Fabrication and measurements of NIS junctions to characterize plasma etching

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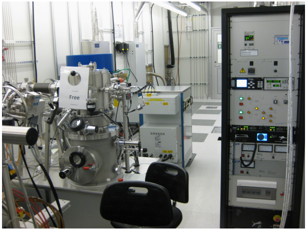
Outline

Introduction

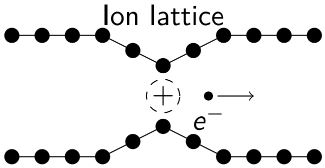
The PICO Group : Heat transport at low temperature, single-electron counting, redefining the ampere.
Context : Evaporator nicknamed LISA and plasma etching



Picture of the evaporator LISA

Superconductivity

- Superconductivity
- Cooper pairs

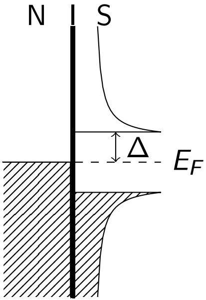


Schematics explaining the cooper pairing

Density of states

- Density of states and NIS junction

$$N(E) = \begin{cases} N_0 \dfrac{E}{\sqrt{E^2 - \Delta^2}} & \text{if } |E| > \Delta \\ 0 & \text{if } |E| < \Delta \end{cases}$$

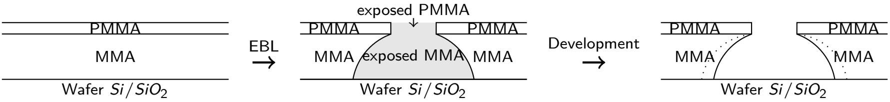


Density of states for a junction

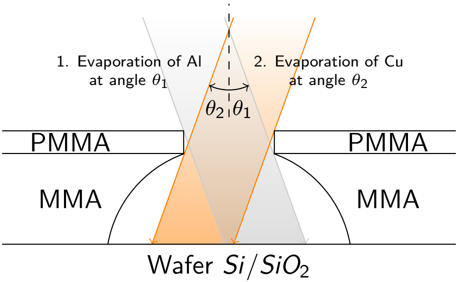
- Dynes density of states : leakage current

Cleanroom Process

Cross section of the wafer during its preparation

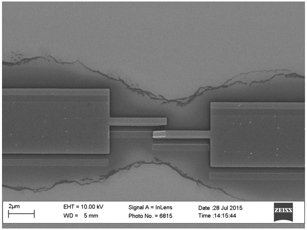


Cross-section during of an evaporation

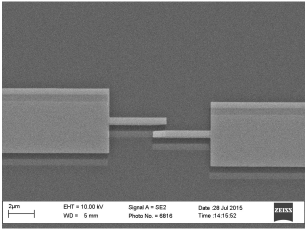


Cleanroom Process

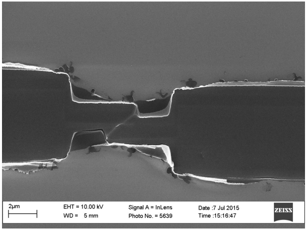
- O_2 valve : Oxidation
- Plasma Gun (with Ar valve) :
  - Low power : Resist weakening → Easier Lift-off
  - High Power : Plasma Etching → Etch materials



Normal mode



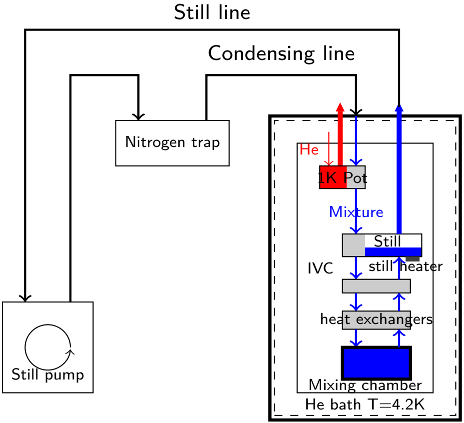
Secondary electron mode



Failed sample

SEM images of some samples

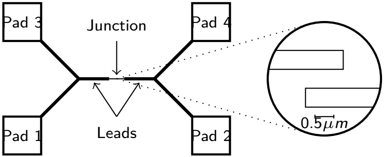
Dilution cryostat



Schematics representing the functioning of a dilution cryostat. In red ^{4}He, in blue ^{3}He/^{4}He mixture and in grey, heat exchangers.

Settings

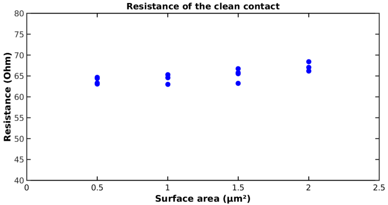
- 4 Pads pattern



Drawings of the pattern used

- 4x5 matrix with 4 Surface areas : 0.5 to 2 by 0.5μm^2 and 5 EBL dose from 2000 to 3000 by 250 $c/\mu m^2$
- Development 20s MIBK, 20s Methyglycol, IPA
- Evaporation : Al 20nm, Cu 25nm
- Optionnal : Strong Oxidation (10min, 200mbar), and/or Plasma Etching, and/or Tunnel barrier Oxidation (2min, 2mbar)
- 4 probe measurements with a probestation
- Eventually : Low temperature measurements : I-V

Reference samples (Without Plasma Etching)

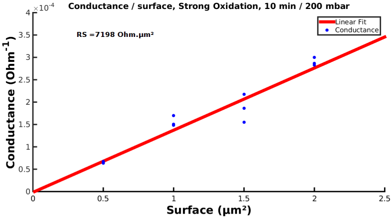


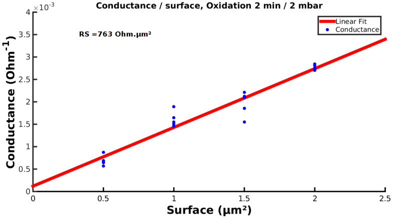
Clean Contact Al + Cu

$$R = \sum_{Cu,Al} \frac{\rho l}{S} \simeq 78\Omega$$

Strong Oxidation (10min/200mbar)

$$RS = 7198\Omega.\mu m^2$$





Tunnel junction (2min/2mbar)

$$RS = 763\Omega.\mu m^2$$

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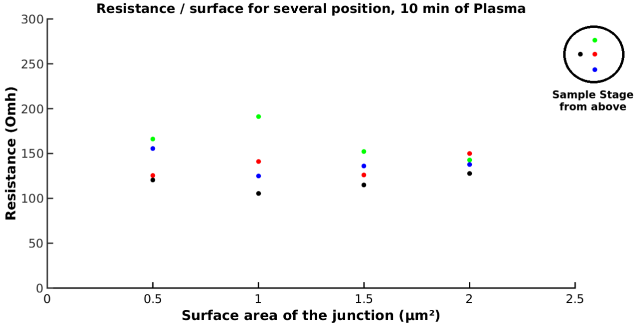
Position of the sample

- Samples with Strong Oxidation, Plasma etching 10 min, Clean contact, before the Oxygen Cleaning.



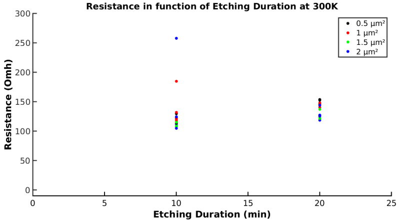
$\Rightarrow$ Plasma is homogeneous & 10min seem enough to etch the Oxide

No surface dependance, same order of magnitude as clean contact.

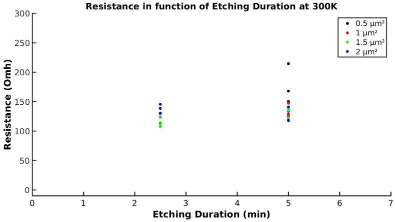
Duration of the Plasma Etching

- Samples with Strong Oxidation, Plasma etching, Clean contact.

- Before the Oxygen Cleaning



- After the Oxygen Cleaning

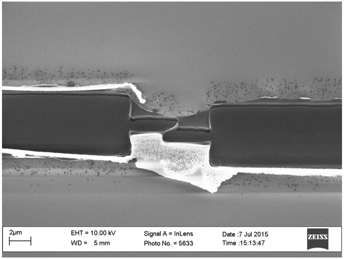


$\Longrightarrow$ Similar results for totally different parameters before and after the cleaning. Before $\longrightarrow$ 10 min of Plasma was a good time. After the cleaning $\longrightarrow$ less than 5 min is enough & 10 min is too much.

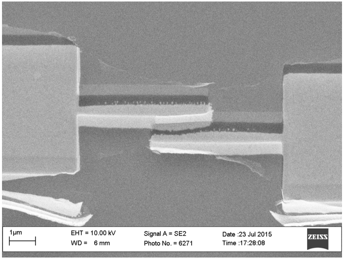
Plasma Problems

- Samples with Strong Oxidation, Plasma Etching 10 min , Tunnel barrier.

- Before Oxygen Cleaning



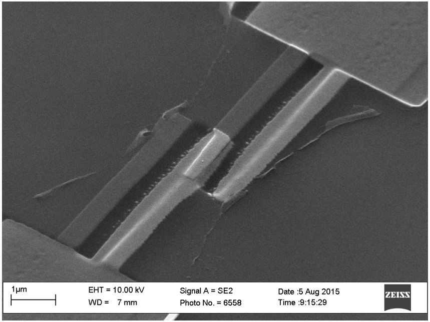
- After Oxygen Cleaning

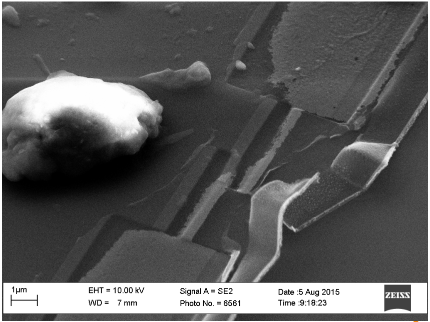


$\Longrightarrow$ Exact same parameters, before the cleaning : resist burned, after the cleaning : unidentified areas.

Wafer Etching

- Sample with Strong Oxidation, Plasma Etching 10 min, Tunnel barrier, after Oxygen Cleaning.

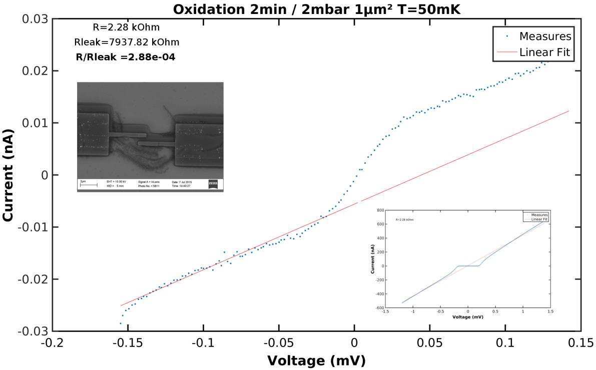




SEM images with a tilted angle : The darkest area is a hole in the wafer.

Tunnel barrier before Oxygen Cleaning

- Sample with Tunnel barrier (NIS) without Plasma

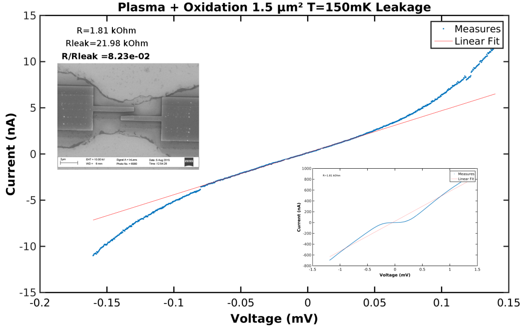


Current in function of bias voltage applied

- Leakage $\simeq 10^{-4} \rightarrow$ Correct junction

Tunnel barrier with Plasma Etching

- Sample with Strong Oxidation, Plasma Etching 2min30s, Tunnel barrier, after the Oxygen Cleaning.

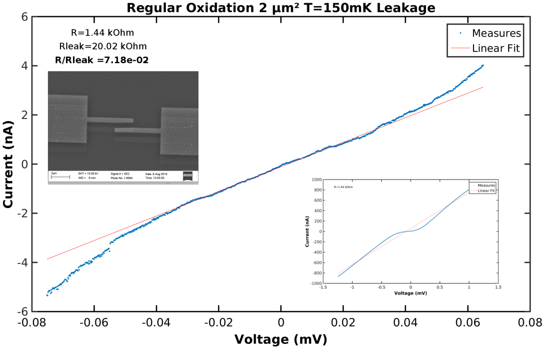


Current in function of bias voltage

- Leakage $\simeq 10^{-2}$ The leakage is quite bad but...

Tunnel barrier reference for previous sample

- Sample with Tunnel barrier, after the Oxygen cleaning.



Current in function of bias voltage

- Leakage $\simeq 10^{-2} \rightarrow$ Same order of magnitude for plasma etched sample and reference : something else wrong with the LISA

Summary

- Studied bibliography to understand important points of theory
- Learned and getting used to use cleanroom tools
- Set up an experimental protocol
- Learned to cool down and warm up a dilution cryostat
- Made measurements at room and low temperature
- Exploited and interpreted the results

Thank you for your attention !

If you have any questions please ask.