Photonics Research Group

Reducing optical losses in Focused-ion-beam etched silicon by annealing

ePIXnet JRA Focused Ion Beam for Photonics

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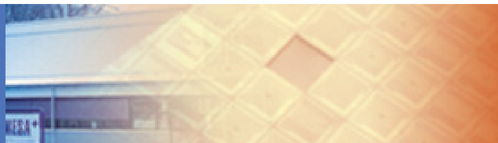
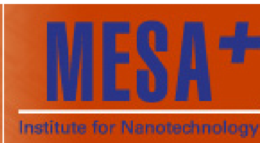
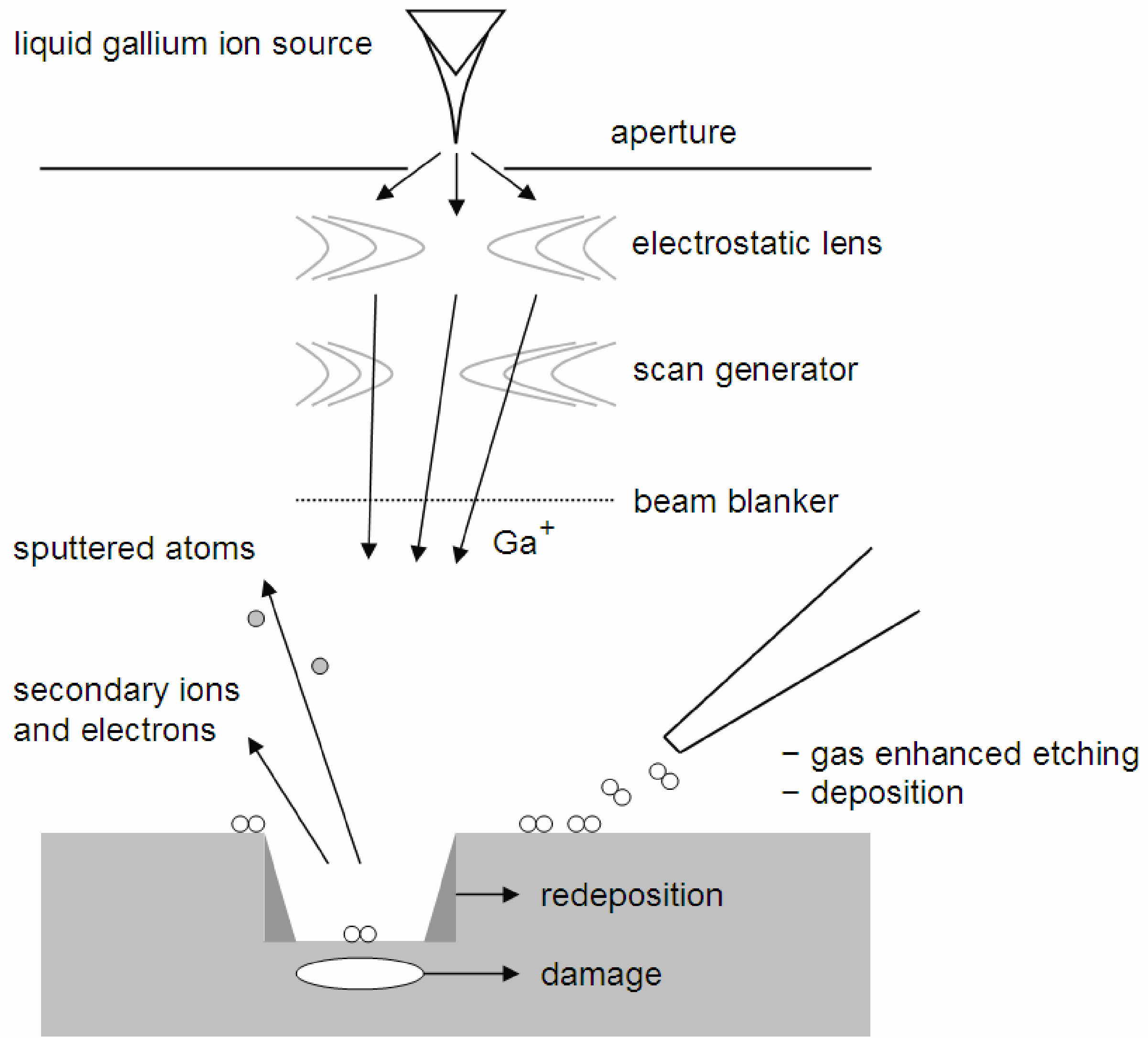
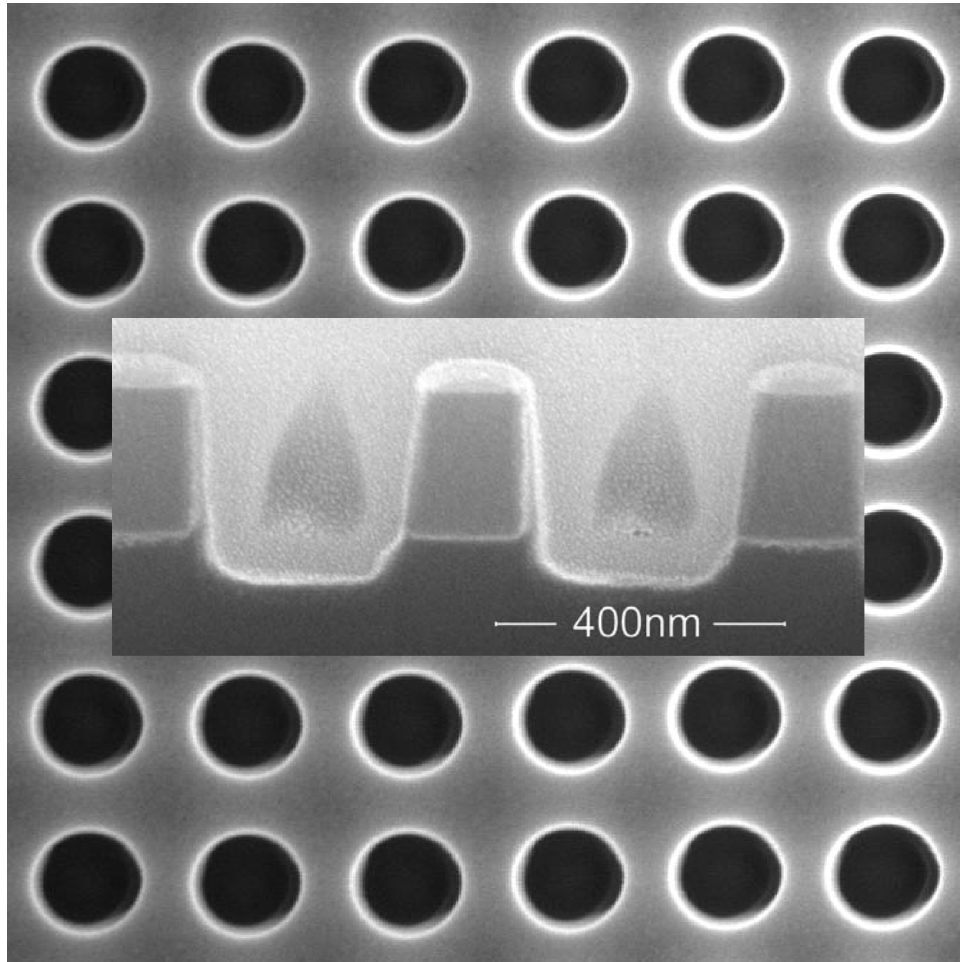
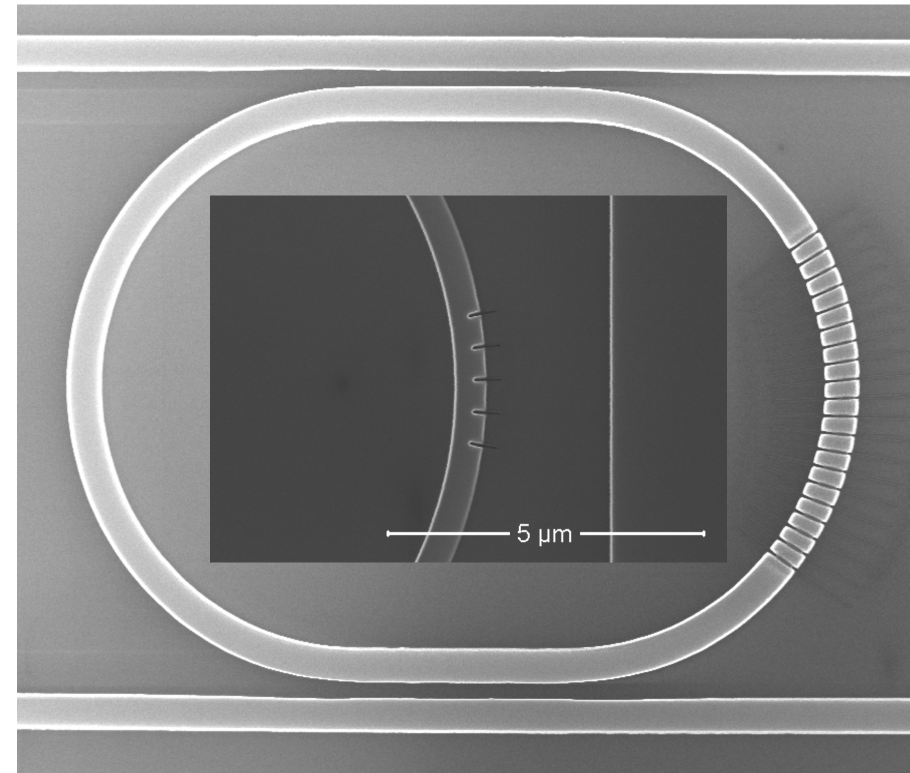



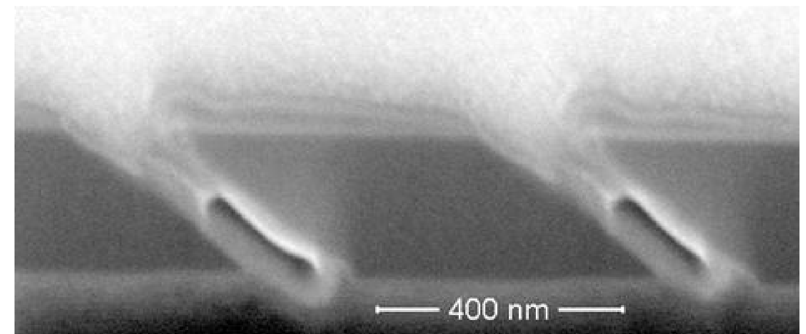
What is Focused ion beam?



Why exploit FIB in silicon?







How to reduce the GIGANTIC losses?

High optical losses in FIB etched silicon due to:

- Gallium implantation
- Crystal damage

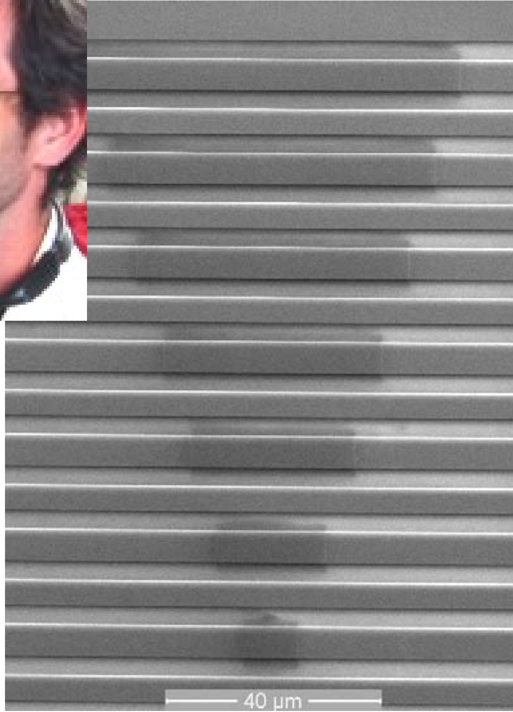
What we propose to do:

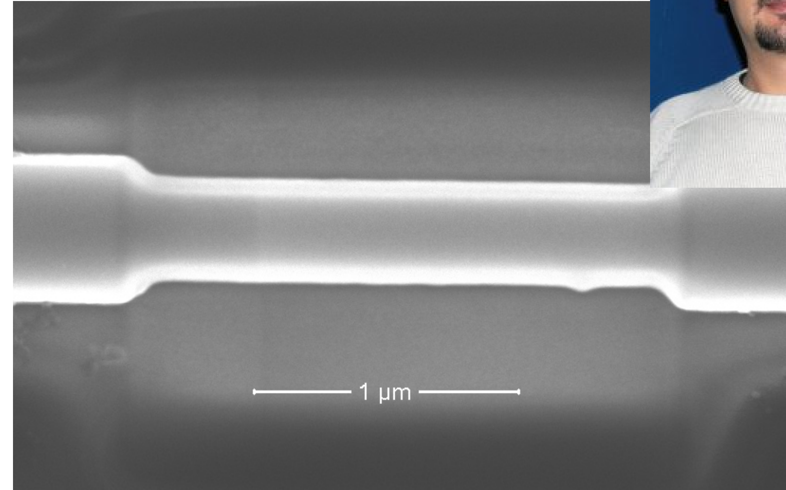
- Preventive:
  - I_2 enhanced etching
- Regenerative:
  - Recrystallization and out-diffusion by annealing
  - Dry etching of a thin damaged layer

Outlook

1. Introduction
2. The experiment
3. The results:
   - I_2 etching
   - Annealing
   - Dry etching

Etching broad and narrow waveguides



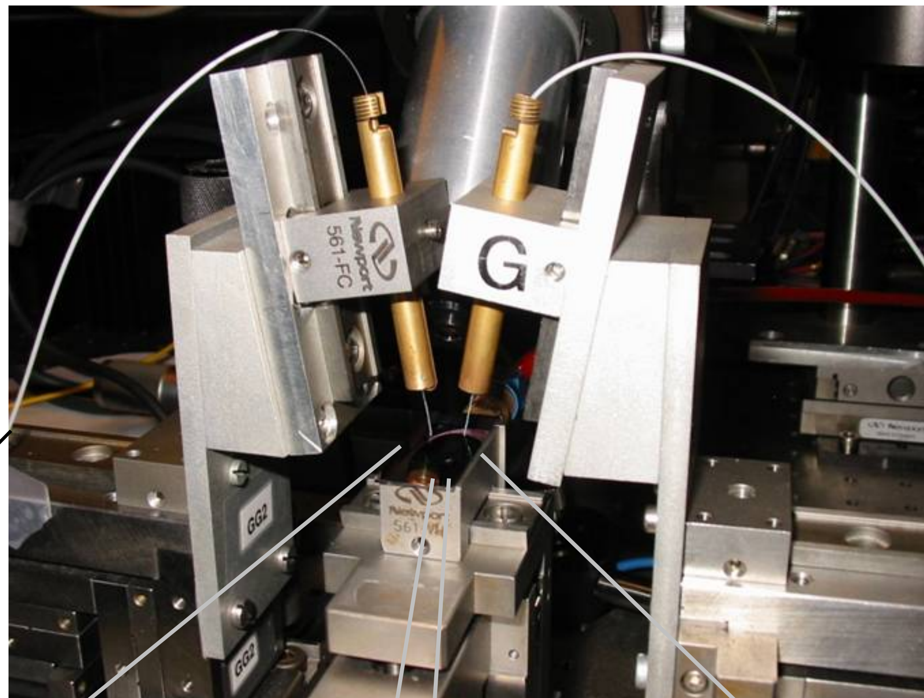


Dose:	5×10^{15}	1×10^{16} and	1×10^{17} Ga/cm^2
Etch depth:	0 nm	0 nm	80 nm

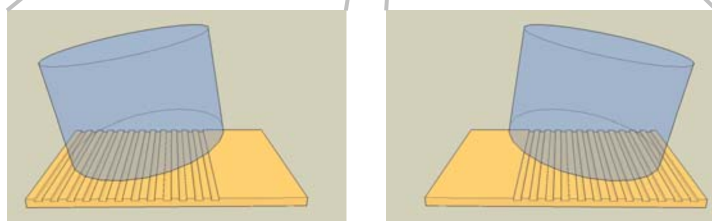
Measurement setup

S-LED

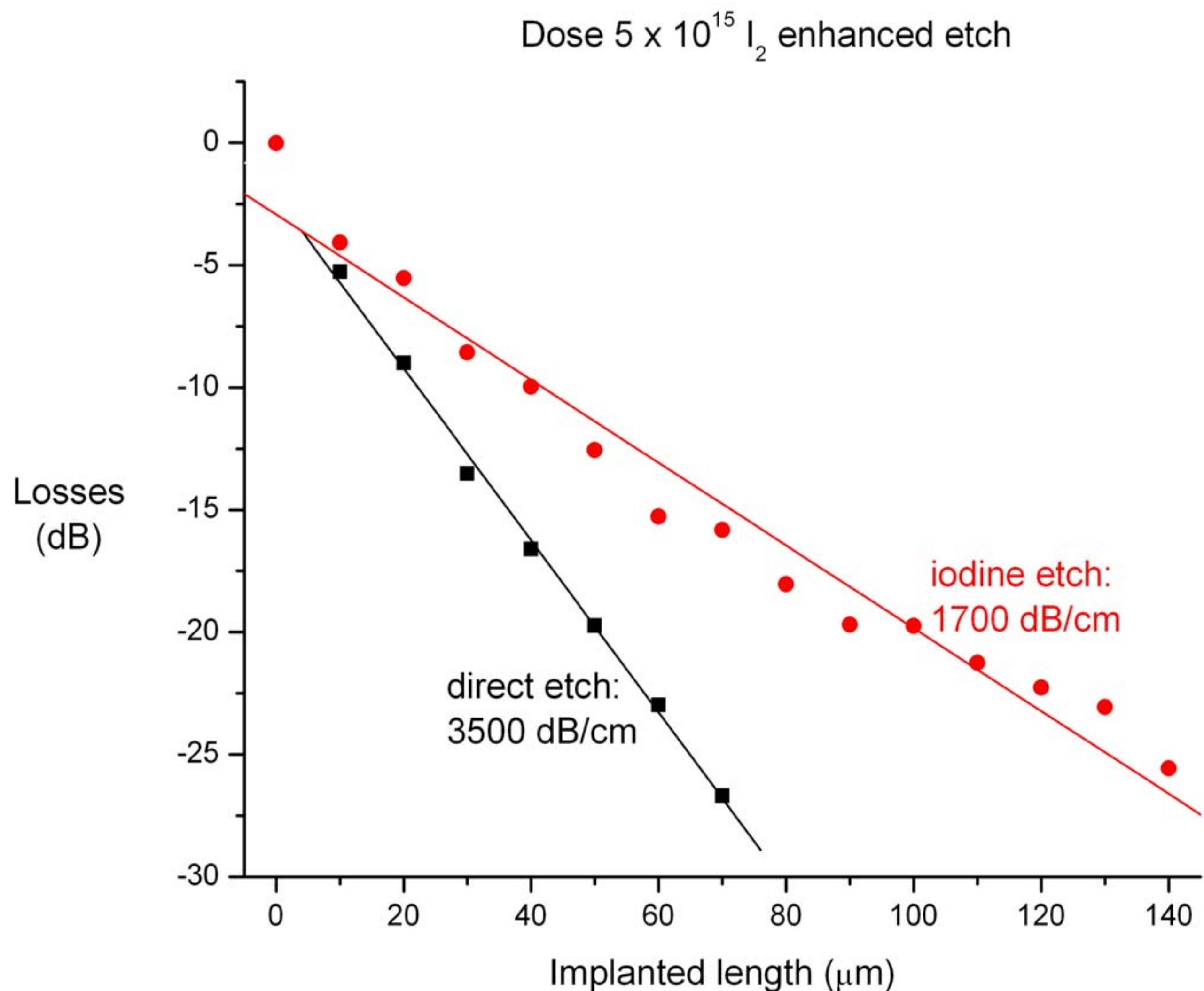
Pol control



Spectrum analyser

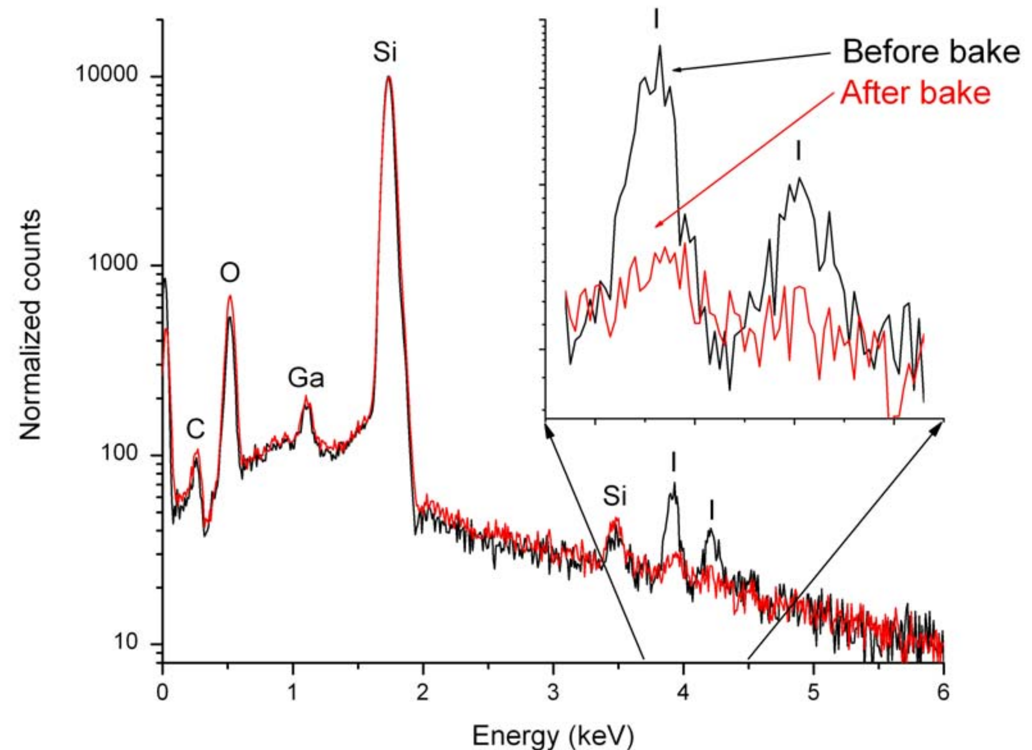


Iodine reduces losses



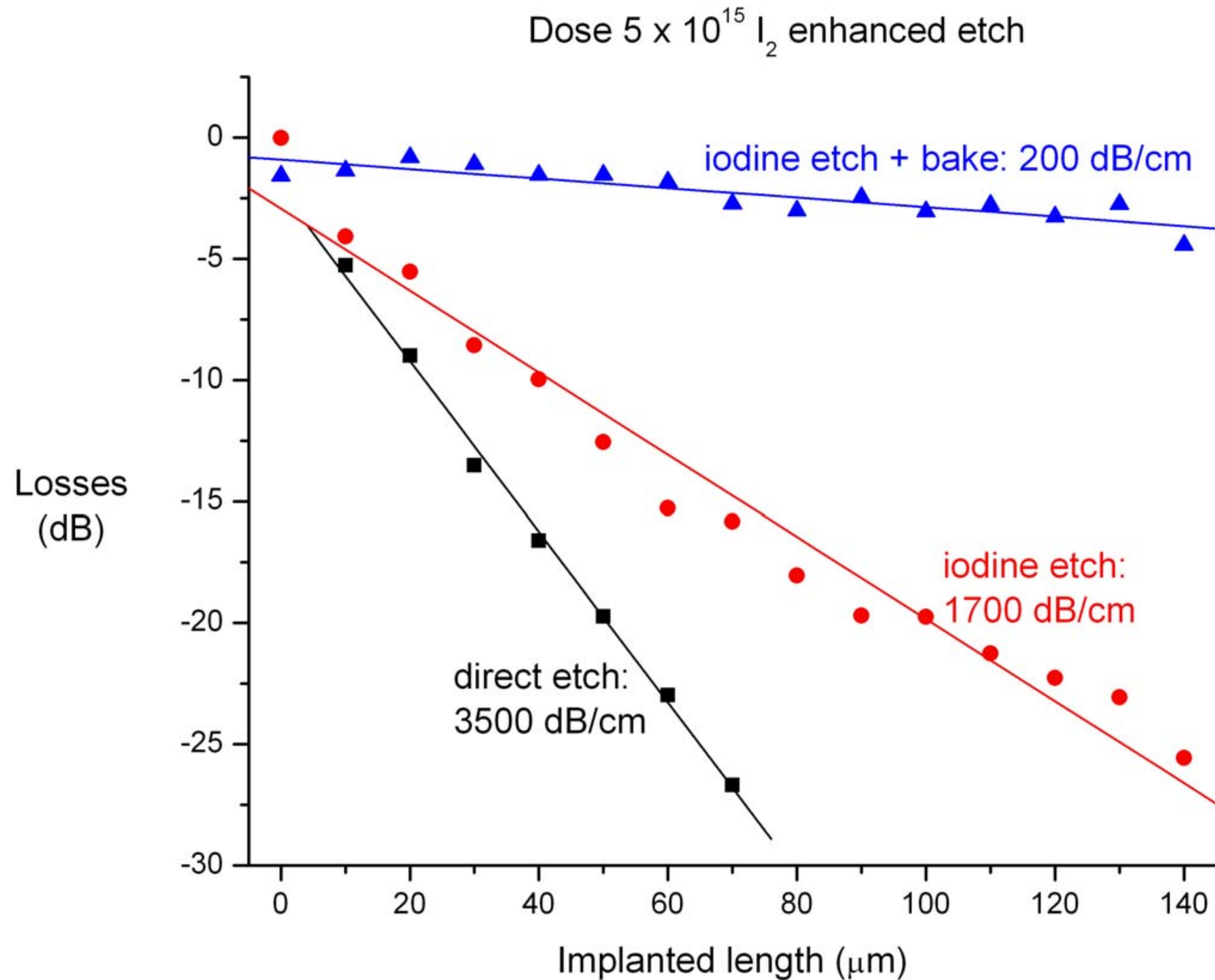
BUT iodine sticks and must be baked out

- Iodine desorbs by baking 2 hours in N_2 at 300°C
- Energy Dispersive X-ray spectroscopy (EDX) supports this



Confirmed by X-ray Photo-electron Spectroscopy (XPS)!!

Iodine desorption reduces the losses



Annealing: what do we expect?

FROM SEMICONDUCTOR WORLD:

2h @ 500-600ºC:

- Recrystallization of the amorphized region (Solid Phase Epitaxy)
  - Might reduce losses
- Electrical activation of gallium
  - Increases losses

2h @ 800-1000ºC:

- Diffusion of Ga in Si over > 100 nm
- Diffusion of Ga in SiO_2 over > 1000 nm

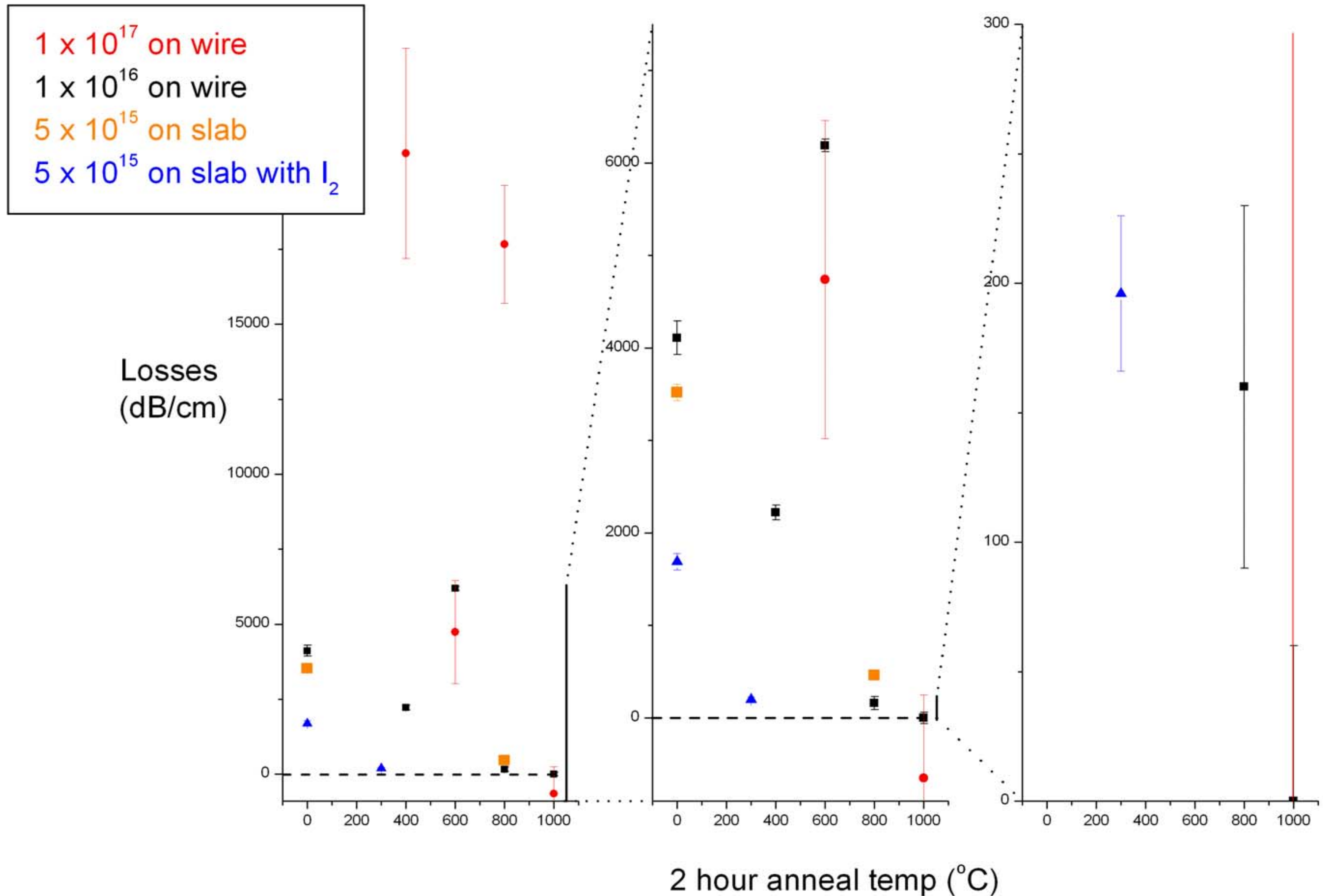
BUT: Semiconductor world??

5×10^{15} Ga/cm^2 ~ peak concentration of 3.5 at% Ga in Si

1×10^{17} Ga/cm^2 ~ peak concentration of > 20 at%

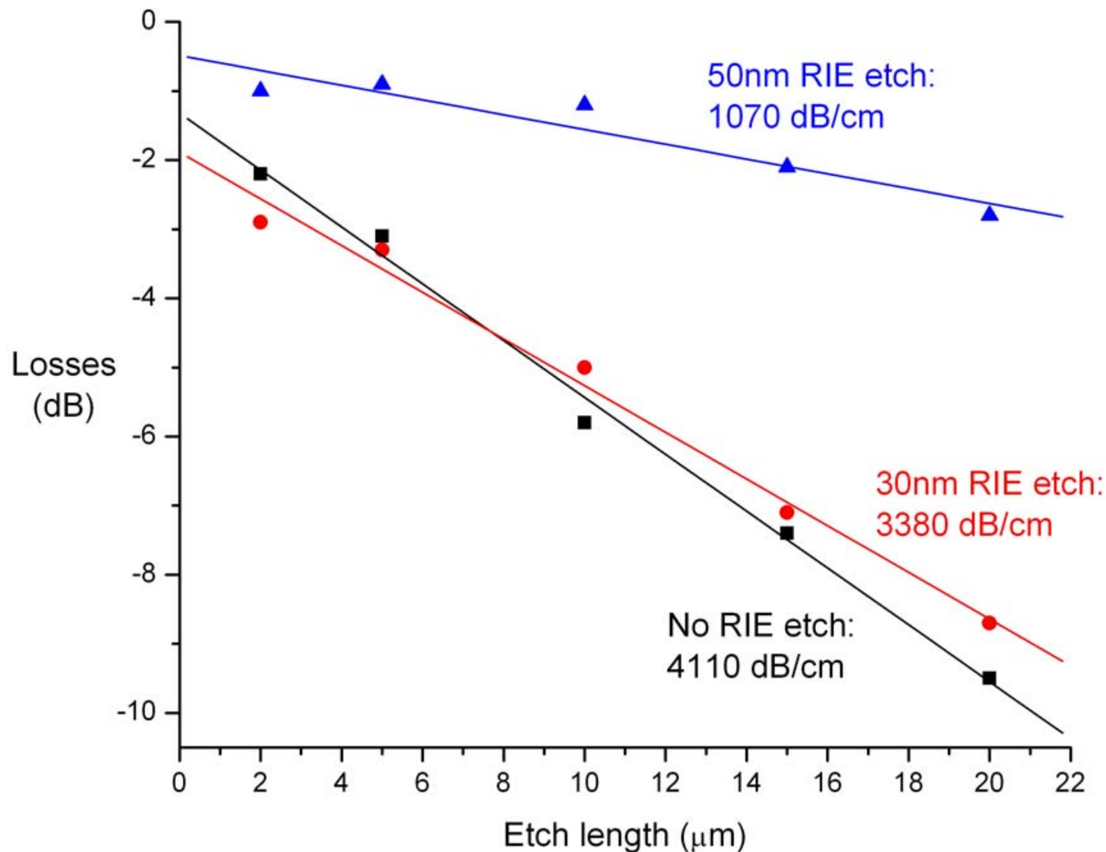
= Very High !!

Annealing reduces the losses



Reactive ion etch removes damaged layer

- Ga is implanted shallowly into Si (<70 nm)
- This shallow layer is removed by dry etching in CHF_3/O_2 plasma



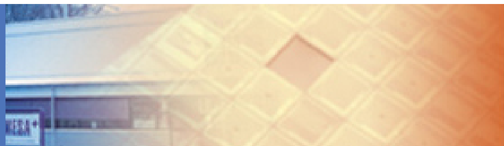
Conclusions

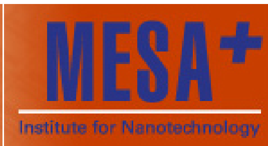
JRA FIB for Photonics: Loss reduction of FIB etched silicon by annealing

- The experiment
- The results:
  - I_2 etching: 200 dB/cm @ 300ºC
  - Annealing: 75 dB/cm @ 1000ºC
  - Dry etching: 1000 dB/cm

imec
aspire invent achieve

IOMS

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Confirmed by SIMS