Recent Progress in Quantum Applications via the Q-One Single Ion Implantation System

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Quantum computing has the potential to revolutionize many aspects of modern technology, including digital communications, “quantum-safe” cryptography, and incredibly accurate time measurements. The development of this technology represents the next great frontier of science and engineering.

Devices based on single impurity atoms in semiconductors are receiving attention as potential quantum technologies and shown to be promising proof-of-concept.
However, such devices are incredibly challenging to manufacture, as single atoms must be placed within nanometric precision in isotopically pure host matrix such as ^{28}Si.

All working devices thus far have been fabricated using hydrogen lithography with an STM followed by atomic layer deposition. This is labor-intensive and requires several days of meticulous preparation to create just a single quantum bit (qubit). Real-world devices will require arrays of hundreds or thousands of impurity atoms, highlighting the requirement for a scalable method of positioning single atoms with nanometer precision.

In 2019, Ionoptika launched a new commercial focused ion beam (FIB) instrument specifically made for the fabrication of quantum materials and devices via single ion implantation, the Q-One.
With a continuously expanding range of available ion species, a high-resolution mass-filter system, high-precision stage and proven capability of single ion deterministic implantation with isotopic resolution, Q-One is, nowadays, the instrument of choice for Universities and Research Institutes.

During last year’s EIPBN Conference we reported on the overall Q-One performances and Liquid Metal Alloy Ion source development carried out at Ionoptika, since the instrument launch.
This year we will report on the results achieved with the Q-One instrument by different research groups. Due to the fact that the ion dose delivered to the sample can be adjusted across a wide range, providing many nanoscale material engineering capabilities in a single tool, examples of the Q-One use as a photolithographic tool[1], to achieve a ^{28}Si matrix[2], and single ion implantation will

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[1] M. Adshead *et al.*, Adv. Eng. Mater. 2023, 25, 2300889
[2] R. Acharya *et al.*, arXiv:2308.12471 [cond-mat.mtrl-sci]

be reported and discussed.

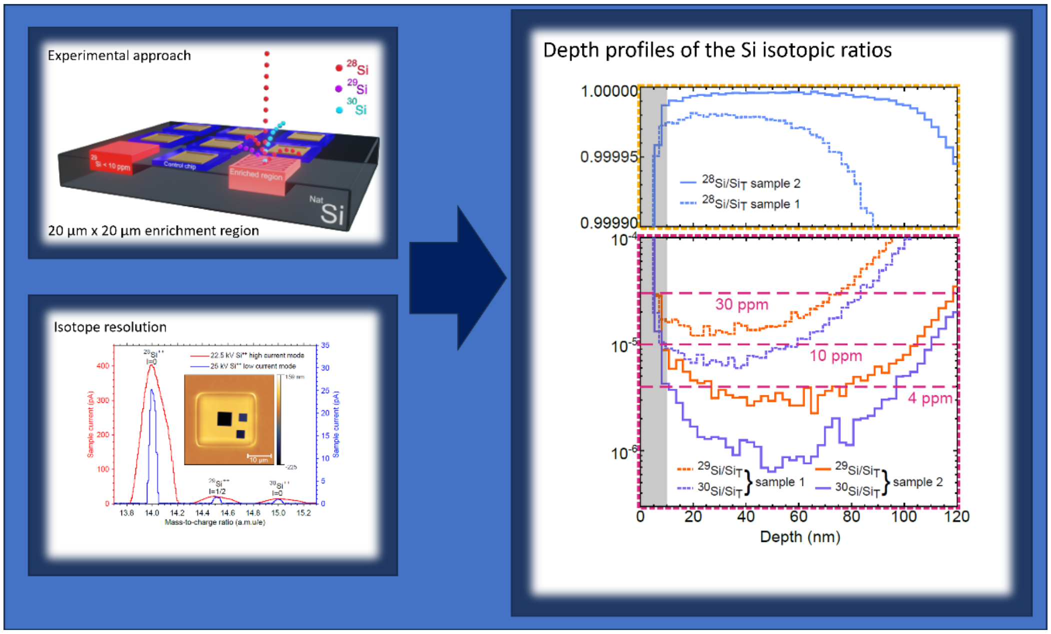

Figure 1: Localized ^{28}Si enrichment as reported In ref. [2] performed with a Q-One Implantation system (P-NAME).
Si^{++} Wien filter scans highlighting the isotopic mass resolution of the Q-One (P-NAME) tool.
NanoSIMS isotopic elemental analysis on isotopically enriched samples showing depth profiles of the measured isotopic ratios for each of the three silicon isotopes from samples 1 (dotted line) and 2 (solid line), which have been normalized by dividing each by $Si_T = {}^{28}Si + {}^{29}Si + {}^{30}Si$.