Conductance matrix in silicon nanosandwiches

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The quantum conductance studies are the subject of a considerable amount of researches that is caused by applying to quantum computing phenomena [1]. The Landauer-Buttiker formalism (LBF) is well-known to be a powerful tool for the analysis of the quantum conductance revealed by measuring the transport characteristics of multi-terminal devices [2]. Within frameworks of the LBF approach, the total current in such systems is presented in the matrix form as $\boldsymbol{I} = \boldsymbol{GV}$, where $\boldsymbol{I}$ and $\boldsymbol{V}$ are column vectors for the probe currents and voltages, whereas $\boldsymbol{G}$ is an $N \times N$ - conductance matrix and N is the number of probes.

Here we present the developments of the conductance matrix to study the spin-dependent transport in the eight-terminal device that was prepared by using the silicon nanosandwich which is the high mobility p-type silicon quantum well (Si-QW), 2 nm, confined by the δ-barriers heavily doped with boron on the *n*-type Si (100) surface. These silicon nanosandwiches performed within frameworks of the Hall geometry of leads have been shown to be interested in the studies of the ballistic and mesoscopic transport, because the boron centers inside the δ-barriers appeared to be the impurity dipoles formed by the negative-U reconstruction of the shallow boron acceptors along the <111> crystallographic axis, $2B^0 \rightarrow B^+ + B^-$ [3]. Moreover, the dipole negative-U centers of boron have been found to be electrically ordered thereby forming the topological edge states in the Si-QW that are vertically separated, with the variations of both the sheet density of 2D holes and Rashba spin-orbital interaction by biasing the top gate voltage.

In order to identify the conductance matrix, we measured the values of voltages $U_{i,j}$ between all probes at different directions of the highly-stabilized current $I_{i,j}$, where i,j – indexes of probes. Then, the data obtained were used to solve the system of the linear algebraic equations based on the Kirchhoff's circuit laws for each from the eight terminals. Thus, the conductance matrix $\boldsymbol{G}$ was achieved taking account of the instrument and statistical accuracy of every element $G_{i,j}$, which are able to demonstrate the quantum conductance of the silicon nanosandwich in units of e^2/h.

The longitudinal, $G_{xx} = 4e^2/h$, and transversal, $G_{xy} = e^2/h$, conductance of the silicon nanosandwiches that were registered at extremely low value of the stabilized source-drain current, 0.25 nA, has been found to indicate the exhibition of the Quantum Spin Hall effect [4]. These results are discussed in the LBF terms applied to the topological edge states that are vertically separated being belonged to different δ–barriers.

The conductance matrix allows the verification of the top-gate bias dependence on the conductance matrix element $G_{i,j}$ separately. Besides, the multi-current experiment becomes to be performed using four terminals as current probes, while another four terminals are voltage probes. This area appears to be very perspective also to analyze the local coherent transport in the asymmetrical 2D-topological insulators and superconductors.

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