TÉCNICO LISBOA

Funcionalization of Si by ion-implantation:

Influence on the tribomechanical and wettability properties at the micro and nano scales

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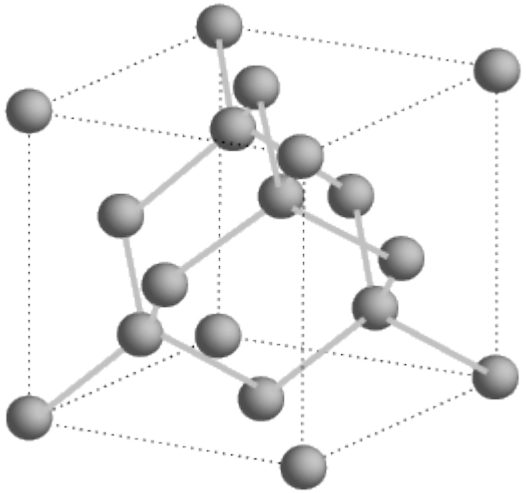
Encontro 2018 NanoLab/BioMat

Outline

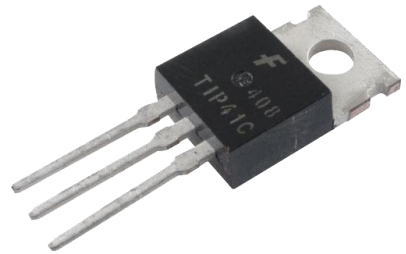
- Introduction
  - Motivation/objective
- Experimental Conditions
- Resultas & discussion
- Conclusions

Introduction

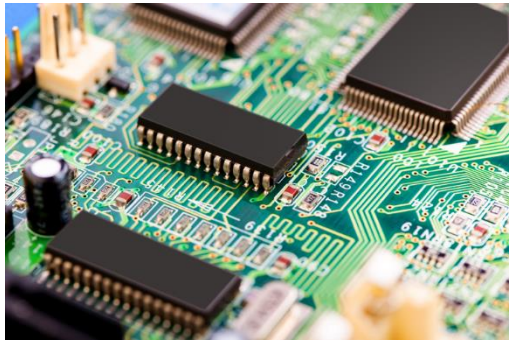
Why Silicon???



Transistor – electronic revolution in th 60´s



2D electronics – IC´s

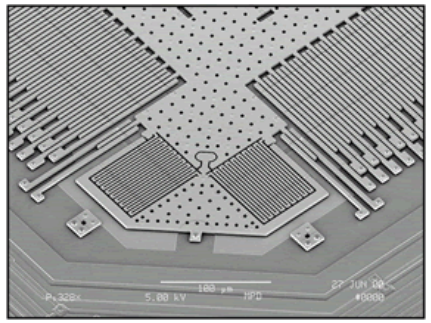


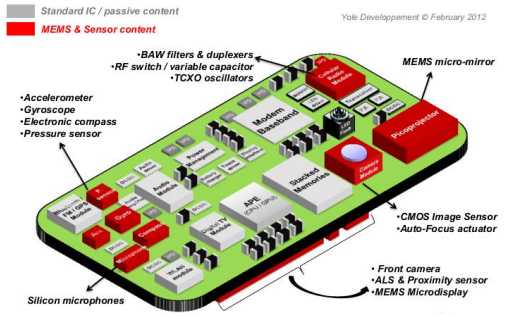
3D devices – MEMS

Introduction

Microelectromechanical System (MEMS)

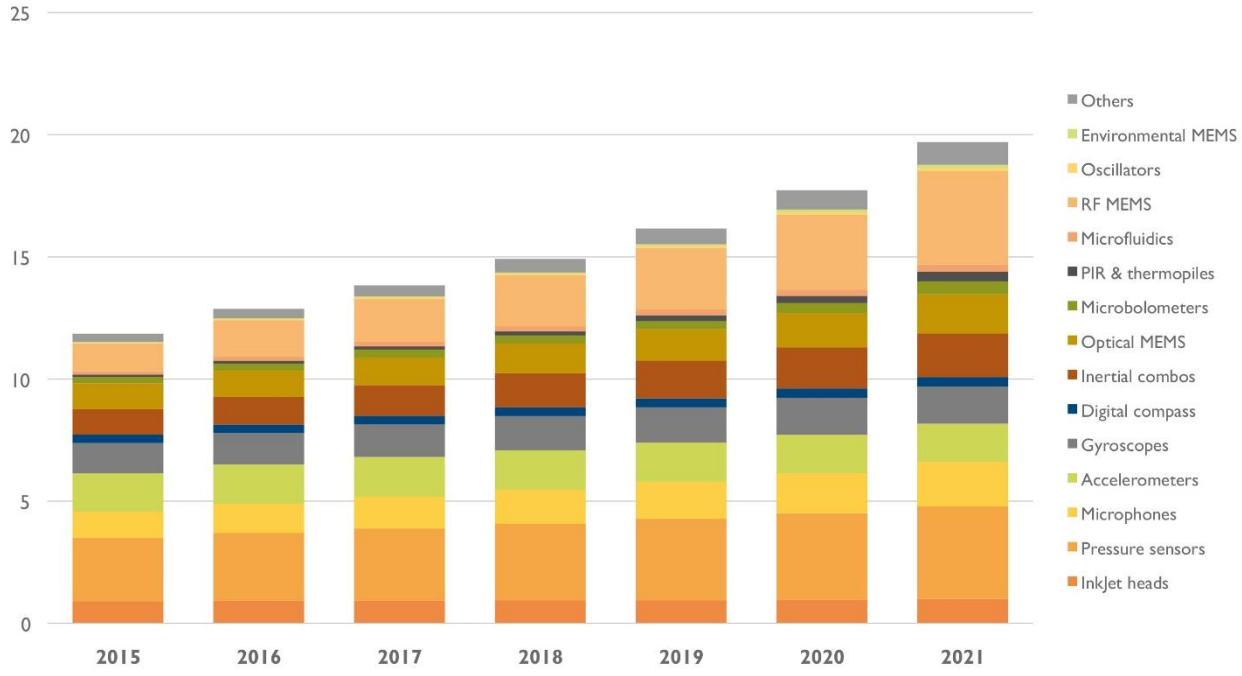
- Devices with a 100 nm < L < 1 mm.
- Produced using IC´s technologies.





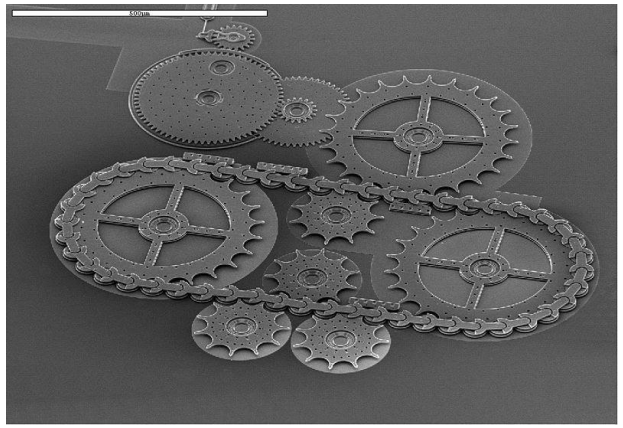
2015-2021 MEMS market forecast in US$B

(Source: Status of the MEMS Industry report, Yole Développement, May 2016)



Objective

- Commercial MEMS do not have rubbing and impacting surfaces



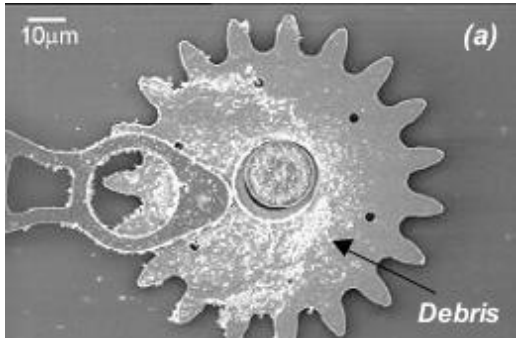
Sandia Lab.

Small dimensions $\frac{A}{V} \uparrow$
Scale effects

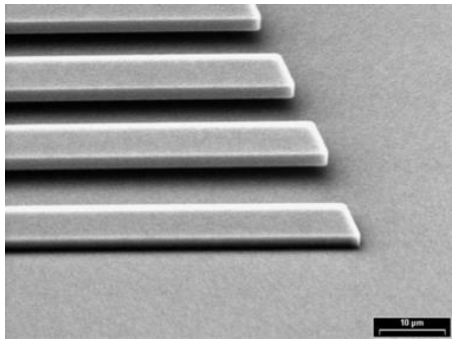
Van der Waals
Capillarity
Surface tension

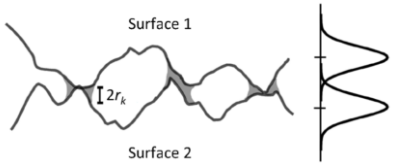
Gravitational /Operating forces

Failure mechanisms: **stiction** and **high friction** resulting in **high wear**



Tanner *et al*. 2002





Si has **poor tribological /mechanical properties**

Enhance the tribomechanical and wettability properties of Si using Ion-implantation.

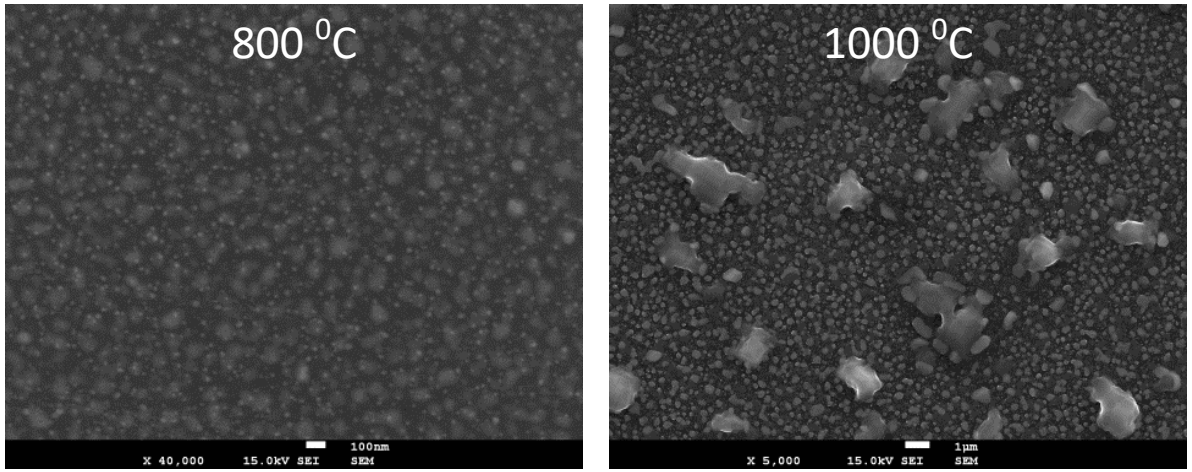
Experimental Conditions

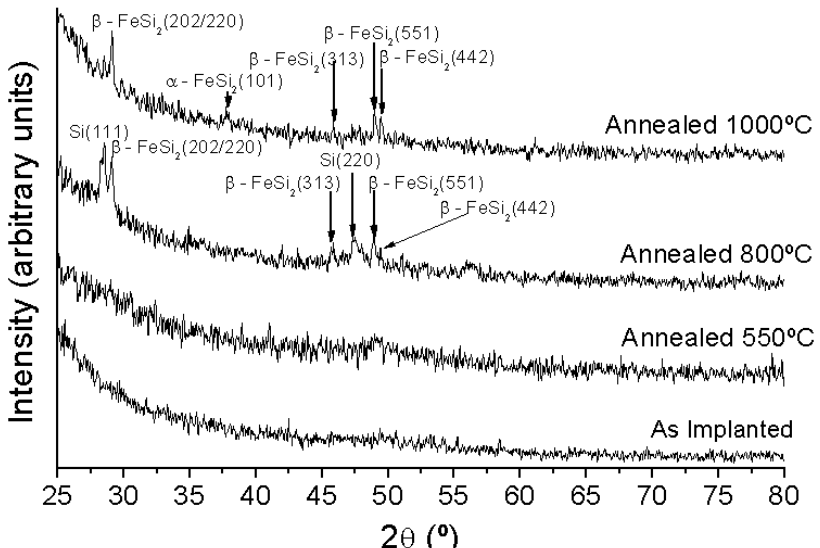
Type	Element (Energy kev)	Fluence (cm^{-2})	Conditions	Annealings (^{0} C)
Single	Fe (150) C (25)	(**low**) $5x10^{15}$ (**medium**) $5x10^{16}$ (**high**) $2x10^{17}$	Room temperature & normal incidence	550 800 1000
Dual	Fe (170) + C (50) Ti (160) + C (50)	(**low**) $5x10^{16}$ + $5x10^{16}$ (**high**) $2x10^{17}$ + $2x10^{17}$		800 1000

Characterization Techniques
FEG-SEM/AFM
GIRXD ($\theta = 1.5^0$)
RBS/XPS
Wettability
Ultramicro hardness
AFM-based Nanowear

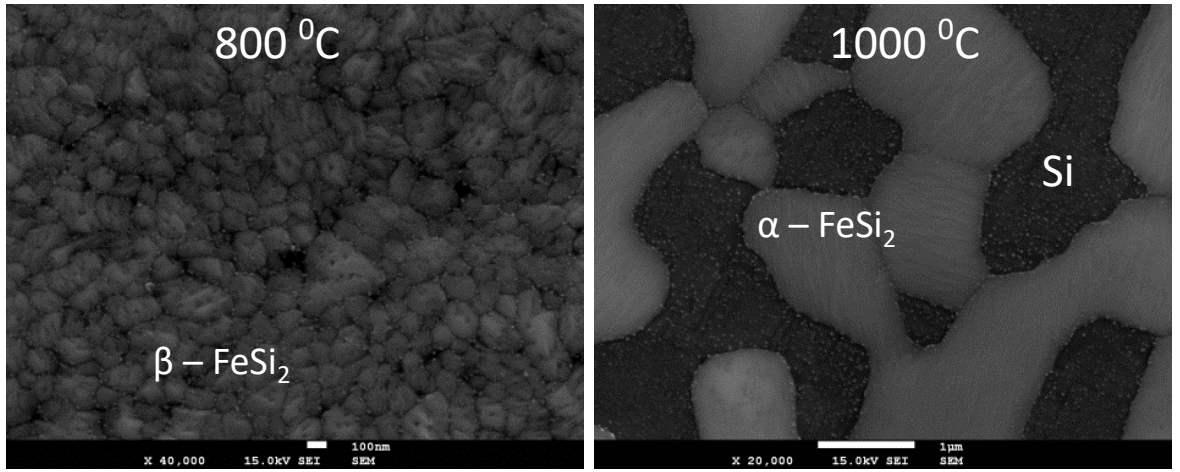
Results & Discussion – Fe^{+} Implantation

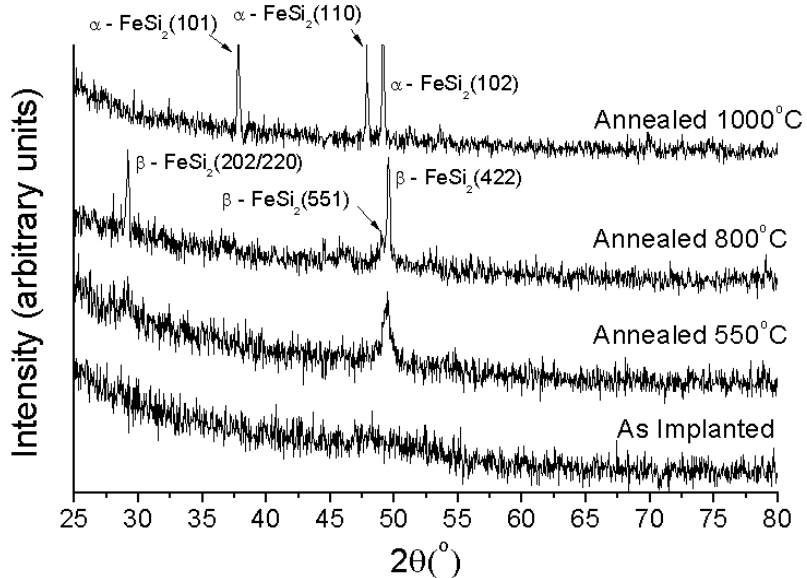
Medium Fluence Φ=5x10^{16} cm^{-2}





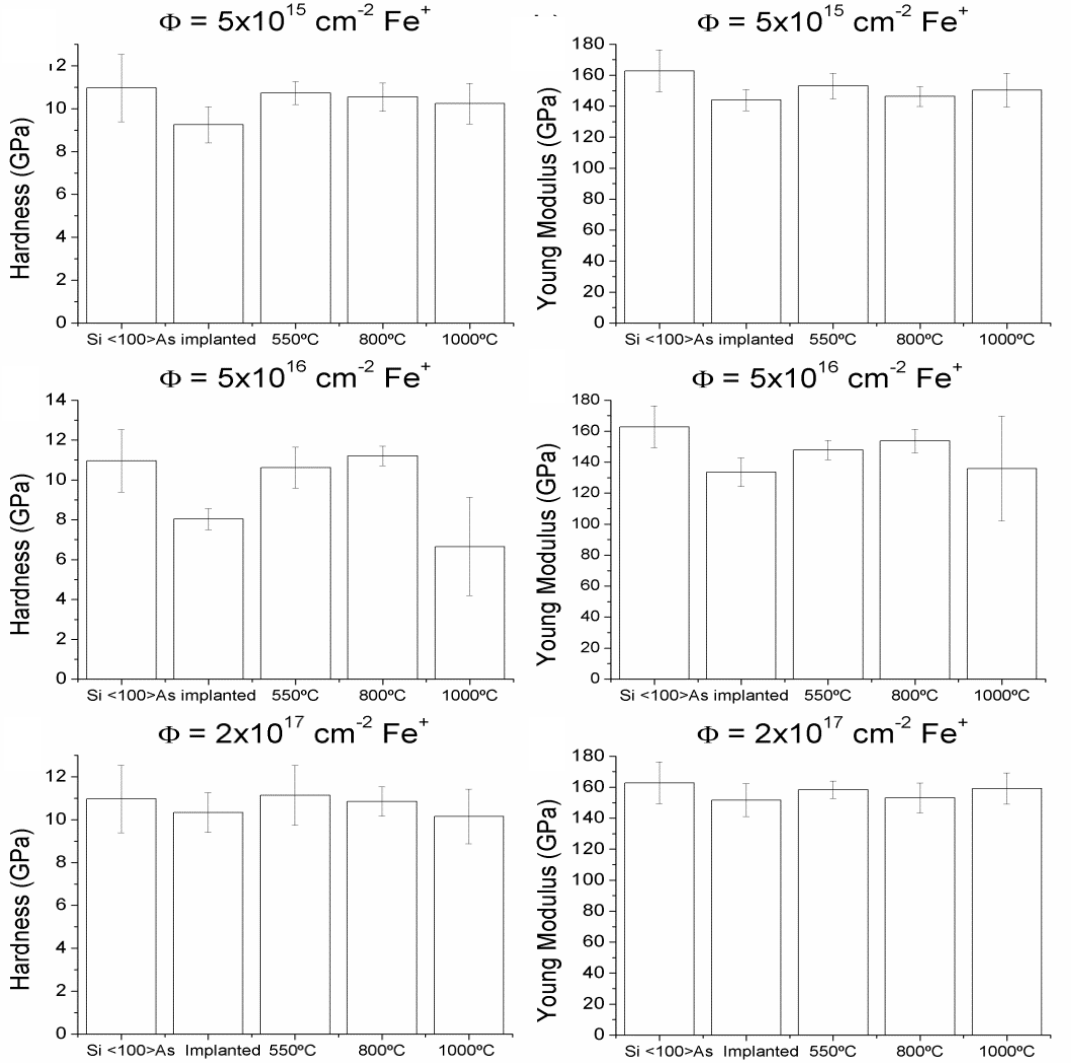
High Fluence Φ=2x10^{17} cm^{-2}



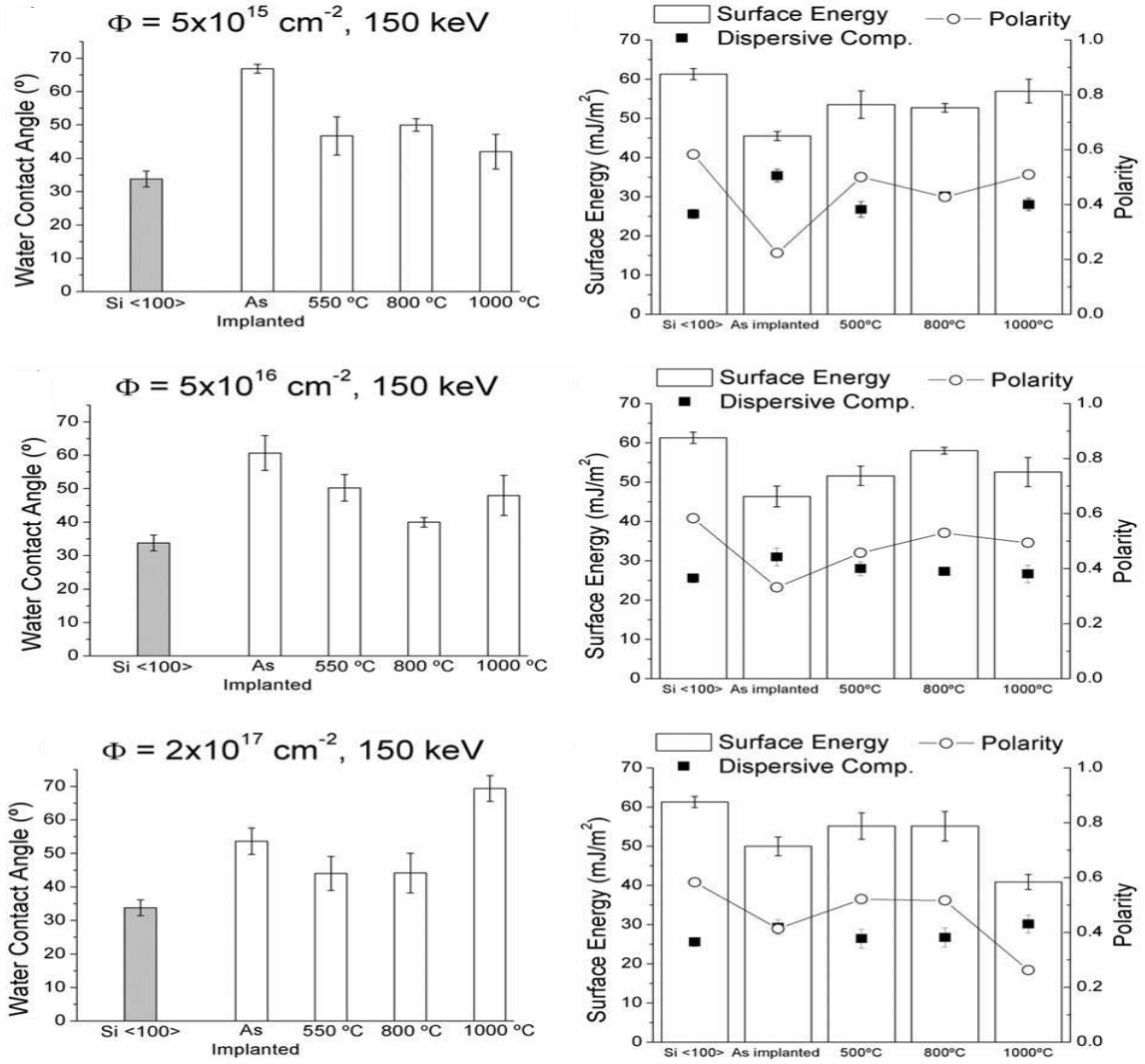


Results & Discussion – Fe^+ Implantation

Ultramicrohardness (5 mN)

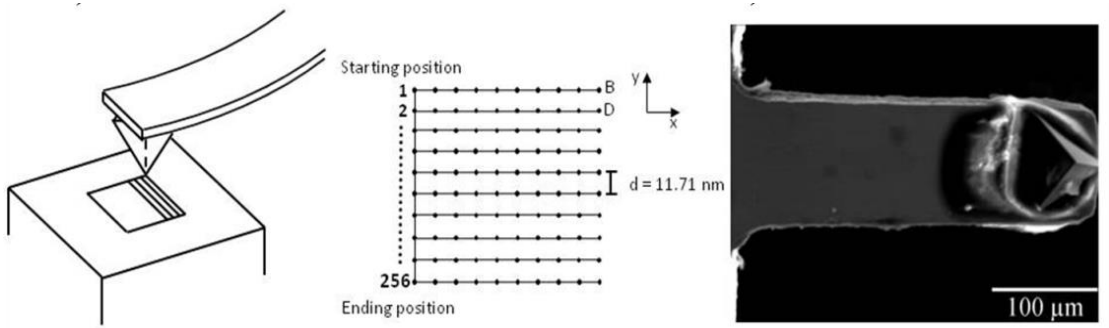


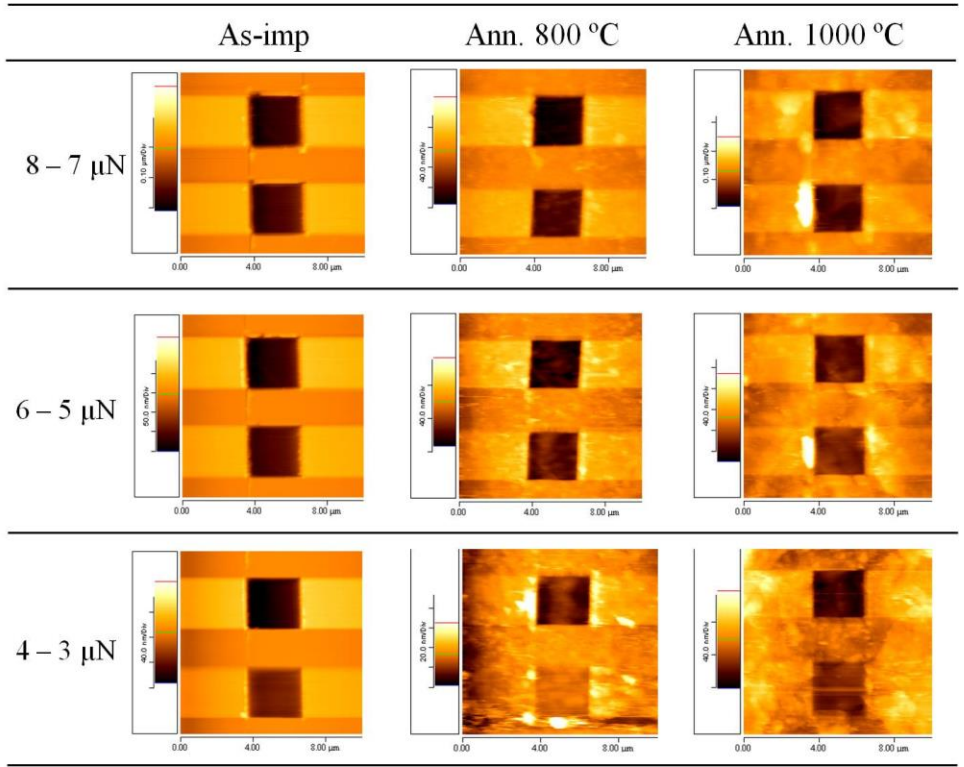
Contact angle and Surf. Energy

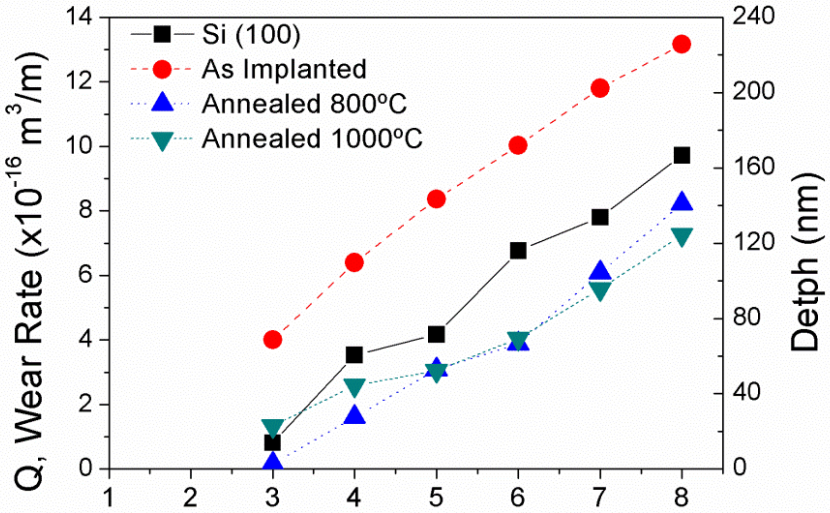


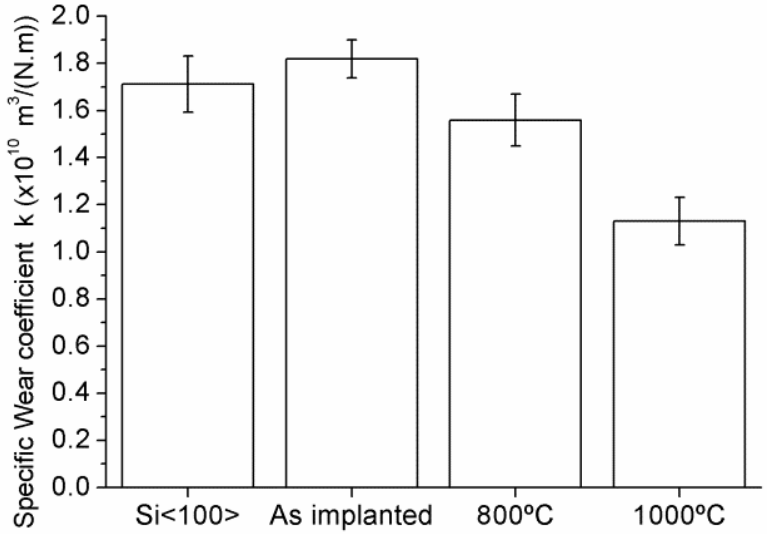
Results & Discussion – Fe^{+} Implantation

AFM-based Nanowear



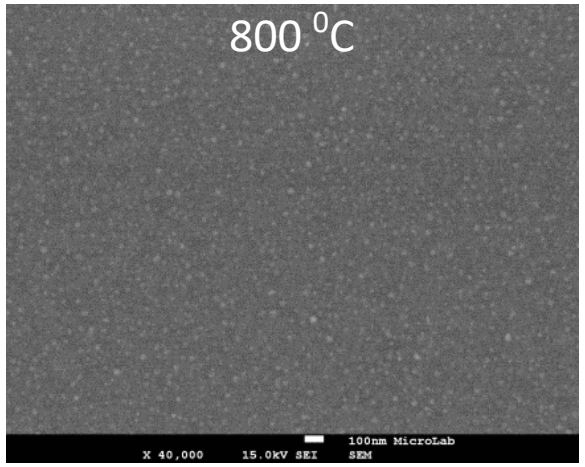


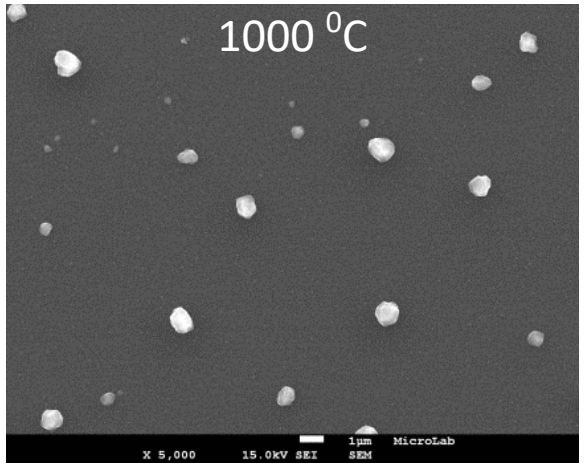


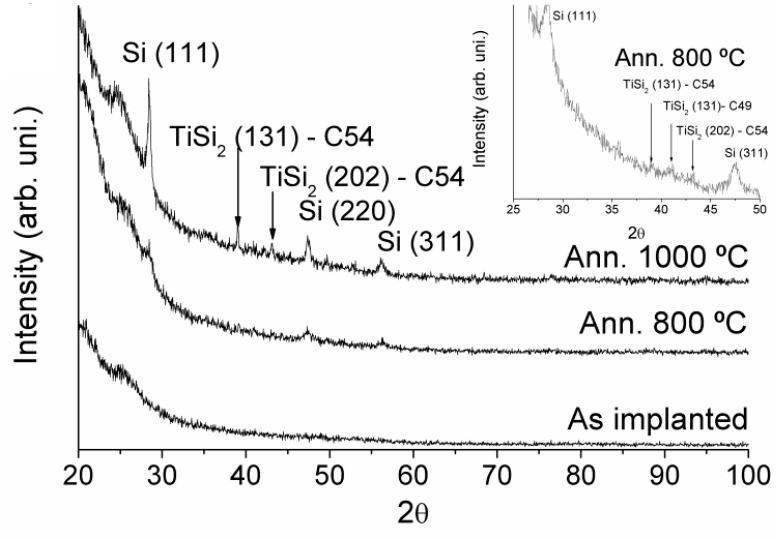


Results & Discussion – $Ti^+ + C^+$ Implantation

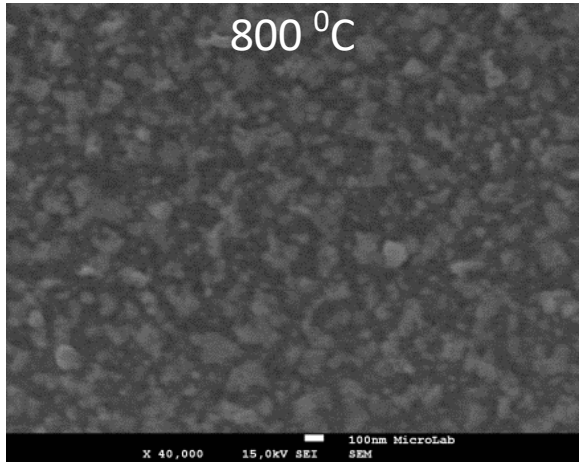
Medium Fluence Φ=5x10^{16} cm^{-2}

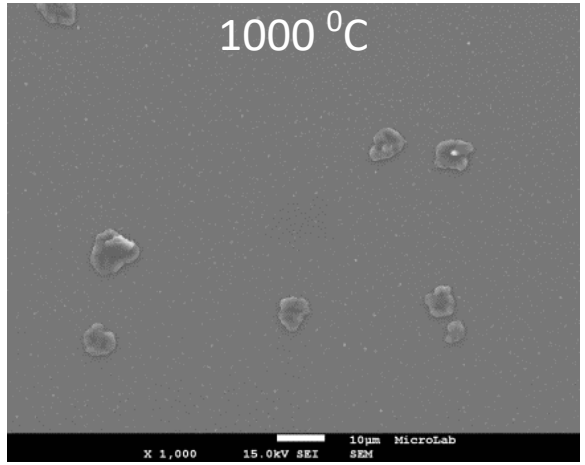


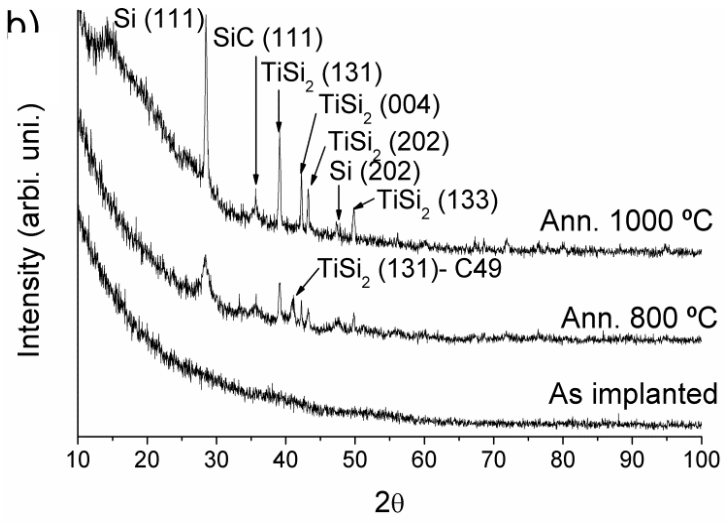




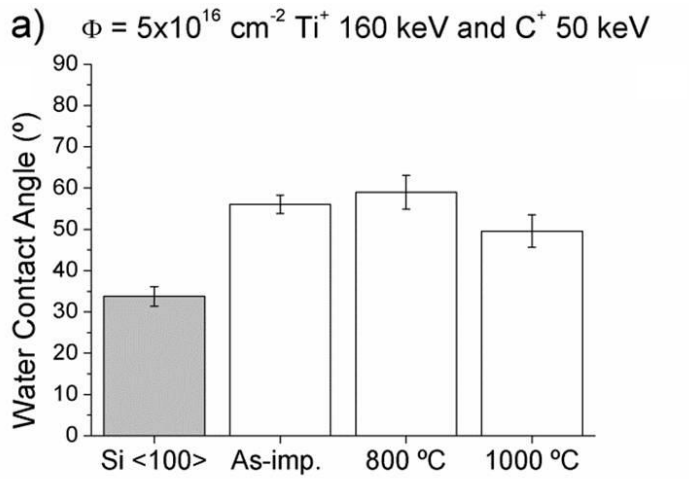
High Fluence Φ=2x10^{17} cm^{-2}

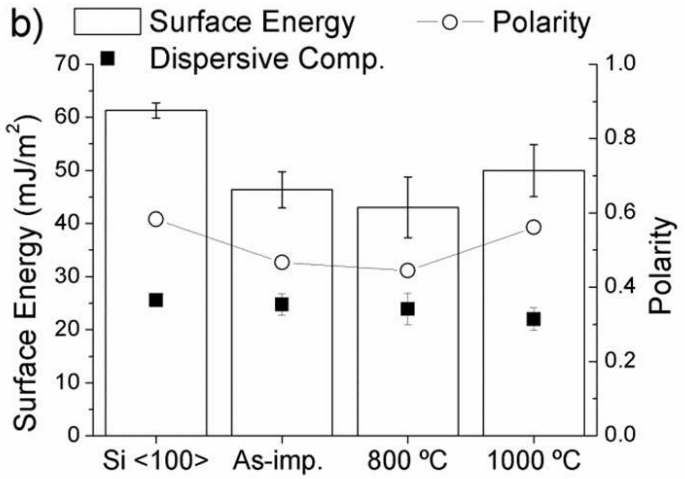


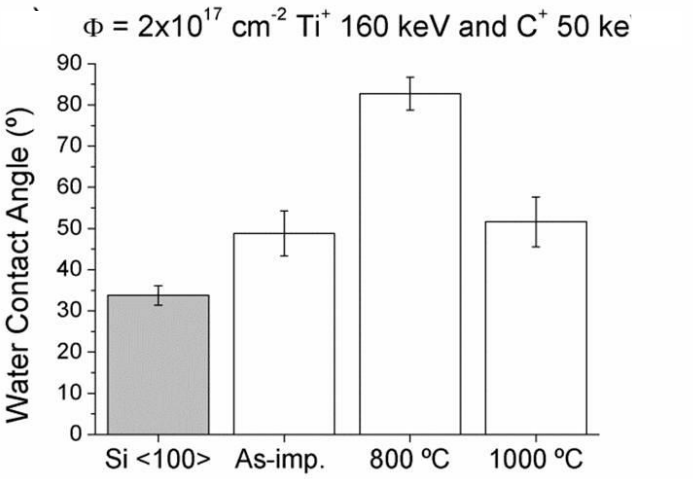


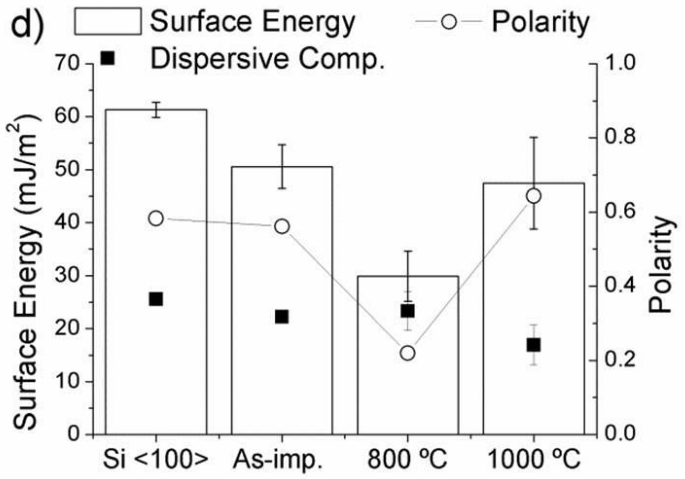


Results & Discussion – $Ti^+ + C^+$ Implantation









Low fluence

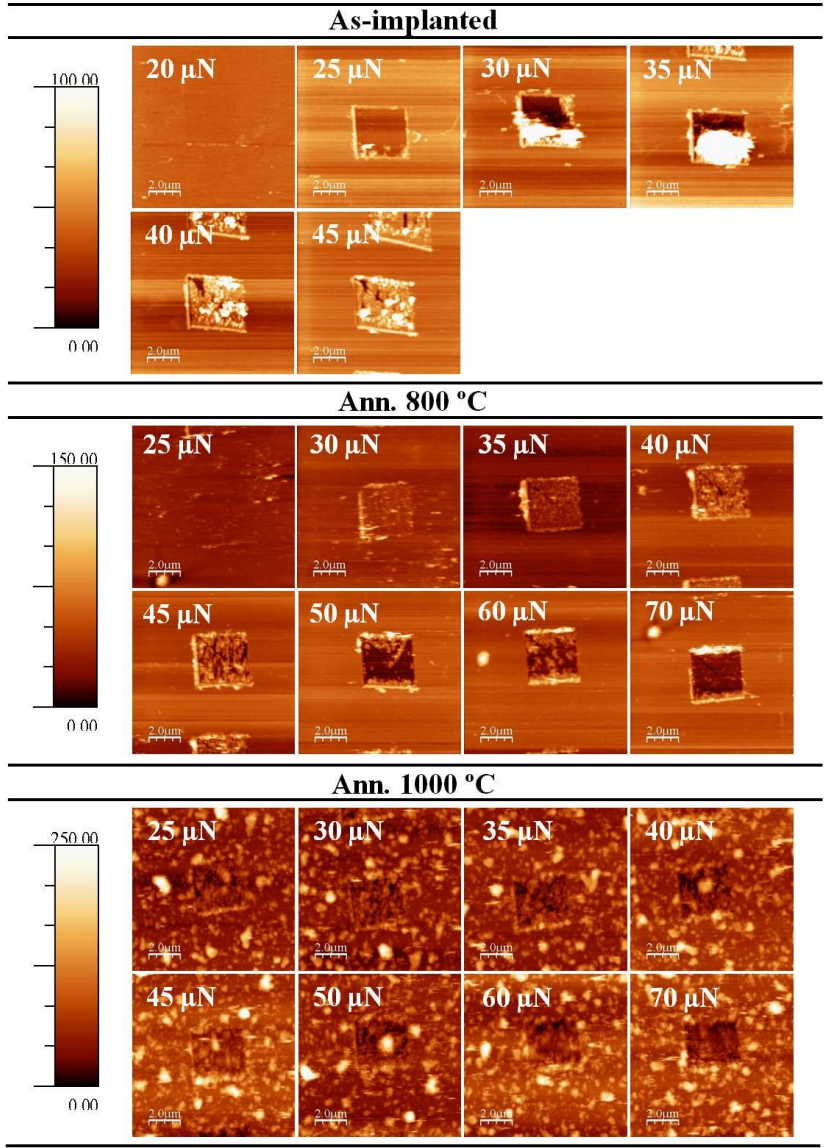
Identical values of θ even after the annealings

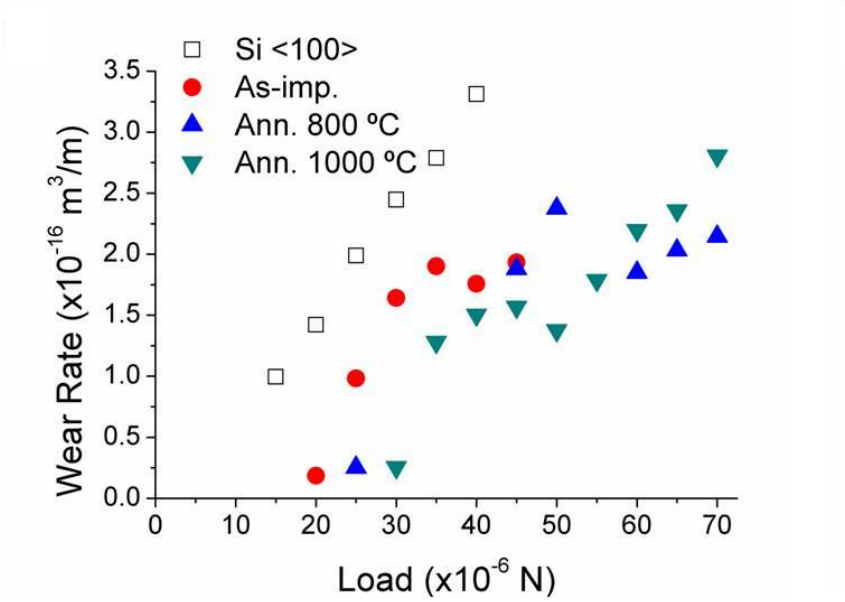
high fluence

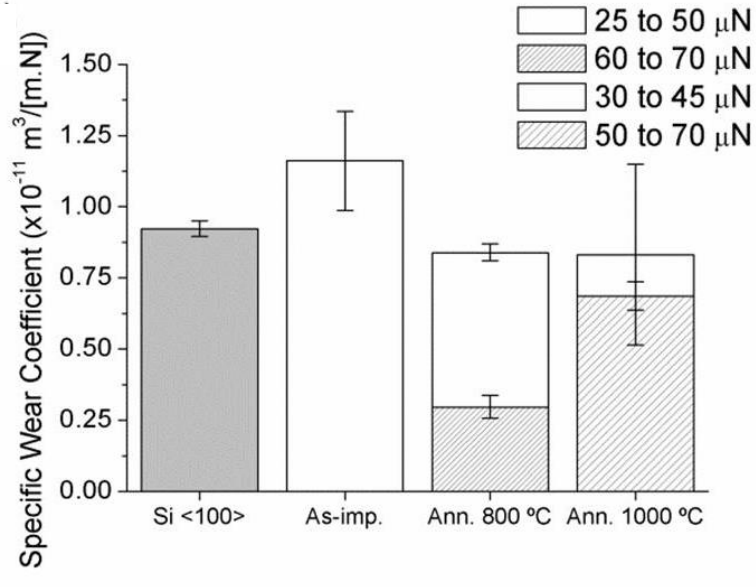
The implanted and annealed samples present > θ.

The 800 ^{0}C sample presented the higher contact angle.

Results & Discussion – Ti+ + C+ Implantation







Almost all the calculated Q´s are below the Si

The combination of $TiSi_2$ and SiC greatly improve the nanowear resistance.

The lowest **k** was calculated for the 800 ^{0}C for the higher loads

Conclusions

- Wettability and Nanowear properties of Si can be upgraded using ion-implantation.

- From all the studied systems
  - The dual systems performed better than the single ones.
  - The singe C+ revealed the poorest performance.
  - Low fluence Fe++ C+ at 800 0C presented an almost hydrophobic behavior.
  - The Ti++C+ system at 800 0C combine both high angle contact angle and low average specific wear coefficient.