Gate Control of the Electron Spin in Semiconductor Quantum Wells

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The control of electron spin in semiconductors for potential use in transport devices or quantum information applications has attracted a great deal of attention in recent years. In nanostructures made of III-V or II-VI semiconductors, the absence of inversion symmetry and the spin-orbit coupling are responsible for the lifting of the degeneracy for spin up and down electrons states in the conduction band. This splitting plays a crucial role for the spin relaxation and spin transport properties. As it depends strongly on the crystal and nanostructure symmetry, it can be efficiently tailored as explained below.
We have measured the electron spin relaxation time in (111)-oriented GaAs quantum wells (QW) by time-resolved photoluminescence and time-resolved Kerr rotation spectroscopy. By embedding the QWs in a PIN or NIP structure we demonstrate the tuning of the conduction band spin splitting and hence the spin relaxation time with an applied external electric field applied along the growth direction [1].
The application of an external electric field of 50 kV/cm yields a two-order of magnitude increase of the spin relaxation time; this is a consequence of the electric field tuning of the spin-orbit conduction band splitting which can almost vanish when the Rashba term compensates exactly the Dresselhaus one [2].
Experiments performed under transverse magnetic fields demonstrate that in addition to the spin lifetime, the electron spin coherence time can be significantly increased.
The role of the Dresselhaus cubic terms on both the temperature dependence of the effect and the anisotropy of the spin relaxation will be discussed.
Finally the gate control of the electron spin diffusion length will be demonstrated.

[1] A. Balocchi , Q. H. Duong, P. Renucci, B. L. Liu, C. Fontaine, T. Amand, D. Lagarde, X. Marie, Phys. Rev. Lett. **107**, 136604 (2011) ; M.E. Flatté, Physics **4,** 73 (2011)
[2] H. Q. Ye, G. Wang, B. L. Liu, Z. W. Shi, W. X. Wang, C. Fontaine, A. Balocchi, T. Amand, D. Lagarde, P. Renucci, X. Marie, Appl. Phys. Lett **101**, 032104 (2012)