INSIGHT SEMINAR - Hole spin qubit in silicon: enhanced coherence and coherent coupling to microwave photons

ROMAIN MAURAND

February 08, 2024
12:00 to 13:00
Seminar Room

Semiconductor spin qubits based on spin-orbit states stand as promising candidates for quantum information processing. In particular, owing to the spin-orbit interaction (SOI) of valence states, hole spins in silicon and germanium are responsive to electric field excitations [1,2], allowing for practical and fast qubit control. This spin-electric response is intimately link to the complex and rich spin-orbit physics. Here I will report on our last efforts leveraging spin-orbit interaction of hole spin in silicon devices produced on a semi-industrial 300mm CMOS foundry [3]. First, I will demonstrate how SOI turns into an asset to engineer mixed spin-charge states in a double quantum dot able to couple strongly with microwave photons. In an hybrid spin cQED platform we reveal a hole spin-photon coupling of 300 MHz largely exceeding the combined spin-photon decoherence rate leading to a cooperativity above 103 [4]. This coupling exceeds the best figures reported so far for electrons in silicon [5,6] and opens the cQED quantum tool box to spin-orbit qubits. Secondly, due to their spin-electric susceptibility, spin-orbit qubits may be vulnerable to electrical noise, which explains the relatively short coherence time reported so far. In a second part, I'll focus on the existence of preferential magnetic field orientation at which a spin-orbit qubit is decoupled from charge noise while keeping its efficient electrical control [7]. To this end, we experimentally achieve a complete characterization of the hole spin gyromagnetic tensor and its susceptibility to electric fields by coherent manipulation techniques. It evidences a strong dependence on the external magnetic field orientation, and reveal optimal operation points at which the longitudinal spin-electric susceptibility is minimal. At these optimal points, we measure a Hahn-Echo decay time in the order of 100 microseconds maintaining Rabi frequencies in the MHz range [8]. All together, the coupling to microwave photon and the ability to hide from charge noise make hole spin in silicon an attractive platform to further develop semiconductor spin qubit-based quantum information processing.

Hosted by Prof. Dr. Adrian Bachtold

BIO:

Romain Maurand is a research director at CEA Grenoble, France. He received his PhD from Grenoble Alpes University in 2011. His graduate research focused on carbon nanotube-based quantum dots in nanoSQUID in the group of Wolfgang Wernsdorfer. For his postdoctoral research, he joined the group of Christian Schonenberger at the University of Basel in 2011 where he studied ballistic electron transport in suspended graphene. In 2014, he joined CE Grenoble in the group of Silvano DeFranceschi to work on single-spin quantum effects i semiconductor quantum dots. In 2016, he measured the first spin qubit based on CMO technology and the following year was awarded an ERC-Starting-Grant for a project aimed a coupling spin qubits to microwave photons on a silicon chip, for the realization o long-distance quantum entanglement. At the same time, he is working on quantum device based on germanium for the study of spin qubits and superconducting hybrids

ABSTRACT:

Semiconductor spin qubits based on spin-orbit states stand as promising candidates for quantum information processing. In particular, owing to the spin-orbit interaction (SOI) of valence states, hole spins in silicon and germanium are responsive to electric field excitations [1,2], allowing for practical and fast qubit control. This spin-electric response is intimately link to the complex and rich spin-orbit physics. Here I will report on our last efforts leveraging spin-orbit interaction of hole spin in silicon devices produced on a semi-industrial 300mm CMOS foundry [3]. First, I will demonstrate how SOI turns into an asset to engineer mixed spin-charge states in a double quantum dot able to couple strongly with microwave

photons. In an hybrid spin cQED platform we reveal a hole spin-photon coupling of 300 MHz largely exceeding the combined spin-photon decoherence rate leading to a cooperativity above 103 [4]. This coupling exceeds the best figures reported so far for electrons in silicon [5,6] and opens the cQED quantum tool box to spin-orbit qubits. Secondly, due to their spin-electric susceptibility, spin-orbit qubits may be vulnerable to electrical noise, which explains the relatively short coherence time reported so far. In a second part, I'll focus on the existence of preferential magnetic field orientation at which a spin-orbit qubit is decoupled from charge noise while keeping its efficient electrical control [7]. To this end, we experimentally achieve a complete characterization of the hole spin gyromagnetic tensor and its susceptibility to electric fields by coherent manipulation techniques. It evidences a strong dependence on the external magnetic field orientation, and reveal optimal operation points at which the longitudinal spin-electric susceptibility is minimal. At these optimal points, we measure a Hahn-Echo decay time in the order of 100 microseconds maintaining Rabi frequencies in the MHz range [8]. All together, the coupling to microwave photon and the ability to hide from charge noise make hole spin in silicon an attractive platform to further develop semiconductor spin qubit-based quantum information processing.

Hosted by: Prof. Dr. Adrian Bachtold