Generating and Detecting the Spin Current in Y-shaped Semiconductor Nanowire with Quantum Point Contact

P. Wójcik, J. Adamowski, M. Wołoszyn, B.J. Spisak
AGH University of Science and Technology, Faculty of Physics and Applied Computer Science,
al. Mickiewicza 30, Cracow, Poland
pawel.wojcik@fis.agh.edu.pl

Abstract
An effective generation and detection of the spin currents are fundamental requirements for the development of spintronics devices and quantum computing based on the electron spin qubits. For this reason the spin-current generators and detectors have been the subject of extensive experimental and theoretical efforts for many years [1,2]. A special attention has been devoted to the devices, in which the quantum point contact (QPC) leads to the effective spin filter operation [3].

In this paper, we demonstrate that the Y-shaped semiconductor nanowire structure with the QPC located in one of the arms can be used as an effective spin splitter (generator) as well as spin detector for the spintronics applications. Our calculations show that by the appropriate tuning of confinement energy in the QPC region, in the presence of external magnetic field the input unpolarized charge current can be splitted into two fully spin-polarized currents whereas the electrons with opposite spins flow out through the different branches of the Y-shaped nanowire. The QPC confinement energy can be tuned by applying the external voltages to the gates defining the QPC. The spin separation mechanism has been explained as the joint effect of the spin Zeeman splitting and orbital effect, which appear in the magnetic field. It is interesting that – under the ideal ballistic transport conditions – the input unpolarized current is perfectly splitted into two oppositely polarized spin currents with no loss of the current. We have demonstrate that the proposed Y-shaped nanowire structure can also act as a detector of the spin current: if the spin-polarized current is injected into the input contact, the output current flows out through only one of the remaining two contacts. In this case, when measuring the current in both the output contacts, we obtain the information about the spin polarization of the current injected into the system.

References:
[1] P. Wojcik, J. Adamowski, M. Woloszyn, and B. J. Spisak, Appl. Phys. Lett. 102, (2013) 242411.
[2] R. M. Potok, J. A. Folk, C. M. Marcus, and V. Umansky, Phys. Rev. Lett. 89, (2002) 266602.
[3] S. M. Frolov, A. Venkatesan, W. Yu, J. A. Folk, and W. Wegscheider, Phys. Rev. Lett. 102, (2009) 116802.

Acknowledgment
This work has been supported by the National Science Centre, Poland, under grant DEC-2011/03/B/ST3/00240.