Single Hole Transistor in a Conventional Silicon Metal-Oxide-Semiconductor Structure

R. Li[1], F. E. Hudson[2,3], A. S. Dzurak[2,3], and A. R. Hamilton[1]

[1] *School of Physics, University of New South Wales, Sydney NSW 2052, Australia*
[2] *Australian National Fabrication Facility, University of New South Wales, Sydney NSW 2052, Australia*
[3] *Centre of Excellence for Quantum Computation and Communication Technology, School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney NSW 2052, Australia*

Over the past 15 years much effort has gone into the development and study of electron quantum dots as artificial atoms, ultra-sensitive electrometers, and quantum bits for quantum information applications. To operate as a spin qubit requires a long spin coherence time T_2, which in GaAs and standard Si is limited by the hyperfine interaction between the electron spin and nuclei in the host crystal. Recently hole quantum dots have attracted significant interest since the strong spin-orbit coupling allows all electrical spin manipulation, while the hyperfine interaction is significantly reduced by the lack of overlap between the p-wave hole orbitals and the nuclear spins, promising longer T_2 times [1]. However to date there have been few studies of holes in gate defined quantum dots [2, 3].

In this work, we report the first study of a planar silicon metal-oxide-semiconductor based single hole transistor. The device was fabricated using standard silicon processing techniques on a silicon substrate with a 5.9 nm gate-oxide. Electron beam lithography was used to define multilayer gates separated by AlO_X [4], shown schematically in Fig.1 (a). The $\sim 40 \times 40$ nm^2 dot is formed underneath plunger gate P1. Fig. 1 (b) shows the conductance as a function of gate bias on P1 taken in a dilution fridge, with clear Coulomb Blockade oscillations demonstrating the operation of the single hole transistor. Fig. 1 (c) shows the Coulomb diamonds obtained in source-drain bias spectroscopy measurements. As V_{P1} is made more positive the diamonds open up and the charging energy increases to ∼10 meV, suggesting that we are approaching the last few holes in the dot. Excited states could be resolved, which confirms that the device is in the few hole regime. A second hole dot could be induced by changing the bias on gate P2, with the charge stability diagram showing coupling between the two dots.

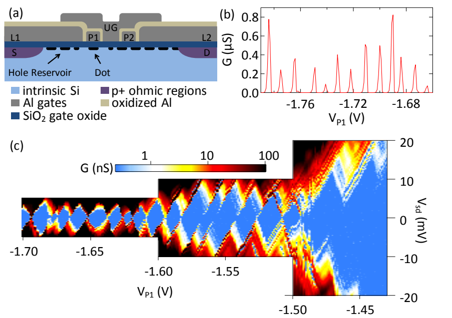

Figure 1: (a) Schematic cross section of the device, showing the hole dot under gate P1. (b) Conductance trace shows periodic Coulomb blockade oscillations. (c) Source-drain biasing shows Coulomb diamonds down to the last few holes, with excited states visible.

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