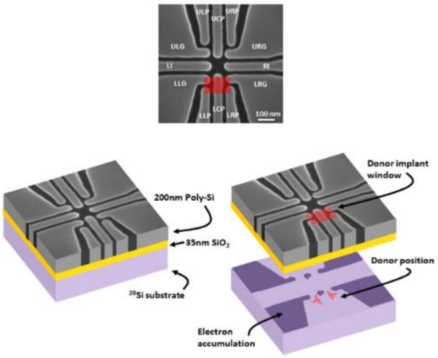
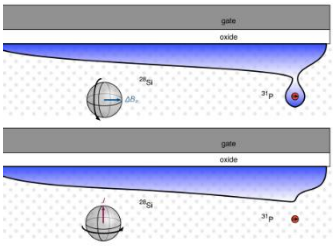
Donor Quantum-Dot Coupled Quantum-Bits

Malcolm Carroll, Sandia National Laboratories, Albuquerque NM



There are numerous efforts to develop quantum bits (qubits) for quantum computing. Silicon is recognized as an appealing material system because, for example, it offers a low decoherence environment for spin qubits combined with its historical foundation in computer chip fabrication. Donors in silicon have been proposed as qubits and promise very high fidelity operation, uniformity (i.e., every donor is the same) and extraordinarily well protected idle/memory (i.e., nuclear spins). However, placement, read-out and coherent control of single donors has been notoriously challenging. To date, it has been demonstrated in only two groups in the world, one of which is the Sandia National Lab quantum information, science and technology (QIST) group. At this time a central question is how to couple donor-based-qubits.



In this talk I will discuss high quality MOS lithographic quantum dots and the first demonstration of coherent coupling of a MOS quantum dot to a single ^{31}P donor. This is a key step towards the realization of a long sought general goal of many donor device architectures, to mediate entanglement between two donors using lithographic quantum dots at the interface. Furthermore, using a donor as one of the wells of a canonical double quantum dot system, this two object system forms a new singlet-triplet (S-T) electron qubit configuration, a common electron qubit encoding formed from double quantum dots. This S-T qubit is a potentially very fast and much higher fidelity electron qubit. The approach reduces lay-out complexity compared to other S-T qubits because it relies on only a single MOS quantum dot, instead of two, and provides a reliably repeatable gradient field specific to the donor species without the need for continuous pumping and monitoring of the background nuclear spin bath as is done in GaAs. References: Harvey-Collard et al., arXiv:1512.01606 & Rudolph et al., IEDM 2016

Dr. Malcolm Carroll completed a Bachelor's degree in Engineering Physics from the University of Illinois. From 1994 to 1995 he was a Fulbright fellow at the Johannes-Guttenberg University of Mainz, Germany, working on Monte-Carlo simulation of spin phase transitions. In 2001 he received a Ph.D. in Electrical Engineering from Princeton University for thesis work on scaling of silicon nanostructures. He joined the semiconductor division of Bell Labs/Lucent Technologies at Murray Hill, NJ, which subsequently became Agere Systems in 2002, where he worked on Ge detector integration with CMOS electronics. The results were later used by a start-up company called Noble Peak Vision. He is now a distinguished member of the technical staff at Sandia National Laboratories. His most recent research has centered on materials, device physics and cryogenic circuits for quantum information science (QIS). This includes a world first demonstration of coherent spin manipulation of a MOSFET quantum-dot qubit with a single-donor-atom qubit. He is presently the technical director for silicon quantum computing at Sandia National Laboratories. Dr. Carroll has been a first- or co-author on over 85 peer reviewed articles with an estimated 950 citations. He is also a coauthor of 6 patents.