

# Ion irradiation for engineering superconducting properties in thin films

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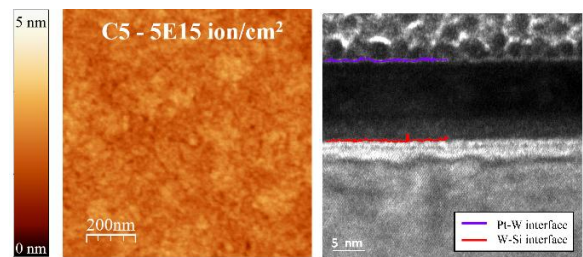
Thin-film superconductors offer a versatile platform for low-temperature devices, where performance is ultimately set by material properties such as critical temperature ( $T_c$ ), resistivity, and kinetic inductance [1,2]. Here, we investigate ion engineering as a post-growth, spatially selective method to tune these parameters and functionalize different regions within a single superconducting layer, enabling monolithic superconducting circuits with fewer interfaces and improved scalability. We present results on W films with thicknesses ranging from 10 to 50 nm, modified by Si and Ge implantation with energies between 5 and 35 keV and fluences from  $1 \times 10^{13}$  to  $1 \times 10^{17}$  ions/cm<sup>2</sup>. Implantations were performed both on large-area thin films using ion implanter and on micron-scale structures using a focused ion beam (FIB). SRIM/TRIM and TRIDYN simulations are employed to guide implantation conditions and to predict fluence-dependent damage, and compositional evolution. Structural and morphological characterization (AFM, HR-TEM) reveals irradiation-induced amorphization while preserving smooth interfaces (Fig. 1). Room-temperature and cryogenic electrical measurements demonstrate a systematic evolution of the superconducting transition as a function of ion fluence (Fig. 2). These results represent a starting point for selective ion irradiation as a powerful tool to locally functionalize different superconducting

device within a single thin film by tuning  $T_c$  and disorder-related transport properties. Finally, we present the design and simulations of first prototype devices, including a transition-edge sensor [3] and a kinetic inductance current sensor [4], fabricated using the modified materials and exploiting this ion-based engineering approach.

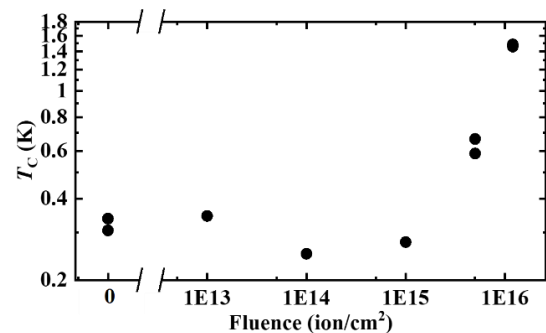
## References

- [1] I. Siddiqi, *Nature Reviews Materials*, vol. 6, no. 10 (2021) pp. 875–891.
- [2] Polini, Marco, *arXiv preprint arXiv:2201.09260* (2022).
- [3] C. Pepe, *PhD Thesis*, Politecnico of Torino (2024).
- [4] P. Szypryt et al., *Communications Engineering*, vol. 3, no. 1 (2024) p. 160.

## Figures



**Figure 1:** AFM image (left) and HR-TEM image (right) of the same ion-irradiated W thin-film sample, showing surface morphology and cross-sectional structure after implantation.



**Figure 2:** Evolution of the superconducting critical temperature of a W thin film as a function of increasing fluence of 5 keV Si<sup>+</sup> ion irradiation.