Conduction Electron Spin Resonance in MBE-Grown Si/SiGe Quantum Wells

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While electron spin is the most important parameter in magnetic storage devices, it has presently no relevance for commercial semiconductor devices. This is about to change, mainly due to the novel quantum computing concepts that emerged in recent years. If quantum computers can ever be realized in semiconductor materials with their superior miniaturization and integration technologies, spin will be of paramount importance. Because for such applications spin coherence times have to be as long as possible, the choice of semiconductors is limited to those that can be fabricated with a negligible amount of nuclear spins. Silicon is certainly the most prominent examples to fulfill that condition.

Here we report on the spin and transport properties of the 2-dimensional electron gases (2DEG) in modulation-doped Si/SiGe quantum wells. In a standard microwave absorption experiment we measured the conduction electron spin resonance (CESR), and simultaneously the cyclotron resonance (CR) signal of the 2DEG. The latter yields a large background signal extending over a broad magnetic field range, whereas the former appears as a very narrow signal at a Landé g-factor of 2. In high-quality samples the CESR signal is as narrow as 30 mG. By measuring the ESR signal as a function of incident microwave power the spin relaxation time can be derived. We find a longitudinal spin relaxation time of up to 30 μs which is 6 – 7 orders of magnitude longer than the momentum relaxation times in these samples, and 3 – 4 orders of magnitude larger than the spin relaxation times in the quantum wells of III-V semiconductors.

A second prerequisite for quantum computing is the setting of a well-defined initial spin distribution. We show that this can be achieved in a rather simple gated structure which allows tuning of the g-factor. This way a spin-flip operation can be switched on and off in the microwave cavity of an ESR set-up by simply applying a gate voltage.