



Characteristics of He ion implanted layers on single-crystal diamond

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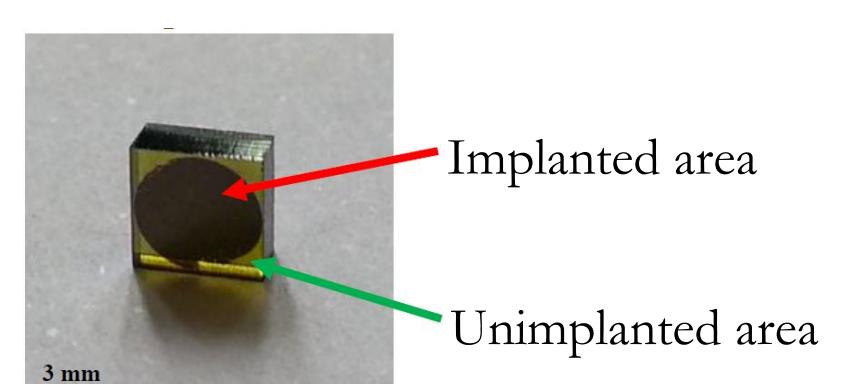
Background and aim of the study

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 $2.10^{17} \text{ cm}^{-3}$

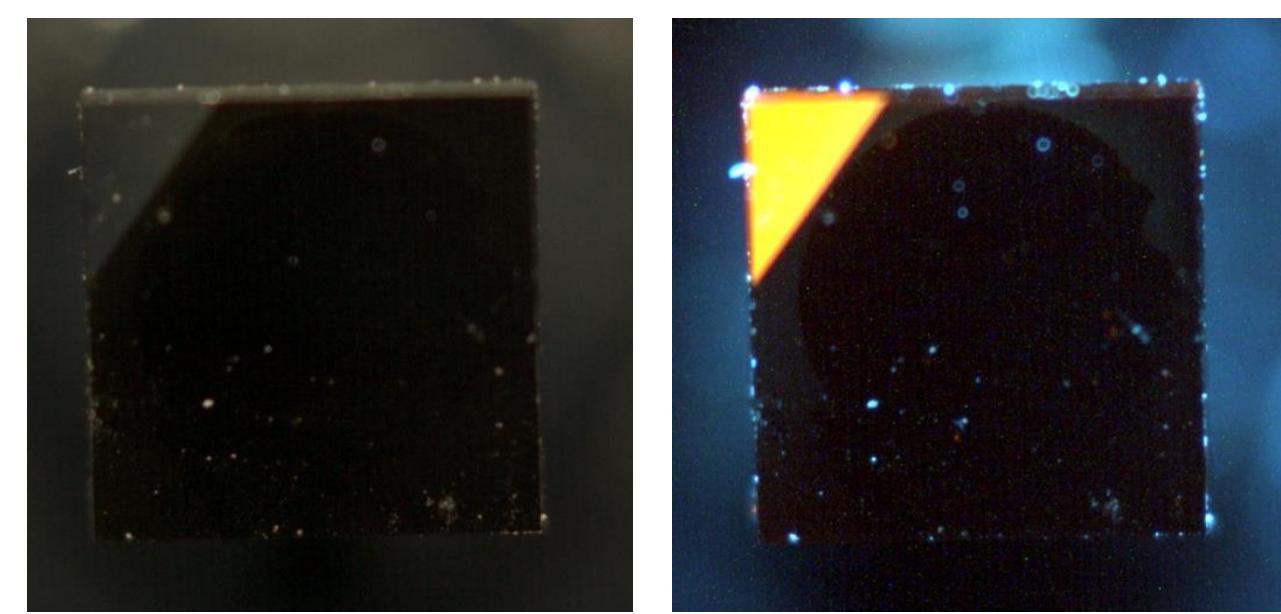


Aim of the study: characteristics of He ion-implanted single-crystal diamond.

Ion implantation

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

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

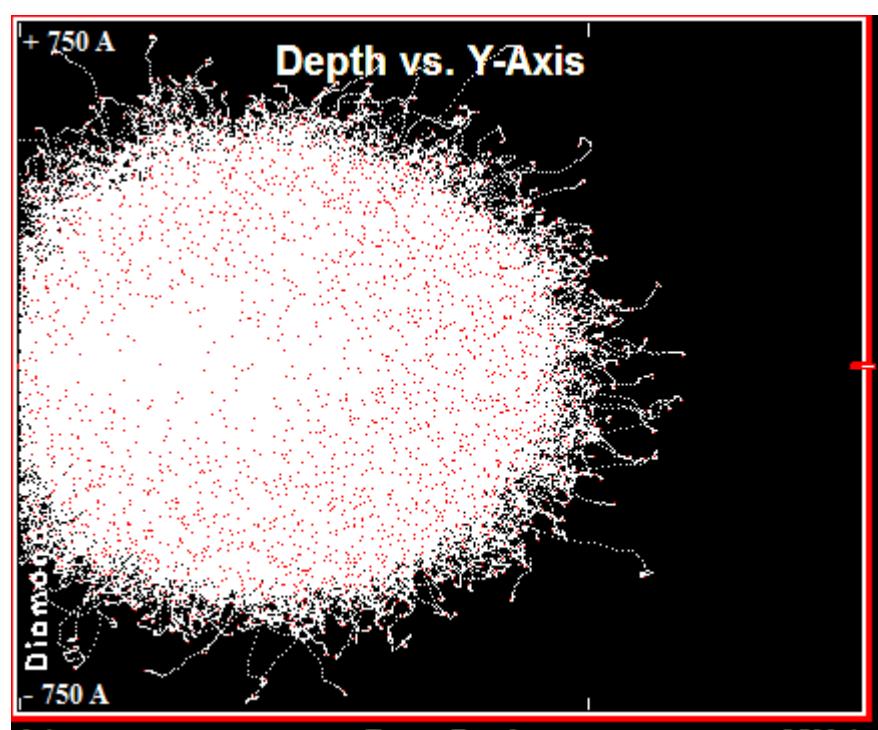
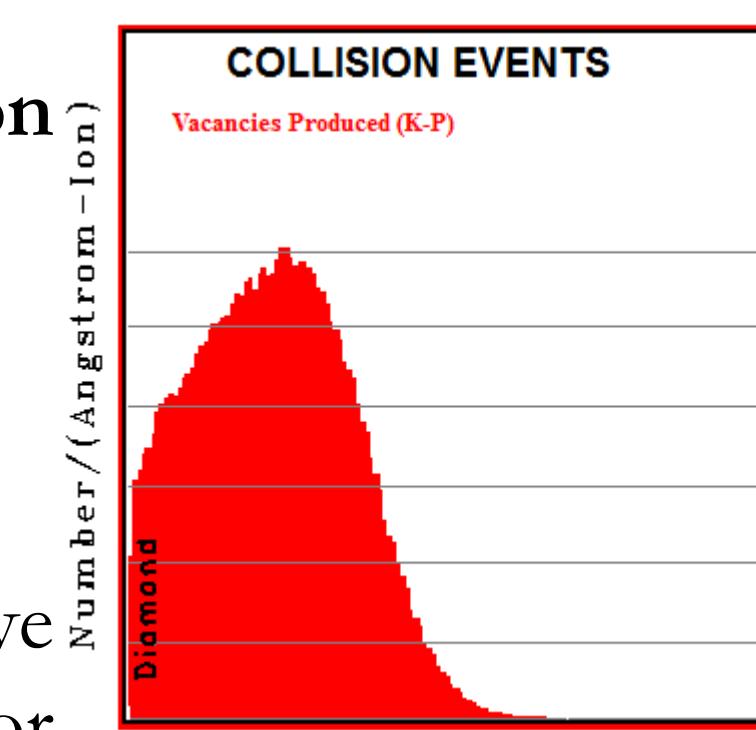


Diamond View images of an implanted sample.

SRIM simulation of ion implantation:

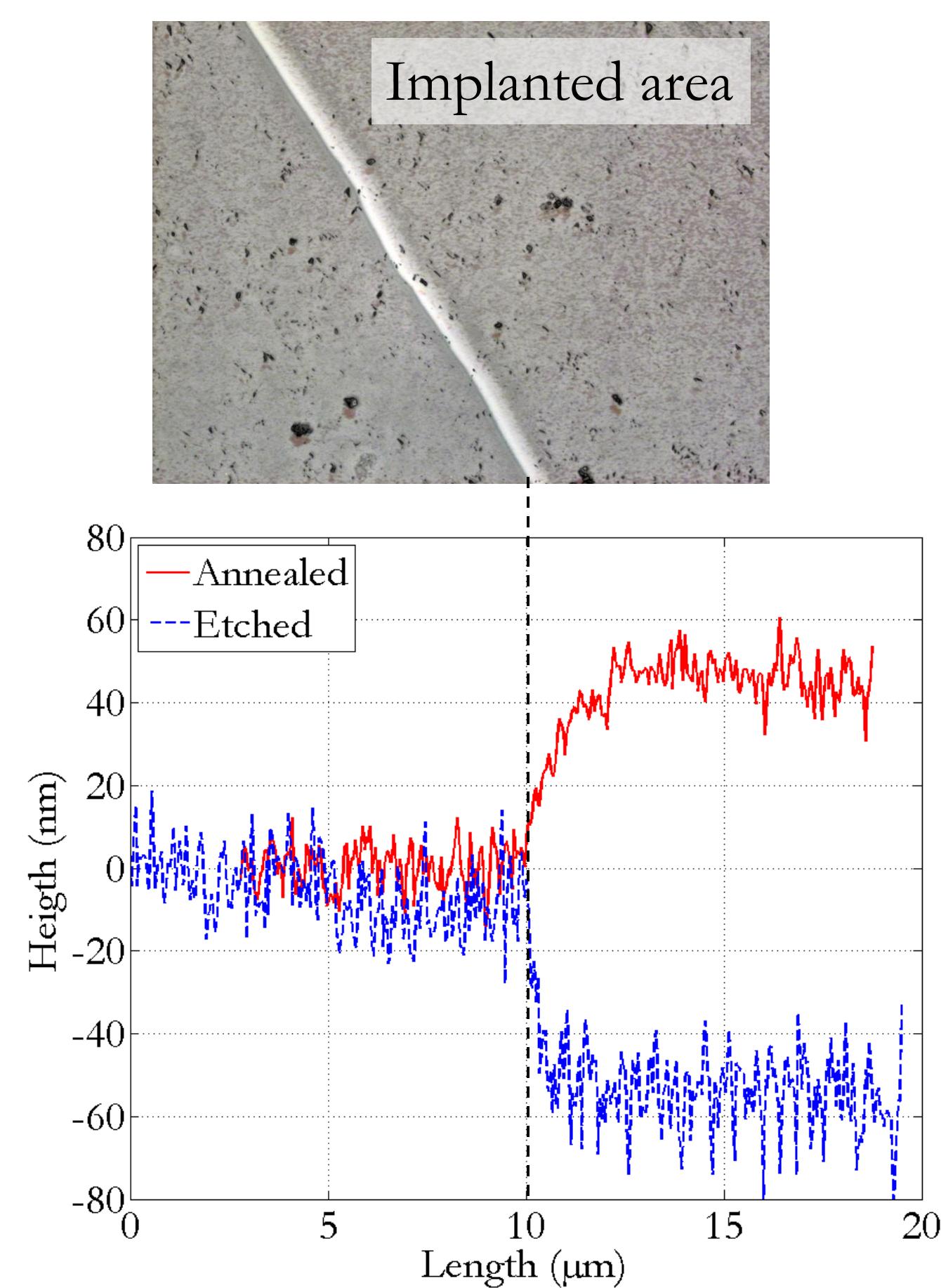
- 15 vacancies/ion
- 50 nm penetration depth

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



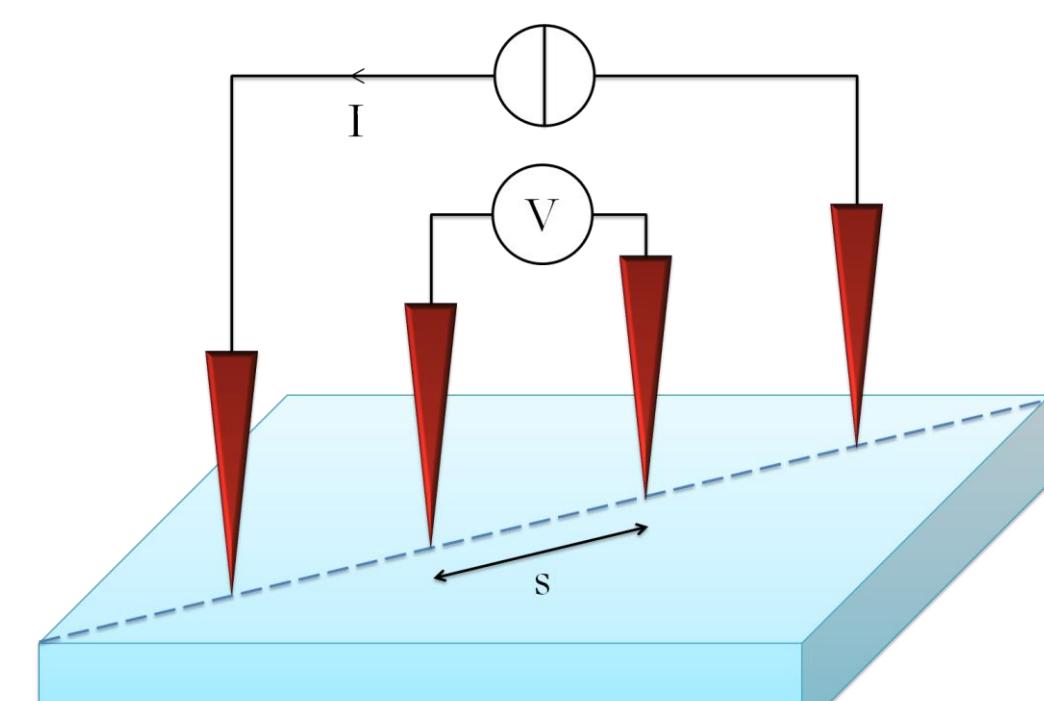
Density profiling

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

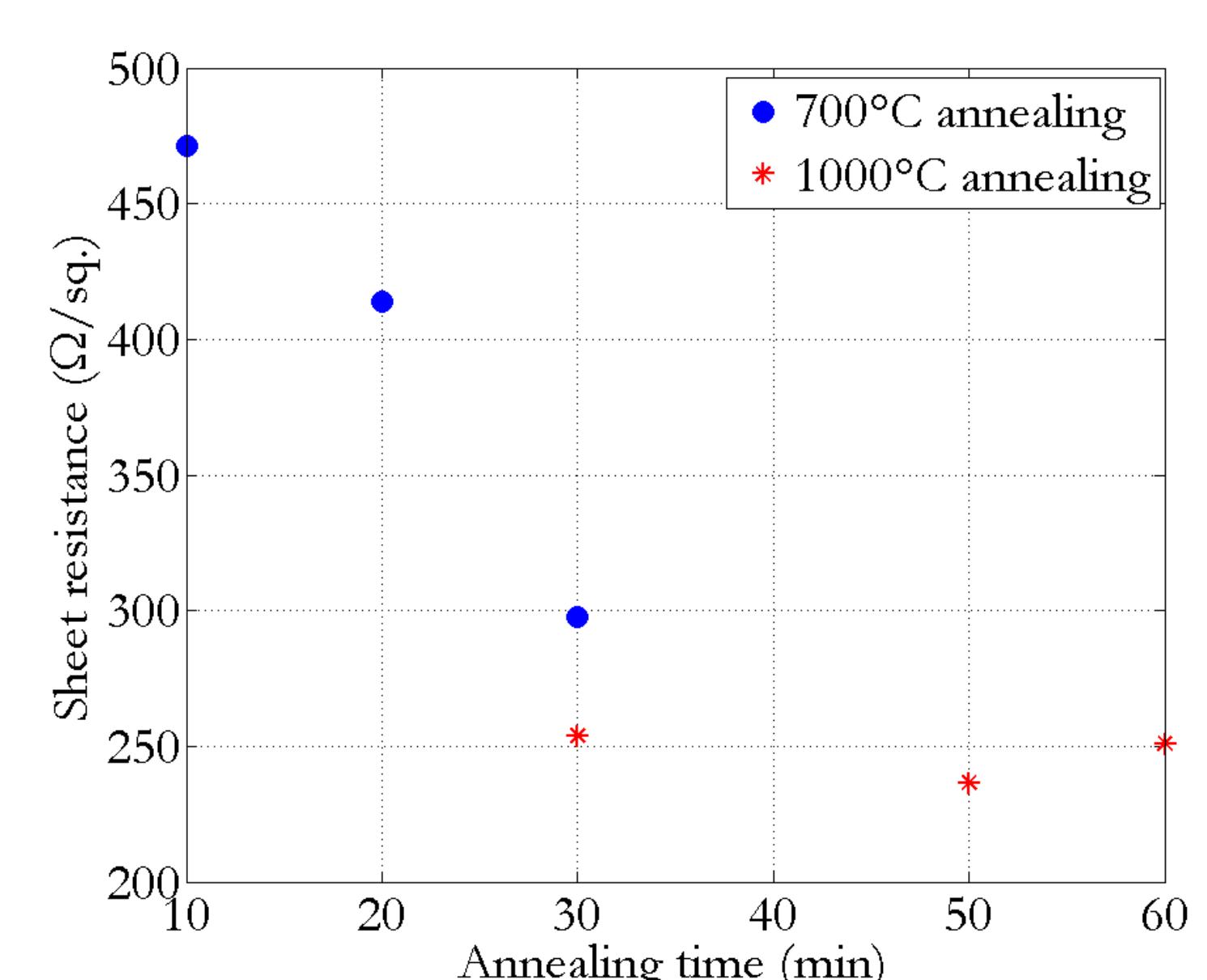
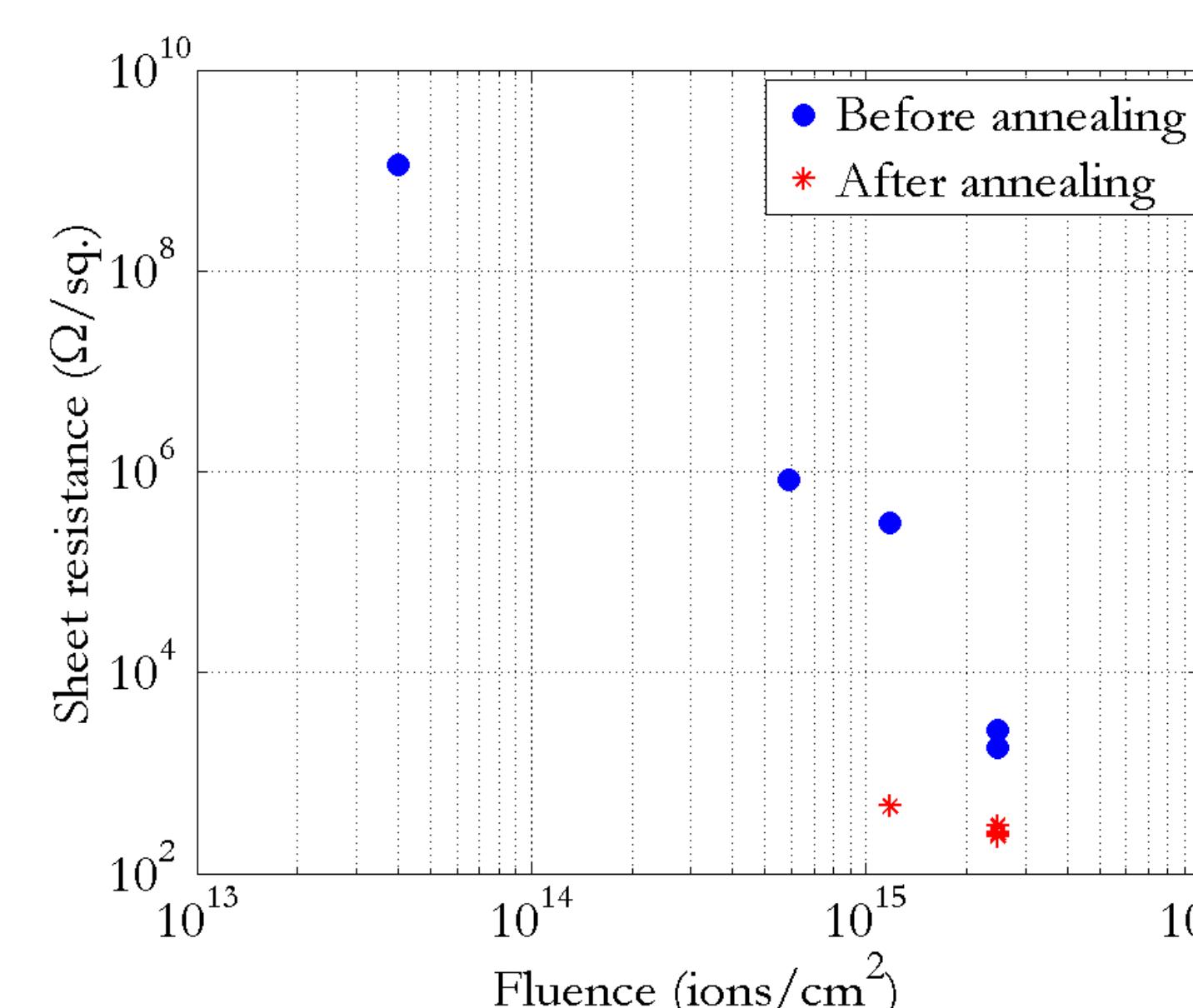


- Before annealing, the effect on density is not observable
- After annealing, a step $\sim +50 \text{ nm}$ appears.
- After etching, a step $\sim -60 \text{ nm}$ is revealed.
- The layer has the same density as graphite.

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



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

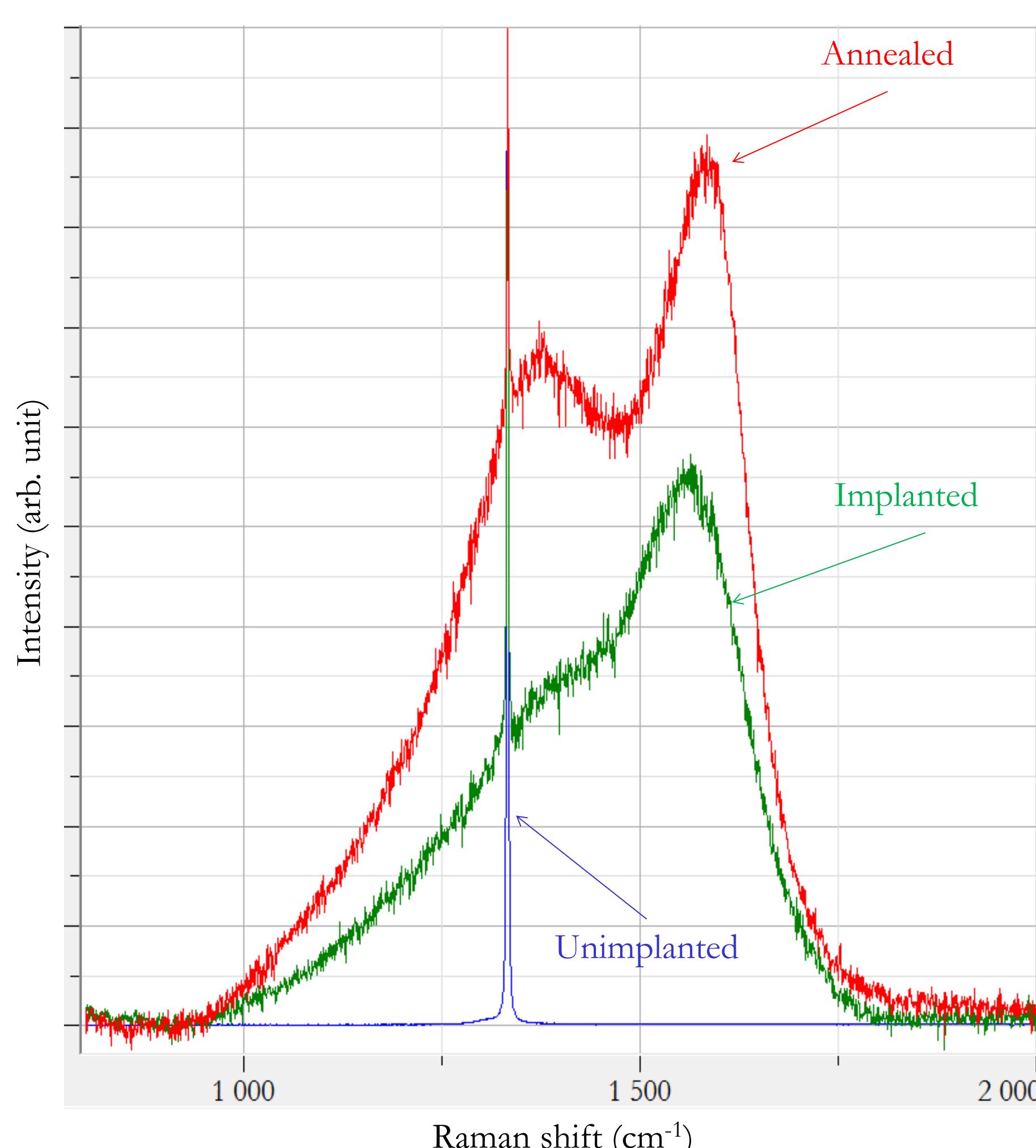


- Before implantation, all the samples are insulating.
- Before annealing : resistivity decreases with increasing ion fluence.
- Annealing decrease the resistivity

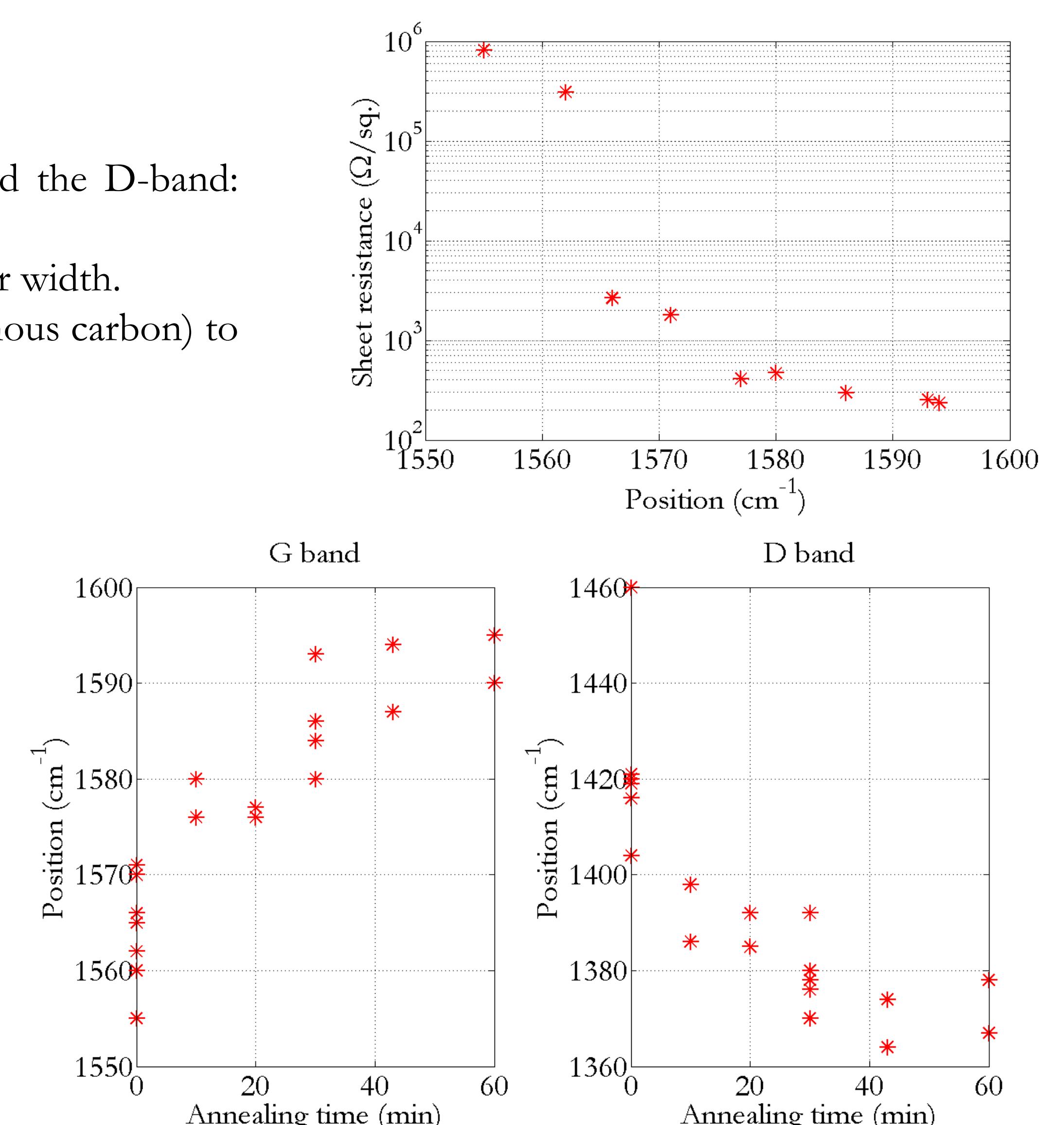
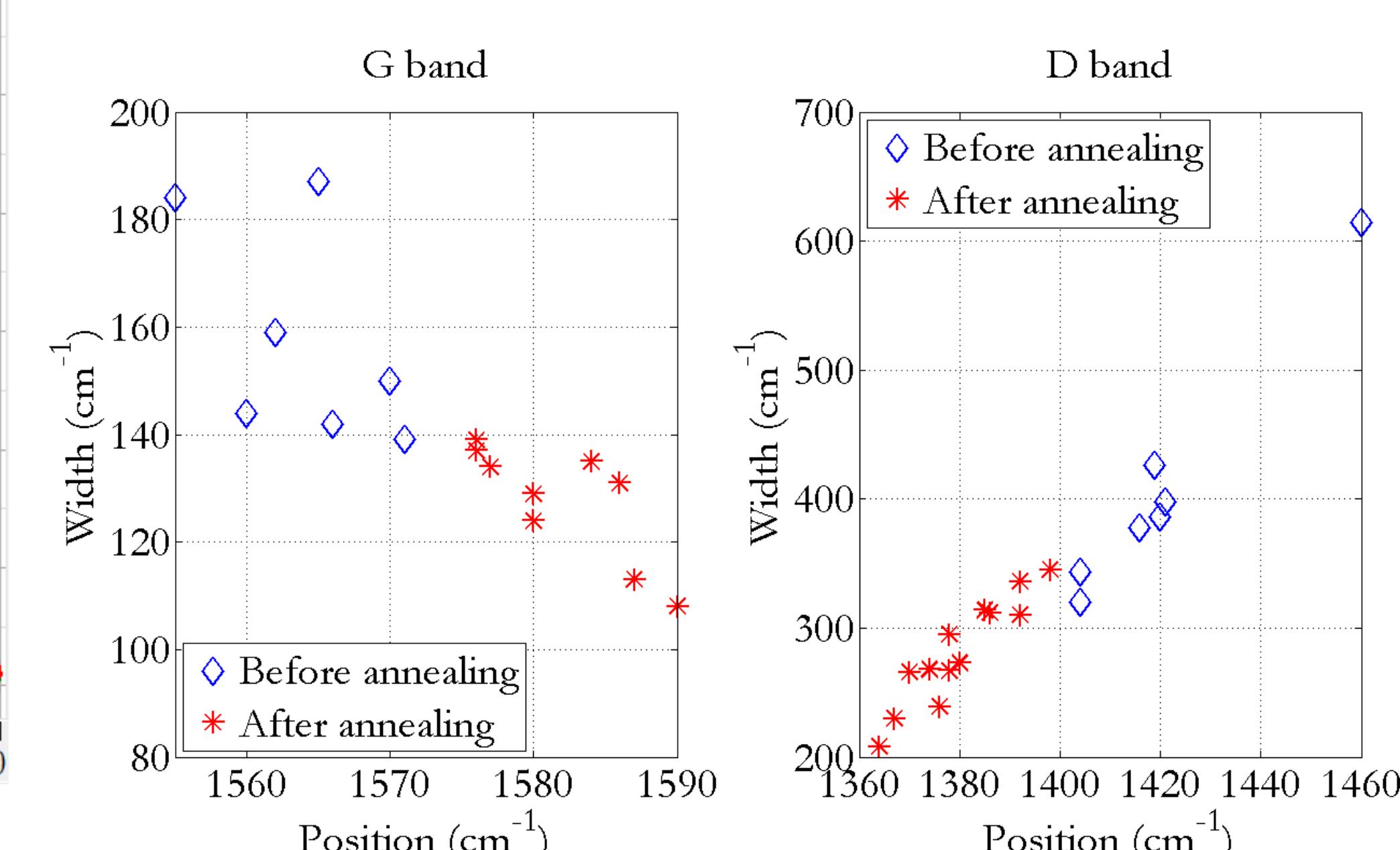
- Long annealing ($> 30 \text{ min}$) does not significantly affect the resistivity.
- The final sheet resistance is close to the graphite sheet resistance.

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 $1555\text{-}1570 \text{ cm}^{-1}$ (amorphous carbon) to $1585\text{-}1595 \text{ cm}^{-1}$ (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).