Towards a silicon semiconductor vacuum: donor spin coherence in isotopically enriched ^{28}Si from ultra-high fluence ion implantation

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Ion implanted group V donors in silicon is a promising platform for realizing scalable quantum computers [1]. One of the many advantages of using silicon is that its most abundant isotope, ^{28}Si, has zero nuclear spin and thus provides a “semiconductor (spin) vacuum” for donor spin qubits in silicon. Natural silicon, however, contains ~4.67% of ^{29}Si which has a non-zero nuclear spin. These naturally occurring ^{29}Si atoms give rise to local magnetic perturbations in bulk silicon and subsequently result in a greater degree of donor spin decoherence. In our previous work, we demonstrated isotopic enrichment of silicon surface layers by ultra-high fluence ion implantation of ^{28}Si ions (~ 10^{18} cm^{-2}) into natural silicon (^{nat}Si) substrates [2], thus providing a means of greatly diminishing this source of decoherence. Recently, we have also demonstrated the ability to fabricate large arrays (> 250) of individual near-surface dopant atoms using deterministic single ion implantation [3]. This addresses the issue of scale-up, which is one of the biggest challenges faced by the quantum computing research community. We are currently developing the technique of Electrically Detected Magnetic Resonance (EDMR) as a fast-turn-around process for measuring the quantum environment of the ^{28}Si enriched layer to assess the lifetime of donor electron spins, and the potential impact of residual defects and other factors for applications of the enriched material as a platform for realizing scalable quantum computers. This talk will first cover our previous and ongoing works on the isotopic enrichment of bulk silicon and silicon-on-insulator substrates, and deterministic single ion implantation of group V donors in silicon. The second part of this talk will focus on our efforts on performing EDMR measurements on devices fabricated from both ^{nat}Si and ^{28}Si enriched substrates implanted with group V donors. EDMR is an electrical technique that is widely used to study paramagnetic defects in semiconductors and has the advantage of providing the required high sensitivity for donor electrons in silicon without the need for sophisticated device architectures [4, 5]. Through pulsed magnetic resonance experiments, donor spin coherence times in our isotopically enriched ^{28}Si material can be extracted and will be compared directly to coherence times of donor spins in ^{nat}Si.

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