PROJETO INTEGRADOR DE 2º CICLO EM ENGENHARIA FÍSICA TECNOLÓGICA

Structural Characterization of Argon Ion Implantation Effects in 4H-SiC for Advanced Electronic Applications

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Research work performed at CTN (Campus Tecnológico e Nuclear)
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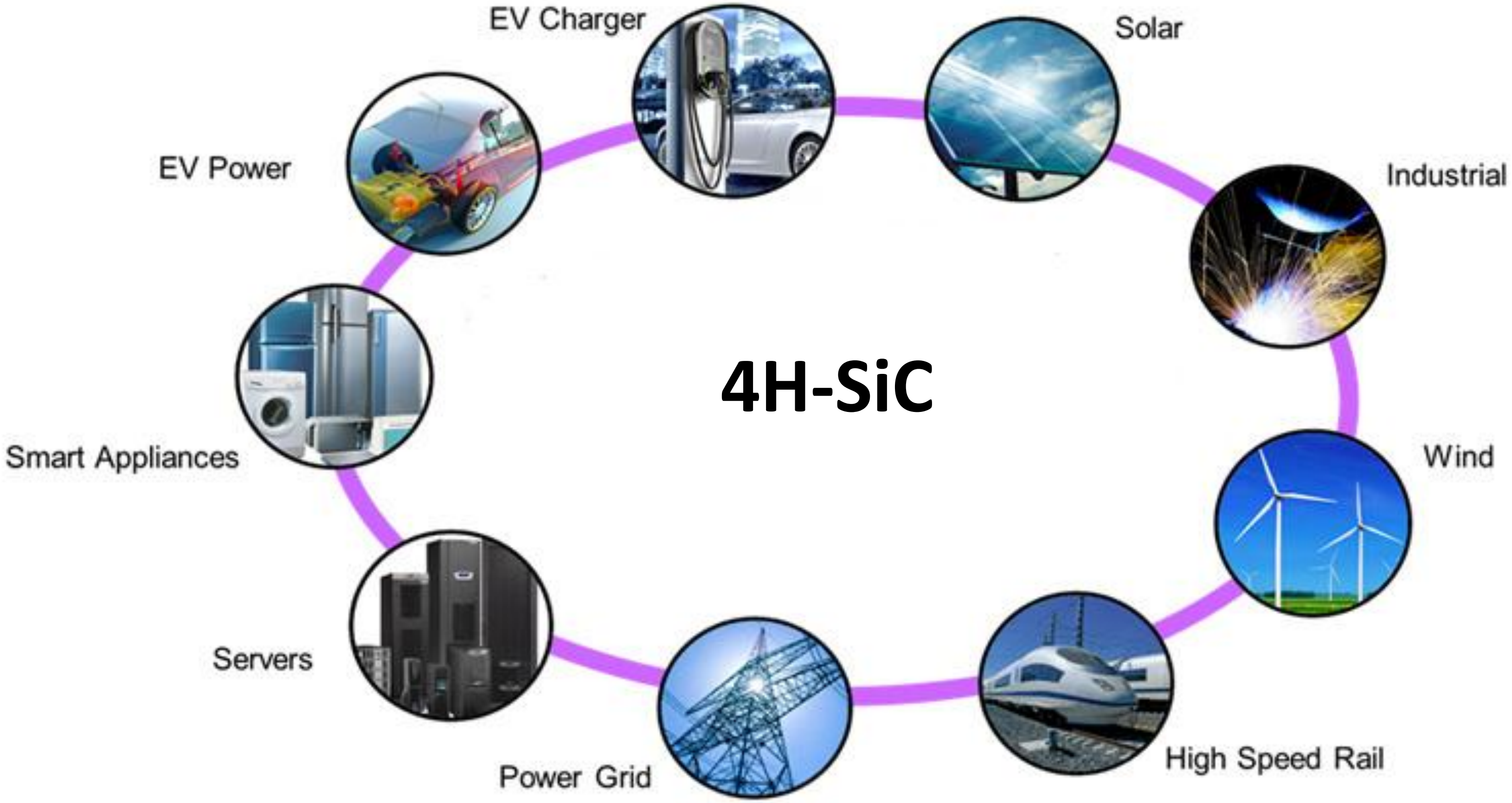


Promising alternative to Si semiconductors.

Has led to significant advancements in industries such as electric mobility, renewable energies, 5G systems and power conversion.

Widely implemented in the battery electric vehicle industry.

Ion Implantation in 4H-SiC

- Ion implantation is the standard method for doping SiC.
- Introduces lattice damage in the form of point defects, extended defects or even amorphization.
- **There is limited comparative work regarding ion implantation in different polytypes, particularly 4H-SiC and 6H-SiC.**

Previous studies:

Damage accumulation strongly depends on implantation parameters.

Strain accumulation increases proportionally with fluence but tends towards saturation at higher doses.

Formation of amorphous layers occurs at higher doses followed by significant recovery of the lattice after high temperature annealing.

This work aims to provide a comparison of damage accumulation and recovery in 4H-SiC and 6H-SiC,as well as both silicon and carbon faces of 4H-SiC.

Planned Experimental Work

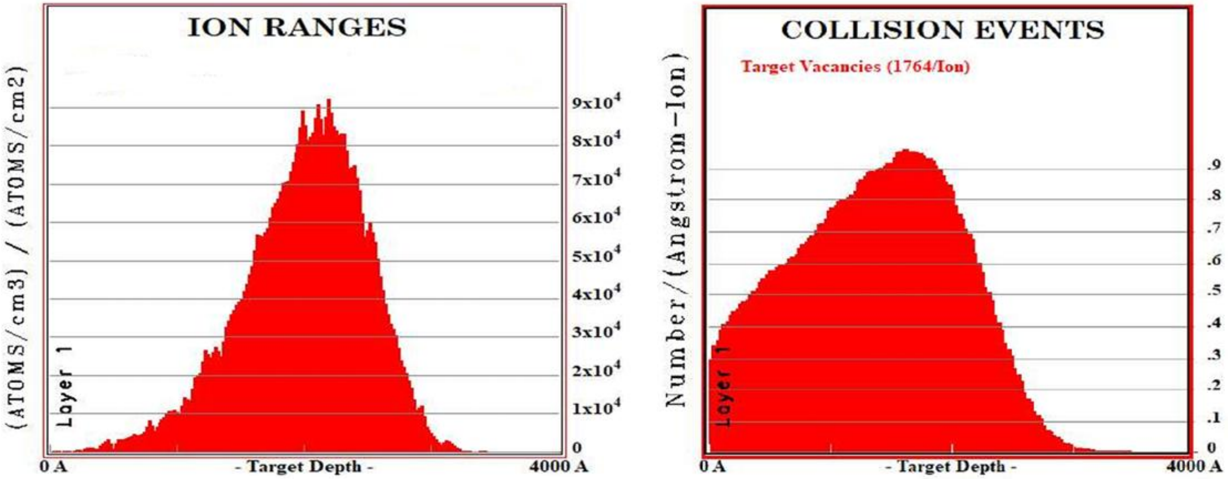
Implantation

Conditions:
- **Room temperature;**
- **300 keV argon.**

SRIM simulations indicate an **ion range of approximately two hundred nanometers,** with a damage peak located close to the end of range.

7 fluences ranging from **1 ×10^{13} and 1×10^{15} ions/cm^2**

Low-damage, intermediate-damage, and amorphous-layer formation conditions.



(A) Ion range distribution

(B) Vacancy depth profile

FIGURE: 4H-SiC SRIM simulations for ion range distribution and vacancy depth profile of 300 keV argon ion implantation.

Post-implantation Characterization

The samples will be characterized through two techniques:

- X-ray diffraction (XRD)

Study of defect formation and lattice distortion through variations in the positions and shape of diffraction peaks.

- Rutherford backscattering spectroscopy in channeling mode (RBS/C).

Study of lattice disorder by determination of the fraction of displaced atoms as a function of depth.

Post-implantation Thermal Annealing

Samples of 4H-SiC and 6H-SiC will be annealed at various selected temperatures, up to a maximum of 1000 ◦C. The annealing temperatures will be selected based on the extent of lattice damage.

Simulations

X-ray diffraction simulation using MROX

For each layer, the local strain and crystal quality are defined, and the total diffracted intensity is obtained by recursively combining the contributions of all layers.

The simulations account for the Cu Kα_1 and Kα_2 radiation components, as well as for the instrumental broadening.

Direct comparison between simulated and experimental results.

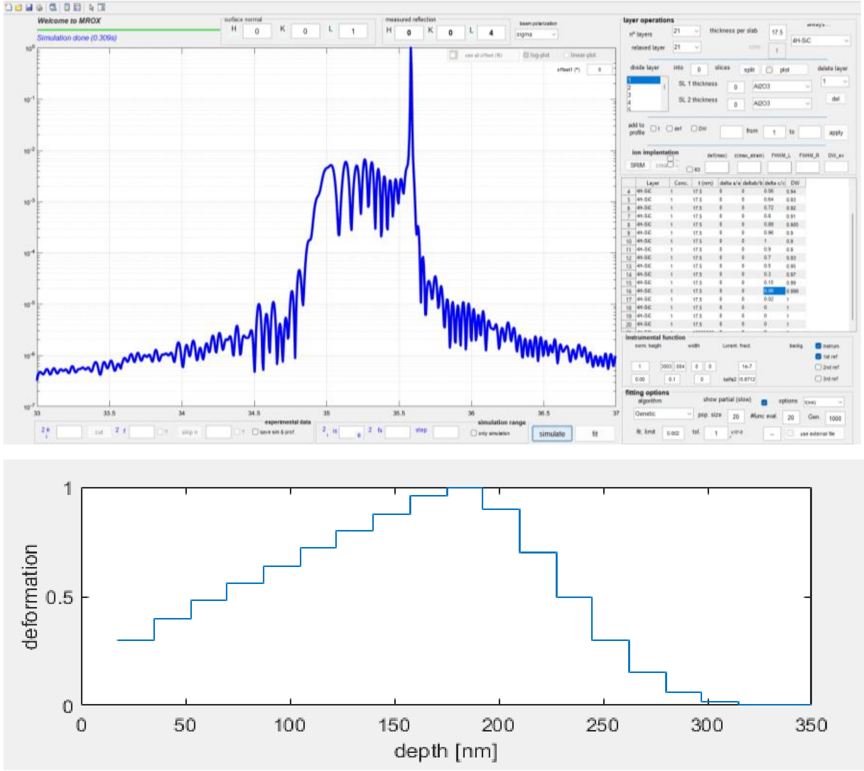


FIGURE: MROX software (S. Magalhães et al. “Compositional mapping of ion implanted damage in Al1−xGaxN via two step high-resolution X-ray diffraction simulation”. In: Physica Status Solidi– Rapid Research Letters 2500144 (2025))

Concluding Remarks

Focus of this work: **Structural characterization of ion implantation-induced damage in 4H SiC, with a comparative perspective between the silicon and carbon faces of 4H SiC and 6H-SiC.**

Preliminary results confirmed the high crystalline quality and structural consistency of the starting material.

The selection of implantation parameters was supported by previous studies and SRIM simulations.

Ion implantation using 300 keV Ar ions was designed to explore different damage regimes, ranging from low-defect densities to conditions approaching amorphization.

Experimental → HR-XRD and RBS/C characterization

Modeling → MROX simulations

The comparison between 4H-SiC and 6H-SiC under identical implantation and annealing conditions aims to clarify the influence of polytype on damage buildup and recovery mechanisms.