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Using Positron Annihilation to Observe the Evolution of a System of Interacting Silicon Quantum Dots

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Silicon quantum dots (QD) stimulated to form excitons can decay by emitting a photon at a wavelength determined by it's size, or tunnel to another QD. Films of a-SiO2 on Si wafer were subject to (<1MeV) Si+ implantation and annealed to form QD in a dielectric matrix. The density of implanted Si+ is non-uniform with respect to depth into the film, as are the densities of ionizations and atomic dislocations caused by the stopping of the implanted Si+. This results in post-anneal distributions of QD size and QD-QD separation distances that vary with depth in an unpredictable way. The ionization and dislocation processes (radiation "damage"due to Si+ implantation) cause a variety of bonding defects in the local structure of a-SiO2. Annealing out the defects helps rearrange atoms to form QD but this is not fully understood, quantitatively. This study uses depth-resolved positron annihilation spectroscopy to observe the evolution of the defect distribution and QDs at each stage of production. Electron spin resonance (ESR) and x-ray absorption near edge spectroscopy (XANES) are used for identifying paramagnetic defects and phase quantification, respectively. Finally, these observations are correlated to the photoluminescent output of finished samples.

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