(Cd, Mn)Te – based quantum structures for electrical gate control of Lande g-factor of two-dimensional electron gas

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Two dimensional systems in which an application of gate voltage would allow engineering of the effective g-factor of carriers hold a strong promise for a number of interesting possibilities in both basic and applied science. Among possible applications of such systems are electric gate controlled conversion of THz radiation induced pure spin currents into spin polarized electric currents [1] and a gate tuning of the frequency of THz radiation pulses emitted from spin waves [2], both important for spin based electronics (spintronics).

Here we report on the growth and studies of (Cd, Mn)Te based quantum well structures that constitute the first step toward realization of magnetic system with gate controlled g-factor of two dimensional electron gas (2DEG). In the proposed system a variation of the effective g–factor of 2DEG is to be achieved by the voltage induced shift of electron wave function (wf) leading to the change of the overlap of the wf with localized spins of Mn ions, which were incorporated at strictly predefined positions inside the CdTe quantum well region.

The structures were grown by molecular beam epitaxy (MBE) taking advantage of recent progress in the technology of diluted magnetic semiconductor quantum structures containing 2DEG [2,3]. One-side iodine modulation doped CdTe quantum wells have the widths of 300 Å and undoped CdMgTe spacer thickness of 300 Å. Mn ions were incorporated at various locations along the width of the QW and hence in respect to both the maximum of electron wf and location of iodine donors. The purpose was to allow for either increase or decrease of the electron effective g-factor for the same polarity of applied gate voltage. Additionally the effective concentration of Mn ions was chosen so that at zero gate voltage the formation of Ising quantum Hall ferromagnetism (QHFm) [4] at the crossing of spin-up and spin-down Landau levels was possible, thus providing a convenient and a sensitive means of detecting gate voltage induced changes of g-factor through the shift of QHFm cusps. Hall bar samples with golden gates were produced by electron beam lithography, wet etching and lift-off techniques.

Low-temperature studies of Hall- and longitudinal- magnetoresistance reviling both well-developed Integer Quantum Hall plateaus and sharp QHFm cusps proved – not beforehand obvious – high quality of structures with strongly inhomogeneous incorporation of Mn ions, which were grown for the first time ever. Measurements performed as a function of gate voltage showed the variation of the 2DEG concentration and thus, indirectly, the shift of the electron wf maximum in respect to the Mn location. First indications of the tunability of g-factor of 2DEG by the gate voltage were also observed and interpreted based on simulations of the spin-splitting performed with the use of Next-nano software package.

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