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Nanoscale mapping of strain variations in vicinity of Si/SiGe spin qubit devices by scanning X-ray diffraction microscopy

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Electron spins in Si/SiGe heterostructures are promising for large-scale integration of solid state qubits in a CMOS compatible material system. A key requirement for realizing large arrays of qubits with shared gate control is a high degree of homogeneity of the strain in the Si quantum well (QW) hosting the qubits. Local inhomogeneities in the crystal lattice affect the band structure the QW and the qubit properties. Here, we use Scanning Xray Diffraction Microscopy (SXDM) to investigate non-destructively the lattice homogeneity in a qubit device based on a Si/SiGe heterostructure. We quantify all components of the strain and rotation tensors by combining SXDM datasets and find local variations on the order of 1e-4. These fluctuations are assumed to be caused by dislocation bunching and the thermal contraction of the gate electrodes. The data is compared to thermomechanical simulations showing a complex depth profile of elastic interaction. We find that the resulting variations of the electron band structure are on the same order of magnitude as the typical charging energy of an electrostatic quantum dot of ca. 1 meV. This indicates that structural inhomogeneities must be taken into account in the optimization of a SiGe-based qubit architecture for quantum computing.

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