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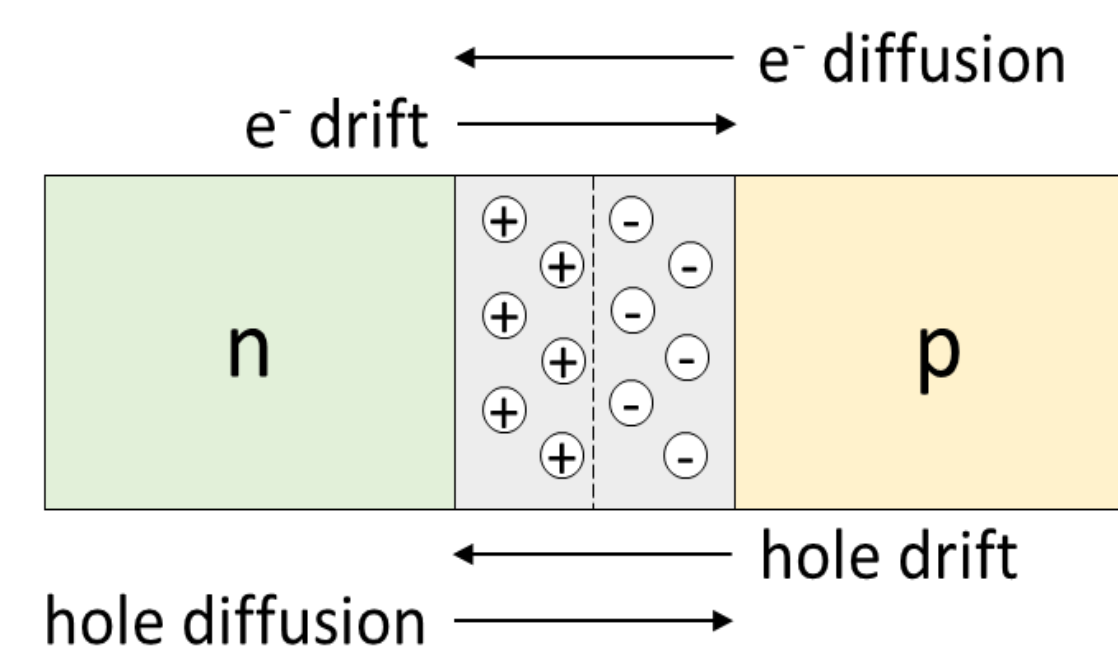
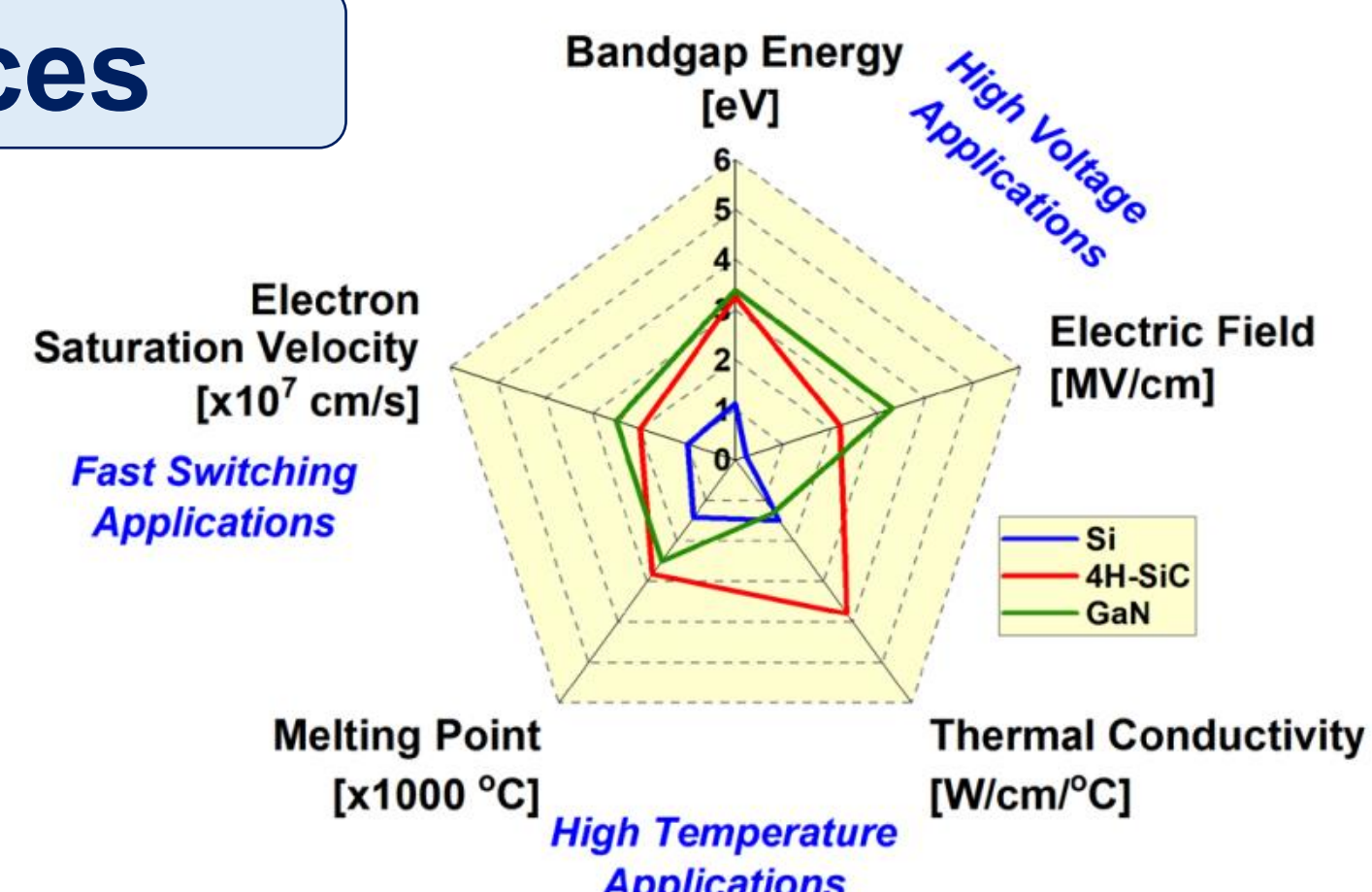
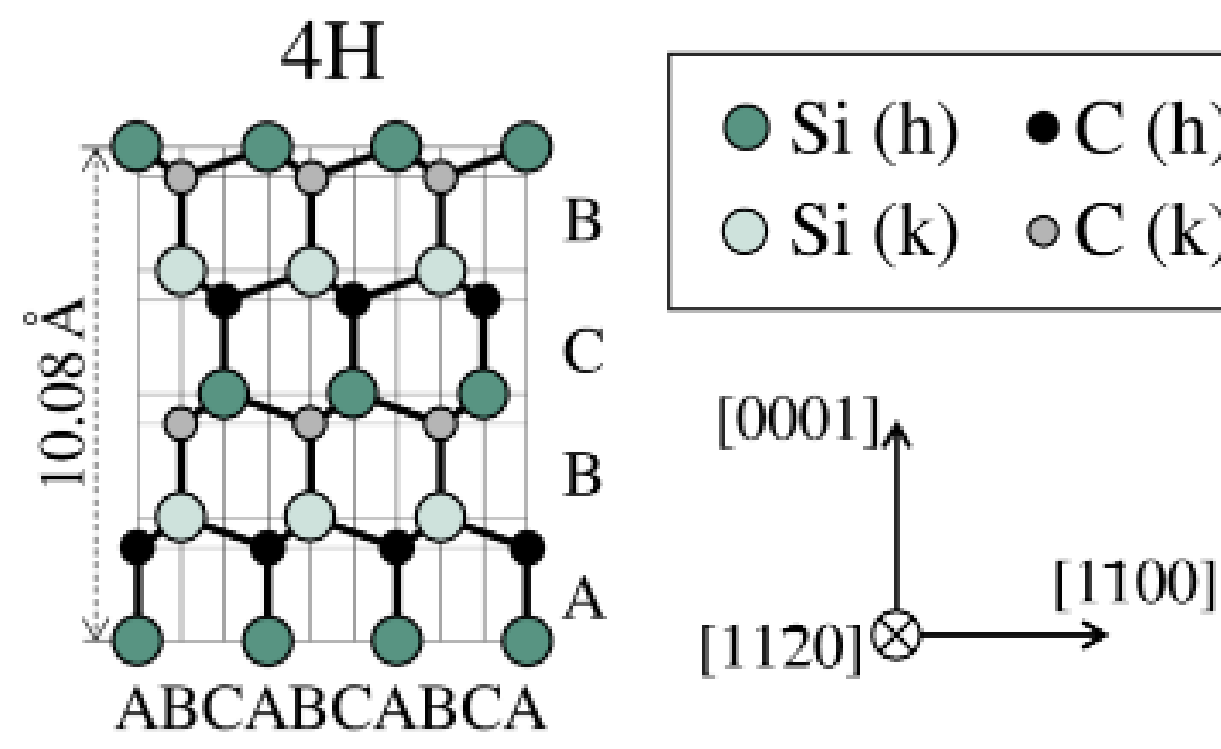
Coupled non-destructive methods, Scanning Electron Microscopy, Kelvin Force Probe microscopy and μ -Raman to characterize doping in 4H-SiC power devices

E. Vuillermet¹, K.T Wu¹, A. Sédilot¹, R. Deturche¹, N. Bercu², E. Usureau¹, J. Béal¹, M. Lazar¹

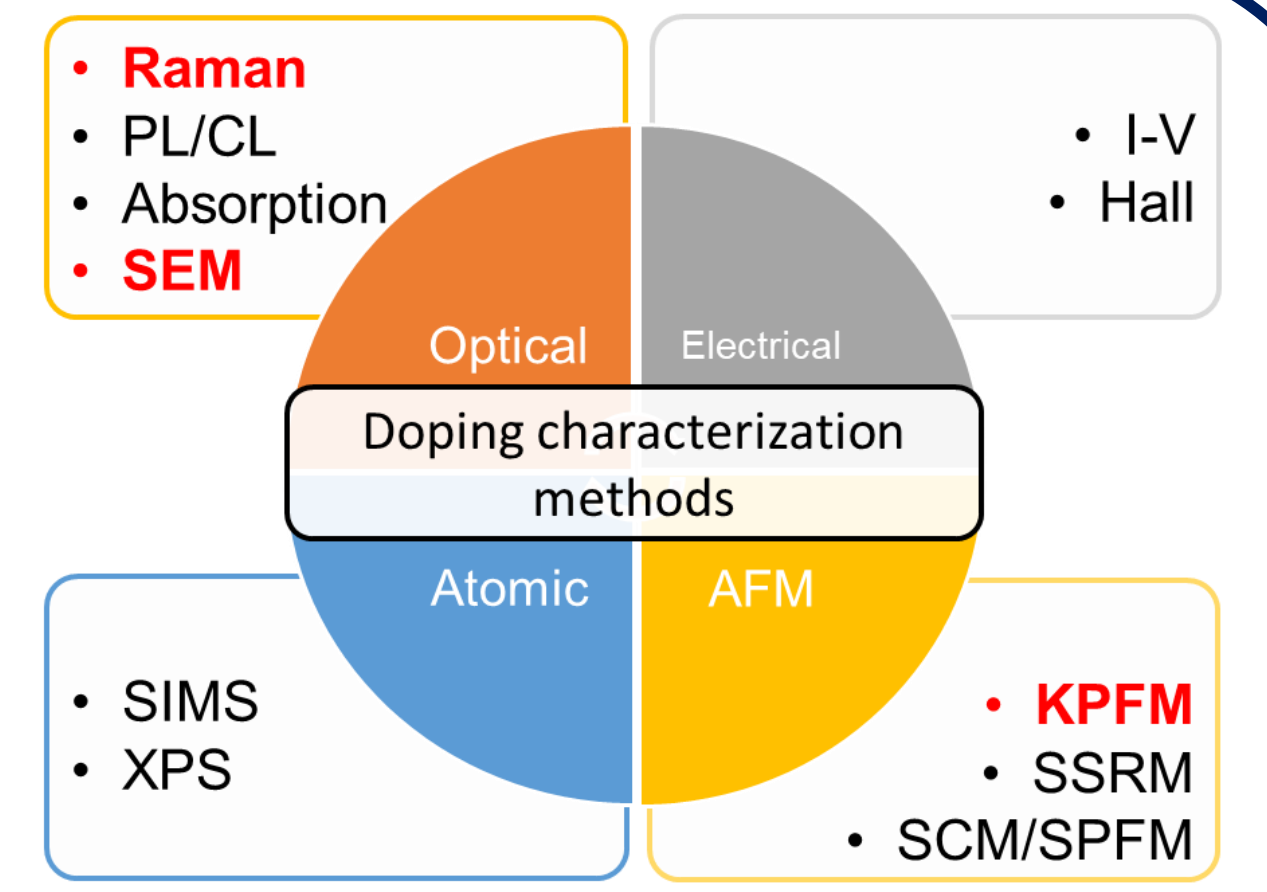
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SiC and power devices



n and p-type doping possible with introduction of nitrogen or aluminum
Formation of p-n junction : power devices fabrication \rightarrow diodes, JFETs, MOSFETs...



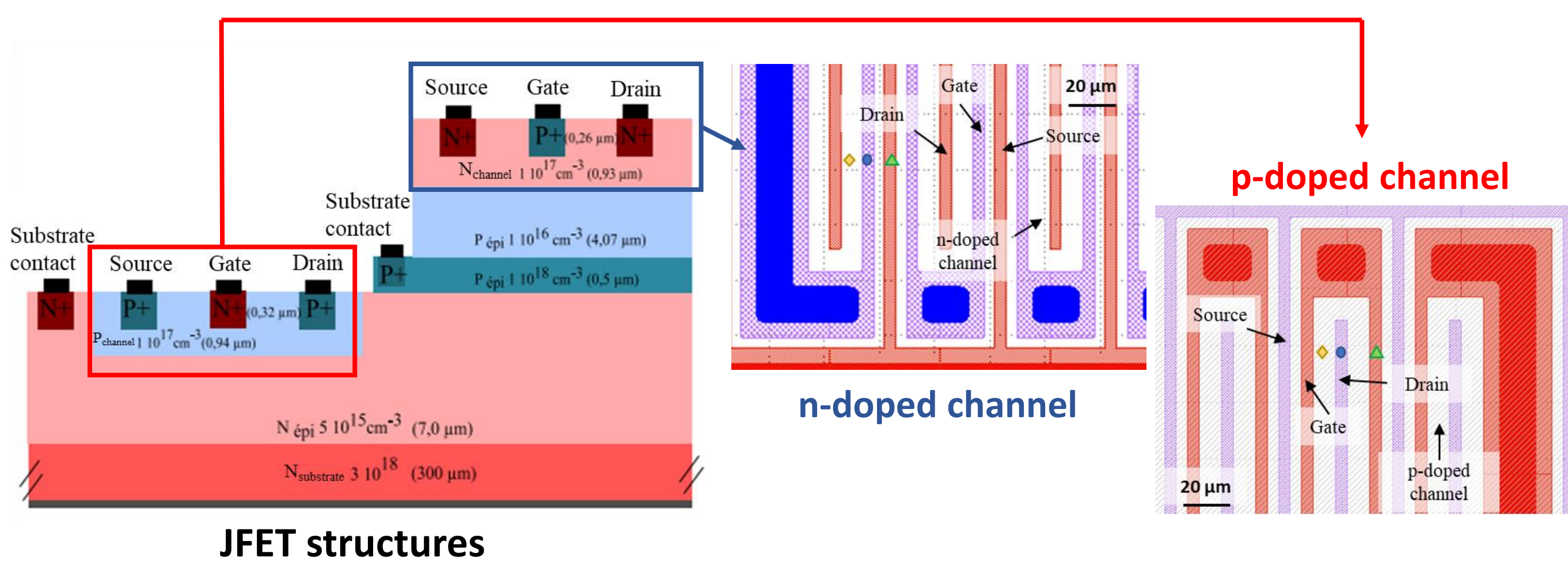
Local doping : manages the equipotential distribution in the surface [3], [4]

Objective : Non-destructive local characterization of doping by SEM, μ -Raman and KPFM

✓ Localization of doped areas

✓ Verification of surface potential distribution

Power devices fabrication

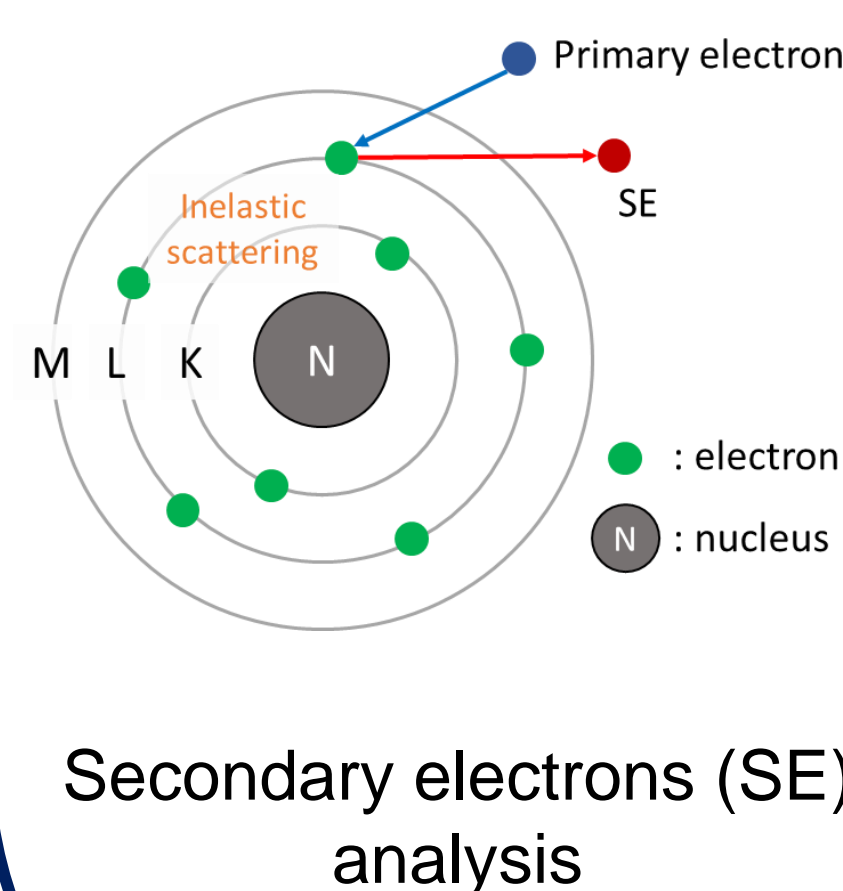
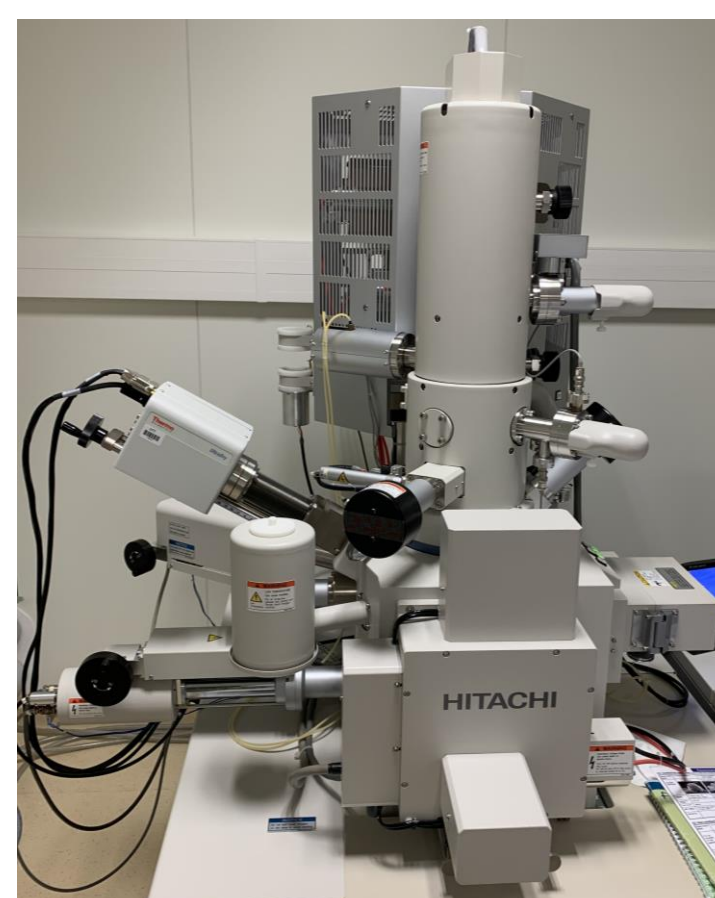


JFET structures

- **Junction Field Effect Transistors (JFETs)** : the bias applied between the gate and the substrate control the current flow between the source and the drain [5]
- Applications as buffer amplifiers, electronic switches or voltage variable resistors

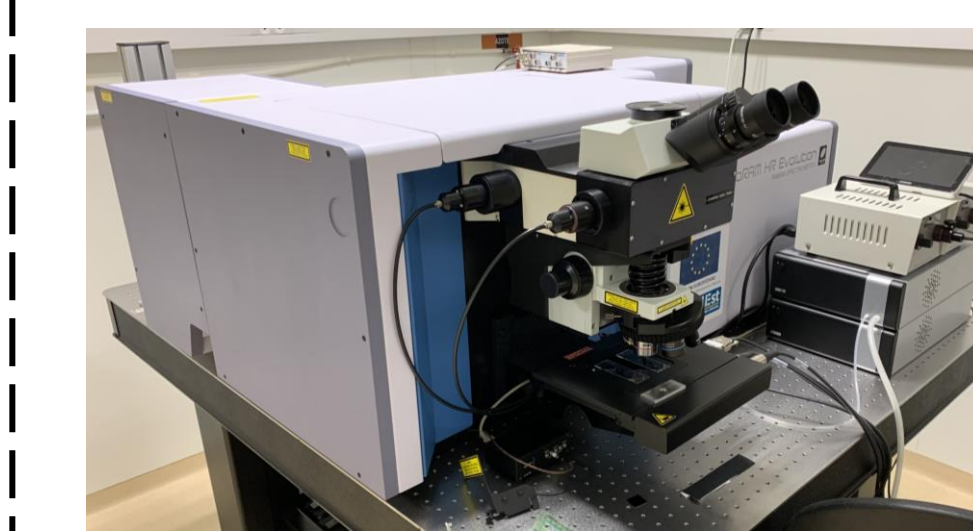
Characterization methods

Hitachi SU-8030 FEG-SEM

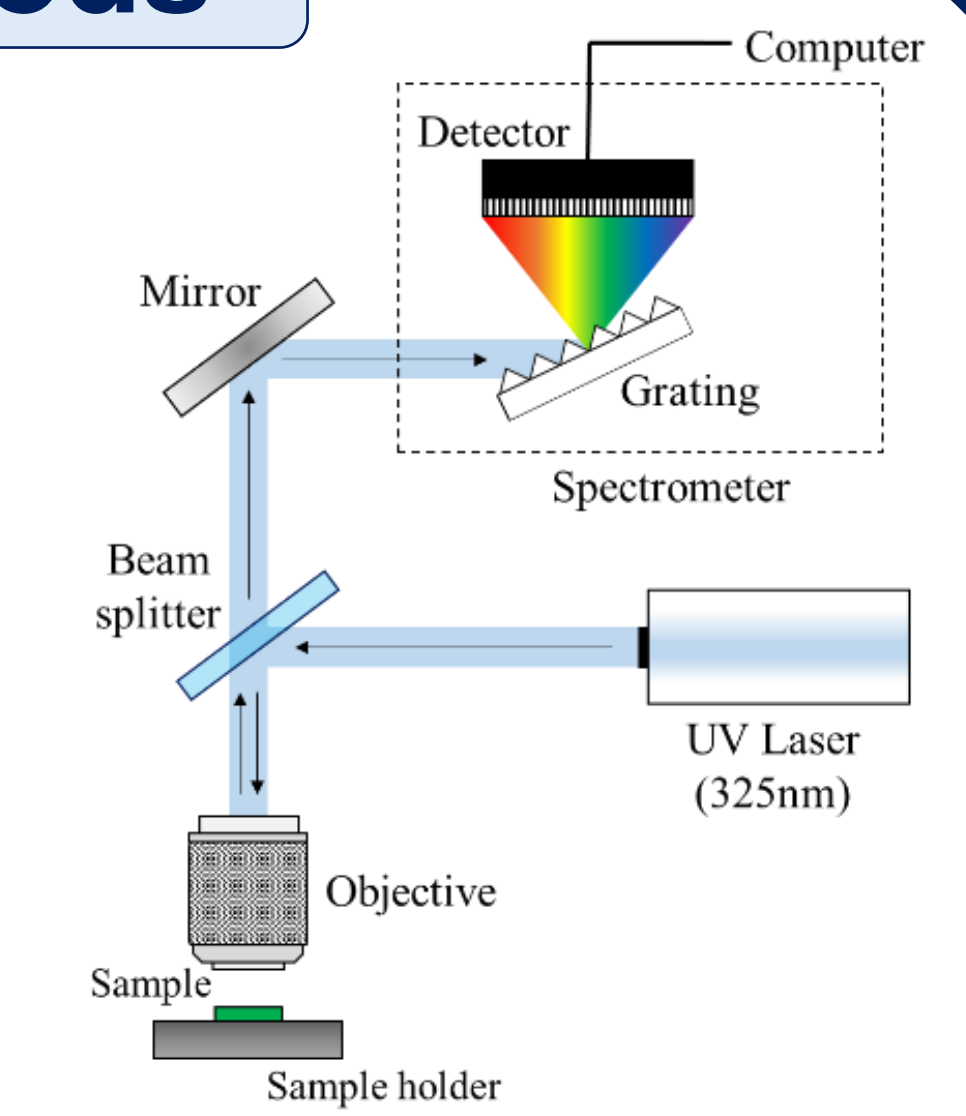


Secondary electrons (SE) analysis

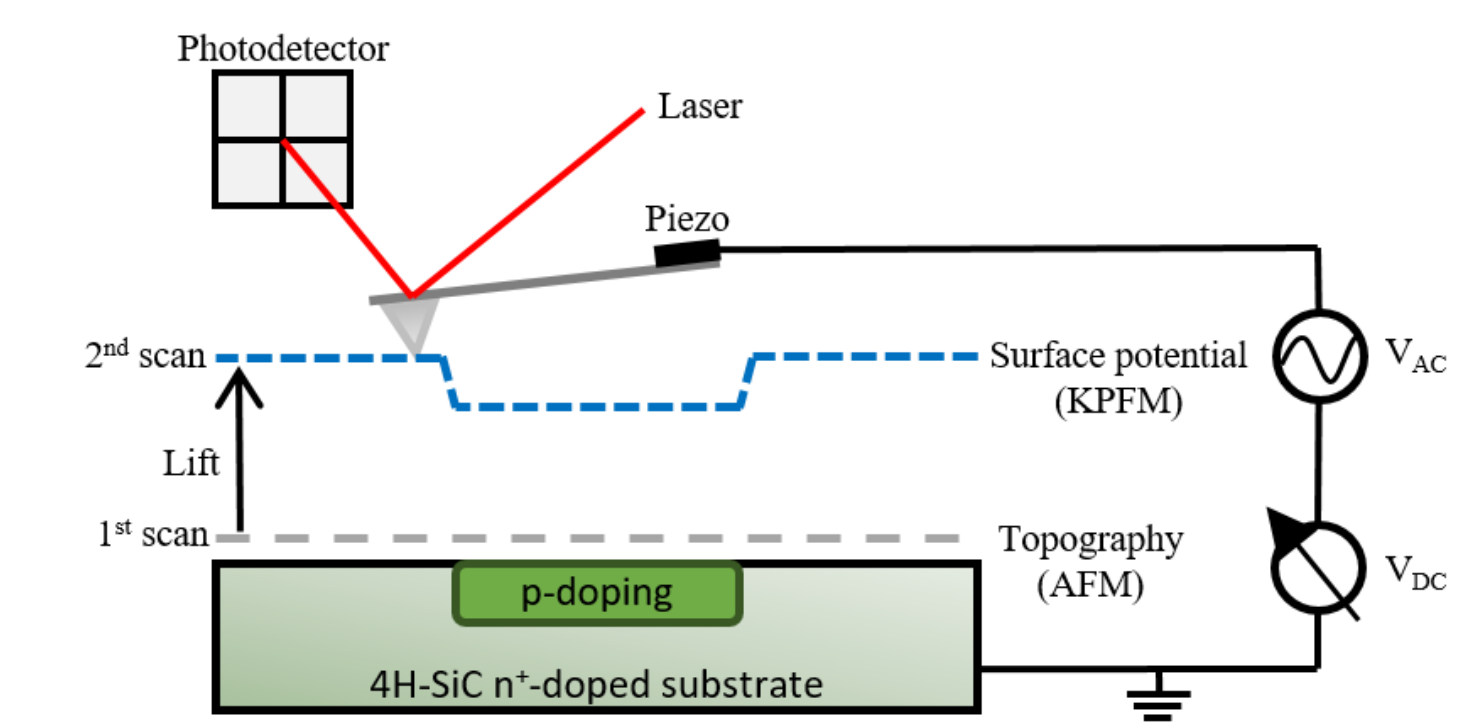
Labram HR Evolution Raman microscope



- Objective x40
- Grating 1800g/mm
- Laser 325nm

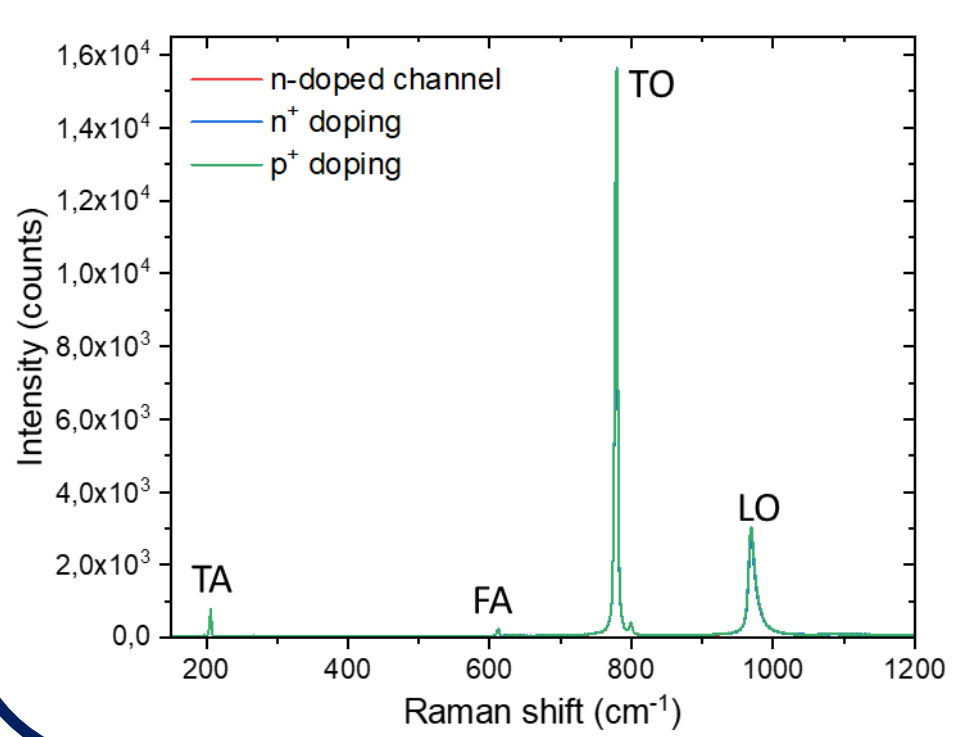


Dimension Icon AFM : FM-KPFM mode



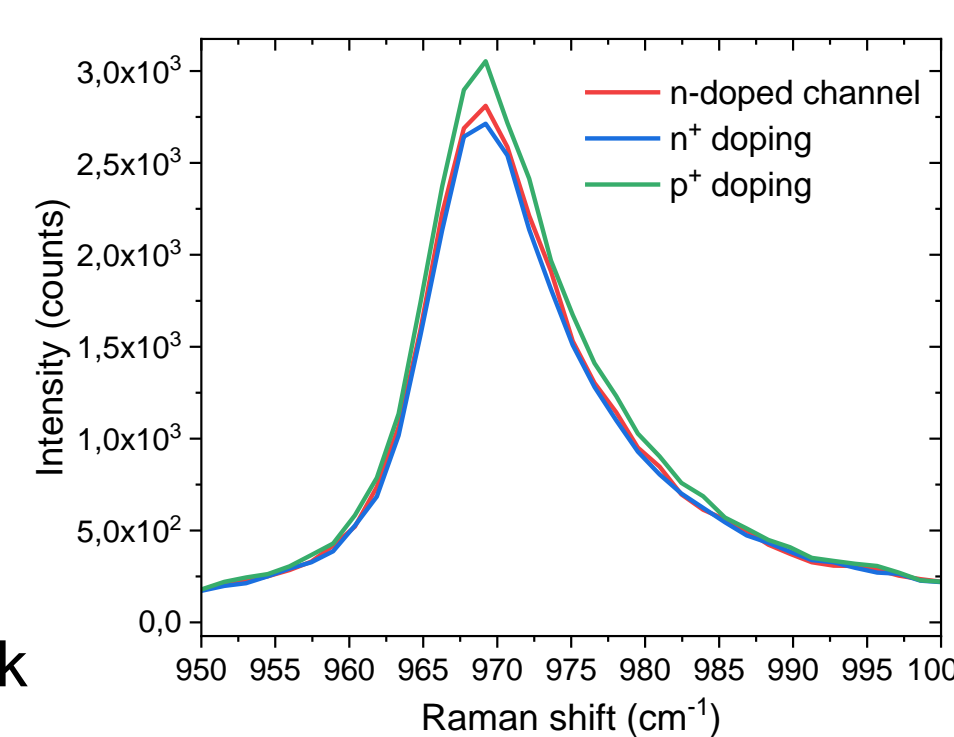
- Measures the **contact potential difference (CPD)** between the AFM tip and the sample's surface [7]
- Peak Force Tapping mode associated to FM-KPFM
- SCM-PIT-V2 tips
- Low-speed scanning < 0,1Hz

Raman spectra



Doping influences the intensity and width of 4H-SiC LO peak [6]

We look at the height variation of the LO peak

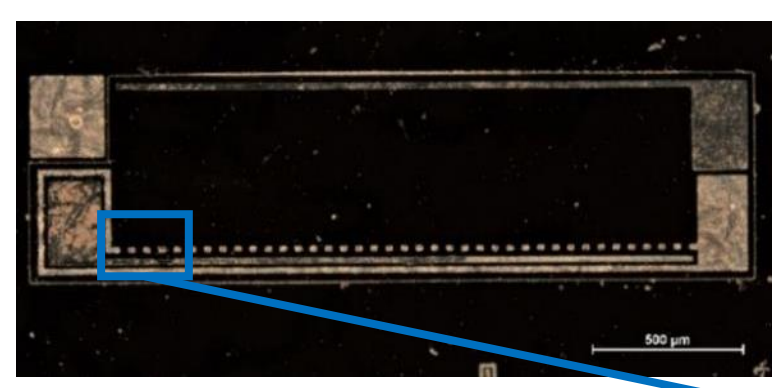


Secondary electrons (SE) analysis

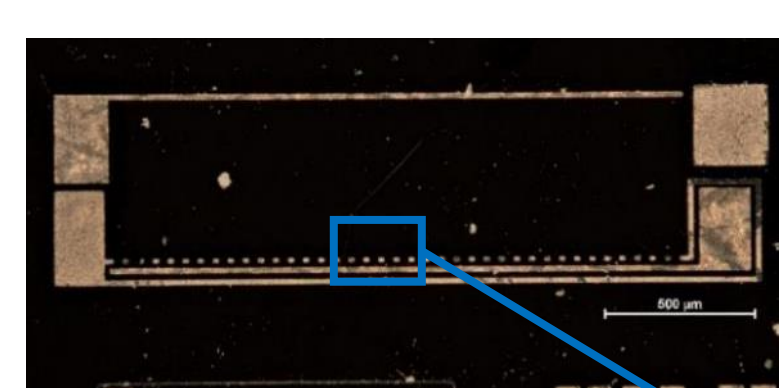
Mappings

Optical microscope (x5)

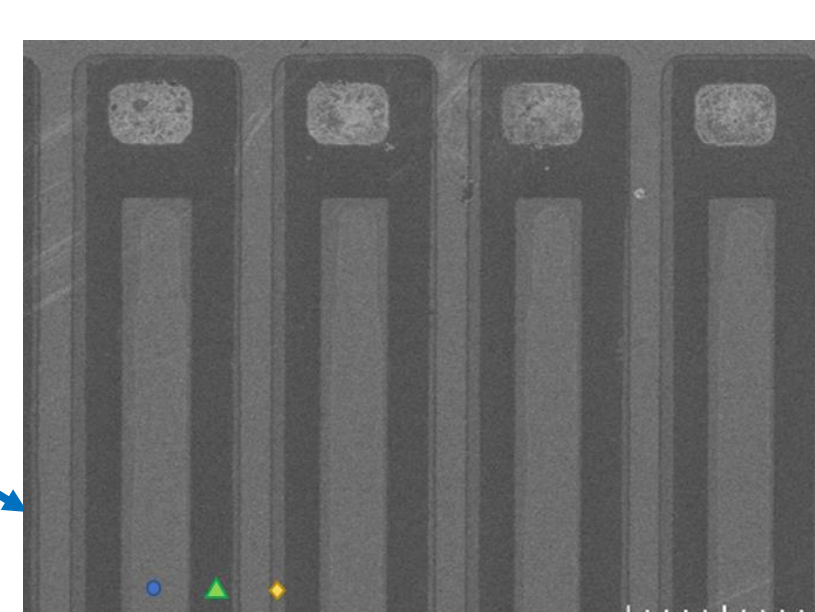
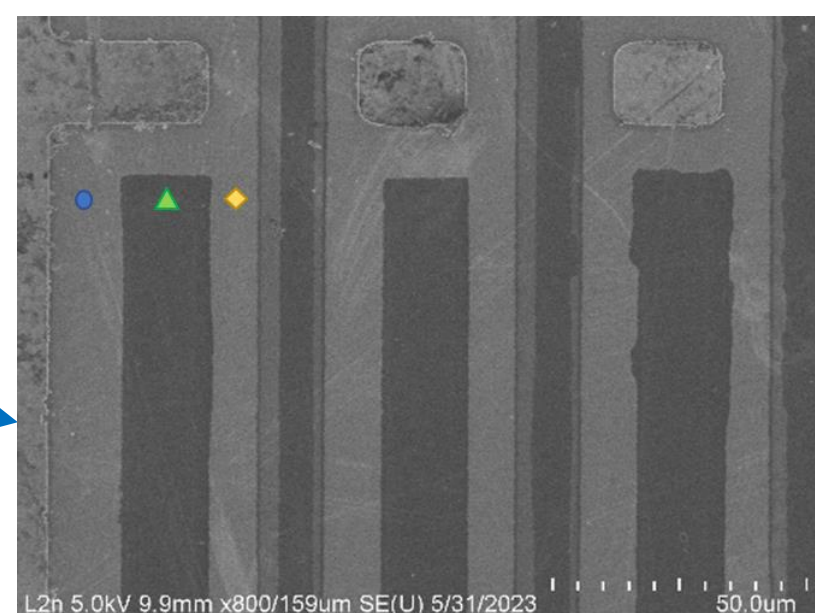
n-type JFET



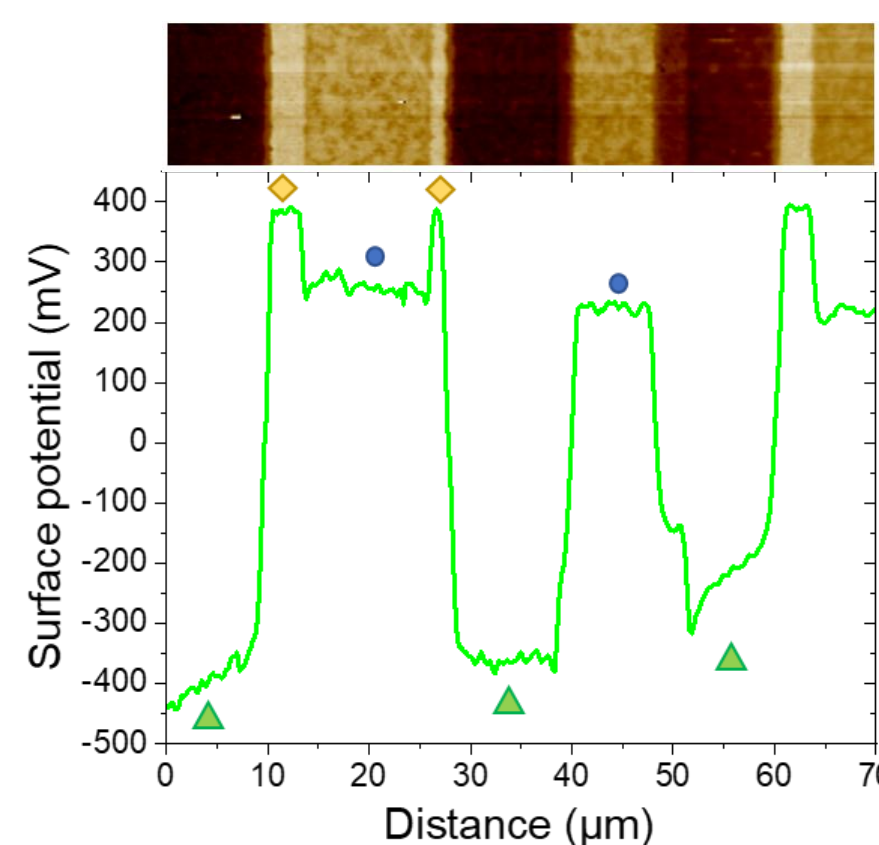
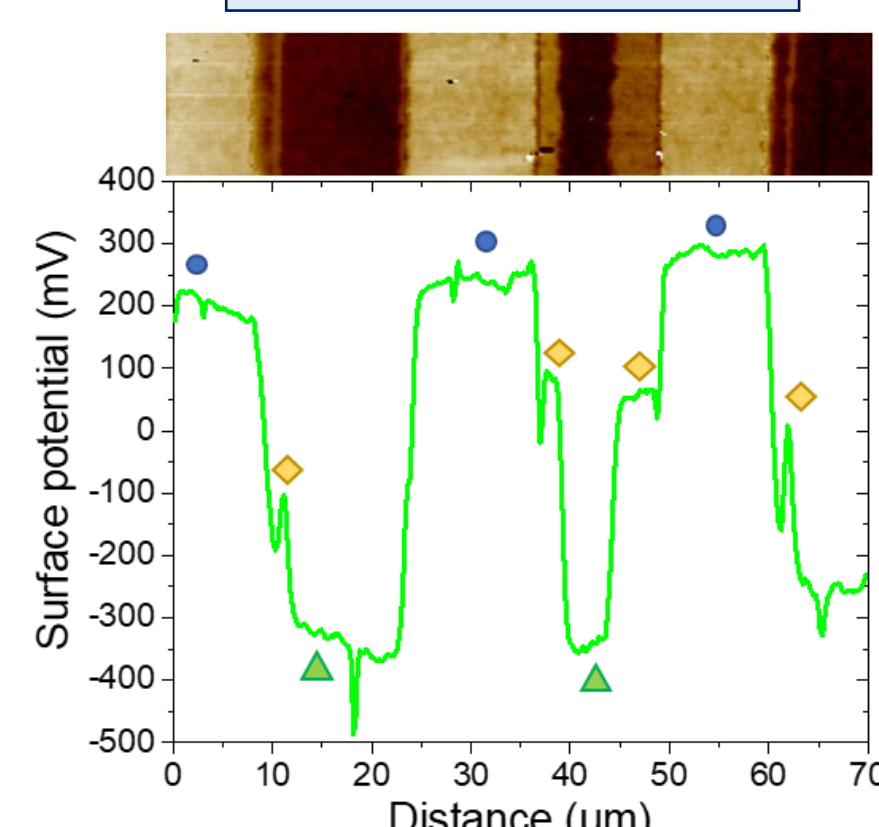
p-type JFET



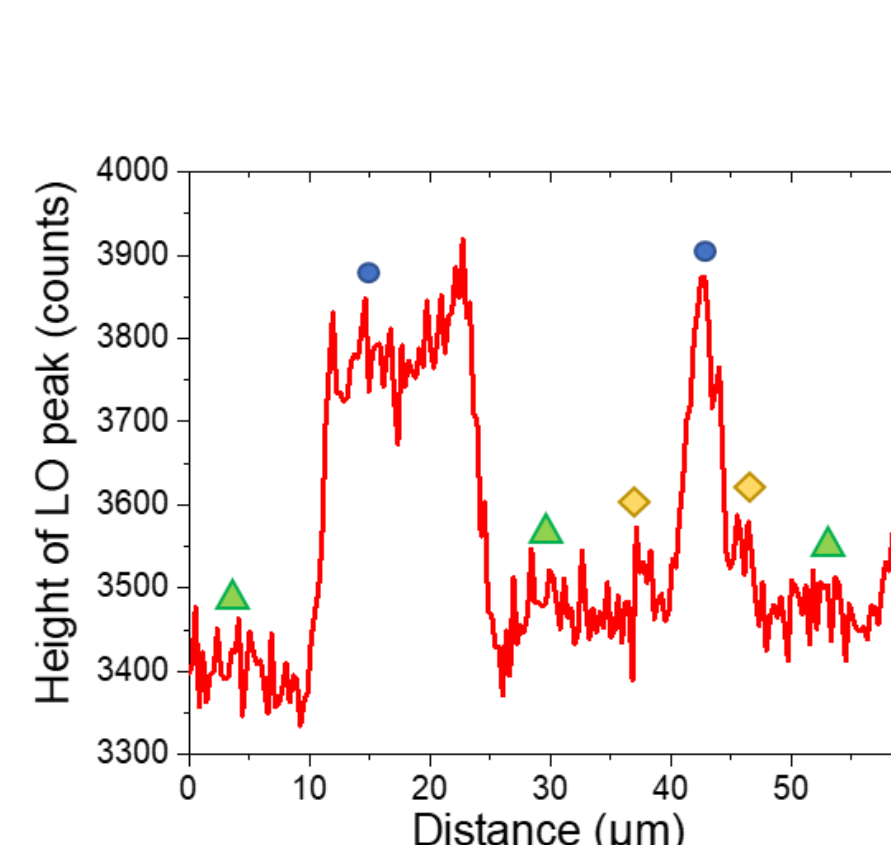
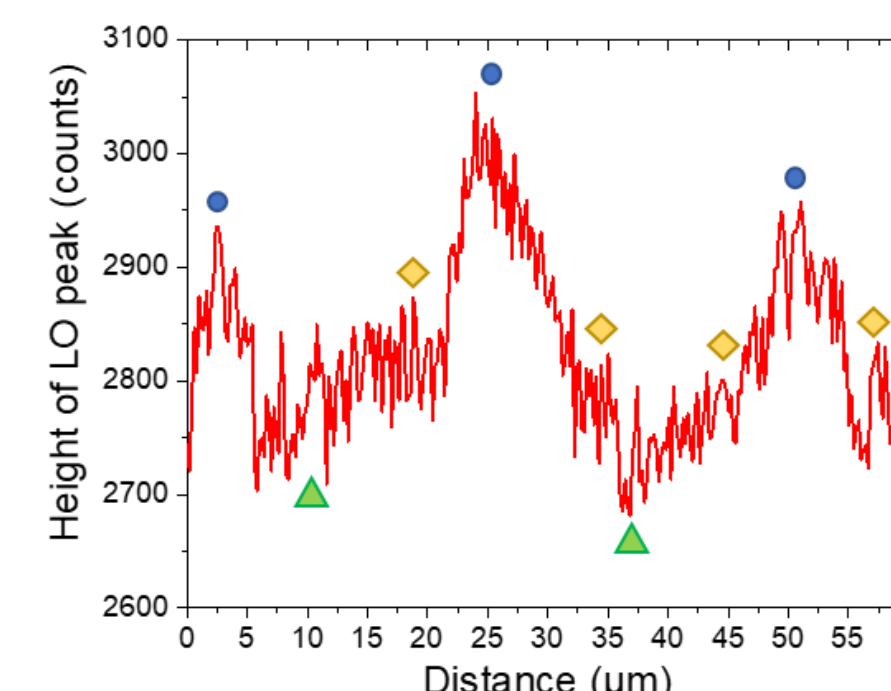
SEM images



KPFM



μ -Raman



- ▲ n⁺-type doping
- p⁺-type doping
- ◆ n or p-doped channel

- SEM : electric field due to the p-n junctions \rightarrow electrons attracted to n-type doping and repelled from p-type doping [8]
- KPFM : n-type doping \nearrow the Fermi level of 4H-SiC and so its work function $\searrow \rightarrow$ defect states in the bandgap can change the work function of 4H-SiC [7]
- μ -Raman : when doping \searrow , intensity \nearrow and width of LO peak $\searrow \rightarrow$ n-type doping affects more the LO peak than p-type doping. Laser penetrates in 4H-SiC a few μ m deeper and beyond the implanted area \rightarrow signal of the epitaxial layer disturbs the measurements [6]

Conclusion

SEM, KPFM, and μ -Raman characterization as a way to identify doping in semiconductor devices

- ✓ **Non-destructive methods**
- ✓ **Localization** of the differently doped areas
- ✓ **Monitoring** of the presence of high electric fields at the surface.
- ✗ **KPFM** : impacted by surface defects and the charges present in the material.
- ✗ **μ -Raman** : also dependent on the defects inherent to the material or created during the ion implantation doping process. Laser depth is not adapted for the investigation of thin 4H-SiC layers

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Acknowledgments

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