Title
Improvement of brightness for multicusp-plasma ion source

Author
Standiford, K.

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Single Ion Implantation for Solid State Quantum Computer Development

T. Schenkel*, [1], D. H. Schneider[2], J. Meijer[1, 3], J. R. Kingsly[4], J. W. McDonald[2], J. P. Holder[2], and A. Persaud[1]
[1]E. O. Lawrence Berkeley National Laboratory, Berkeley, CA 94720
[3]Charles Evans and Associates, Sunnyvale, CA 94086
[4]Lawrence Livermore National Laboratory, Livermore, CA 94550

Several solid state quantum computer schemes are based on the manipulation of electron and/or nuclear spins of single ^{31}P atoms in a solid matrix (e. g., Si or Si_xGe_y hetero-structures) [1]. The fabrication of qubit arrays requires the placement of individual atoms with nanometer precision and high efficiency [2]. We are currently developing a low energy (<10 keV), single ion implantation scheme for $^{31}P^{q+}$ ions. When $^{31}P^{q+}$ ions impinge on a wafer surface, their potential energy (9.3 keV for P^{15+}) is released, and about 20 secondary electrons are emitted [3]. The emission of multiple secondary electrons allows detection of each ion impact with 100% efficiency. The beam spot on target is controlled by beam focusing and collimation. Exactly one ion is implanted into a selected area avoiding a Poissonian distribution of implanted ions. A schematic of the setup is shown in figure 1. Secondary electrons are detected in an annular microchannelplate detector. Spot size limiting apertures are formed in thin (~100 nm) low stress silicon nitride membranes by reactive gas assisted focused ion beam (FIB) milling with 30 keV Ga^+ ions. Figure 2 shows an aperture with a diameter of about 35 nm in a 30 nm thick SiN membrane. Preliminary data suggest an aspect ratio limit of FIB of about 4:1 for 200 nm thick membranes. One challenge for qubit array formation by ion implantation is dopant range straggling and diffusion during annealing. In figure 3 we show magnetic sector secondary ion mass spectrometry depth profiles from low dose (2.5E11 cm^{-2}), low energy (2 and 5 keV) $^{31}P^{1+}$ implants in silicon. Straggling can be minimized by reducing the implantation energy. We will discuss key issues of process integration (implant alignment, annealing and gate formation) for qubit arrays with control and readout structures for prototype multi-qubit devices.

Acknowledgments

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[3]permanent address: Department of Physics, Ruhr University Bochum, Germany

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* e-mail: T_Schenkel@LBL.gov

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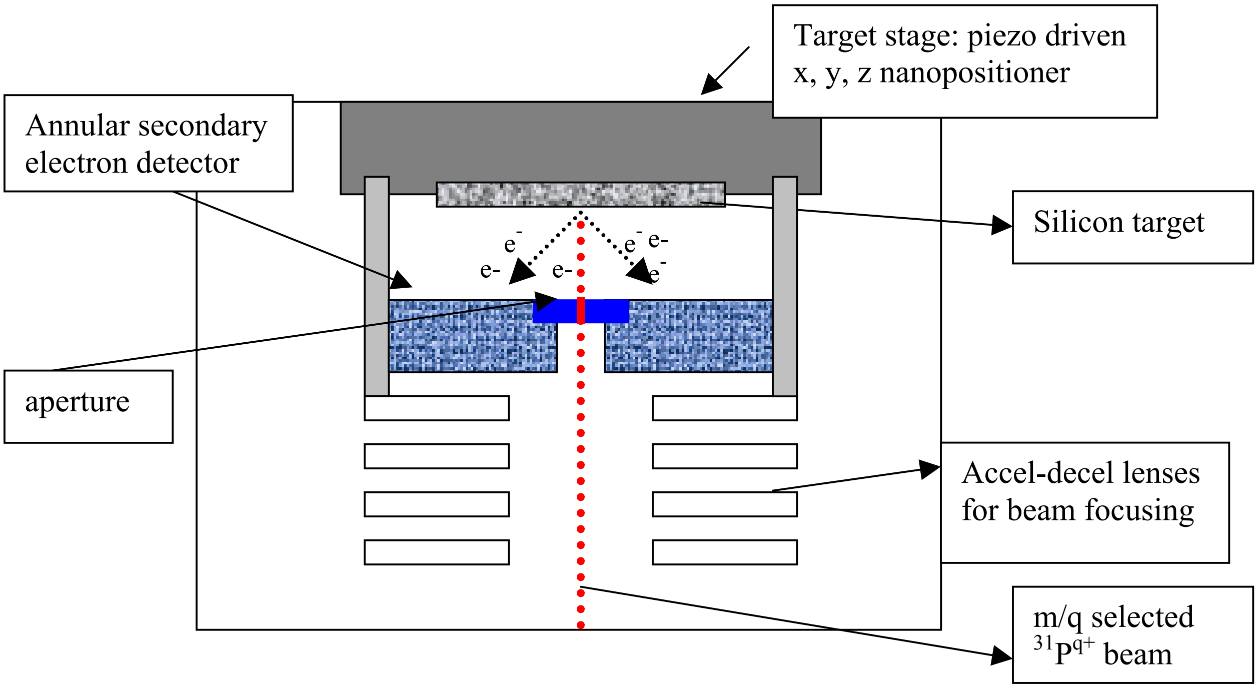

Figure 2.: Schematic of the single ion implantation system.

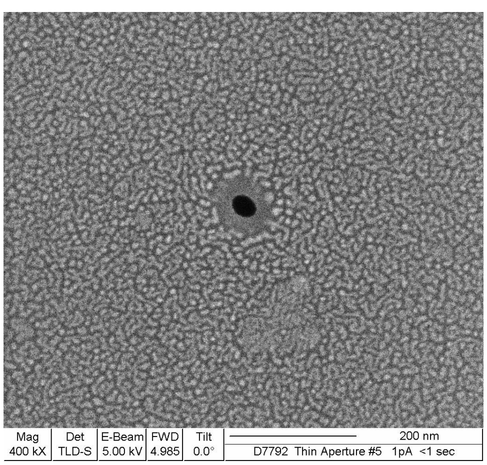

Figure 2: Example of a 35 nm wide test aperture from FIB drilling in 30 nm thick SiN membranes.

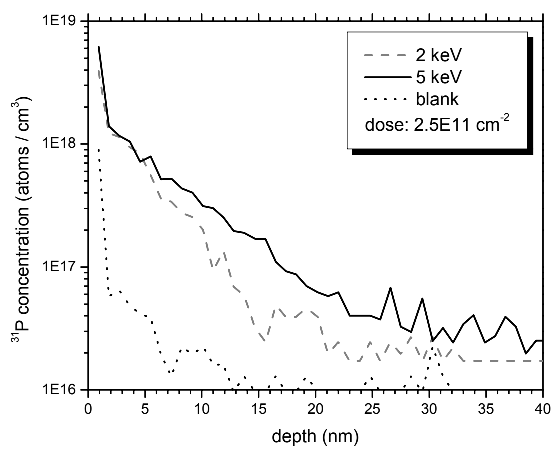

Figure 3: Magnetic sector SIMS depth profiles of low dose, low energy phosphorous implants in silicon.