Spin filtering in hybrid nanostructures

J. Wróbel

Institute of Physics, Polish Academy of Sciences
Lotników 32/46, 02-668 Warszawa, Poland

The physics of spin-polarized electron beams propagating freely in vacuum provides a sound starting point in the process of developing solid state spintronic devices. For example, the effect of beam polarization which occurs during the elastic scattering via the spin-orbit interaction, turned out to be very useful for analyzing transport properties of doped semiconductors. Such approach, however, should be complemented by taking into account substantial differences between a classical motion in vacuum and quantum transport in low-dimensional solids, such as the self-consistent nature of a one-electron confining potential, exchange interaction in Fermi liquid, renormalization of the Landé factor, disorder etc. In this paper we summarize the outcome of our recent works in which we aimed to *take advantage* of such differences when developing spin polarizers of semiconductor nanostructures. In particular, by model quantum calculations we show that the spin separation by magnetic field gradient can occur for a one dimensional electron gas - contrary to the free electrons case for which the Stern-Gerlach effect was never observed. Experimentally, we studied the effect of a *local* in-plane magnetic field on ballistic currents in a quantum wire patterned of GaAs/(Al,Ga)As heterostructure [1]. The results are obtained for a ferromagnet-semiconductor hybrid device which is highly optimized in order to toggle between uniform field and field gradient internal spin barriers. The observed effects are attributed to switching between Zeeman and Stern-Gerlach modes — the former dominating at low electron densities.

Furthermore, we discuss how rather unique characteristics of IV-VI semiconductor PbTe, such as a huge value of the static dielectric constant, $\varepsilon_S = 1000$, and a large magnitude of the Landé factor of electrons in PbTe, $|g^*| \approx 66$, can be exploited to improve the efficiency of solid state spin filters. For that purpose we hayed fabricated a series of 1D nanostructures containing MBE-grown modulation-doped PbTe quantum wells embedded by $Pb_{0.92}Eu_{0.08}Te$:Bi barriers [2]. We detect spin resolved half-integer quantization plateau already in a magnetic field as low as 0.2 T and therefore our nanostructures constitute an efficient spin filter, in which the entirely spin-polarized electron current can be carried by several electric subbands. Following our work on GaAs/(Al,Ga)As, we extend these filtering capabilities to eyen bower magnetic fields by depositing micromagnets of ferromagnetic metals in the channel vicinity. Finally, in order to develop an electrical spin detector as well as to fabricate an electrically controlled source of entangled electron pairs, we investigate nanojunctions of PbTe with various superconducting metals. We find that the interface In/PbTe is transparent making it possible to observe pronounced conductance maxima associated with the Andreev reflection and the proximity effect, which we examine by correlated shot noise spectroscopy. This work has been supported by ERATO Semiconductor Spintronics Project of JSL.

[1] J. Wróbel *et al.,* Phys. Rev. Lett. **93** (2004) 246601.
[2] G. Grabecki *et al.,* Phys. Rev. B **72** (2005) 125332 (and references therein).

Name of the presenting author (oral): Jerzy Wróbel
e-mail address: wrobel@ifpan.edu.pl
url's: http://www.ifpan.edu.pl