Multiplexed characterisation and automatic tune-up of 45 SEB + DQD unit cells in Si MOS for device process control

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As arrays of spin qubits based on semiconductor quantum dots (QDs) continue to scale, a detailed understanding of device variability is required to accurately design large quantum processors. For that purpose, QD characterisation at scale has gained increasing attention in the field by making use of cryowafer probers (Si/SiGe), as well as cryogenic time-domain multiplexing (Si FDSOI) and device matrix arrays using shared control (Ge). In this work, we present a quantum device matrix array (QDMA) fabricated using a 300 mm wafer metal-oxide-semiconductor process to enable device statistical characterisation. The unit cell consists of a radiofrequency single-electron box (SEB) charge sensor and a double quantum dot (DQD) in a linear topology featuring control of all tunnel barriers. Sequential access to individual cells is achieved by an on-chip multiplexed gate layout fabricated using just three polysilicon gate layers while high frequency signals are delivered through integrated circuit high-frequency multiplexers. We present QDMAs with up to 45 unit cells testable in a single cool down, the largest number for any matrix array to date. We make use of probabilistic machine learning techniques to develop protocols for automatic tuneup of the SEBs, followed by tuning the DQD into a pre-defined electron occupation. These protocols are designed to minimise the required measurements needed to tune-up the electron occupation of the device. In particular, Bayesian Optimisation is used for efficient SEB tune-up, while Bayesian changepoint detection is employed to robustly load electrons into the adjacent double quantum dot cells; building on this framework, we are now extending these techniques to automated Pauli spin blockade (PSB) tune-up.We characterise the QDs in terms of their lever arm matrix, addition energies, tunnel rates and coupling and compare the measurements with simulations of the unit cells. Having developed an automatic SEB + DQD tune-up routine, we are well positioned to study spin qubit dynamics at scale.