Spin-polarized one dimensional transport in PbTe/(Pb,Eu)Te nanostructures

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There is a growing amount of concepts suggesting potential functionalities of spin degrees of freedom and of spin-polarized currents. In this context especially useful are magnetic or narrow-gap semiconductors, in which Zeeman splitting can compete with the cyclotron energy. In this work, we report on the generation, in a magnetic field below 1 T, of the entirely spin-polarized current that is carried by several electric subbands.

Our spin aligner consists of a submicron PbTe quantum wire patterned by electron beam lithography of 50 nm PbTe quantum well. This well is embedded between Bi-doped $Pb_{0.92}Eu_{0.08}Te$ barriers grown by MBE onto 2.5 μm $Pb_{0.92}Eu_{0.08}Te$ undoped buffer layer and BaF_2 substrate. The initial electron concentration and mobility were typically $4\cdot10^{12}$ cm^{-2} and 10^5 cm^2/Vs, respectively. Two side gates make it possible to vary the electron concentration in the device. The trenches that define the conducting channel and gates are 1 μm deep. The interfacial layer between the lattice mismatched substrate and the buffer layer is highly dislocated and p-type. While it is isolated from the nanostructure, it serves to transfer the gate bias under the conductor. Such nanostructures can be tuned in a wide range of the carrier concentrations, and their properties are reproducible between subsequent cooling cycles.

Owing to an extremely large dielectric constant ($\varepsilon_0 \approx 1300$), the long-range Coulomb potentials are suppressed, so that the electron transport is ballistic. Accordingly, conductance quantization $G = ne^2/h$ is observed in the two-contact geometry. Interestingly, only *plateaux* corresponding to n = 2, 6, 12, … are resolved. This is caused by a relatively large thickness of the quantum well making the conductor cross-section to be rectangular. The resulting sublevel distribution [1] is then consistent with the orbital degeneracy we detect.

Due to a large spin splitting of the electrons in PbTe, $\frac{1}{2}g^*m^* \approx 0.7$, the spin-resolved steps start to appear already below 1 T. Moreover, the spin-splitting becomes larger than 1D quantization energy. This manifests itself as halving of the zero-field quantization step numbers: in the magnetic field, we observe n = 1, 3, 6,… not 1, 2, 3, ... This unusual sequence demonstrates that the electron liquid is entirely spin-polarized despite that several subbands are occupied.

[1] Sherbakov et al. Phys. Rev. B 53 (1996) 4054.