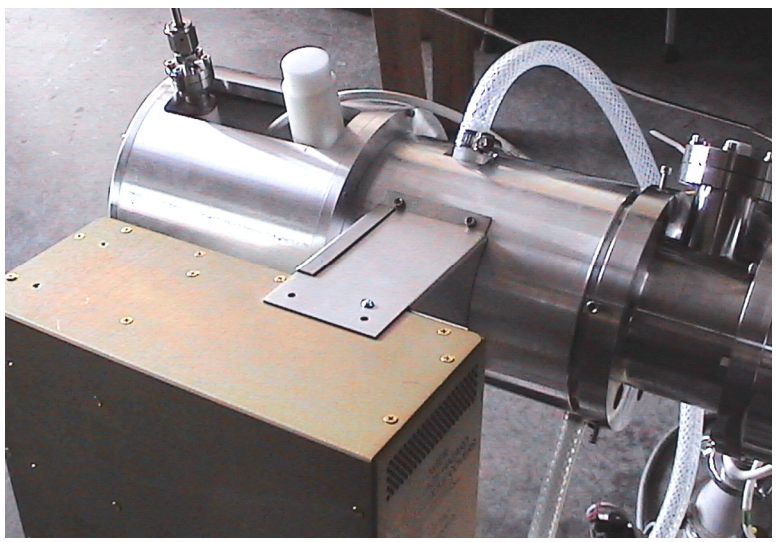
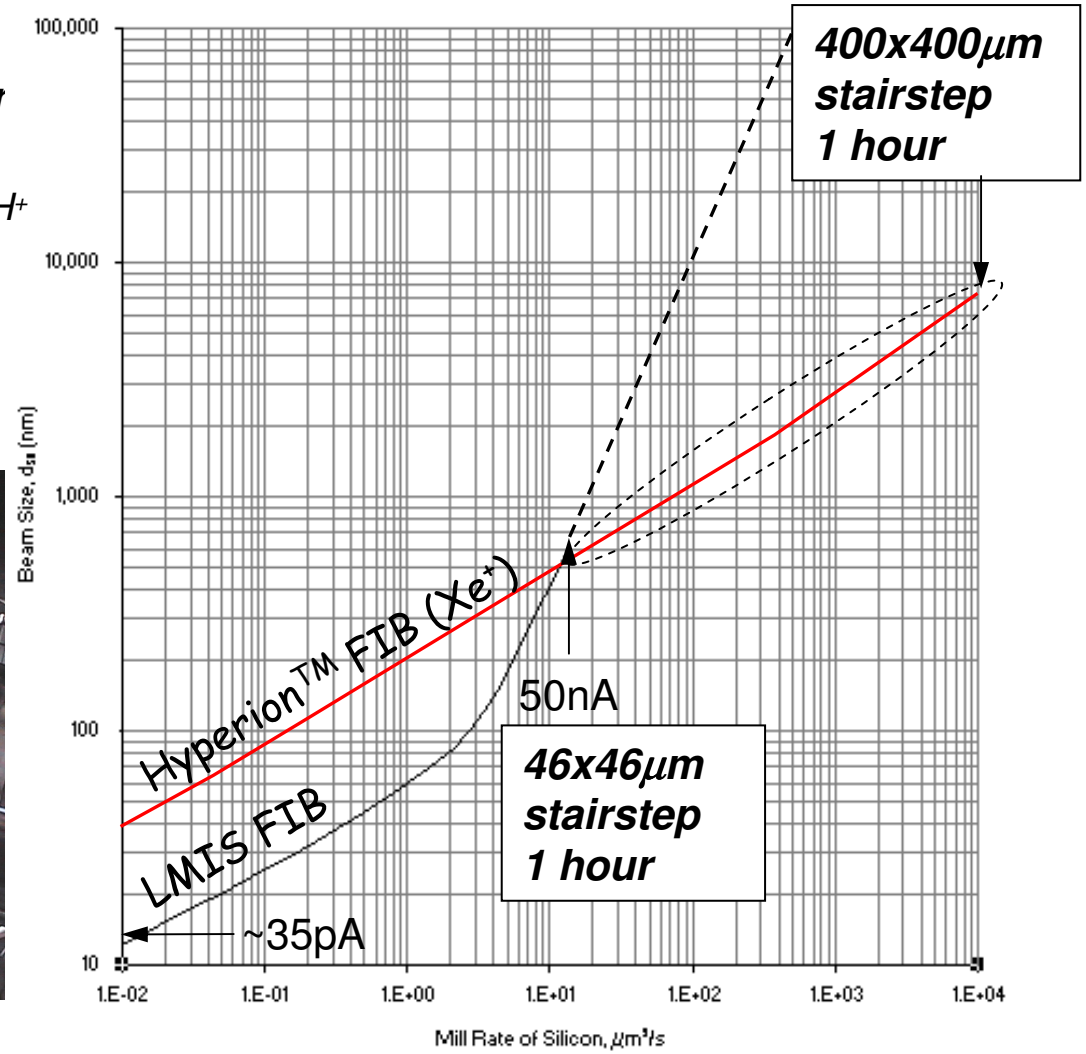
Attributes of the Ion Source

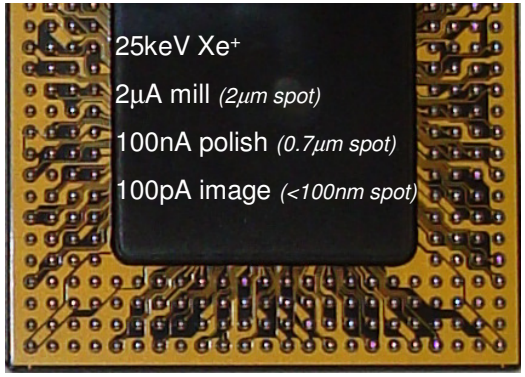
- ***High density, quiescent and cold plasma.***
- ***Formed by inductively coupling RF power to plasma electrons.***

Ion Species:	*Xe^+, Ar^+, O_2^+, He^+, and H^+*
Brightness:	*$>1x10^4$ $Am^{-2}sr^{-1}V^{-1}$ (Xe^+)*
Energy Spread:	*5-6eV*
Lifetime:	*>2000 hours due to cathode-less design*

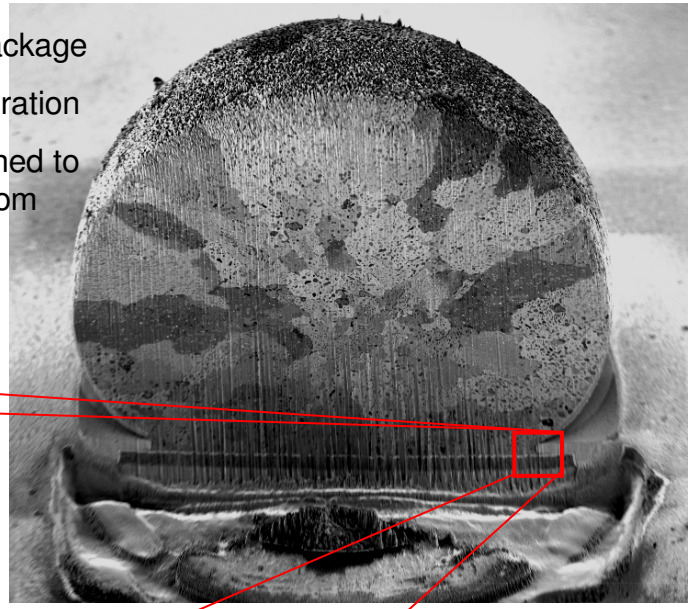


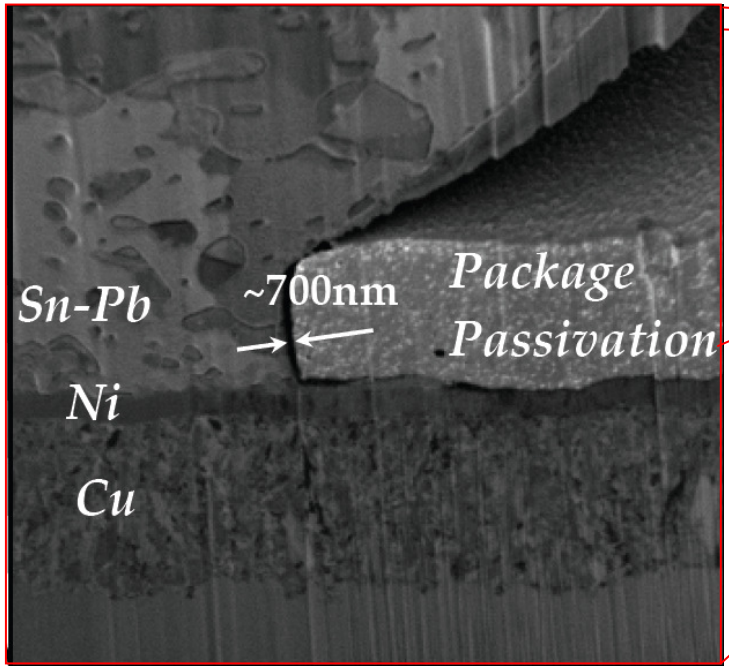


IC Packaging Failure Analysis



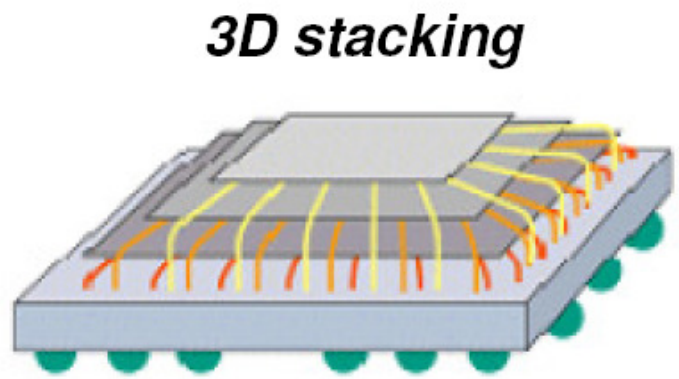
- RM7000-266T microprocessor package
- No chemical or mechanical preparation
- 750µm BGA solder balls x-sectioned to inspect for voids or delamination from UBM.

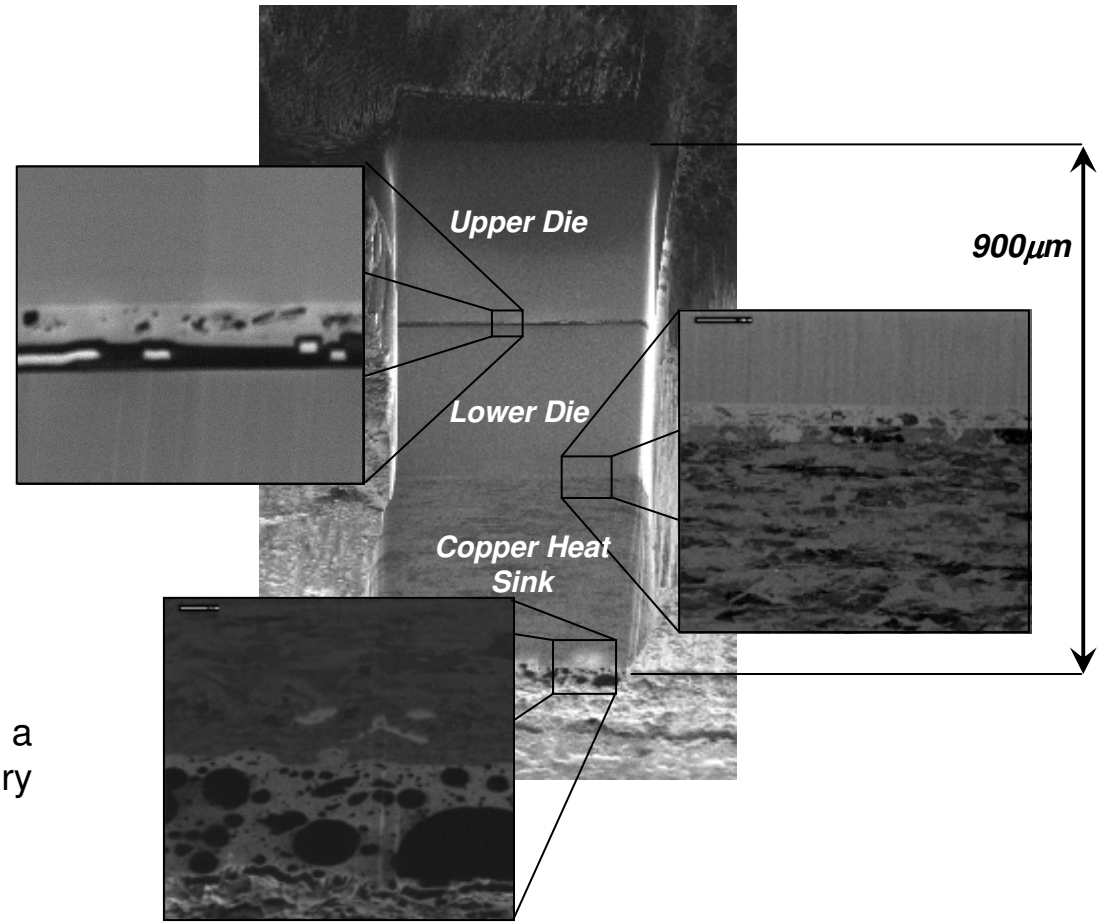




50nA Gallium FIB
260 hours of milling required.
At $400/hr, that's $100k!
Oregon Physics Hyperion™ FIB
OP Lab today - $2.5k (*250 million µm³*)
In 1 year it'll be $250.

3D-IC's





Wire bond interconnects are routed external to the wafer in this example.

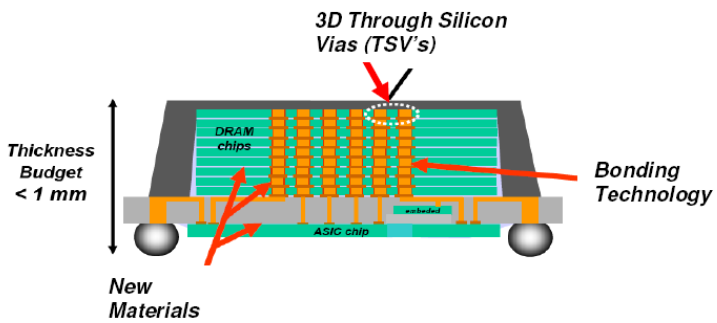
Low power STMicroelectronics RTC.

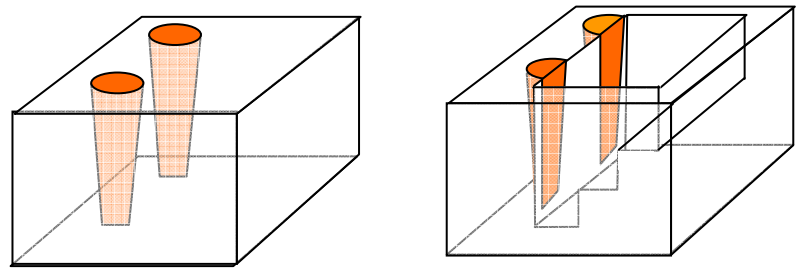
32.7kHz on-board oscillator driven by a quartz crystal, allowing the device to be very accurately calibrated by the manufacturer.

900μm x 300μm x 60μm -16 million μm^3

- **1 hour**, 3μA 25keV Xe^+ with **Hyperion^{TM}-FIB** (5000μm^3/s)
- 12 hrs for a JEOL 'cross-section polisher'

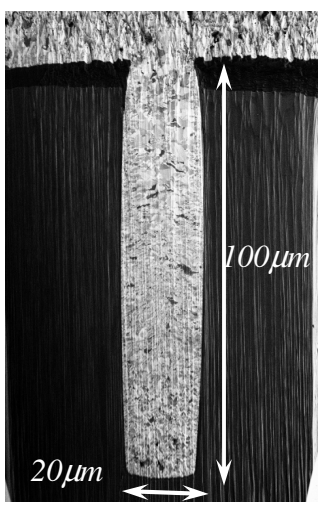
3D-ICS's with TSV's



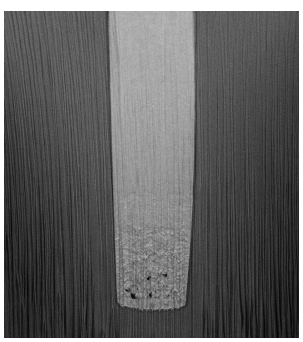


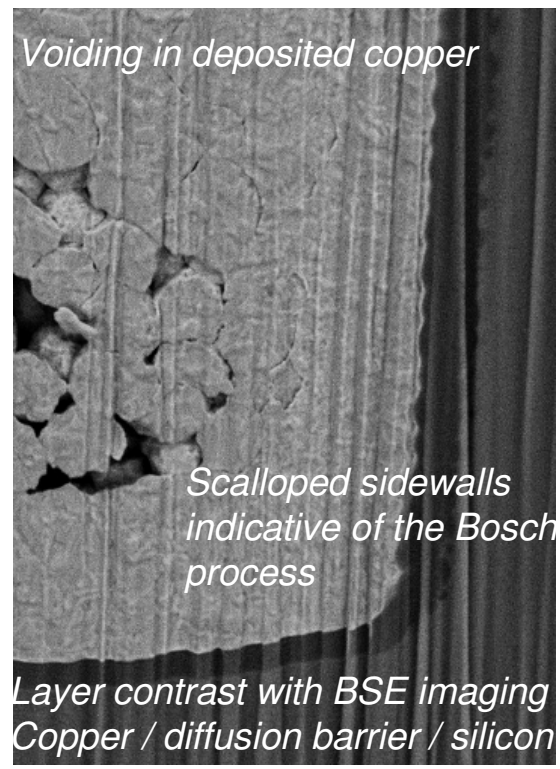
500nA – 20 min mill
100nA – 10min coarse polish
SEM imaged

High Resolution FIB induced secondary electron imaging for copper grain contrast



High Resolution SEM induced, backscattered electron imaging for topographical contrast.



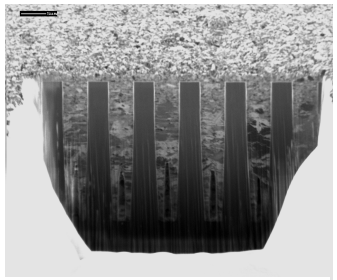


IMEC TSV's *(Courtesy of Dr Hugo Bender)*

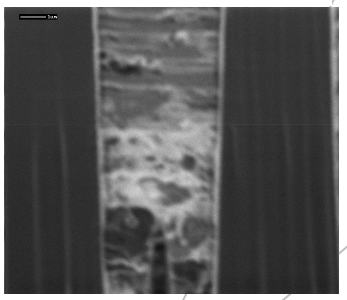
Before Process Development

TSV's
50µm deep and 5µm diameter.

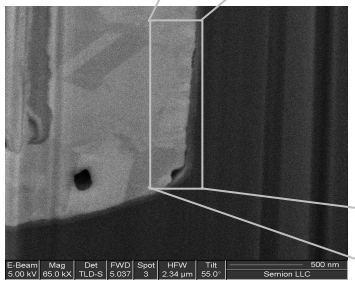
Bulk Mill
12 mins
250nA, 25keV, Xe^+,850nm@16-84%
Coarse Polish
10 mins
50nA, 25keV, Xe^+, 450nm@16-84%
Fine Polish
15mins
5nA, 25keV, Xe^+, 200nm@16-84%

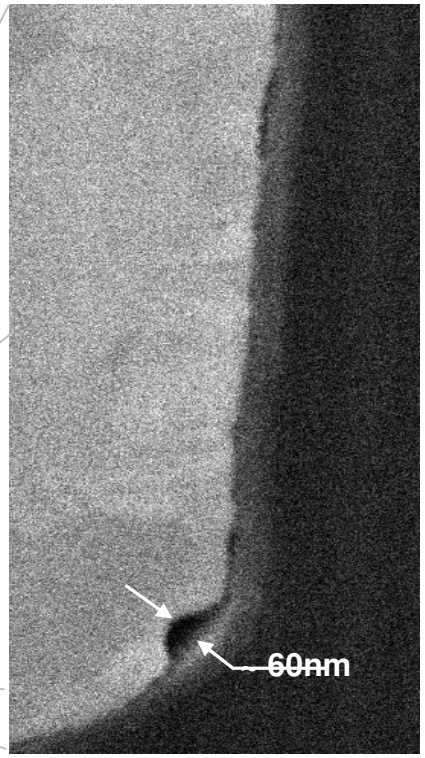


Xe^+ 100pA



Xe^+ 100pA





IMEC TSV's *(Courtesy of Dr Hugo Bender)*

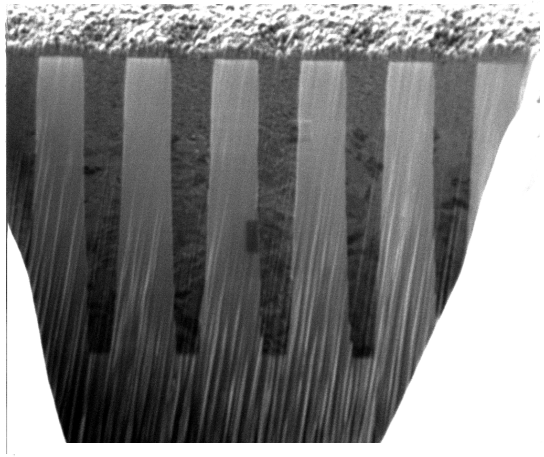
Void-Free After Process Development

TSV's
50μm deep and 5μm diameter.

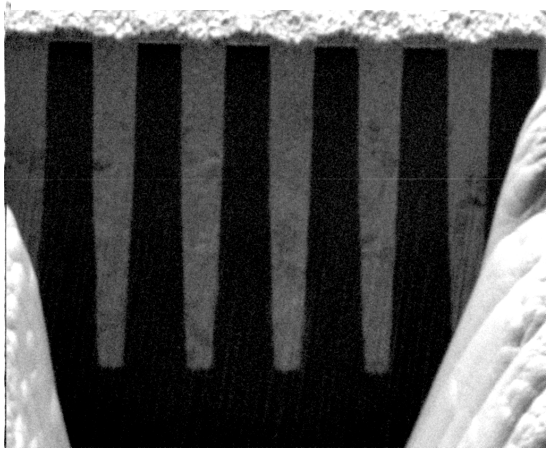
Nominally the Same Bulk Mill and Polish Conditions

Imaged with a 250pA proton beam (150-200nm d_{50} spot)

Secondary Electrons



Backscattered Protons

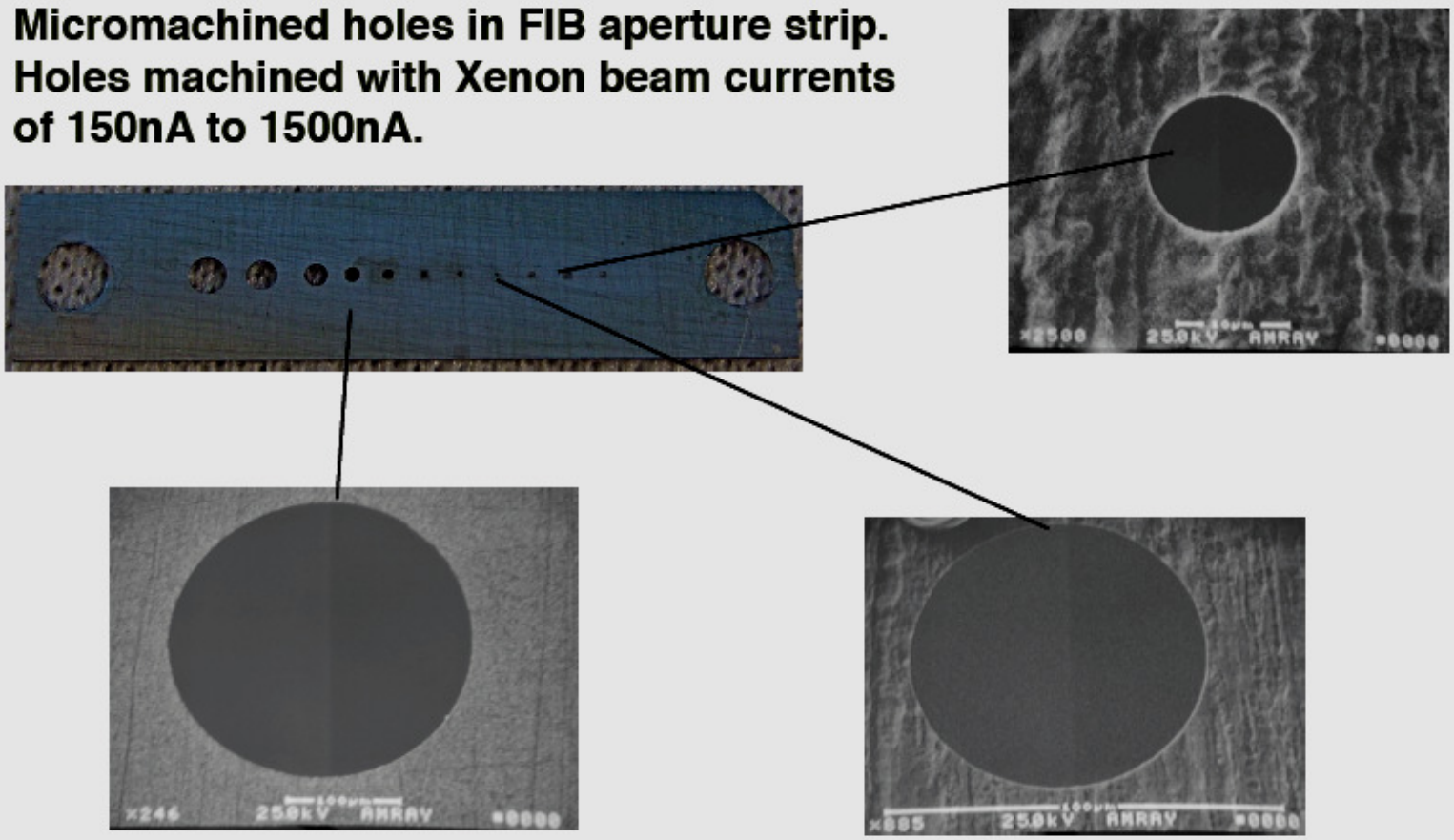


Yole Développement say that in four years:

- 3D wafer volume will increase 10x
- 10^5 TSV's per die
- Many new materials and fabrication processes *(thermal management, high density stacking).*
- Stacks up to 1mm high.

Low Volume Micromachining

Micromachined holes in FIB aperture strip. Holes machined with Xenon beam currents of 150nA to 1500nA.



Conclusions and Future

- Hyperion™ significantly extends FIB application space.
  - Advanced packaging structures
  - High performance FIB-SIMS
  - Micromechanical and Fluidic device FA and editing.
  - Rapid Backside editing
  - etc…etc..
- Ion source is now a product getting a lot of pull from the SIMS users.
  - Easily integrated onto existing SIMS optical columns. (ie 3 lenses, vac handling, high angular intensity etc.)
- Technology has not reached it's limit.

National Science Foundation
WHERE DISCOVERIES BEGIN

- Further Developments:
  - Matched/Optimized Hyperion-FIB column product.
  - Alternative ion species (eg C_{60}^+ and N_2^+)
  - Considerable Applications Research

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