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P83 - Geiger mode mapping: a new imaging modality for focused ion microprobes

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Geiger mode detector structures in substrates intended for the construction of single atom nano-scale devices leads to a new form of deterministic ion implantation. Single photon detection is possible in a solid state detector operating in Geiger mode where a single electron-hole pair can trigger an irreversible avalanche current that is quenched with a gated bias potential. Our detectors that exhibit this phenomenon are fabricated with an architecture based on the p-i-n diode structure and operated with a transient bias voltage that activates the Geiger mode. After the avalanche breakdown triggered by ion impact and diffusion of an electron-hole pair the device is quenched by removal of the transient bias voltage which is synchronised with a beam gate. Incorporation of such a device allows the exceptional sensitivity of Geiger mode to register an electron-hole pair from sub-10 keV donor atom implants needed for the deterministic construction of shallow arrays of single atoms only 10 nm deep in the substrate required for emerging quantum technologies. In this paper we describe the development of an imaging system for a nuclear microprobe system that allows micron-scale mapping of the Geiger mode zones fabricated into substrates designed for the development of quantum computer devices from deterministic sub-10 keV P ion implants. Our system exploits the large breakdown current in the device to remove the need for a pre-amplifier. It also incorporates a fast electrostatic ion beam switcher gated by the transient device bias, duration 800 ns, with a time delay, duration 500 ns, that allows for both the ion time of flight and the diffusion of the electron-hole pairs in the substrate into the sensitive region of the device following ion impact of a scanned 1 MeV H microbeam. We demonstrate images of the micron-scale Geiger mode zones in silicon substrates engineered with this ultimate-sensitivity detector structure.

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