An isolated charge qubit in silicon

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We present the fabrication and DC electron transport measurements on a single-island single-electron transistor (SET), capacitively coupled to an isolated double quantum dot (IDQD) and control gates, realized in highly doped silicon-on-insulator (SOI) material (Fig. 1). The structure was fabricated using high-resolution electron beam lithography and reactive ion etching (RIE). Such trench-isolated double quantum dot systems are strong candidate charge-qubits for an eventual silicon-based solid-state quantum computer. [1]

All dots have a lithographically defined diameter of 50 nm, which increases to around 60 nm after thermal oxidation. This process passivates the surface states and reduces the electronic diameter of each dot to less than 30 nm. The tunnel barriers are formed through a lithographically defined constriction of 20 nm between the dots, which is small enough that all dopant atoms at the constriction are inactive due to surface depletion. The electronic dimensions of the dots result in a small capacitance between them, and between the SET dot and its leads. The small dot size also means that we are at most dealing with a few dopant atoms on each dot, implying that under normal operation temperatures (T = 4.2 K) the device operates in the regime where single-electron charging effects play a major role, unlike similar isolated systems with larger islands.[2]

In order to operate an IDQD as a charge qubit, one must be able to exploit polarization states, and set-up superposition of those states, using externally applied fields at the appropriate timescales determined by their energy-separation. Thus a first step in experimentation is to determine the charging energies of the dots. Fig. 3 shows a stability diagram of the SET as a function of V_{SD} and V_{G4}. The data asserts a Coulomb charging energy for the SET of E_C^{SET} ? 5 meV .

No direct electrical measurements can be made on the IDQD, however it is possible to indirectly measure its polarization through a capacitively coupled SET, as the conductance of the SET is highly sensitive to small electric fields and can be used as a sensitive electrometer. We present the results of these measurements and discuss the use of these structures as silicon qubits.

[1] P A Cain, H Ahmed, and D A Williams, Appl. Phys. Lett., **78**, 3624 (2001)
[2] E. G. Emiroglu, D G Hasko, and D A Williams, J. Vac. Sci. Technol. B, **20**, 2806 (2002)

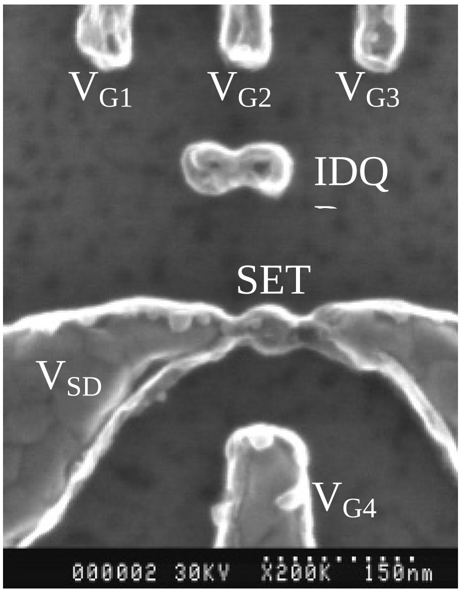

Fig 1: SEM micrograph of the fabricated device, with the isolated double dot capacitively coupled to a connected single dot.

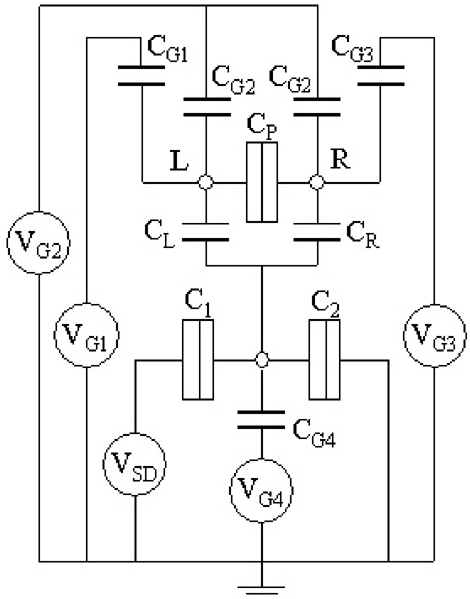

Fig 2: Simplified schematic circuit diagram of the device. Cross-capacitances have been omitted for clarity.

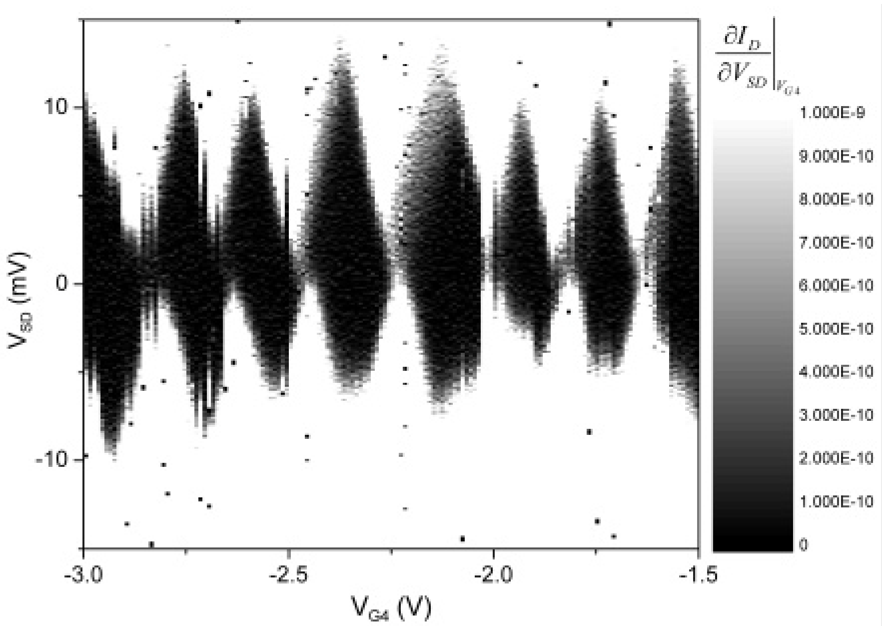

Fig 3: Differential current stability diagram of the single quantum dot electrometer at 4.2K. The device exhibits Coulomb blockade within the black regions. Each Coulomb diamond corresponds to the addition of an electron to the SET-island as V_{G4} becomes more positive.