Conductivity oscillations of GaAs-InAs nanowires in parallel magnetic field

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Cylindrical nanowires are increasingly used in exploring fundamental quantum transport physics in low-dimensional systems [1]. Building a shell of a narrow bandgap semiconductor (InAs) around a core having a wider gap (GaAs) is a promising path for tubular confinement of electrons within the nanowire structure. Apart from core-shell nanowires, strong electron confinement can be achieved in shell nanowires fabricated via wet chemical etching of the GaAs core of the GaAs-InAs core-shell nanowires. Magnetoconductance measurements of both GaAs-InAs core-shell and InAs shell nanowires subject to magnetic field applied along the nanowire axis show that the nanowire conductance oscillates with the magnetic field [1, 2]. Here we focus on the theoretical interpretation of this phenomenon.

For modeling of the electron transport in the nanowires we calculate the conduction band structure solving coupled Poisson and Schrödinger equations within the envelope function and effective mass approximations. We show that increase of external magnetic field leads to quasi-periodic oscillations of the electron density. This is due to the exchange of charge carriers between surface and angular momentum states of the nanowire. The oscillation shape is determined by the electron population of the energy levels in the vicinity of Fermi level. As shown in Fig. 1, the relative amplitude of the oscillations reaches its maximum value of about 1% for the nanowires with the shell thickness below 20 nm and does not depend on the number of occupied electron states, which is in agreement with the experimental data.

The simulation of electron transport in the nanowires in both static electric and magnetic fields, performed using the Monte Carlo method, determine the influence of different scattering mechanisms on electron drift along the nanowire axis and reveals the relative contributions of electrons populating different energy levels to electric conductivity of the nanowires. The theoretical findings are in agreement with experimental data, thus explaining the observation of flux-periodic oscillations in nanowires without invoking ballistic transport.

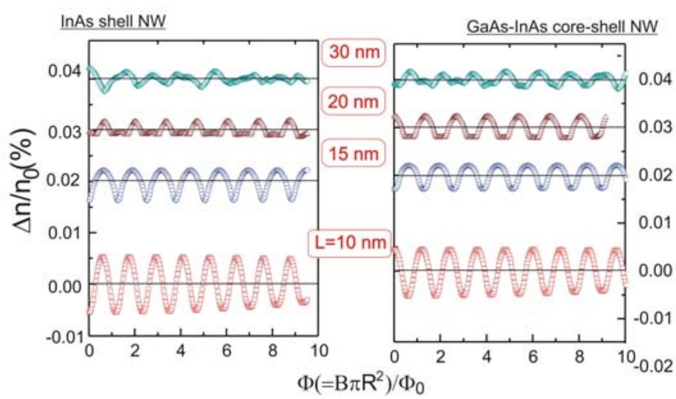

Fig. 1. Relative electron density in InAs shell (left) and GaAs-InAs core-shell (right) nanowires *vs*. magnetic flux (Φ, $\Phi_0 = h/e$); the shell thickness is set to 10, 15, 20 and 30 nm and the total nanowire radius is set to 70 nm.

1. O. Guel, *et al.*, *Phys. Rev. B* **89**, 045417 (2014).
2. T. Wenz, *et al.*, *Appl. Phys. Lett.* **105**, 113111 (2014).