Towards Hole Spin Qubits in Strained Ge/SiGe Quantum-Well Heterostructures

Gonzalo Troncoso [1]
E. Kiyooka,[1] C. Tangchingchai,[1] S. Zhilmann,[1] B. Brun-Berriere,[1] V. Schmitt,[1] F. Lefloch,[1] J-M. Hartmann,[2] S. de Franceschi,[1] R. Maurand,[1]

1) Univ. Grenoble Alpes, CEA, IRIG-Pheliqs, Grenoble, France.
2) CEA, LETI, Grenoble, France.
gonzalo.troncosofernandez-bada@cea.fr

A strained germanium quantum well sandwiched between relaxed SiGe barriers can host a high mobility two-dimensional hole gas (2DHG). The low in-plane effective mass and the large spin-orbit coupling make this hole system a good candidate for quantum devices [1]. It has been used to demonstrate spin qubits [2,3] as well as Josephson field-effect transistors [4].
Here, we report the realization of quantum dot devices starting from SiGe heterostructures RPCVD-grown on 200-mm Si wafers using direct grading of the SiGe buffer (i.e. Ge concentration increasing from zero to 79%). In the investigated heterostructures the strained Ge quantum well has the same thickness (16 nm) but different depths, ranging from 22 to 55 nm. Our fabrication process consists of several steps of UV and electron beam lithography, Ion Coupled Plasma etching (ICP), Atomic Layer Deposition (ALD) and Electron Beam Metal evaporation (EBM).

At low-temperature (4 K), we measure hole mobilities as high as 10^5 cm^2/Vs for carrier densities of $3x10^{11}$ cm^{-2}. Preliminary measurements in devices with two-level gate structures (e.g. see Fig. 1) show Coulomb-blockaded hole transport and characteristic signatures of quantum-dot physics (e.g., see Fig. 2).

References

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[3] Daniel Jirovec. Nat. Mat. 20, 1106-1112 (2021)
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Figures

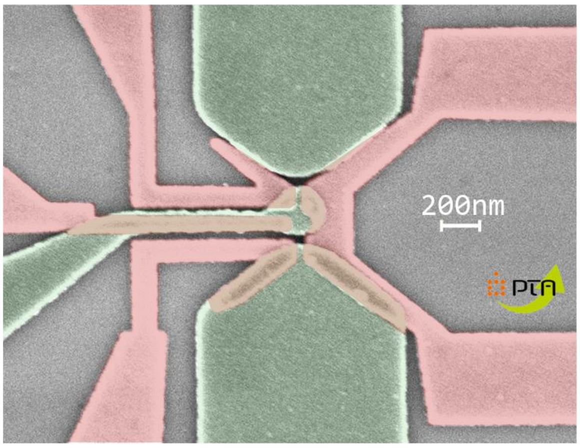

Figure 1: Colorized SEM picture of a single dot device. Red(green)-color structures correspond to the first (second) gate layer.

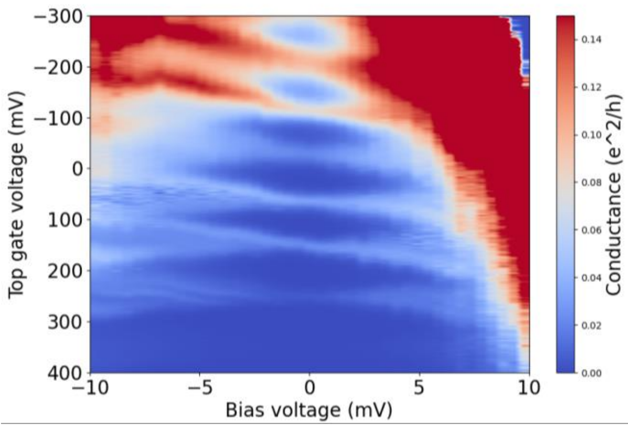

Figure 2: Coulomb diamonds for a single dot. Extracted charging energy is 5.4meV which gives an approximately dot size of 15nm.