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## Characteristics of He ion implanted layers on single-crystal diamond

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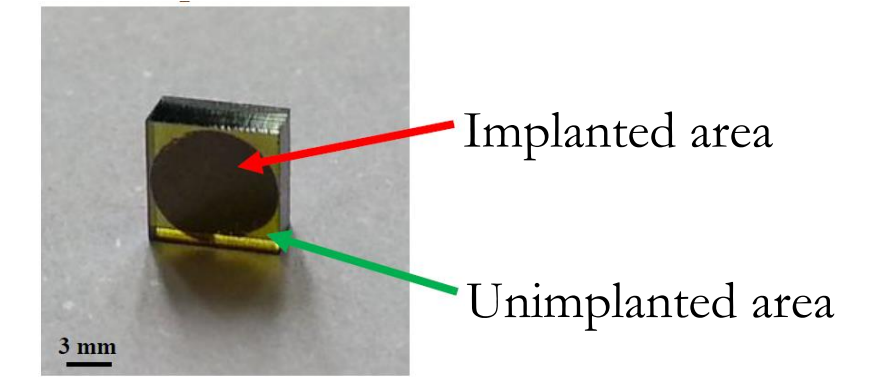
## Background and aim of the study

### Context:

- Heavy ion implantation used for contact fabrication [1]
- He ion implantation for N-V centers [2]

He ion implantation for the enhancement of ohmic contacts

- 1st result [3]:** ohmic contact fabricated on He ion-implanted boron-doped samples
- ohmicity improved
  - contact resistance decreased
  - ohmic contacts obtained even at a doping level of  $2.10^{17} \text{ cm}^{-3}$



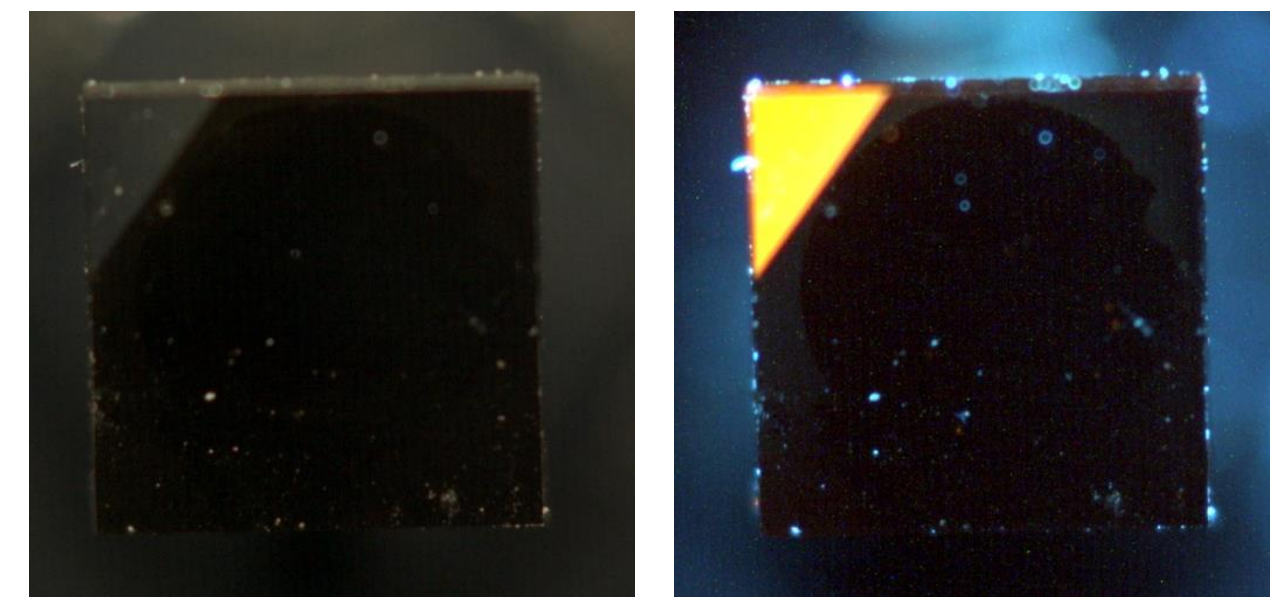
**Aim of the study:** characteristics of He ion-implanted single-crystal diamond.

## Ion implantation

**Experimental:** He ion implantation at various fluences (from  $4 \times 10^{13}$  to  $5.5 \times 10^{15}$  ions/cm<sup>2</sup>) with a home-made low-cost ion implanter.

One of the sample corners is masked during the implantation process.

Several annealing steps are performed after the implantation process.

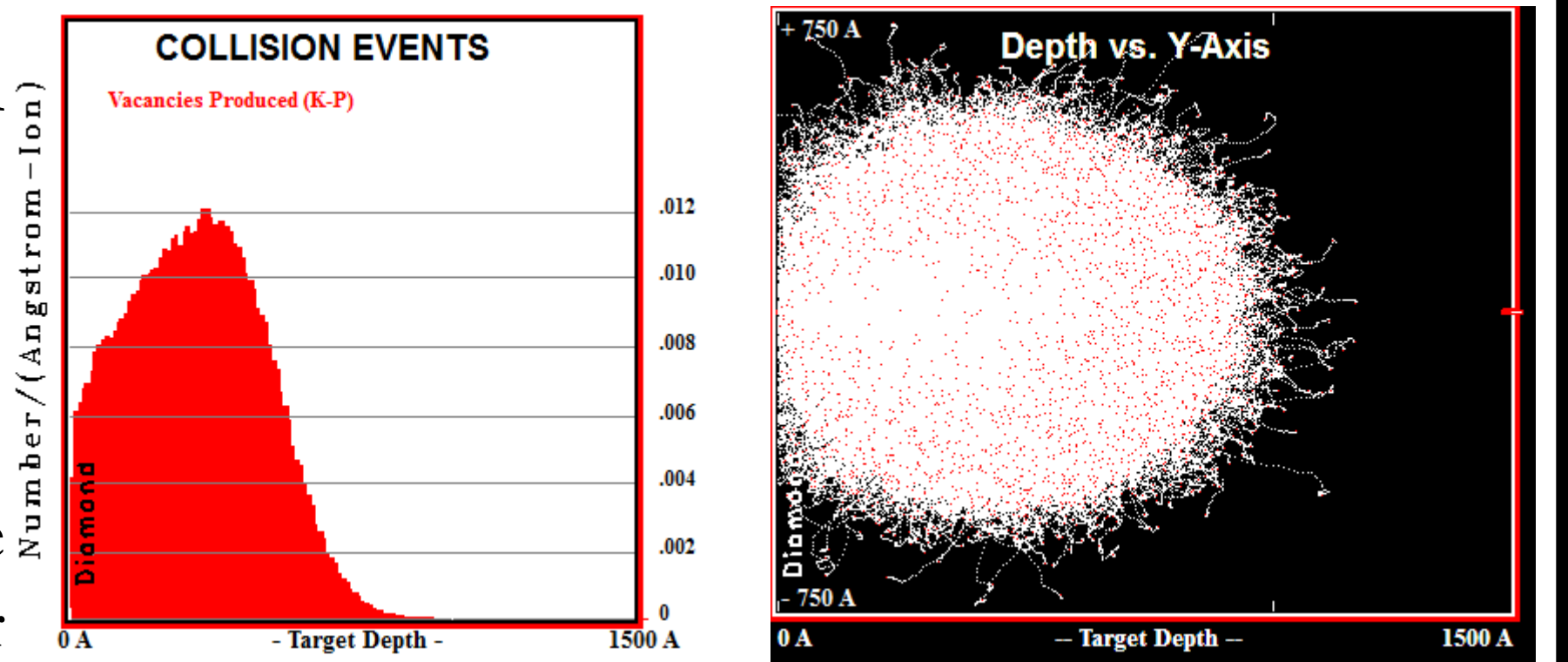


Diamond View images of an implanted sample.

**SRIM simulation of ion implantation:**

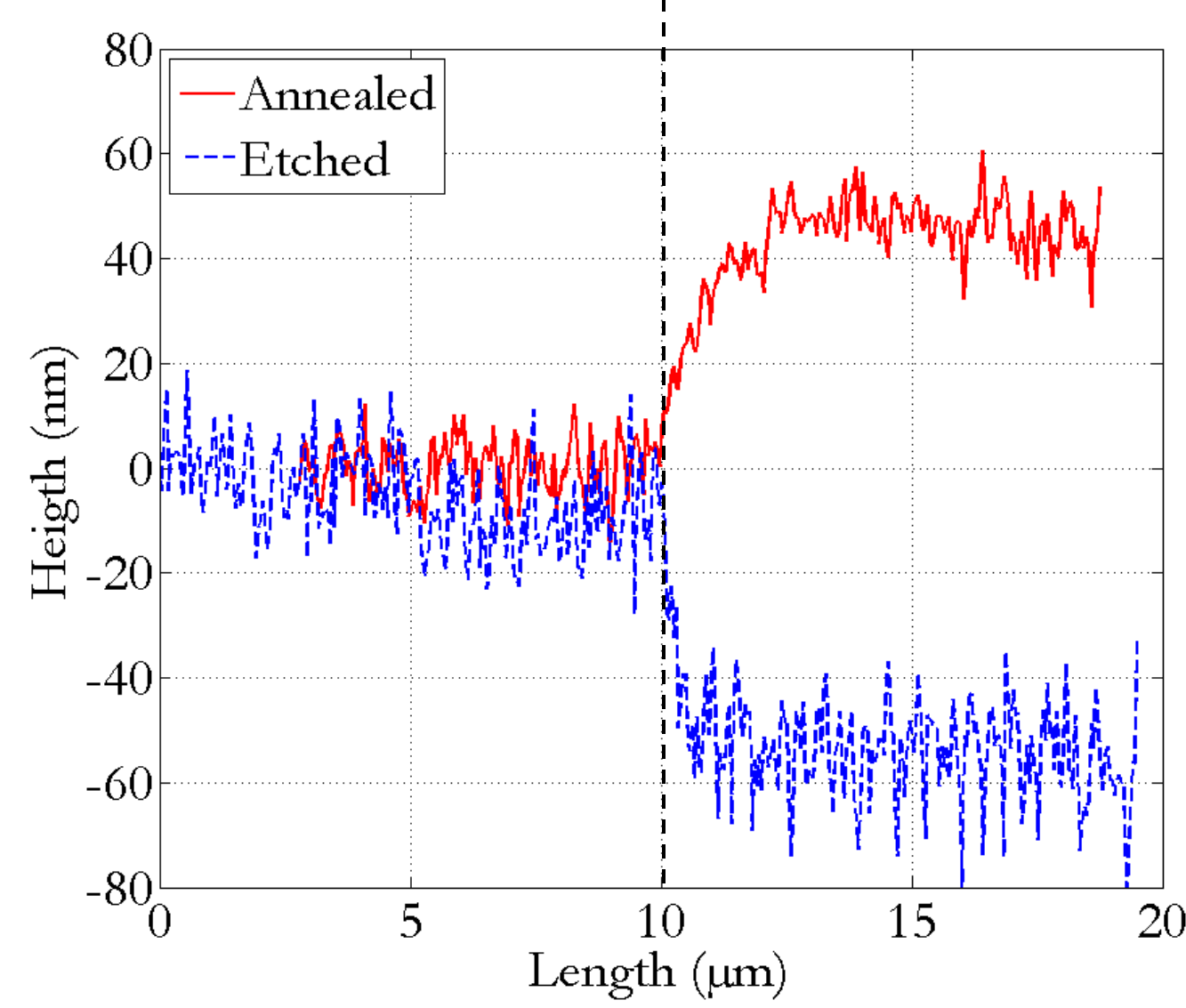
- 15 vacancies/ion
- 50 nm penetration depth

→ The density of vacancies is above the amorphisation threshold for considered fluences.



## Density profiling

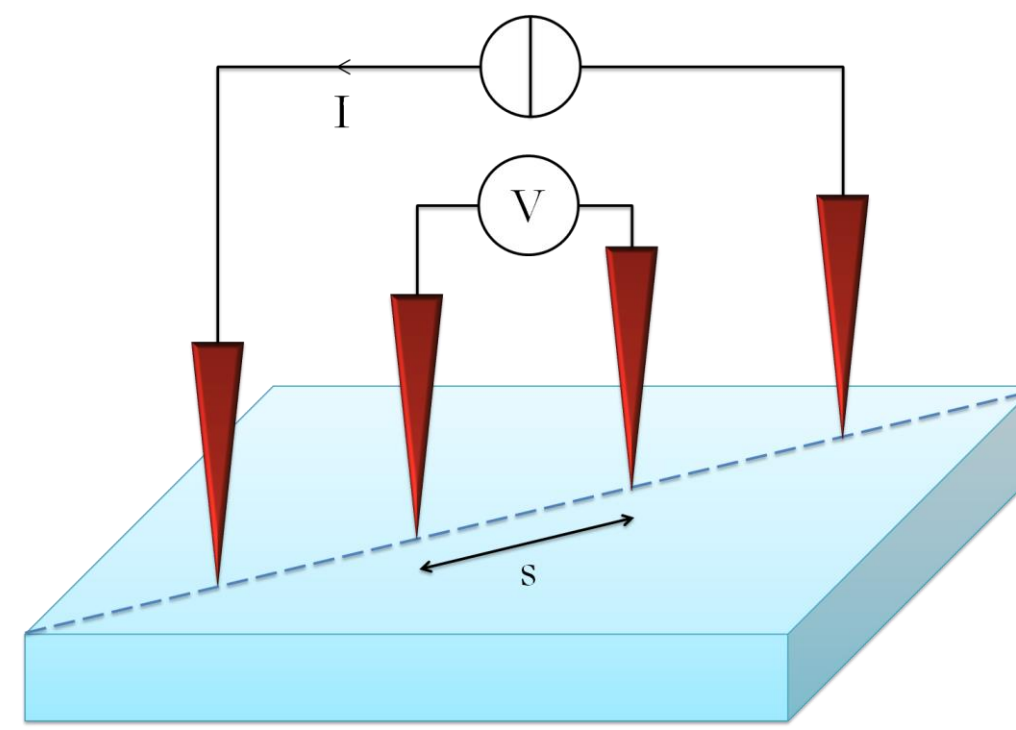
**Experimental:** Surface profile measured by confocal microscopy (Keyence VK 9700)



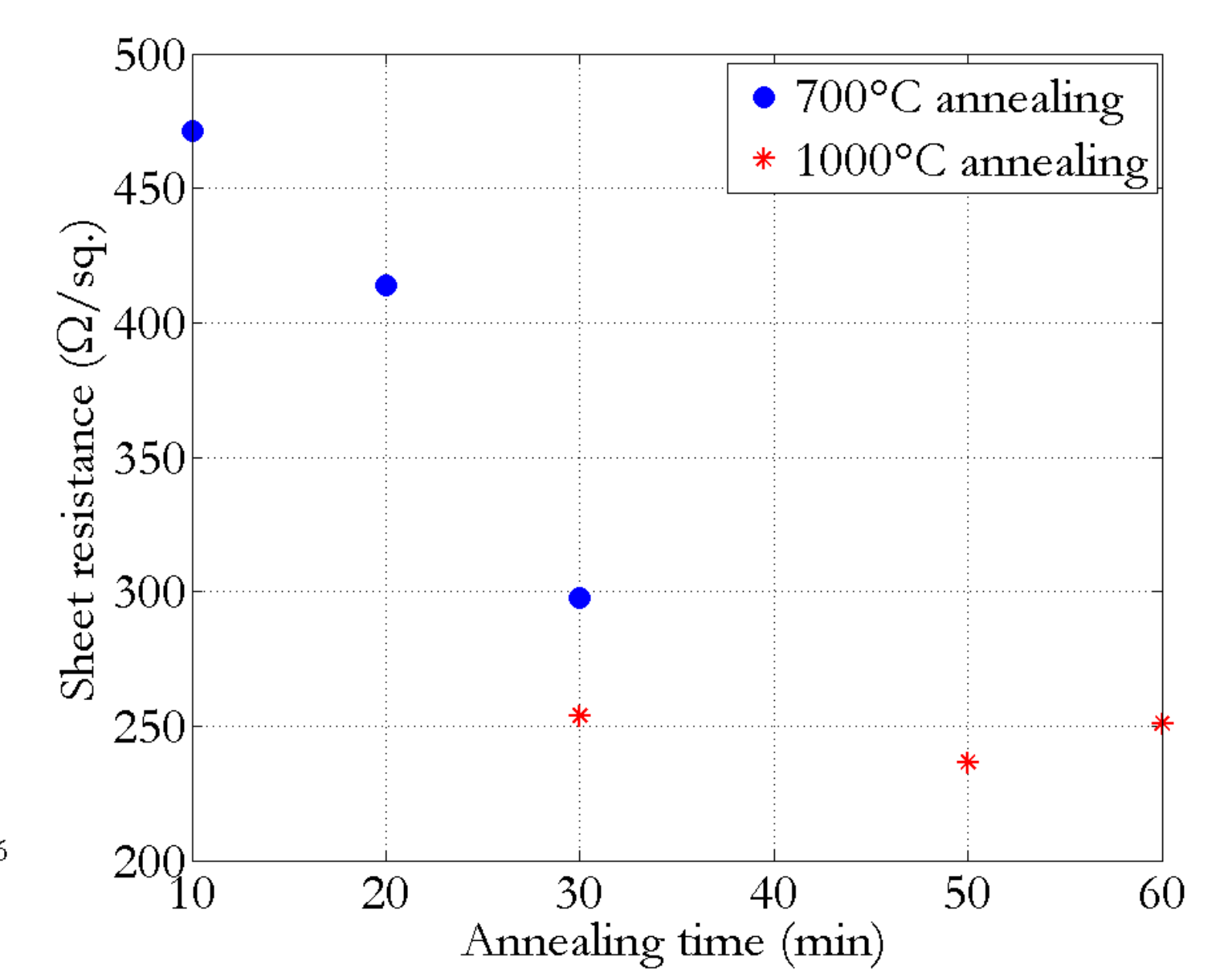
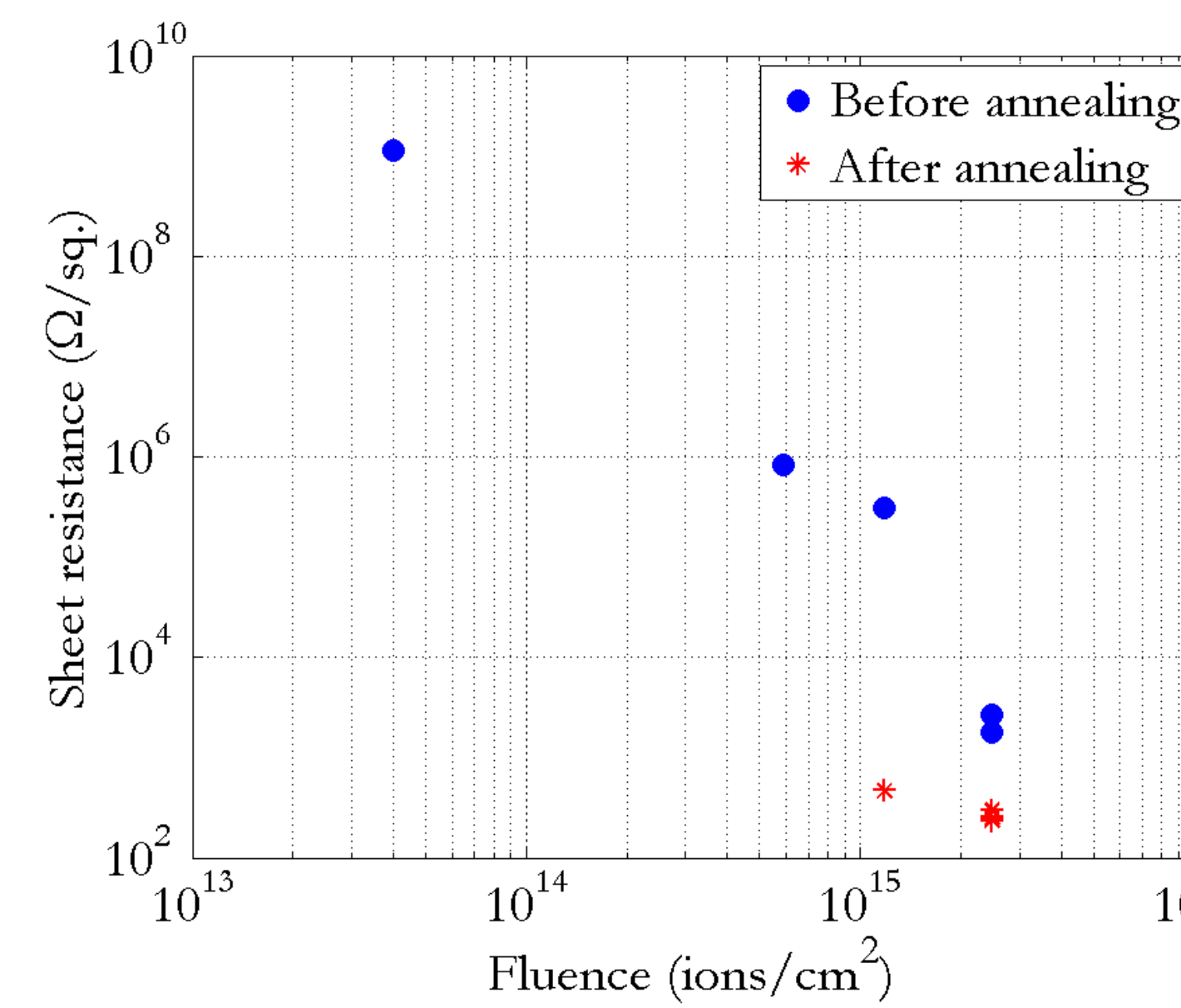
- Before annealing, the effect on density is not observable
  - After annealing, a step  $\sim +50$  nm appears.
  - After etching, a step  $\sim -60$  nm is revealed.
- The layer has the same density as graphite.

## Resistivity measurement

**Experimental:** 4-point probe resistivity measurement using a Keithley 4200 semiconductor characterization system.



**Sheet resistance evaluation:**  
Classical formula  $\rho = 2\pi F_s \cdot V/I$   
where  $F$  is calculated using the procedure detailed in [4] in our specific geometric case.

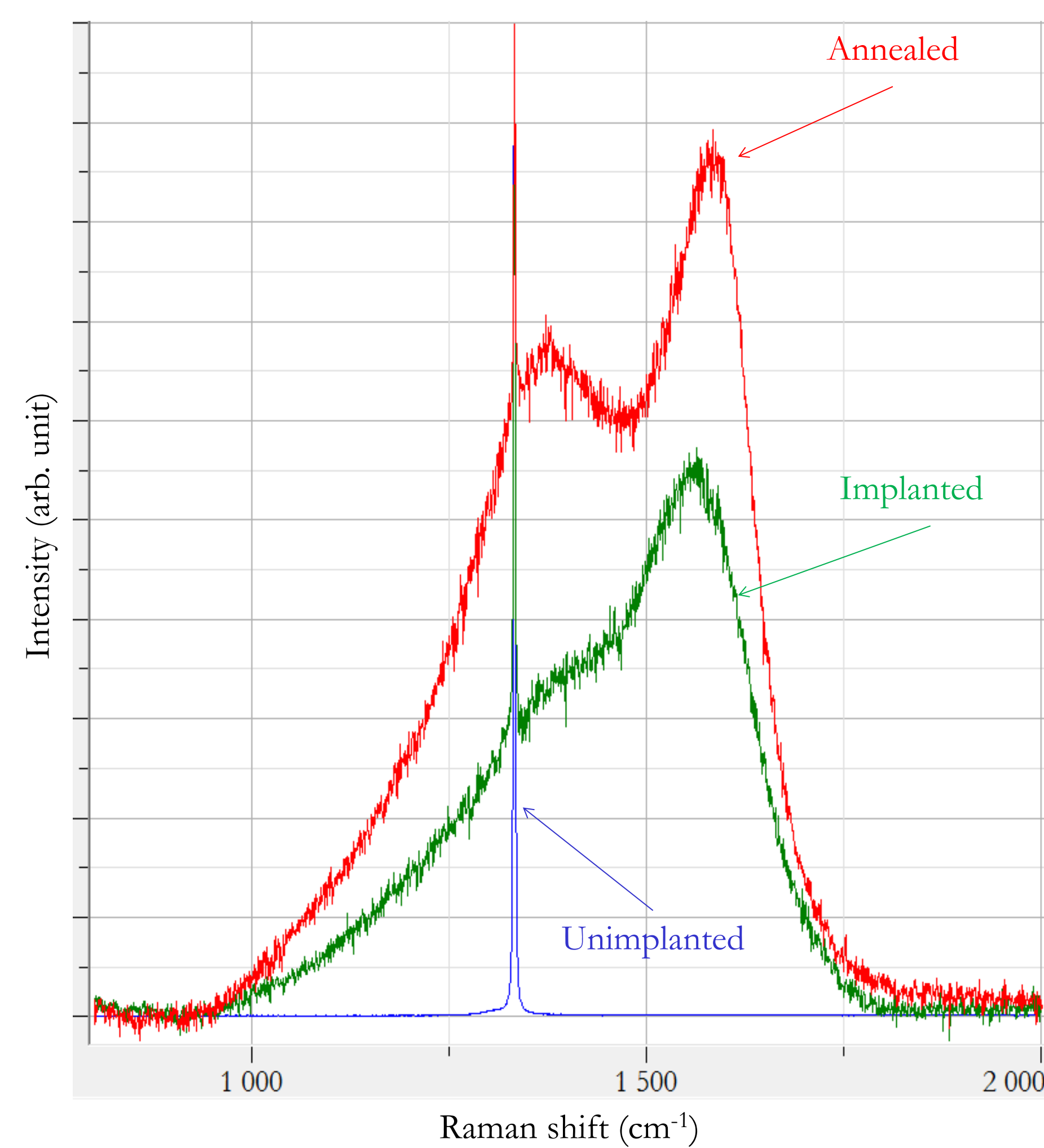


- Before implantation, all the samples are insulating.
- Before annealing : resistivity decreases with increasing ion fluence.
- Annealing decrease the resistivity

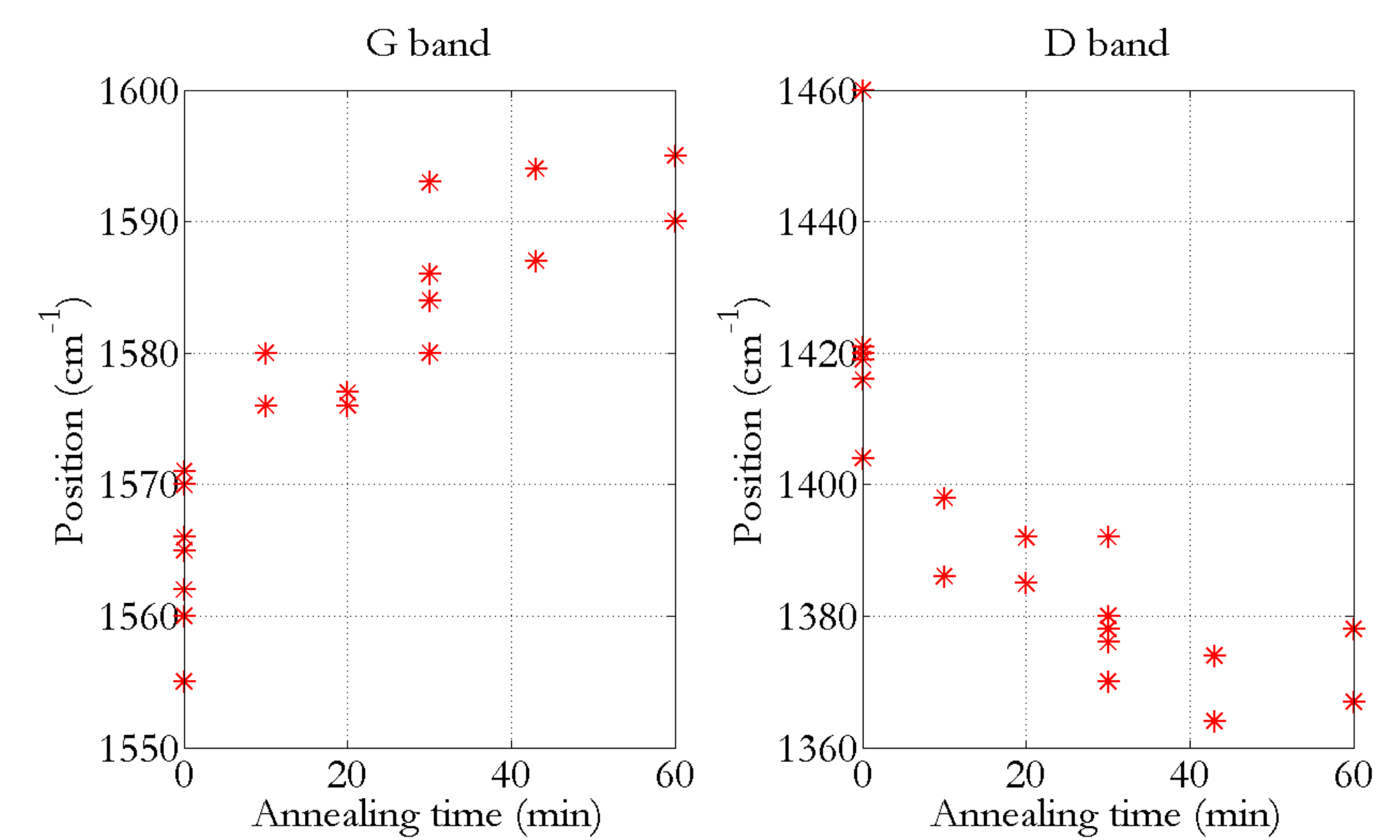
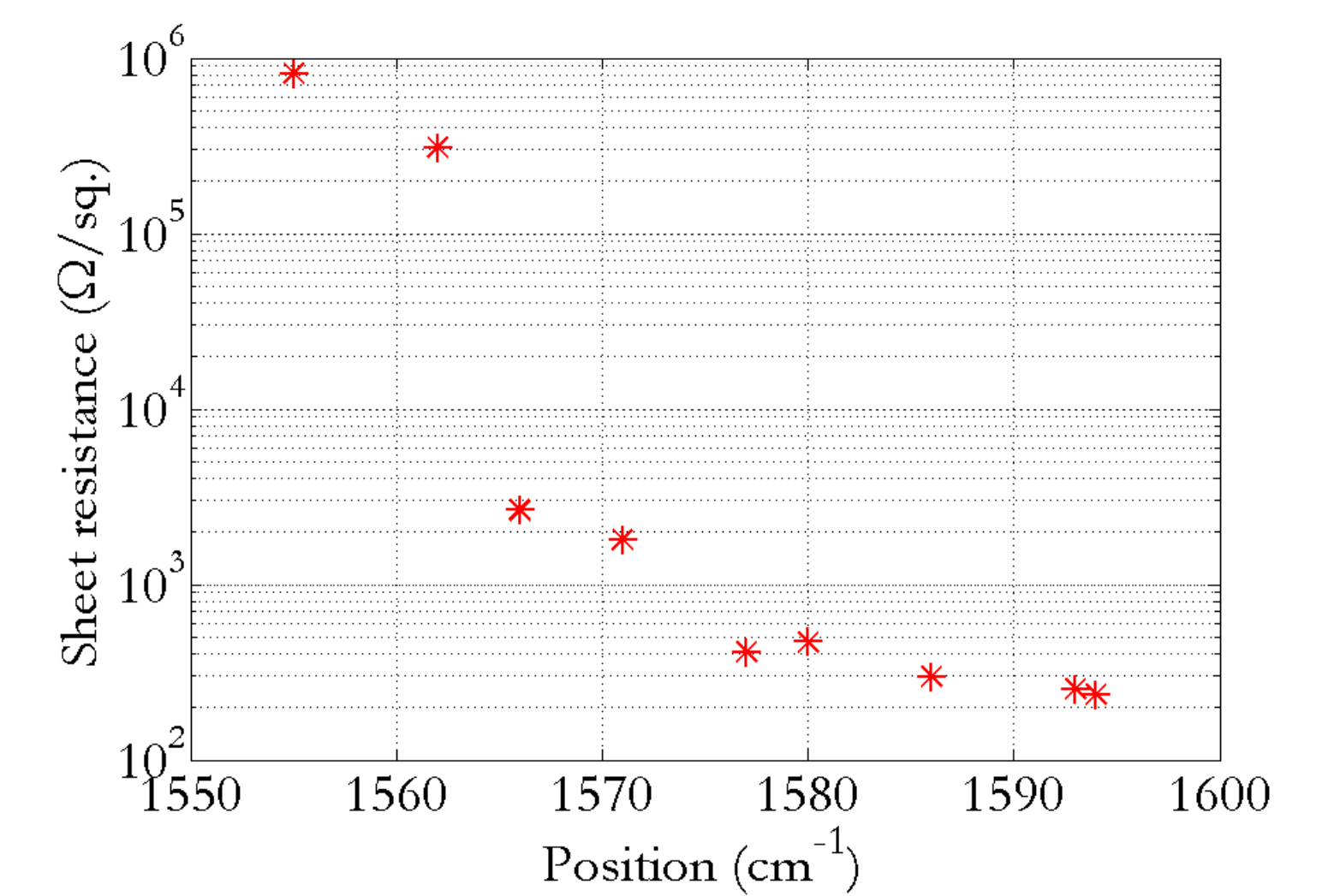
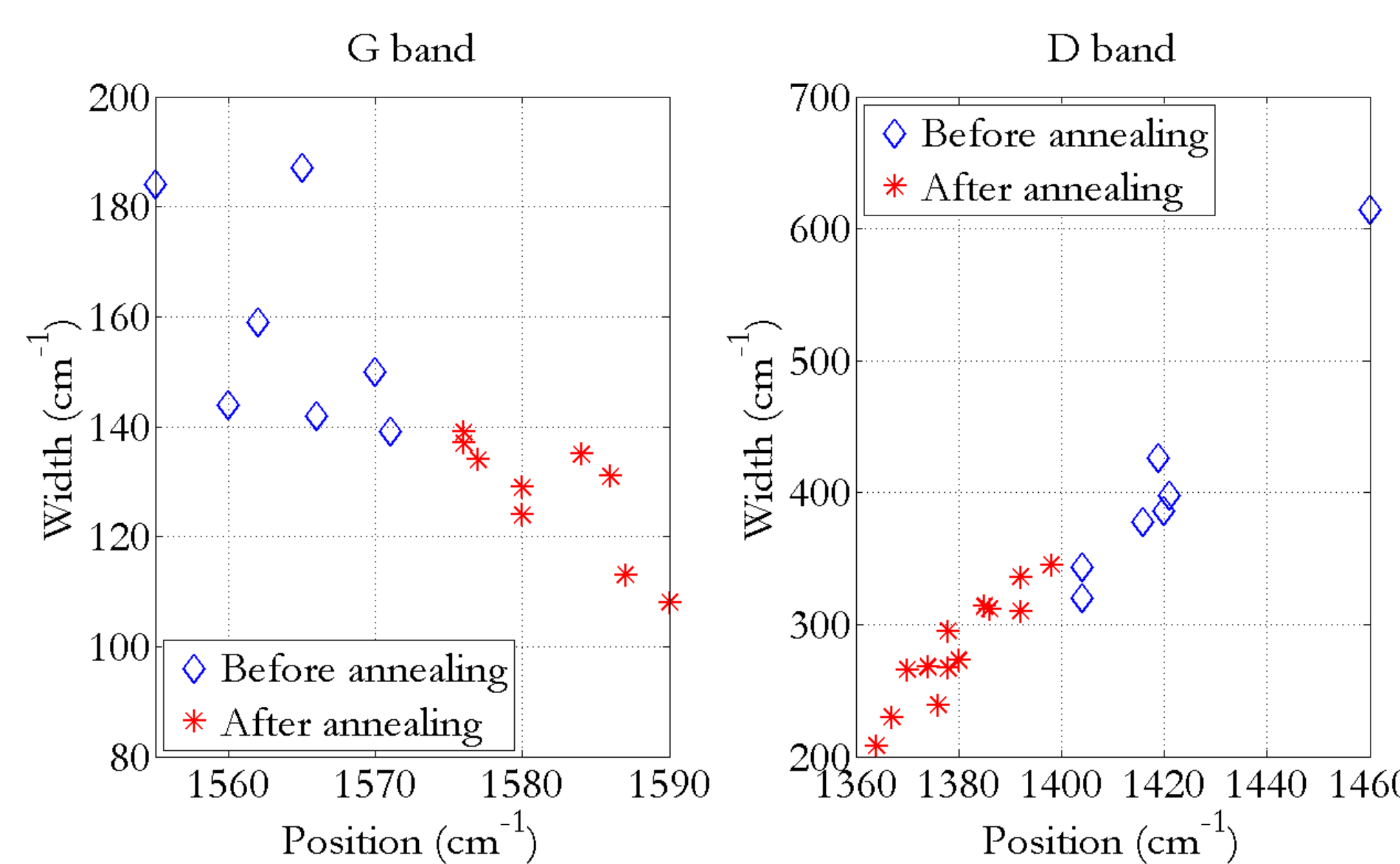
- Long annealing ( $> 30$  min) does not significantly affect the resistivity.
- The final sheet resistance is close to the graphite sheet resistance.

## Raman spectra

**Experimental:** Spectra acquired using a Horiba HR800 spectrometer @RT – 473 nm.



- Implantation induces the appearance of the G-band and the D-band: coexistence of disordered graphite and diamond.
- Annealing shifts the G-band et D-band and decreases their width.
- The G-band position shifts from  $1555-1570 \text{ cm}^{-1}$  (amorphous carbon) to  $1585-1595 \text{ cm}^{-1}$  (nanocrystalline graphite).



## References

[1] Y. Chen *et al.*, Diamond Relat. Mater. **13**, 2121 (2004).

[2] F. Favaro de Oliveira *et al.*, Nano letters **16**, 2228 (2016).

[3] M. De Feudis *et al.*, ICDCM 2017.

[4] L. B. Valdes, Proceedings of the IRE **42**, 420 (1954).