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Single-donor transport in silicon: Atomic physics in restricted momentum space[1]

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Technology reached a level of miniaturization where we can realize transport through a single dopant atom in a transistor. Such transport spectroscopy can probe the atomic orbitals and the interaction of the atom with the environment. This interaction with the environment in a nano-device leads alters the dopants properties, such as the level spectrum and the charging energy, from those of the bulk. The system discussed here is a gated arsenic donor in a silicon field effect transistor. Electronic control over the wavefunction of dopants is one of the key elements of quantum electronics. This talk focuses on the role of the restricted momentum space which has a severe impact on the charge and spin configuration of a donor atom in a nano-device. The combined experimental and theoretical study of the gated two-electron state of the donor led to the realization of the pseudo spin nature of the valleys. We observe a blocked electronic relaxation due to combined spin and valley selection rules. Time averaged transport measurements put a lower bound of 50 ns on the rate of the blocked transition, 1000 times slower than a bulk transition. For the low lying excited states Hund's rule is violated due to vanishing exchange in orthogonal valleys. Furthermore, we observe reduced charging energies and bound singlet and triplet excited states for this negatively charged donor that can be explained in the self consistent tight binding model. Finally, experiments demonstrating coherent coupling between two donors and between a donor and the leads will be discussed.

[1]In collaboration with G.P. Lansbergen, R. Rahman, J. Verduijn, G. C. Tettamanzi, N. Collaert, S. Biesemans , G. Klimeck, and L.C.L. Hollenberg.