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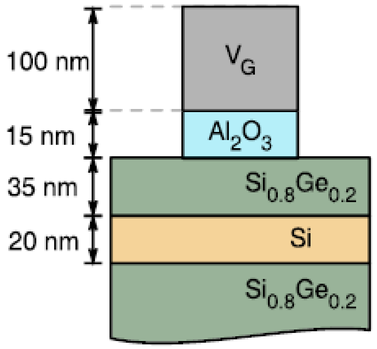
Enhancement-mode two-channel triple quantum dot from an undoped Si/$Si_{0.8}Ge_{0.2}$ quantum well heterostructure

Si / $Si_{0.8}Ge_{0.2}$ heterostructure



Schematic cross-section of the measured FET.

In most of the reported dot designs, the starting Si/SiGe heterostructure has a Ge concentration close to 30%, and the gates used to define the quantum dots are structured in multiple metal layers.

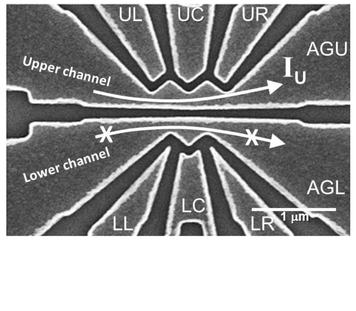
We used undoped Si/$Si_{0.8}Ge_{0.2}$ heterostructures grown by Lawrence Semiconductor Research Laboratory. A virtual substrate was made by growing a 2-Imlinearly graded buffer layer on a Si wafer at a grading rate of 10%/Im, followed by a 1-Im$Si_{0.8}Ge_{0.2}$ relaxed buffer layer. Chemical mechanical polishing (CMP) removed 150nm of the relaxed buffer layer to reduce the surface roughness. After CMP, epi-layers of 400nm $Si_{0.8}Ge_{0.2}$, 20nm Si, 35nm $Si_{0.8}Ge_{0.2}$,and 3nm Si were grown in order. The heterostructures were processed in the Si foundry at Sandia National Laboratories.

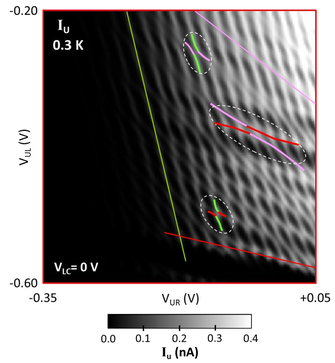
The fabrication process flow presented here uses only a single metal-gate layer, which greatly simplifies device fabrication, shortens device turnaround times, and improves yield by avoiding potentially leaky metal-insulator-metal stacks.

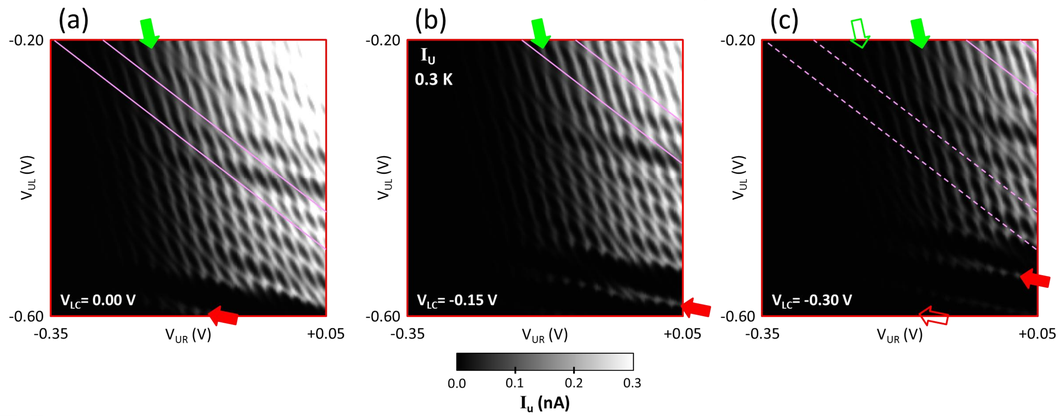
Transport through tunnel coupled triple quantum dot

- Current measured through upper double quantum dot tunnel coupled to lower single quantum dot which is energized even though lower channel is non-conducting.

- A typical charging diagram of the device with three quantum dots energized in the many-electron regime. Three distinctive slopes can be identified in the charging diagram.

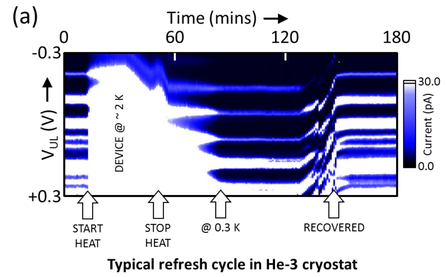




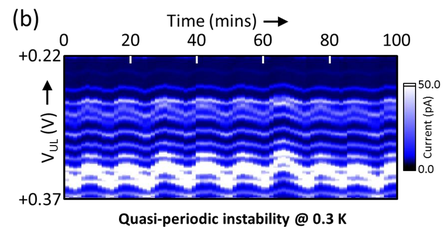


Examples of observed instabilities of Coulomb blockade peaks

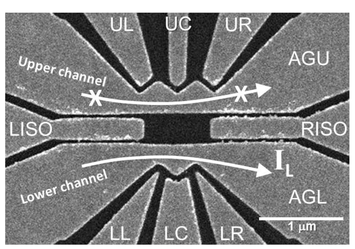
A stable temperature environment is preferable. During refresh cycle in He-3 cryostat drifting and metastability occur. And even at base temperature quasiperiodic instabilty can occur.

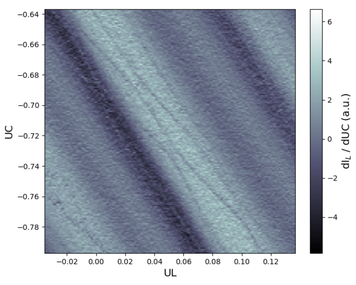


Typical refresh cycle in He-3 cryostat



Quasi-periodic instability @ 0.3 K





Charge detection of double quantum dot

- Modified designs are intended to improve channel isolation and enhance control of quantum dots in single-electron regime.

- A typical charging diagram of the device with three quantum dots energized in the many-electron regime. Three distinctive slopes can be identified in the charging diagram.

Conclusion

-Enhancement-mode Si/Si0.8Ge0.2 QD devices characterized.

-Single and double quantum dots formed and charge sensing demonstrated.

-Tunnel coupled triple quantum dots in a ring formed.

-Technological issues related to device stability identified.