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Spectroscopy of Few-Electron Quantum Dots in Silicon[1]

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Valley states in Si offer interesting opportunities for new physics through their interaction with spin and orbital states. At the same time, such valleys could in principle create undesired decoherence pathways in quantum devices. Recent advances have allowed new experiments studying these effects. Here we report measurements of few-electron quantum dots in Si quantum wells. Both the Kondo and Fano effects are found in this system. Valley states, if their splitting is small, would produce additional peaks in the non-linear conductance - a feature not observed in the experiments. We propose that their absence is due to enhanced valley splitting in Si quantum dots compared with quantum wells (where measurements have long shown very small splitting). We experimentally confirm such large valley splitting in Si nanostructures by performing measurements of Si quantum point contacts. We find valley splittings of order 1 meV, comparable to the largest predicted theoretical values, and much larger than numerous experiments, by ourselves and others, on laterally unconfined 2DEGs. We offer an explanation based on the role of steps and disorder at the quantum well interface. Finally, building on this understanding of the role of disorder, we discuss recent advances in silicon membranes that offer new ways to create quantum wells with lower disorder. Si membranes with thicknesses as thin as one hundred nanometers and lateral widths as large as a centimeter have been achieved. We discuss their application as hosts for quantum wells and as an enabling technology for the formation of Si/SiO2/Si multilayers in which all Si layers are single crystal. Work performed in collaboration with L.M. McGuire, C. Simmons, N. Shaji, K.A. Slinker, S. Goswami, L.J. Klein, W. Peng, M.M. Roberts, J.O. Chu, R. Joynt, M. Friesen, S.N. Coppersmith, R. Blick, M.G.Lagally, and D.E. Savage.

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