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Nonstationary phenomena in Si MOSFETs in the quantum Hall effects regime

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Abstract. We report the observation of nonstationary hysteresis phenomena in charging of Si MOSFET at a quantizing magnetic field. In these experiments (Pudalov *et al* 1984; Pudalov and Semenchinsky 1985) the charging current J_g of the capacitance gate-2D-layer was measured while sweeping of the magnetic field H or a gate voltage V_g at a constant rate. The numerical integration of the measured values J_g with respect to time gave the dependences of change in Q_s vs V_g or vs H.

At low temperature $T<1$ K there arise deviations from the linear dependence $Q_s(V_g)$ near those integer values of Landau level filling $\nu = n_s/n_H = 2, 4, 6, 8, 12$, which correspond to the most deep minima in ρ_{xx} and flat plateaux in ρ_{xy}. Here n_s is the 2D electron density, n_H being Landau level degeneracy number, ρ_{xx} and ρ_{xy} —the resistivity tensor components. The inherent feature of the curve $Q_s(V_g)$ is the hysteresis: at increasing V_g the charge Q_s is less than the equilibrium value, while at decreasing V_g the charge exceeds the equilibrium one.

The maximum difference of charges at an increase and decrease of V_g grows-rapidly at lowering T and at $T = 0{\cdot}42$ K amounts to $\sim 10\%$ of the full charge confined by one Landau level ($n_H \cdot e \cdot S$). It is worth to note that such behaviour of $Q_s(V_g)$ does not influence the values of ρ_{xy} (with accuracy of $\sim 10^{-5}$) and the shape of ρ_{xy} plateaux and ρ_{xx}-minima.

Measurements at various sweep rates dV_g/dt demonstrated that if the sweep rate is lower, the hysteresis region is narrower and the deviation of charges Q_s from its equilibrium value is smaller. By extrapolating the dependence of hysteresis loop width on dV_g/dt, the ultimate sweep rate may be estimated, for which a hysteresis will completely disappear. Thus, for instance, at $T = 0{\cdot}42$ K and $\nu = 4$ it will occur when the time interval of one Landau level filling τ_H will be equal to 100 years.

A similar hysteresis in 2D-layer charge occurs in varying magnetic field also, when the gate voltage is disconnected with the battery and hence the charge in MOSFET is maintained constant. This hysteresis loop rapidly vanishes at temperatures >1 K.

The long relaxation time of a nonequilibrium charge in 2D-layer can be connected phenomenologically with small drift velocities of electrons along the potential gradient due to a small value of conductivity σ_{xx}. This relaxation time may be estimated as $\tau \sim C/\sigma_{xx}$ where C is the electrical capacitance of MOSFET area with a nonequilibrium charge. The value of $\tau \sim 10^9$ s gives $\sigma_{xx} < 10_a^{-18}$ Ohm$^{-1}/\square$, i.e. $\rho_{xx} < 10^{-11}$ Ohm$/\square$. Simultaneously with nonequilibrium charge relaxation in 2D-layer there arise circular Hall currents decaying with the same rate.

In conclusion, we observed and investigated nonequilibrium charging of 2D-layer in quantum Hall effect regime. To explain the phenomenon we supposed that circular Hall currents is comparable to the eddy currents excited in a superconducting ring.

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