Contribution ID: **211** Contribution code: **O-39** Type: **Oral**

Carrier lifetimes in high-lifetime silicon wafers and irradiation induced recombination centres

Thursday, 1 September 2022 15:20 (20 minutes)

Photoexcited muon spin spectroscopy (photo-μSR) was used to measure excess charge carrier lifetimes in passivated silicon wafers. Optically generated excess carriers interact with muonium centres via carrier exchange interaction and induce relaxation in the μSR time spectrum. The photo-μSR technique utilises this additional relaxation rate as a measure of the excess carrier density, which in turn enables us to measure carrier lifetime spectra by controlling delays between a muon and laser pulse [1]. In addition, the depth-resolved measurement can characterise carrier kinetics at specific depths within a Si wafer and enables us to separate bulk and surface recombination rates [2]. Based on these developments, we recently applied the technique to passivated Si samples with extremely long effective lifetimes (>1 ms) and observed that prolonged muon irradiation resulted in significant degradation of a measured lifetime [3]. Follow-up characterisation measurements, including deep-level transient spectroscopy, strongly suggested that beam damage generated defect-related recombination centres in bulk. Our results demonstrate an extremely rare case in μSR applications, where beam damage to crystalline lattice was clearly detected by virtue of high-lifetime Si wafers and, in turn, low native defect densities.
[1] K. Yokoyama, et al. Phys. Rev. Lett. 119, 226601 (2017); Appl. Phys. Lett. 115, 112101 (2019).
[2] K. Yokoyama, et al. Appl. Phys. Lett. 118, 252105 (2021).
[3] J. D. Murphy, et al. submitted to Journal of Applied Physics.

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Session Classification: Oral contributions

Track Classification: Semiconductors