Transversal Hall Effect in Quasi-2D-system

M.V. Entin and L.I.Magarill

Institute of Semiconductor Physics, Siberian Branch,
Russian Academy of Sciences, 630090 Novosibirsk Russia

The conventional Hall voltage in 2D systems is caused by the normal component of the magnetic field and arises along the sample surface. At the same time it is evident that in-plane component of the magnetic field together with the lateral electric field may redistribute electrons and produce a voltage across the quantum layer. This voltage can be measured between gate and back electrodes by means of a capacitive method.

We study 2D system with arbitrary confining potential $U(z)$ in tilted magnetic field $\mathbf{B}$. Considering lateral magnetic and electric $\mathbf{E}$ fields as perturbations, we have found the response of charge density and the voltage across the structure. In the limit of low surface density the voltage V is given by

$$V = 8\pi \frac{e}{\kappa c}(\mathbf{n}[\mathbf{Bj}]) \sum_{n \neq 0} \frac{z_{0n}^2}{\varepsilon_n - \varepsilon_0}.$$

Here $\mathbf{n}$ is the ort of z-axis, κ is the dielectric constant, ε_n is the energy of the n-th transversal state in the quantum layer. The current density $j_i = \sigma_{ij}(B_z)E_j$; σ_{ij} is the conductivity tensor of 2D system. The lowest subband of transversal quantization, $n = 0$, is supposed to be occupied only. The voltage V is determined by the drift current for $\mathbf{B} \perp \mathbf{E}$ or by the Hall current for $(\mathbf{B} - \mathbf{n}(\mathbf{Bn}))||\mathbf{E}$.

Besides above-mentioned orbital contribution the in-plane magnetic field induces a specific voltage originated from the magnetic-field-induced spin orientation and spin-orbit interaction with confining potential. The effect is explained by the difference of charge distribution in z direction for electrons with a given momentum and different spin projections. Taking into account spin-orbit interaction of electrons with the quantum well boundaries $H_{SO} = 2\alpha([\mathbf{sp}]\nabla\mathbf{U})$ ($\mathbf{p}$ and $\mathbf{s}$ are the electron momentum and spin operators, α is the effective bulk constant of spin-orbit interaction), we have found the corresponding response

$$V_{SO} = 2\pi\alpha \frac{m}{\kappa} g\mu_B(\mathbf{n}[\mathbf{B}\frac{\partial \mathbf{j}}{\partial \zeta}]).$$

Here m is electron effective mass, g is g-factor, μ_B is the Bohr magneton, ζ is the chemical potential. The spin contribution V_{SO} becomes more pronounced in narrow-gap semiconductors with large value of α.

Obtained expressions do not exploit the weakness of intrasubband impurity scattering. They are valid for arbitrary value of normal component of magnetic field B_z. In the quantum Hall regime the transversal voltage exhibits the same peculiarities as the lateral current.

Note that the considered spin-induced transversal Hall effect can be utilized to measure the constant α. One can expect the appearance of analogical transversal voltage under longitudinal current at $\mathbf{B} = 0$ if electron spins are oriented by any way. This allows to measure spin orientation electrically.