Detection efficiency enhancement for deterministic single ion implantation

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Techniques for deterministic implantation of single ions are currently of high interest for quantum technology applications such as single photon emitters[1,2] and solid-state qubits[3]. Here we present our capabilities for single ion implantation over a range of ion species into different target materials at different implant energies (<100keV) using a liquid metal alloy ion source (LMAIS) Ionoptika Q-ONE single ion implanter.

For some systems their low secondary electron (SE) yield can limit our ability to efficiently detect single ion implantation, and this therefore limits the number of error-free deterministic implants we can expect to achieve. We present on-chip ion beam induced charge (IBIC) detection for 25keV Bi+ and 50keV Bi2+ implantation into a Si device. The detection efficiency using IBIC is increased close to 100%. Although coincident SE detection was performed, the active substrate suppressed the emission of SEs such that the on-chip detection dominated.

SiO2 appears to be the target which gives consistently the best secondary electron detection efficiency. We therefore also investigate implantation through thin films of atomic layer deposited (ALD) SiO2 to enhance the detection efficiency of targets where on-chip detection may be incompatible.

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[3] M.T. Mądzik et al. 'Conditional quantum operation of two exchange-coupled single-donor spin qubits in a MOS-compatible silicon device', Nat Commun, vol. 12, p. 181 (2021).