In situ lift-out FIB for preparation of TEM samples:

new applications, future prospects and challenges

A. Benedetti, H. Bender, O. Richard

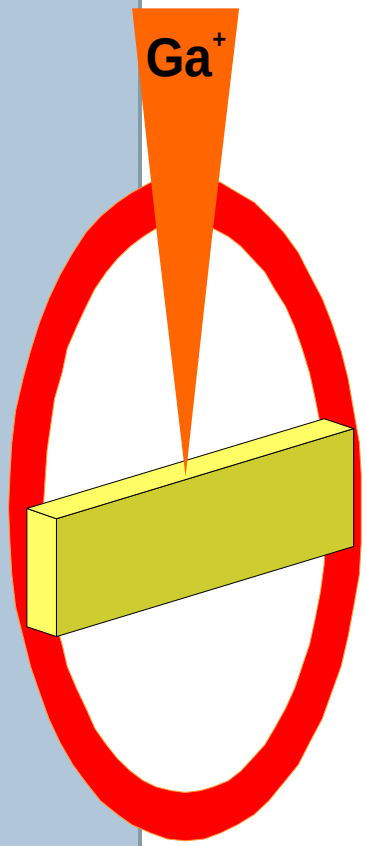
IMEC
Leuven, Belgium

SEEDS FOR TOMORROW'S WORLD

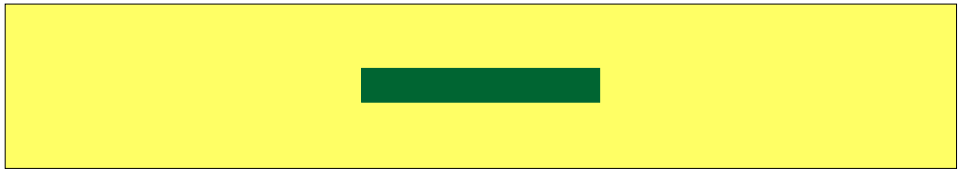
Introduction

- FIB preparation techniques : standard FIB, *ex-situ* lift-out, *in-situ* lift-out
- Why lift-out : no need for mechanical thinning, large tilt range, no pre-FIB wafer cleavage
- Applications
- Practical problems
- Comparison with standard FIB
- Future work

TEM preparation with FIB: Trench milling



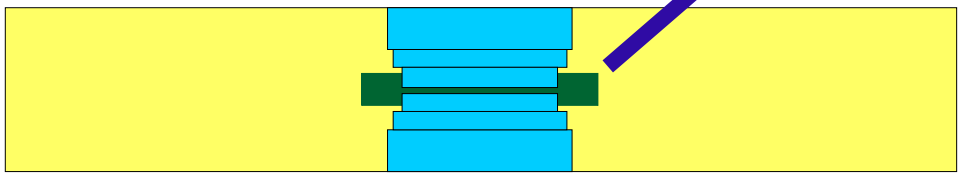
Pt deposition 20x2 μm

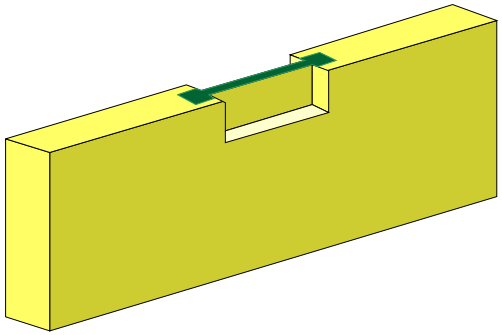


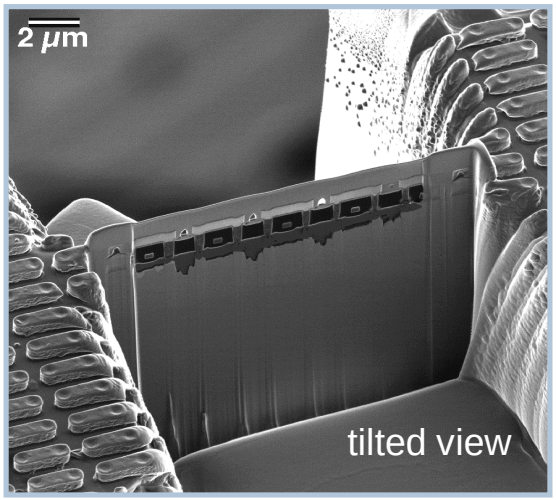
Milling ~15-20 μm wide,
3-5 μm deep
Remaining ~20-100 nm

gas needle

I_2, XeF_2, ...

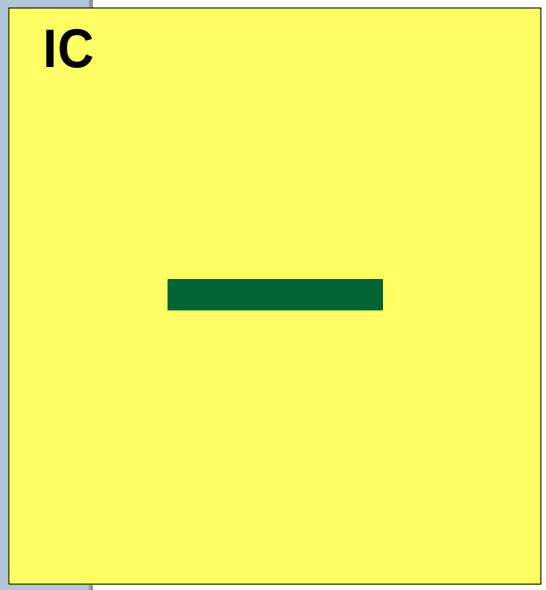




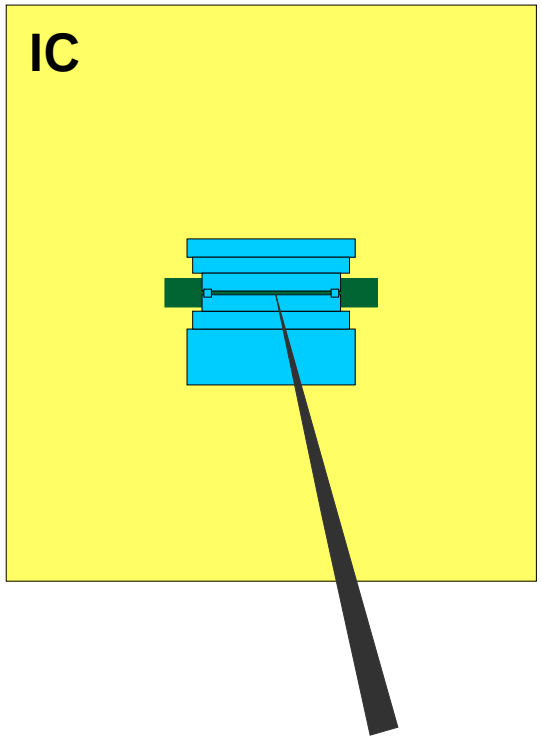


TEM preparation with FIB: Ex-situ lift-out

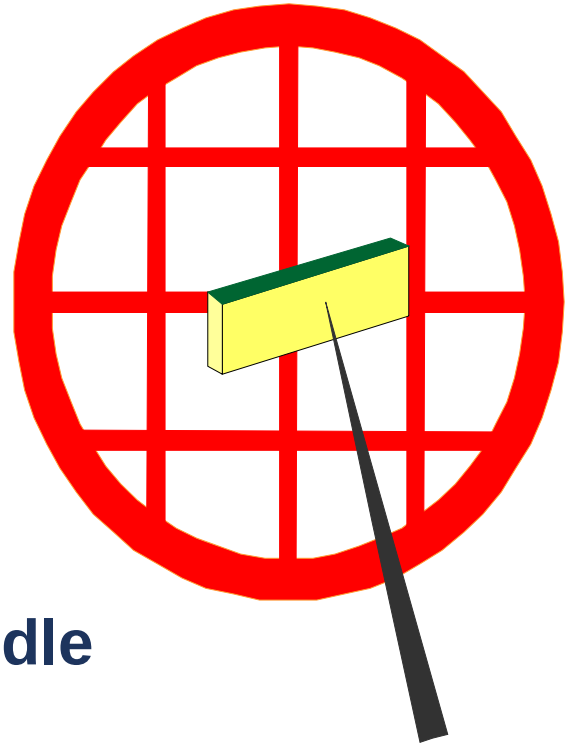
Pt deposition 20x2 μm



Milling ~15-20 μm wide
3-5 μm deep
Remaining ~20-100 nm



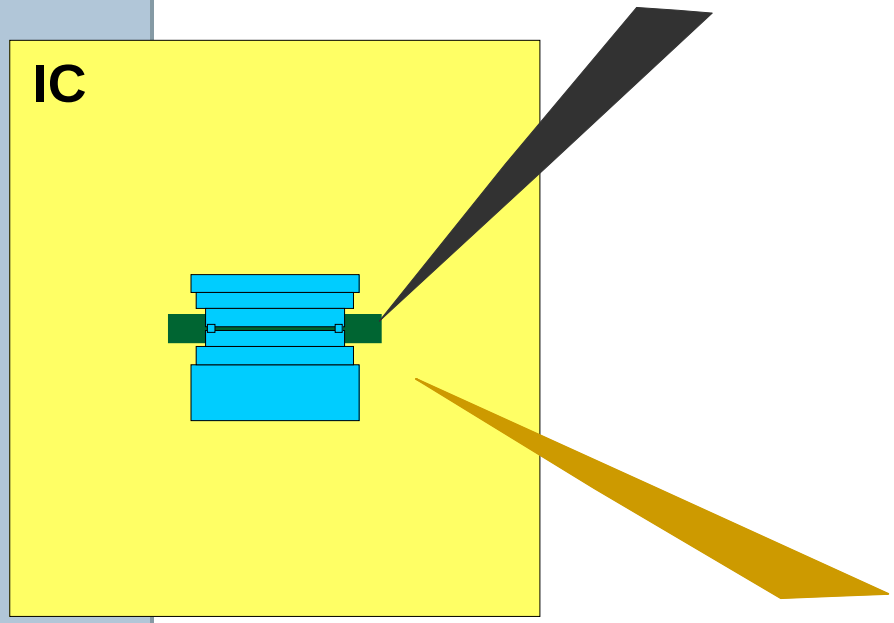
Deposition on grid



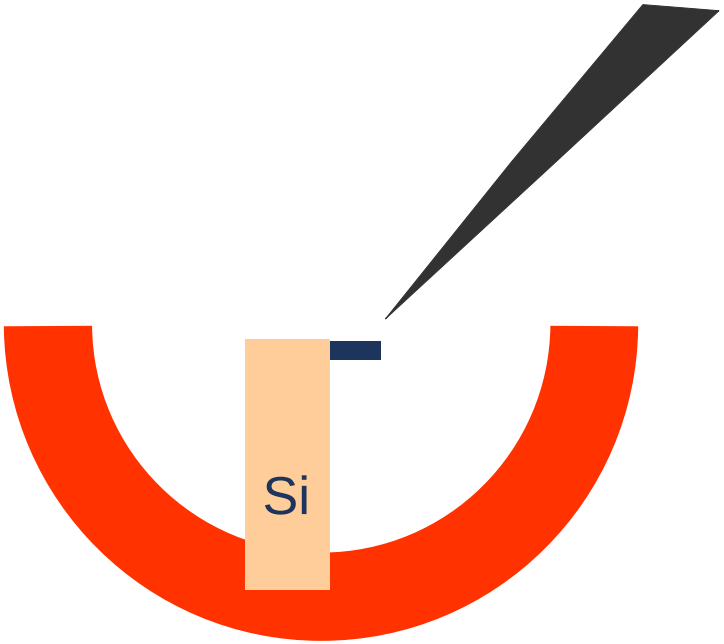
pick-up needle

TEM preparation with FIB: *in-situ* lift-out

pick-up probe on gas needle



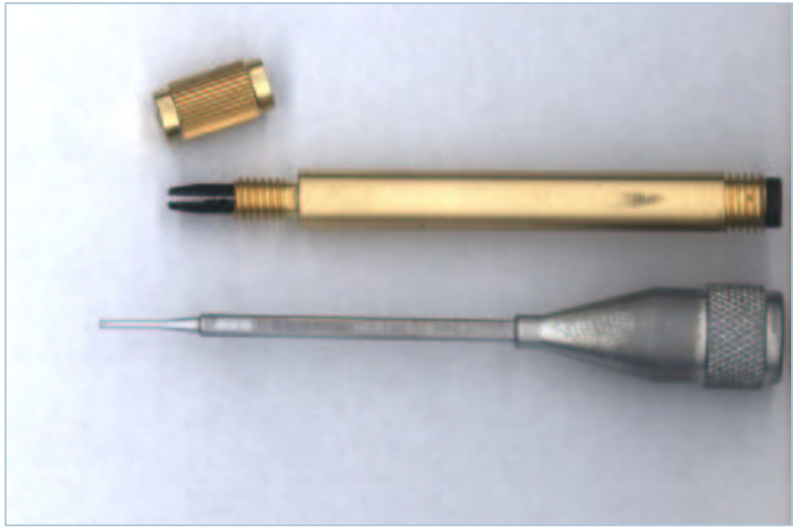
Pt gas needle



fixing with Pt on Si bar

T. Ohnishi et al, Hitachi
Bert Otterloo – Harry Roberts, Philips Semiconductors

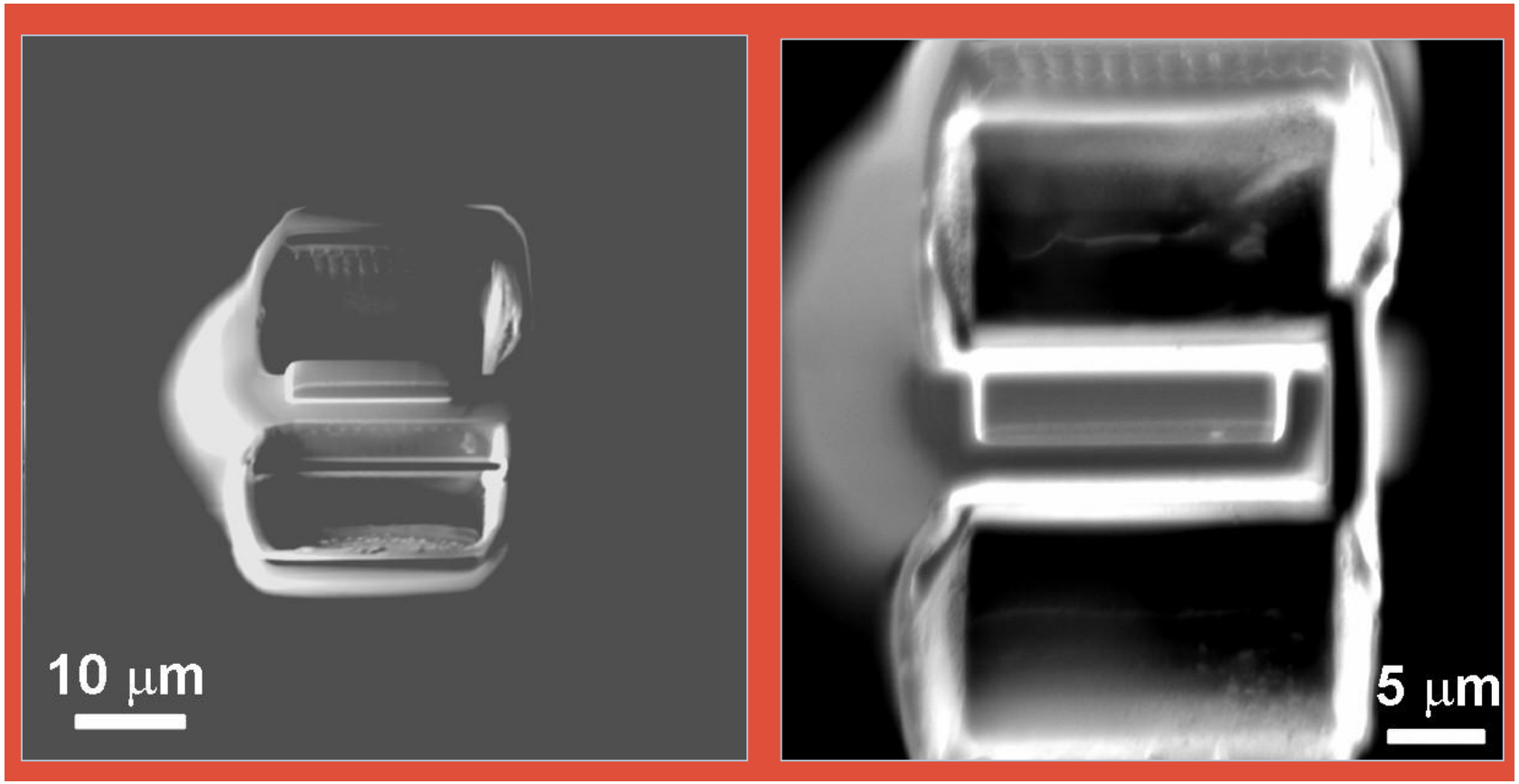
In-situ plucker tool



- optical fiber chuck
- needle gas injector
- fine probe needle

In-situ plucker procedure

- craters and undercut
- cut at the edge

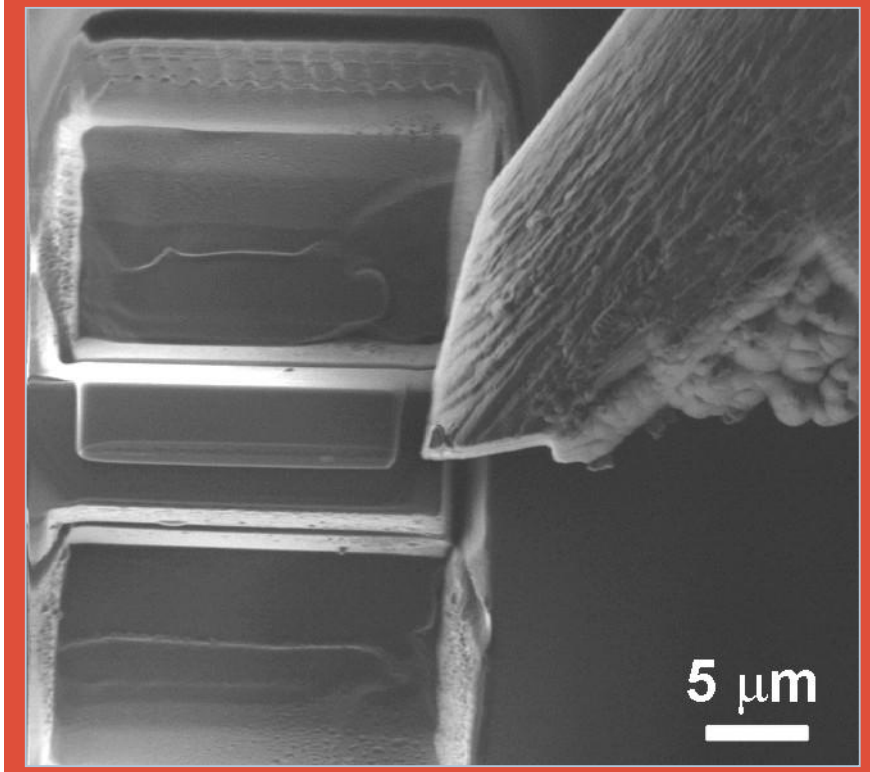


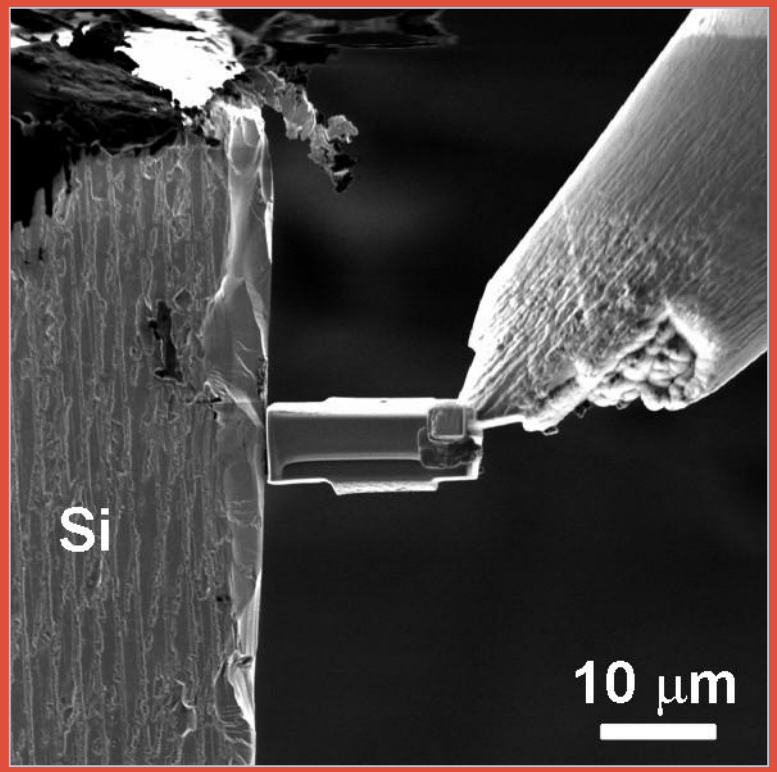
Procedure:
Bert Otterloo – Harry Roberts, Philips Semiconductors

In-situ plucker procedure - 2

- inserting probe needle
- moving stage up

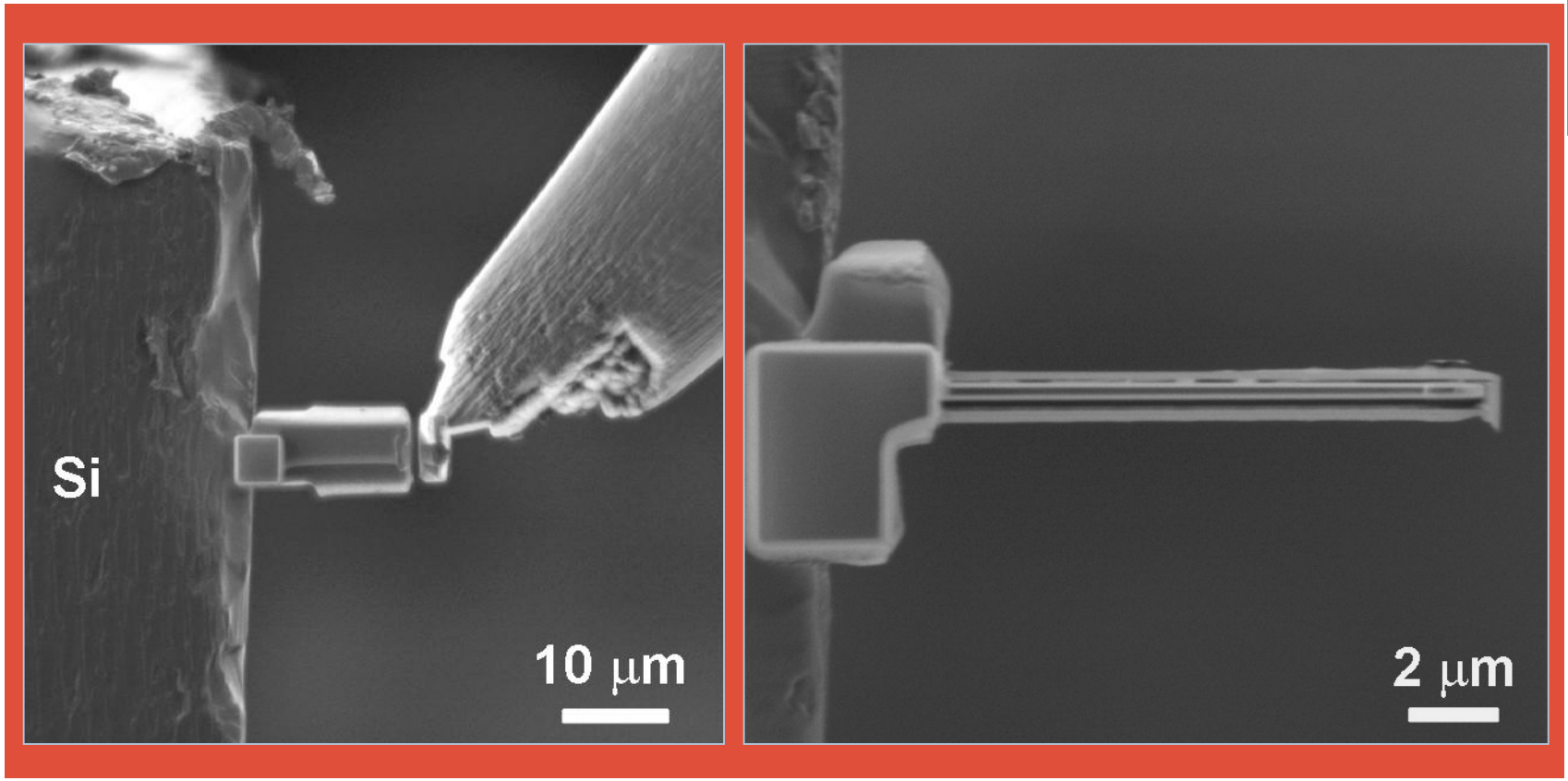
- needle attached
- slice cut free
- stage moved to the grid with Si bar



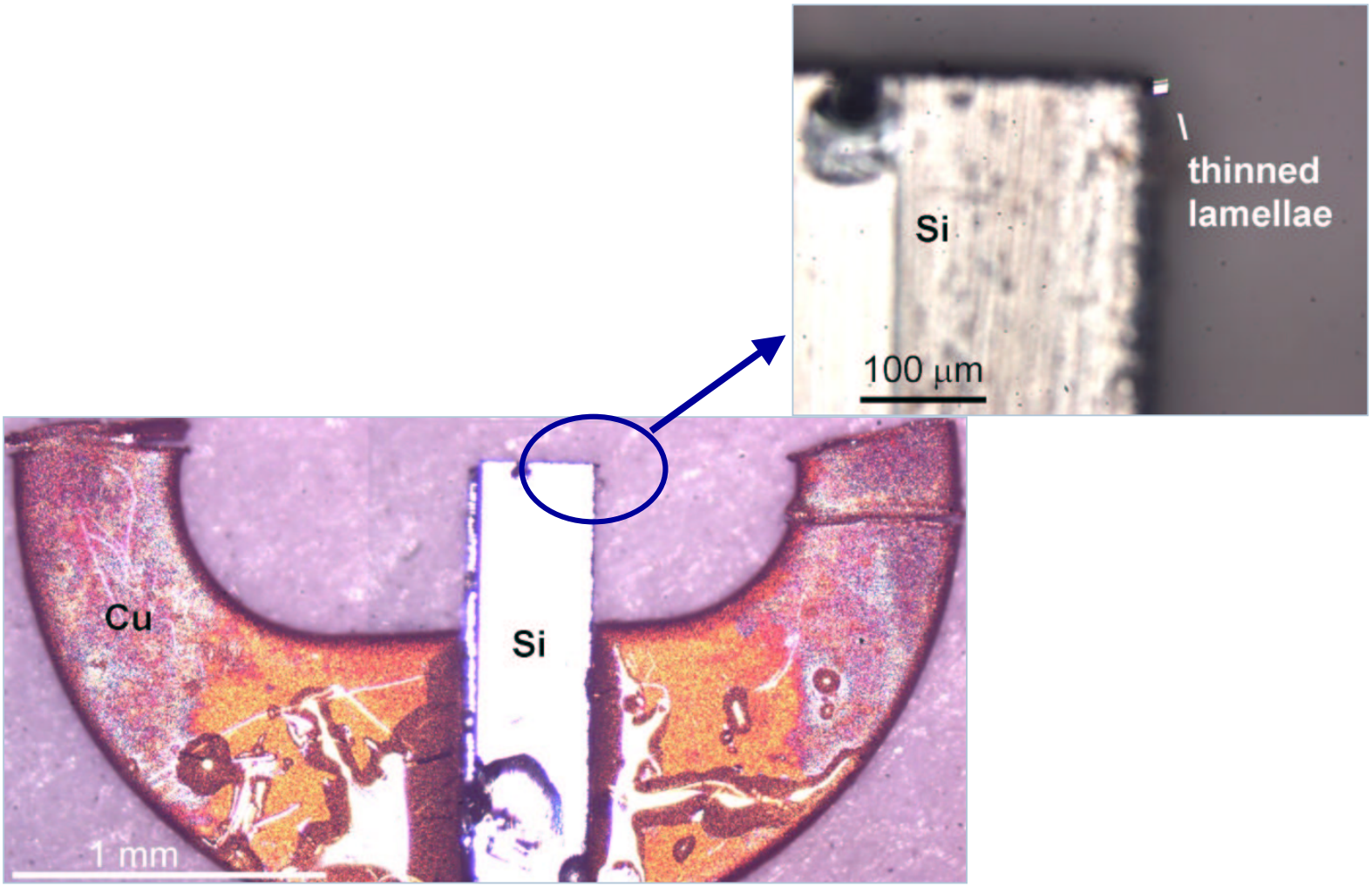


In-situ plucker procedure - 3

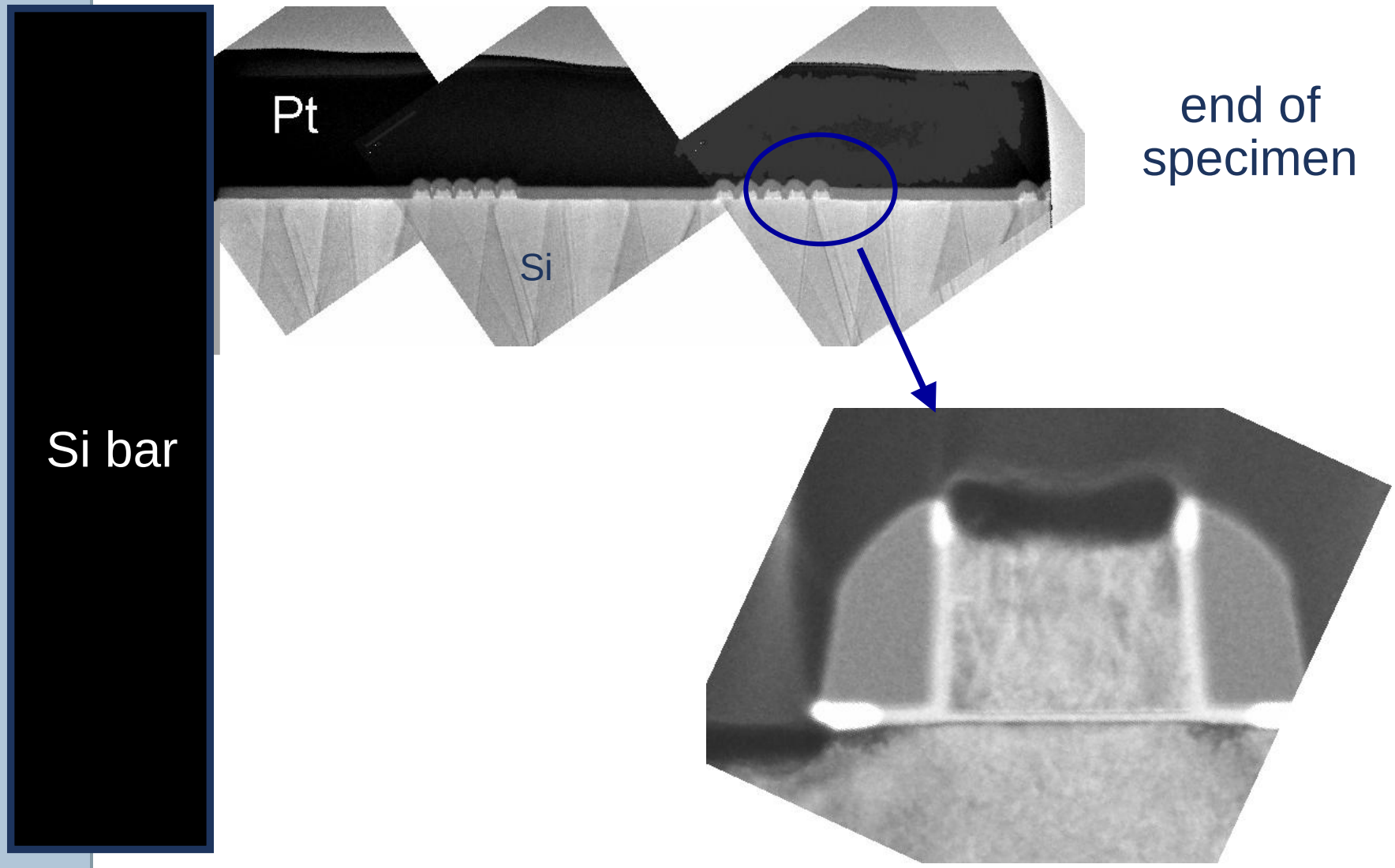
- slice attached to Si bar
- needle cut free
- final thinning to electron transparency



In-situ lift-out specimen

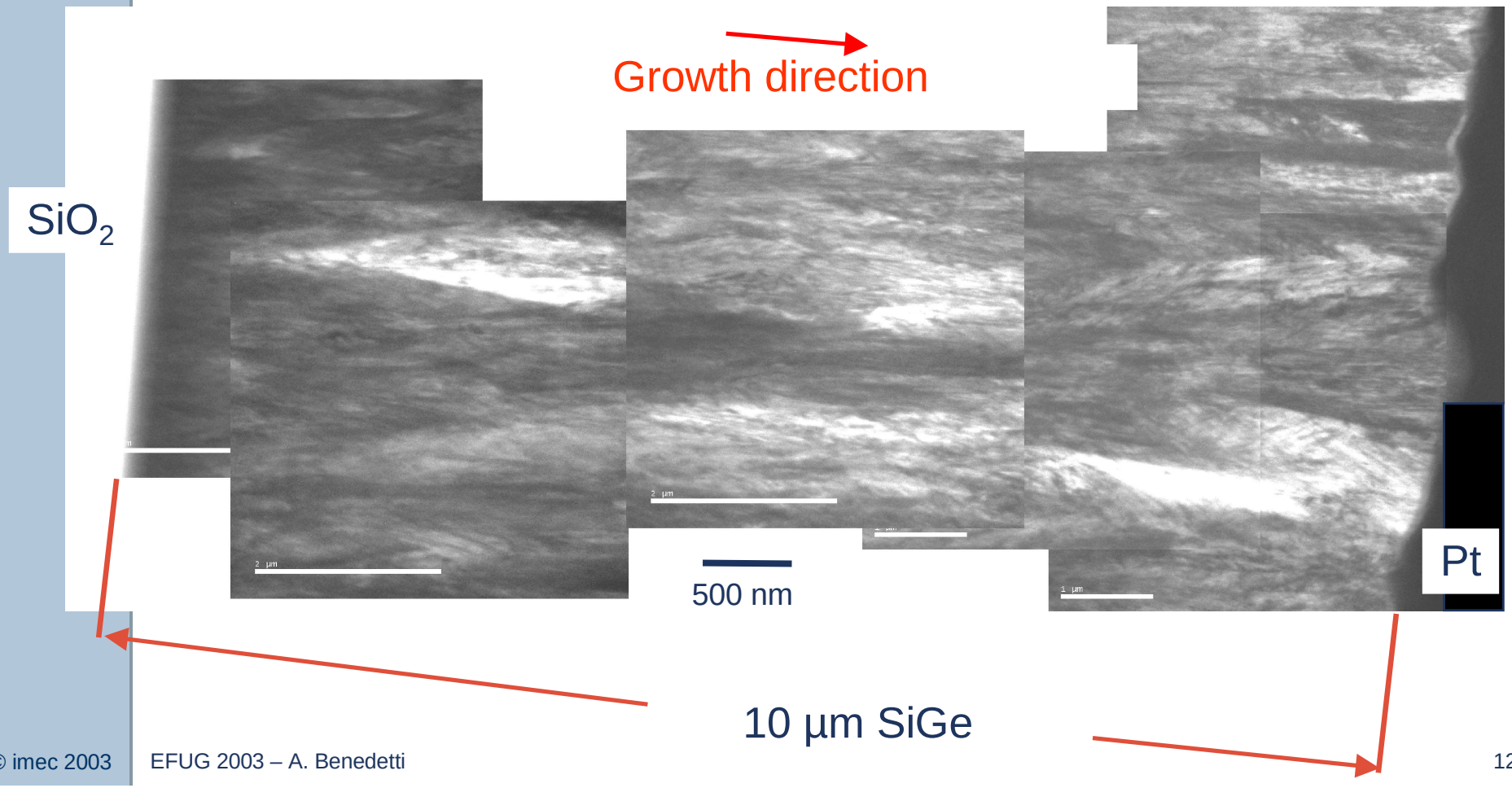


TEM : in-situ plucker specimen

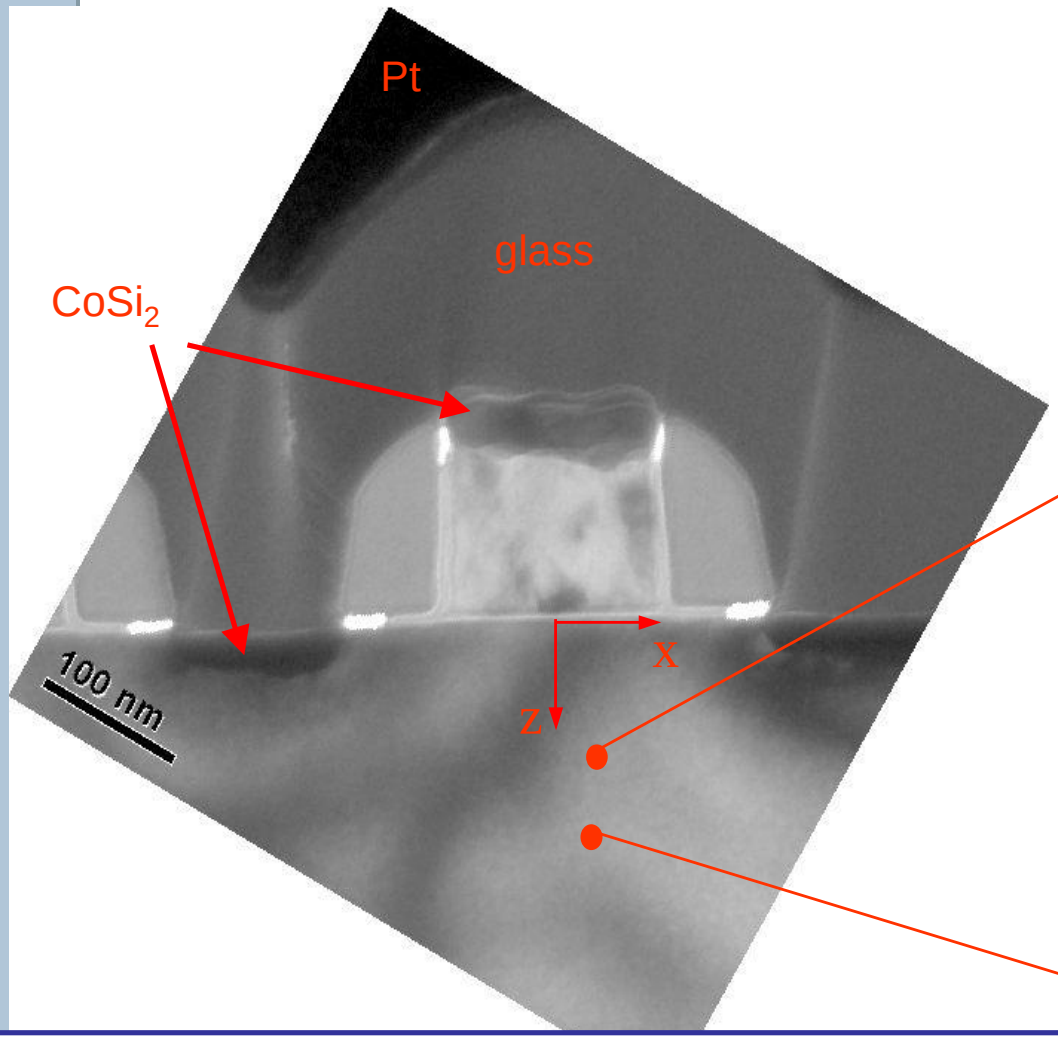


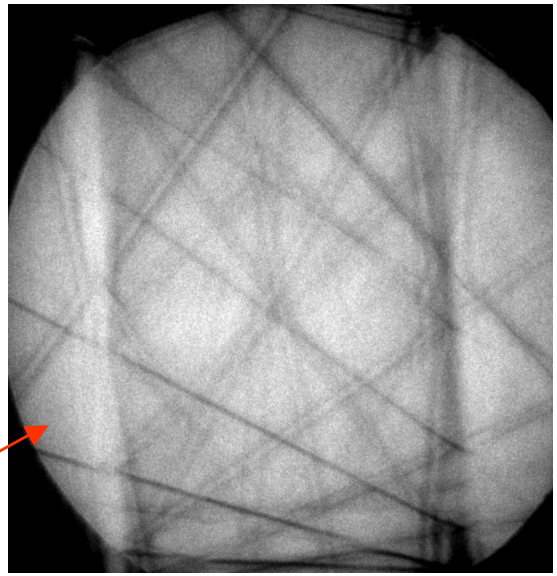
Applications : 10 µm thick poly-SiGe layers

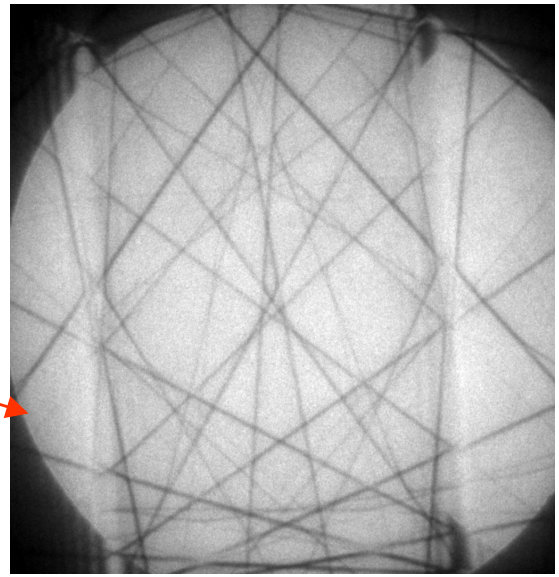
- Samples prepared by either mechanical polishing and ion milling or sawing followed by conventional FIBbing show *delamination* during the sawing
- Lift-out preparation overcomes the problem



Applications: strain analysis by CBED



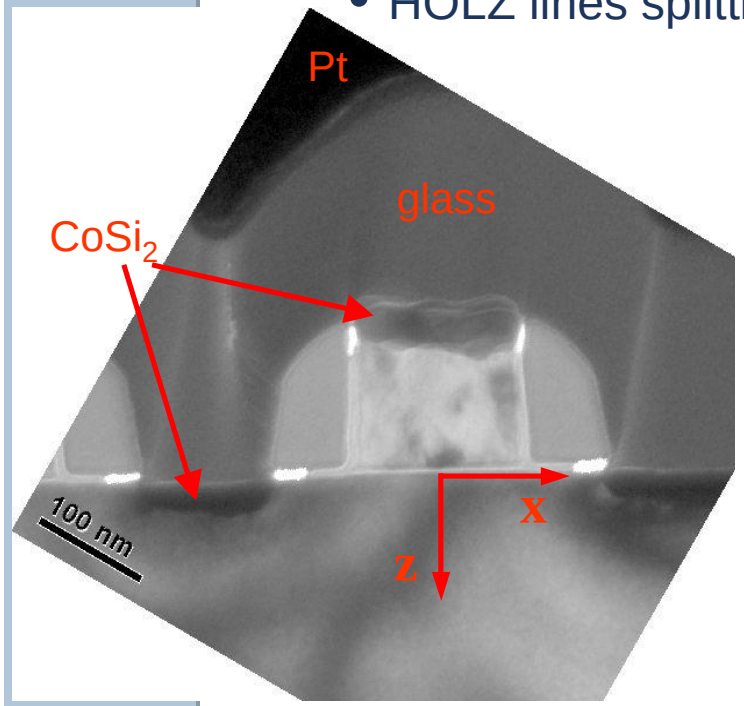




Patterns acquired with A.Armigliato and R.Balboni with a Tecnai TF 30 in STEM-CBED mode at CNR - IMM labs, Bologna, Italy

Applications: strain analysis by CBED (cont'd)

- HOLZ lines splitting near Si/SiO_2 interface: two possible explanations



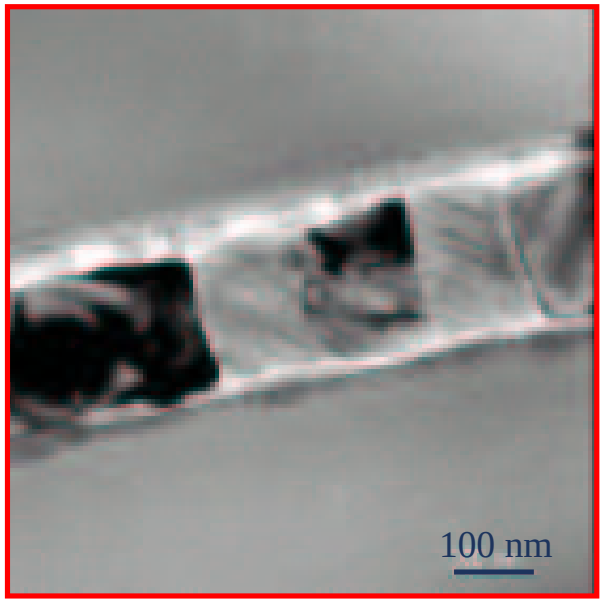
1. Surface relaxation:

should be present everywhere on the x-z plane

2. Two or more $CoSi_2$ grains across the sample:

each grain would deform the lattice in a different way!

- *Previous results on $TiSi_2$ seem to confirm the latter theory!*



Plan view sample of a $TiSi_2$ stripe

Practical problems

- Thermally insulated samples : overheating, contamination ?
- Time consuming : approximately 1.5 times slower than standard FIB (but no sawing needed!)
- Thermal and mechanical properties same as standard FIB? : possible differences in strain results
- Positioning of Si bar : has to be as vertical as possible!

Trench milling vs lift-out

Conventional

+ easy handling : **high yield**
+ further milling possible
- limited tilt in TEM

Lift-out

+ no pre-thinning :
  - delaminating layers
  - packaged devices
+ no sidewalls :

  EDS, large tilt possible
+ orthogonal incidence
+ design overlay possible
+ **in-situ** : further thinning possible
- difficult handling : **medium yield**

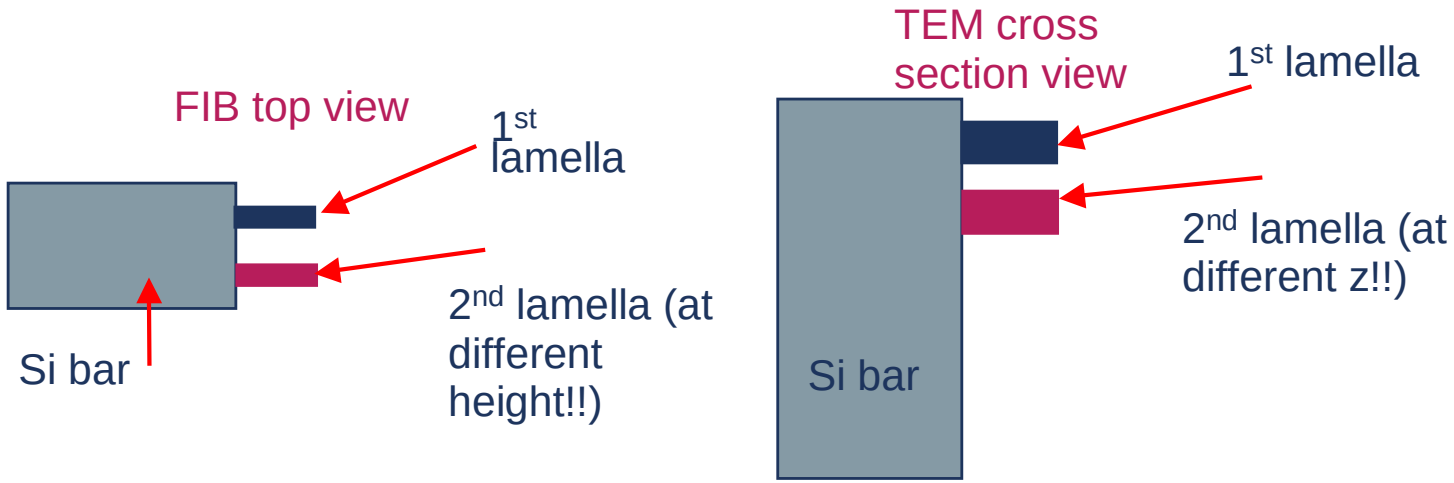
Both

+ site-specific
+ plan-parallel specimens
+ minimal heating

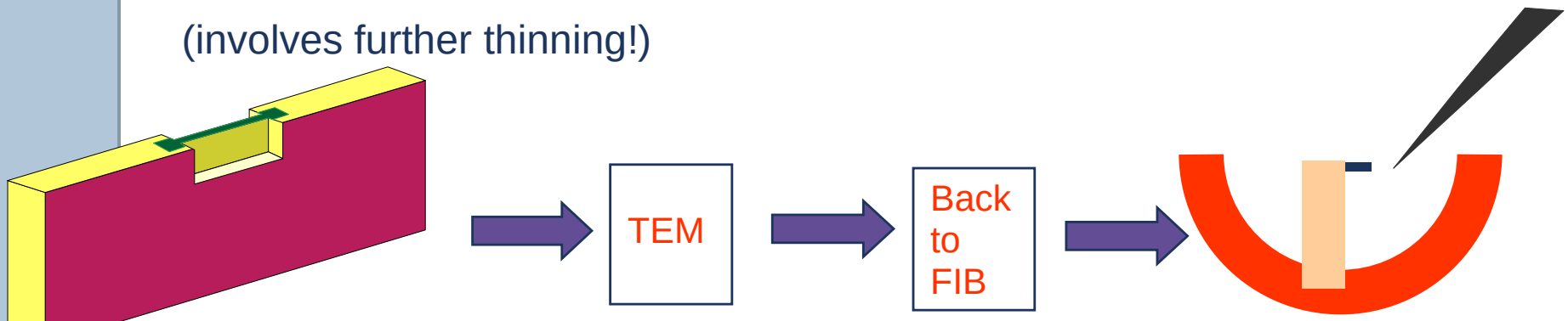
- **limited thin area**
- Ga ion damage

Ideas for the future

- In-line analysis ?? (from growth chamber to FIB and back!)
- Many lamellas on the same Si bar:



- Lift-out samples prepared from already TEM thin standard FIB samples (involves further thinning!)



Acknowledgments

In-situ plucker procedure:

Bert Otterloo - Harry Roberts

Use of STEM - CBED system:

Aldo Armigliato, Roberto Balboni