FIB Milling Applications for the New Hyperion™ Ion Source

Noel Smith, Paul Tesch, Noel Martin, Kevin Filter¹ and Rod Boswell²

Oregon Physics LLC, Hillsboro, Oregon, USA
¹Semion, Hillsboro, Oregon, USA
²Australian National University, Canberra, Australia

OREGON PHYSICS

- Primary mission is to develop and manufacture charged particle optics equipment.


- FIB service lab now online for VERY high throughput FIB applications.
Attributes of the Ion Source

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

**Ion Species:** $\text{Xe}^+$, $\text{Ar}^+$, $\text{O}_2^+$, $\text{He}^+$, and $\text{H}^+$

**Brightness:** $>1 \times 10^4 \text{ Am}^{-2} \text{sr}^{-1} \text{V}^{-1}$ ($\text{Xe}^+$)

**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

3D stacking

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 µm³

- 1 hour, 3µA 25keV Xe⁺ with Hyperion™-FIB (5000µm³/s)
- 12 hrs for a JEOL ‘cross-section polisher’
3D-ICS’s with TSV’s

High Resolution FIB induced secondary electron imaging for copper grain contrast

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

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

Scalloped sidewalls indicative of the Bosch process

Voiding in deposited copper

Layer contrast with BSE imaging
Copper / diffusion barrier / silicon
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
15 mins
5nA, 25keV, Xe⁺, 200nm@16-84%
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)*

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.

- Further Developments:
  - Matched/Optimized Hyperion-FIB column product.
  - Alternative ion species (eg C_{60}^+ and N_{2}^+)
  - Considerable Applications Research