i-FIB

The ECR - FIB

EFUG meeting

Bordeaux, october 3rd, 2011

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OUTLINE

- Today's FIB challenges
- i-FIB principles
- i-FIB results

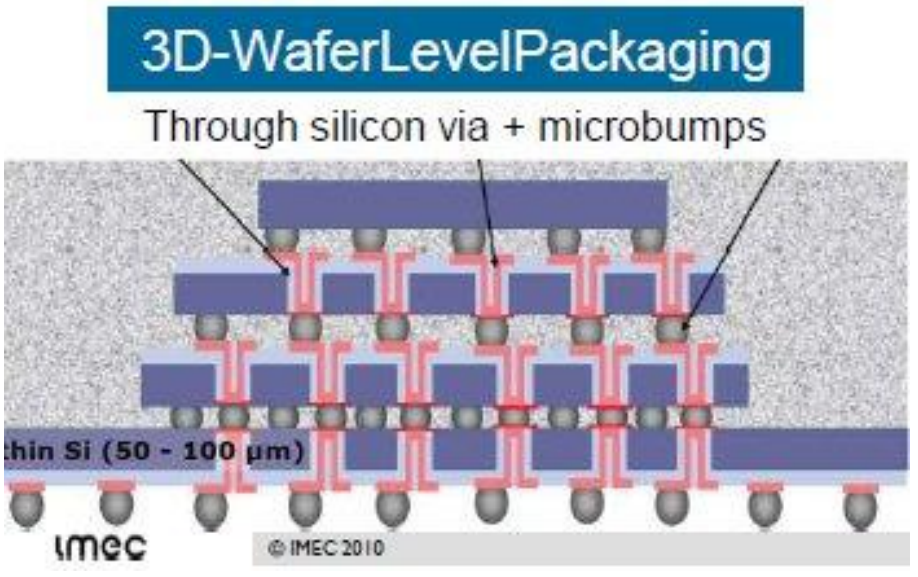
New challenges

Standard Ga FIB faces new Challenges:

- On one side the dimensions are decreasing at the level of the chip itself (High resolution FIB : not the topic here)

On the other side the dies are now Stacked.

- The third dimension is increasing and this requires higher milling capacities



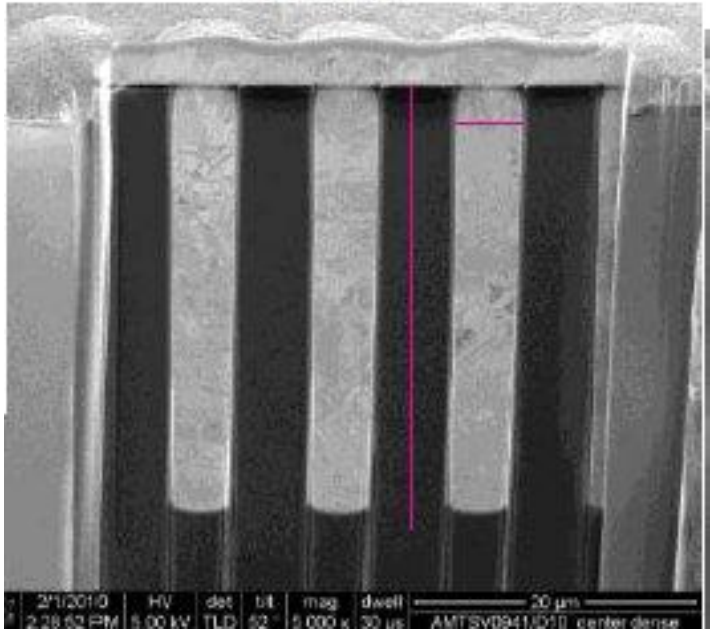
Further details : see previous EFUG presentations from H.Bender IMEC

Courtesy IMEC

New challenges

⇨ Large structures make the FIB Use very time consuming :
Still possible, in some cases (TSV), to cleave
Nevertheless time is also a key parameter.

TSV : 5x40 µm



Typical milling time : 2 hours

Courtesy IMEC

⇨ Need of Higher current (Limits of LMIS)

and / or higher milling rate (Limits of Ga)

⇨ i-FIB offers both options :

Higher current (ECR source)

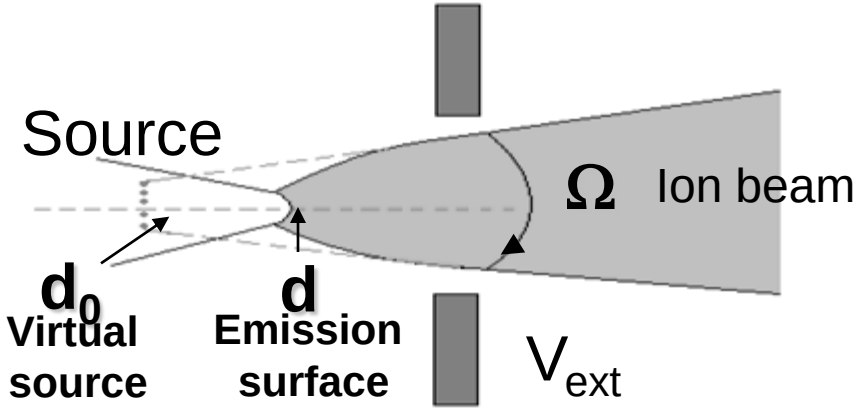
and higher milling rate (Xe)

i-FIB principles

- Plasma source
- Optical structure
- Combination with SEM

Why plasma source ?

LMIS



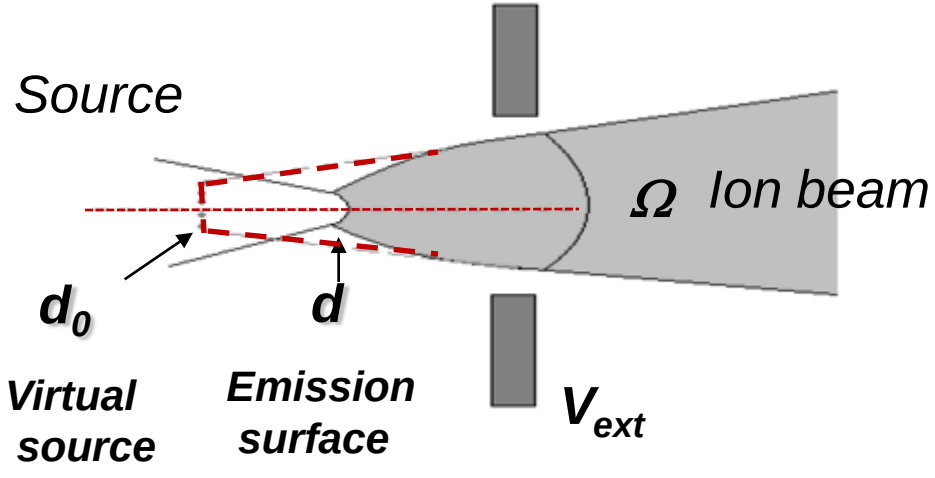
$$d_t = (d_g^{\,2} + d_c^{\,2} + d_s^{\,2})^{1/2}$$

Best choice for
Small and medium sample current:
1pA-50nA

high current limitation

Why plasma source ?

LMIS

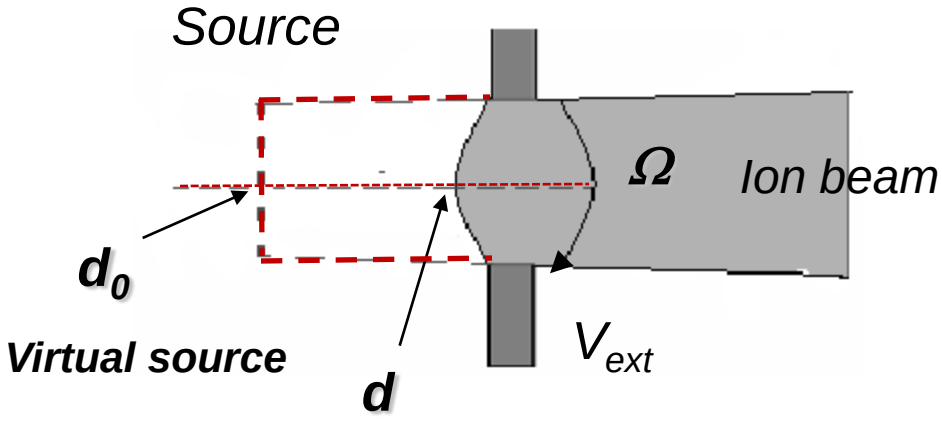


Virtual source size ≈ 50 nm

α ≈ 20°

Angular intensity ≈ 20 µA. sr-1

Plasma source



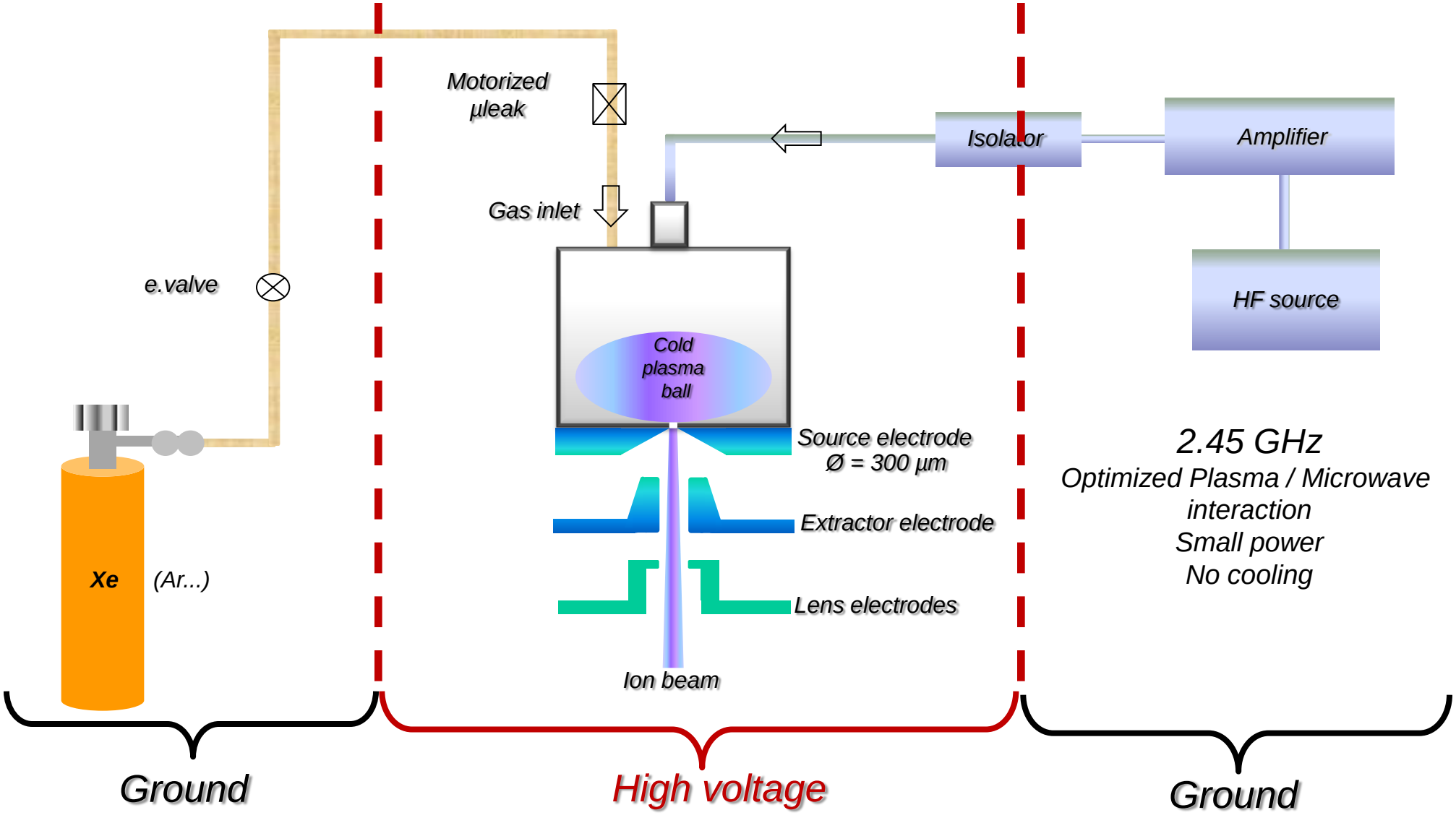
Virtual source size ≈ 15 µm

α ≈ 1°

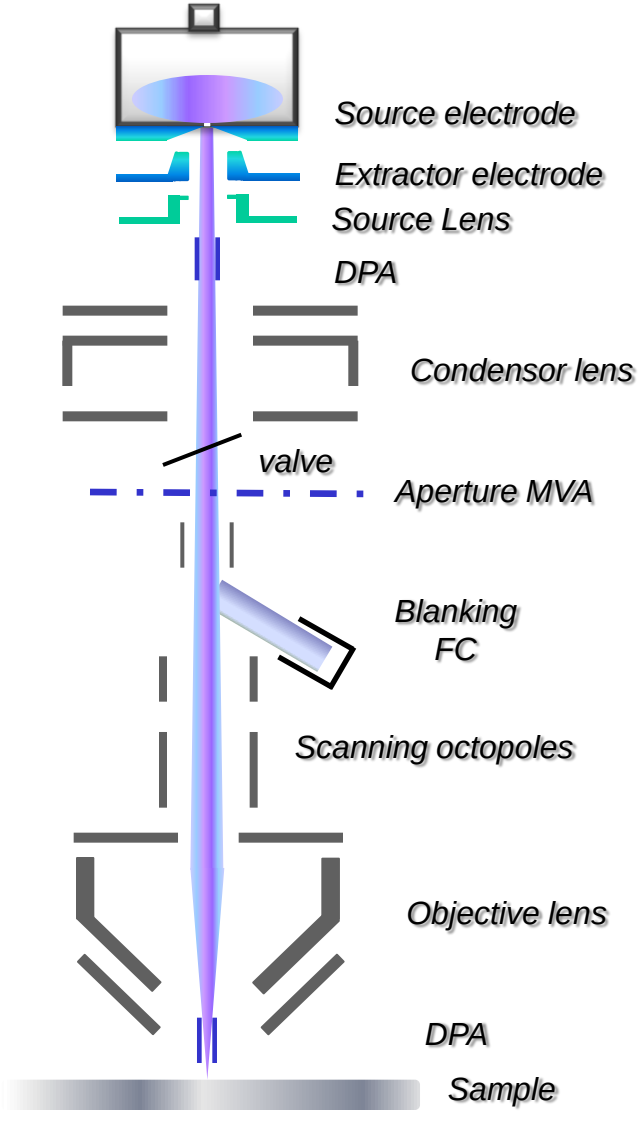
Angular intensity ≈ 18 mA. sr-1

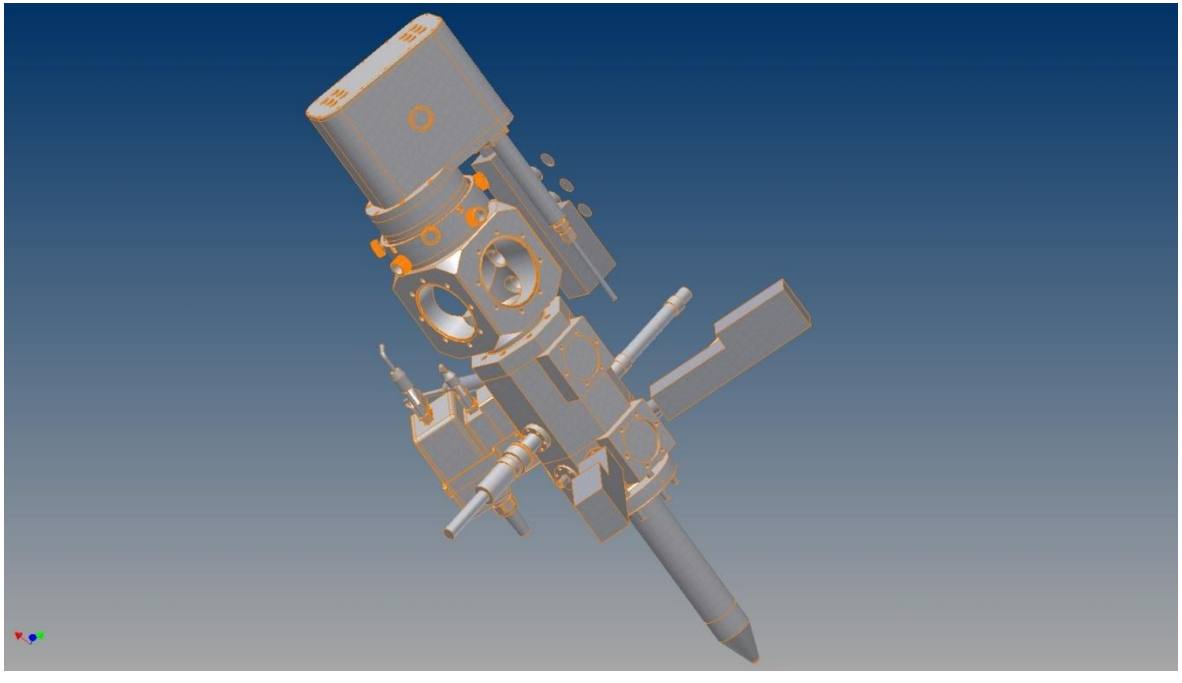
Schematic drawing of the ECR source

Patented OP source



Optical structure

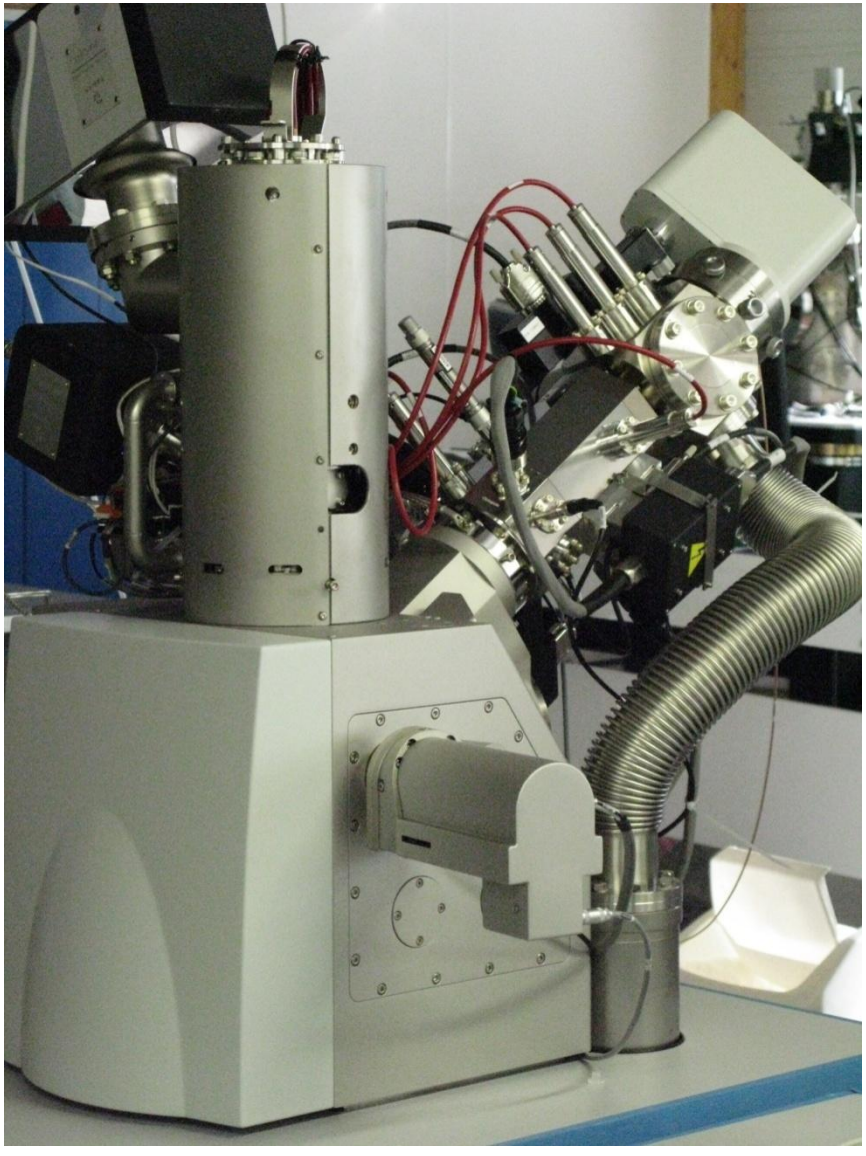




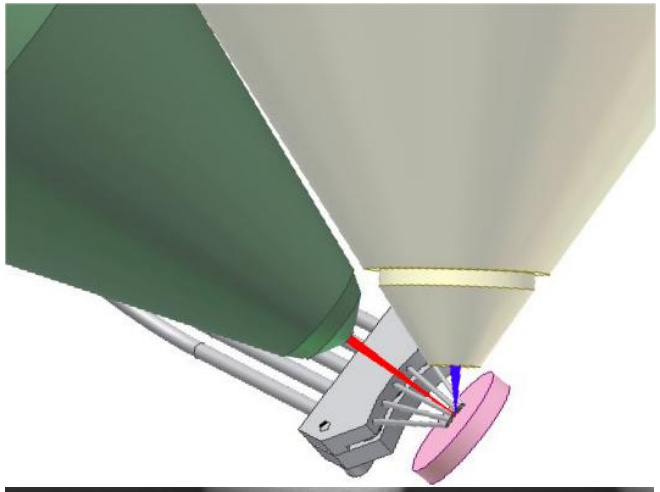
Combination with SEM

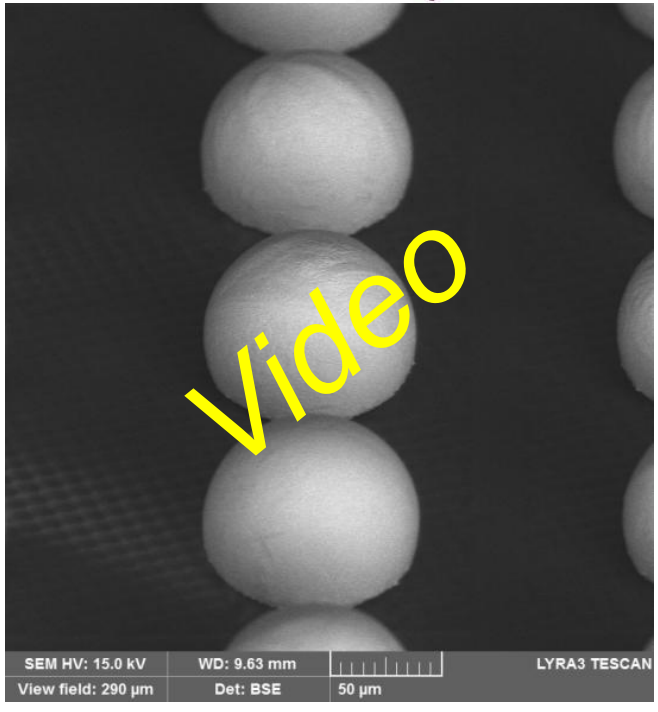
Orsay Physics i-FIB column has been integrated onto a Tescan FE-SEM.

⇒ First commercial ECR-FIB/SEM tool.



Combination with SEM





Interest of having 2 beams :

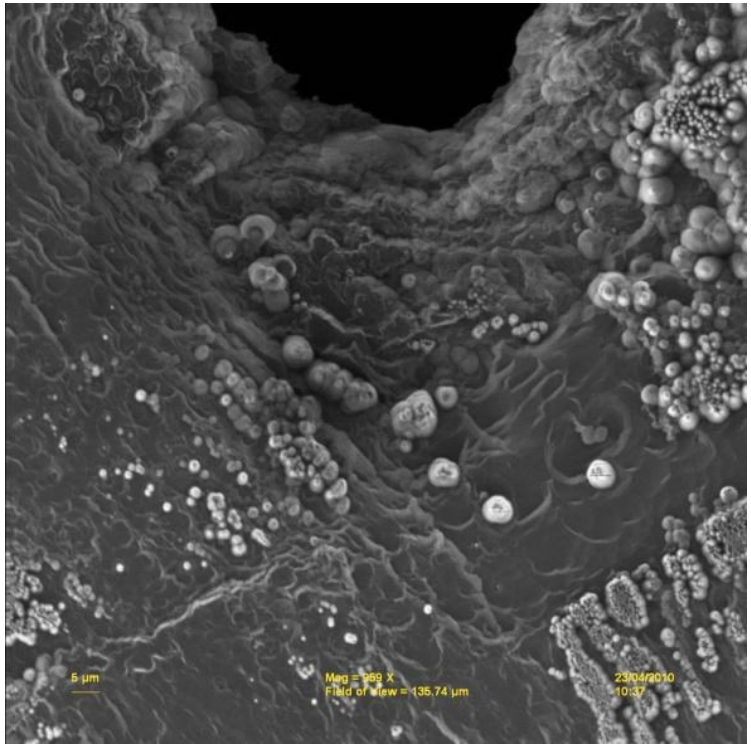
- Resolution of the SEM
- Direct observation of the prepared sample
- Positioning of the milling without any additional damage to the sample.
-Live observation even at very high current (> 1µA).

i-FIB results

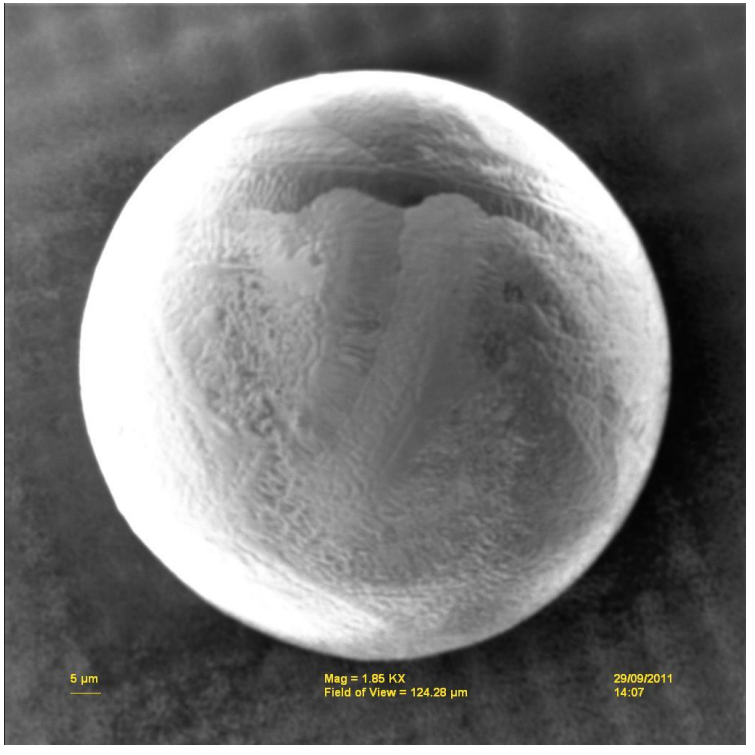
- Imaging at low current
- Sputtering rate
- Milling results

Imaging at low current

Xe images made at 100 pA

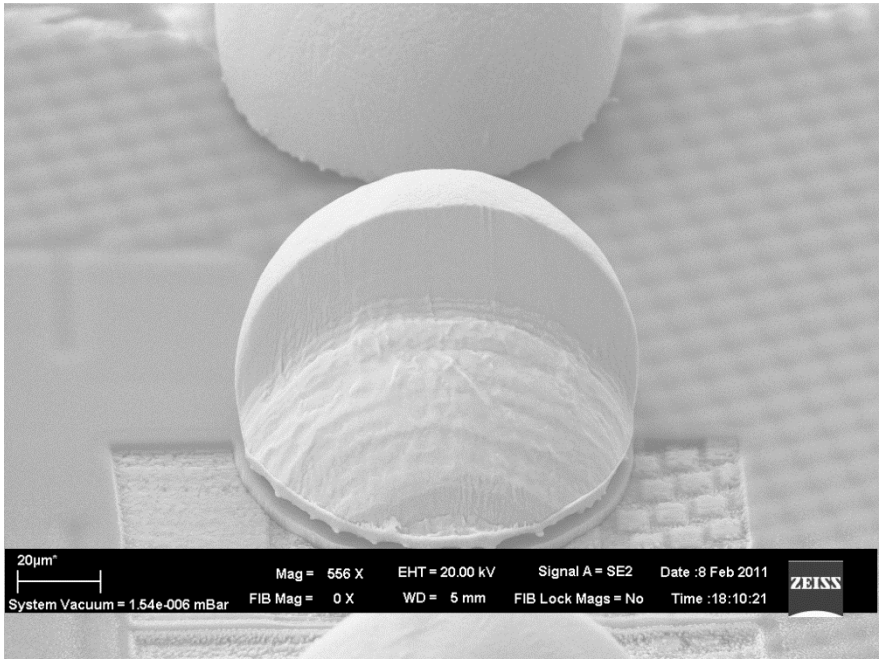


FOV :135 µm
Platinum Sample



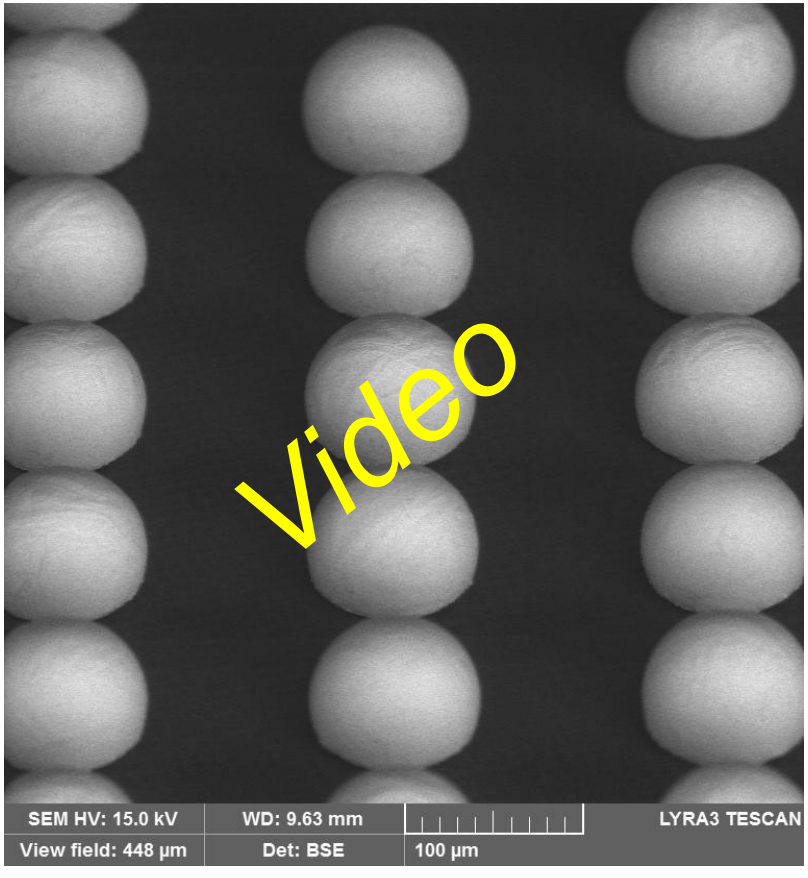
FOV :125 µm
C4 bump

Ga FIB and i-FIB



150x150 µm
20 nA Ga

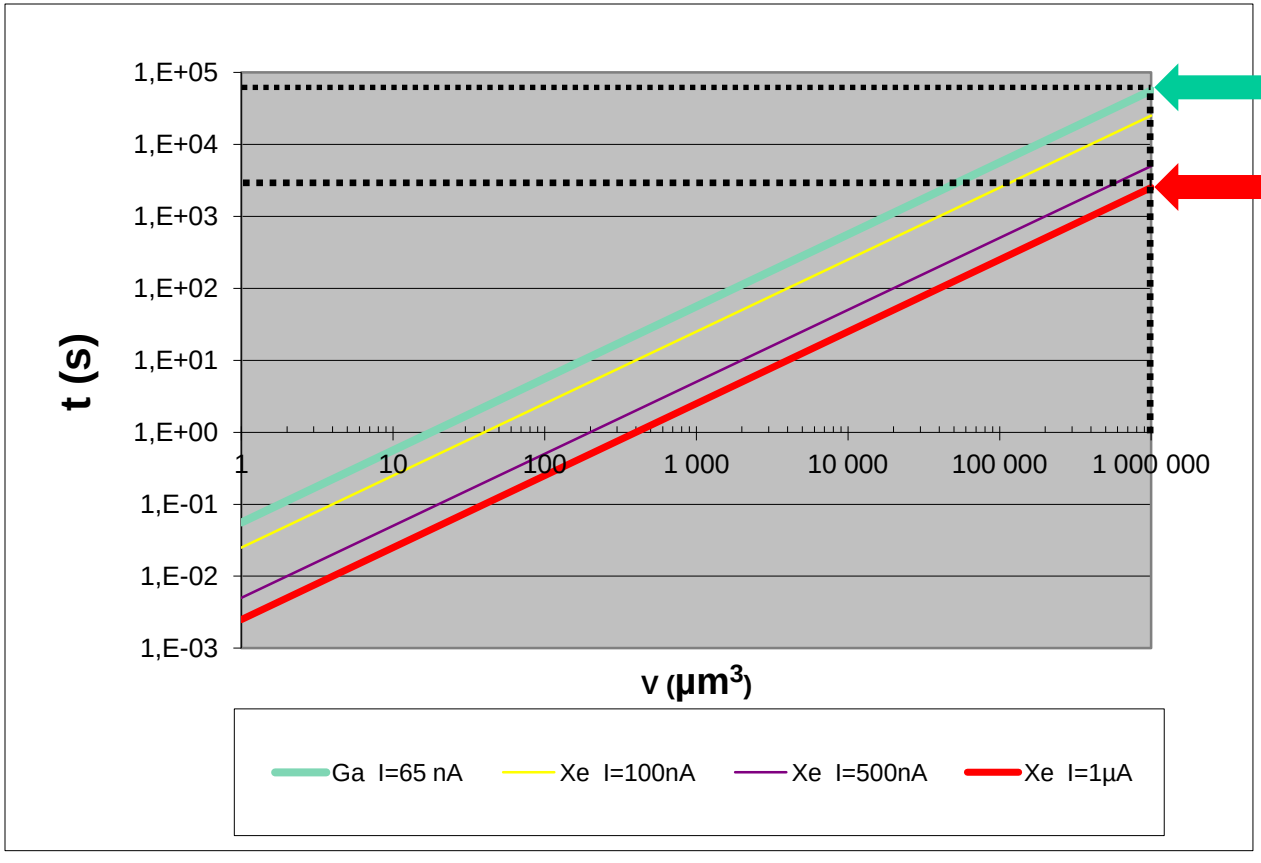
2 hours !



150x150 µm
1.6 µA Xe

3 minutes !!!

Sputtering rates on Si



Ga

Xe

With Xe at 30kV :

0.4 µm³/nC

3.2 at/ion

As a reminder, Ga at 30 kV :

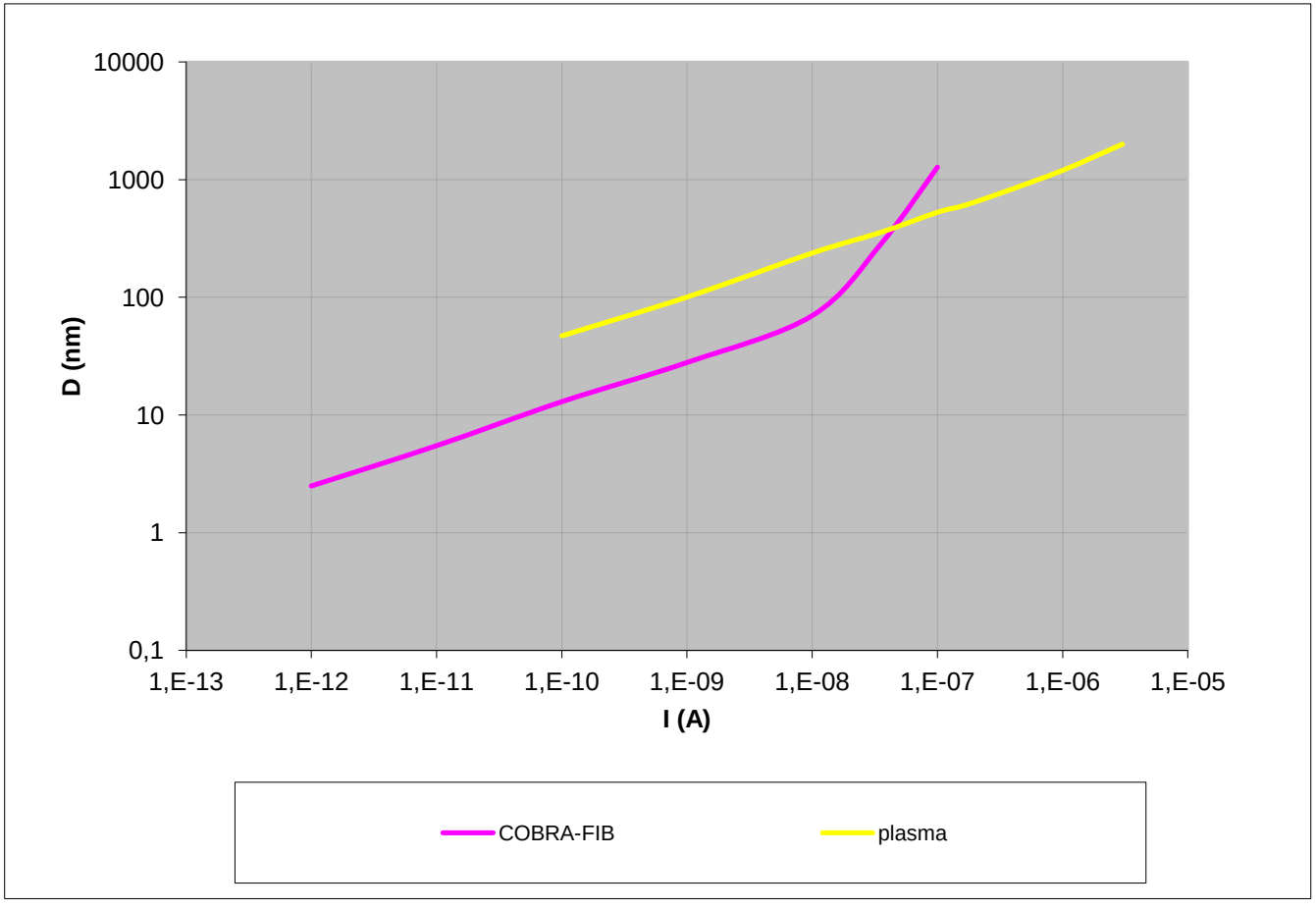
0.28 µm³/nC

2.2 at/ion

100 x 100 x 100 µm³

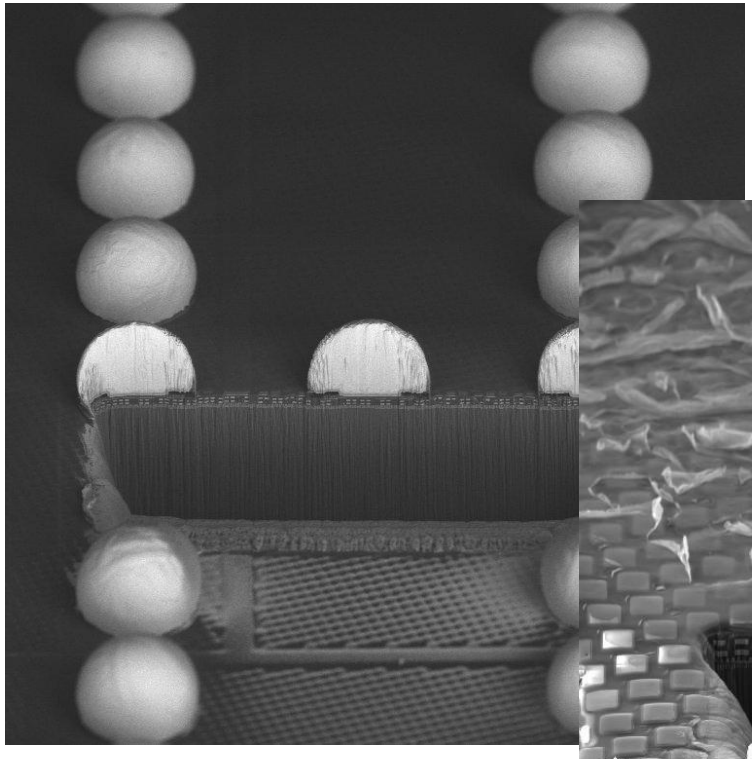
15 hours with Ga (65 nA) = 40 minutes with Xe (1µA)

Plasma FIB

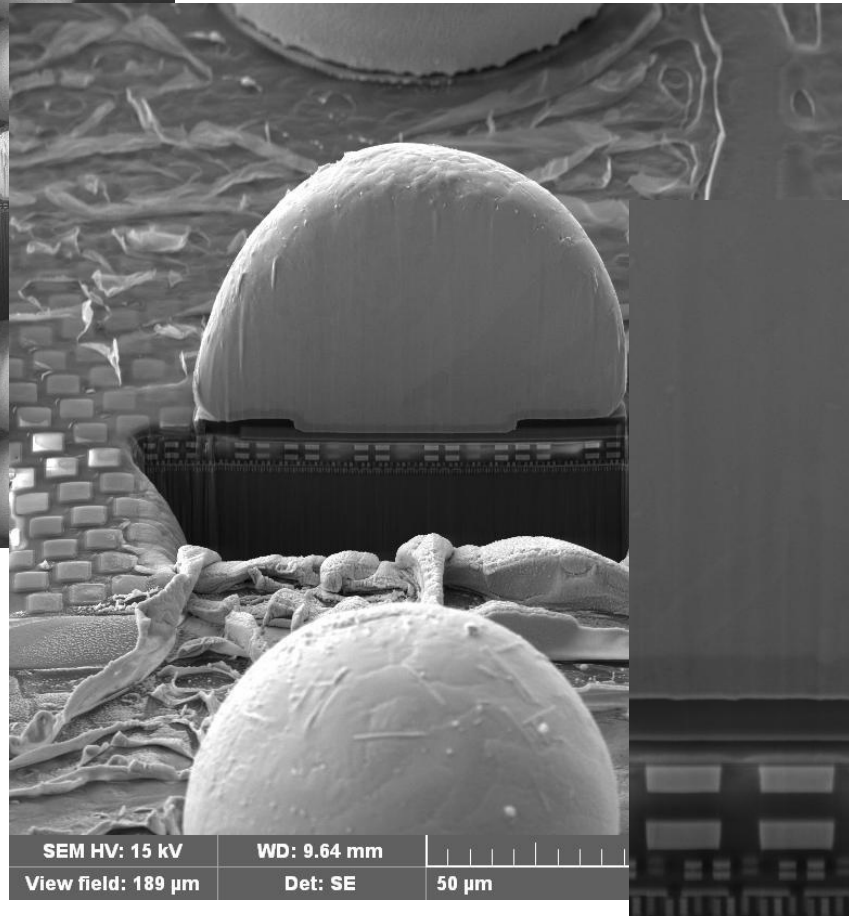


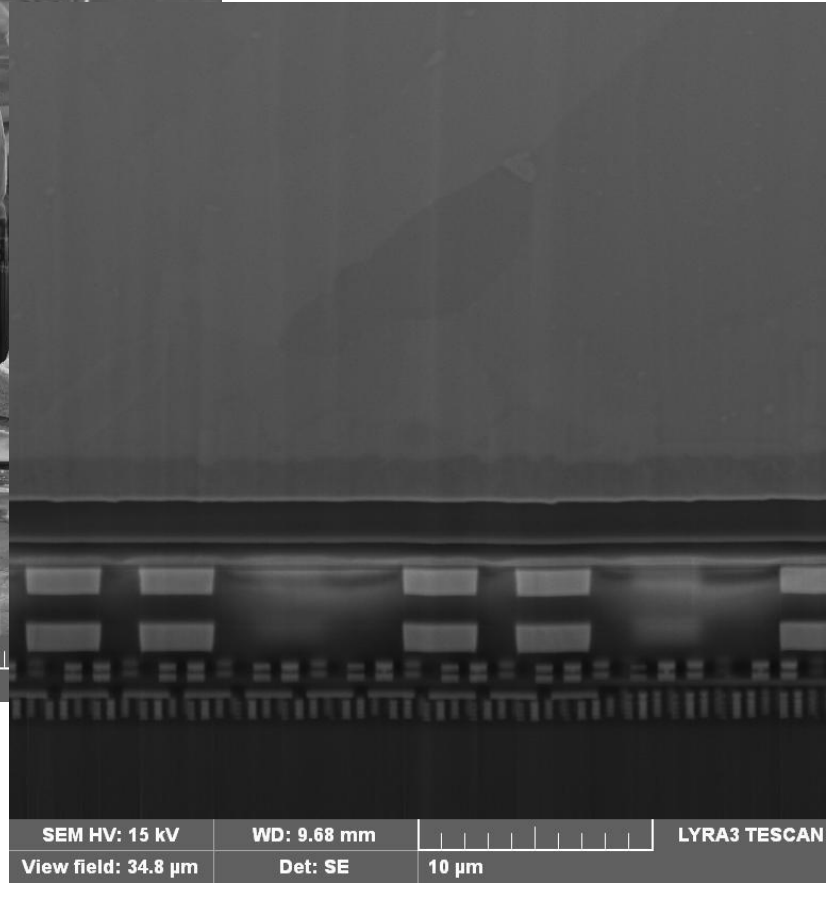
The right side of the curve is coverded by Plasma FIB

Milling results



450 µm x 200 µm
< 1h
(performed on IBM samples)

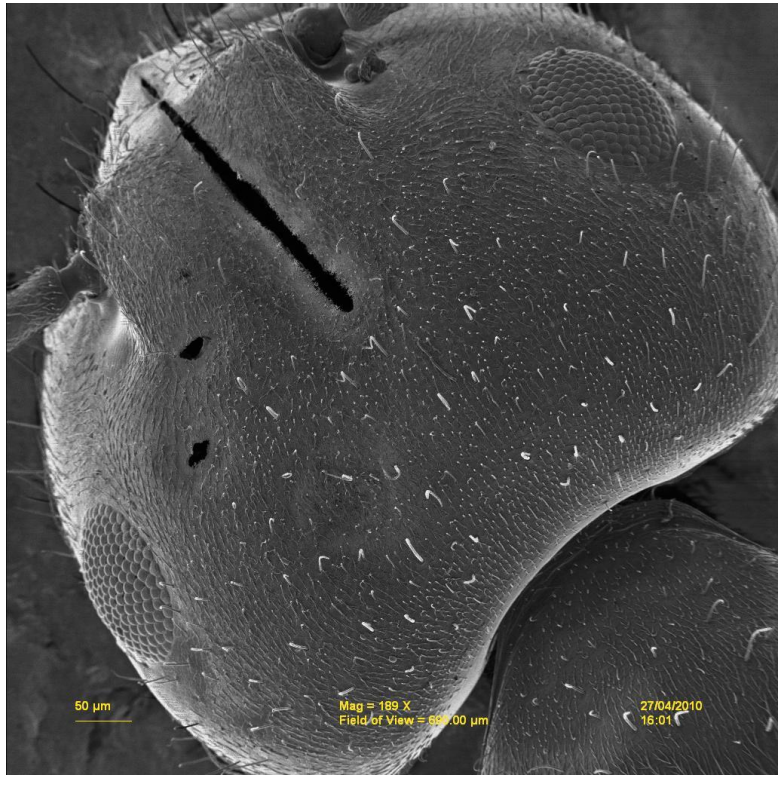




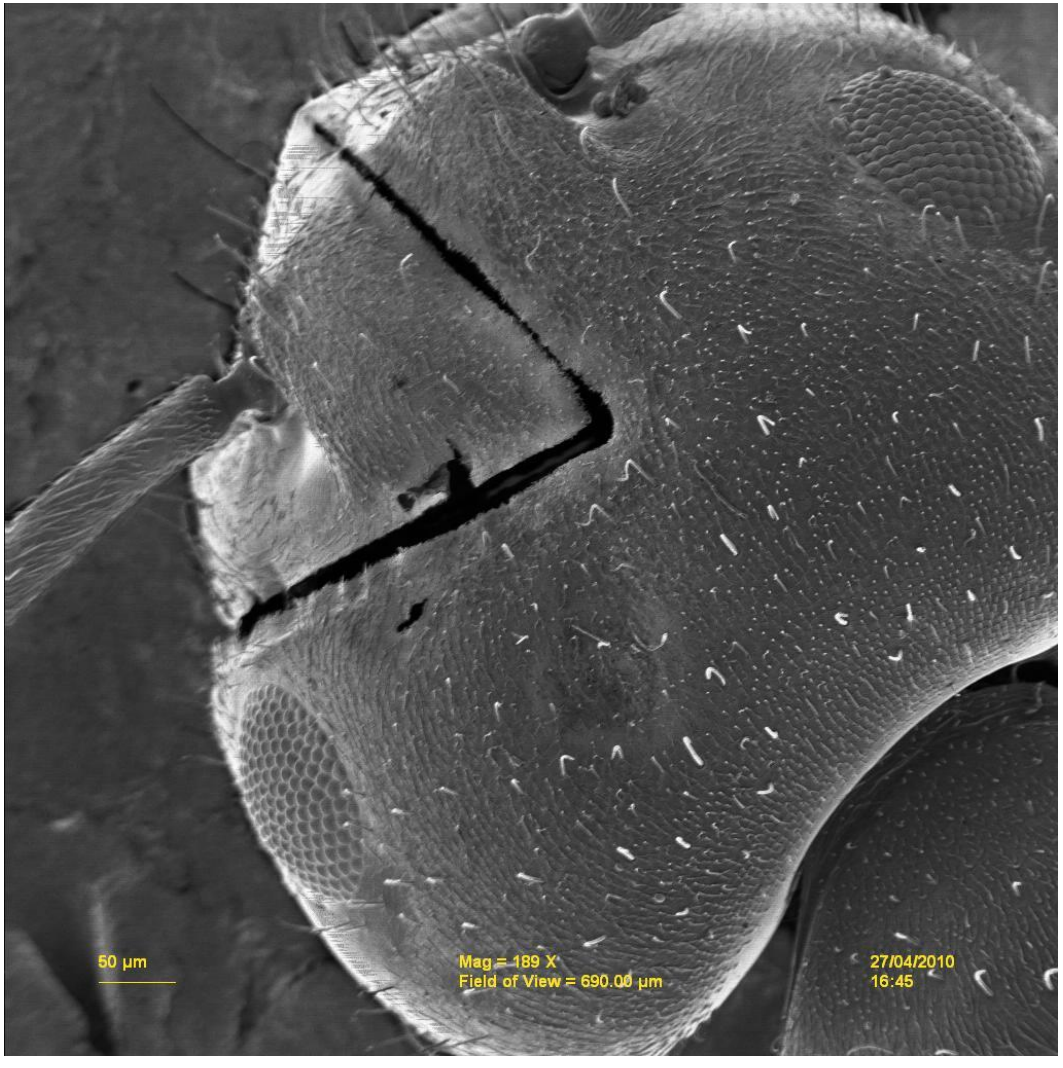
Non semiconductor applications

Applications in Biology, Biotechnology,etc

i-FIB image examples of microsurgery of a ant head



Performed on Orsay garden guest



Conclusion

- i-FIB concept based on ECR plasma designed, manufactured and succesfully tested !

- ECR-FIB combination with SEM fully validated

- Well-known range of applications in semiconductors, but also new fields to be explored, such as biology, biotechnology, microtools, MEMS…

Thank you for your attention