ACOUSTOELECTRIC EFFECTS IN \textit{p}-TYPE Si/SiGe HETEROSTRUCTURES IN THE
EXTREME QUANTUM LIMIT

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Introduction

Acoustoelectric effects, arising as a result of the Surface Acoustic Wave (SAW) interaction with charge carriers are generally studied for determination of the complex high-frequency (hf) conductivity $\sigma(\omega)=\sigma_1(\omega)-i\sigma_2(\omega)$ in low-dimensional systems in a contactless way. In the present work for the first time the investigation of these effects has been undertaken to study hf-conductivity in the \textit{p}-type heterostructures Si/SiGe in the extreme quantum limit.

Experimental and Results

The SAW attenuation coefficient $\Gamma$ and the relative velocity change $\Delta V/V$ have been studied at different SAW intensities at frequencies $f=30-250$ MHz for temperatures $0.3 < T < 5$ K and magnetic fields up to $H=18$ T in the heterostructures Si/Si$_{0.95}$Ge$_{0.05}$ (sample 1, hole density $p=8\times10^{10}$ cm$^{-2}$), and Si/Si$_{0.87}$Ge$_{0.13}$ (sample 2, $p=1.6\times10^{11}$ cm$^{-2}$) with mobility $\mu_T\approx1\times10^4$ cm$^2$/Vs. Since Ge and Si are not piezoelectric the only way to measure the acoustoelectric effects in these structures is via a \textit{hybrid} method: a SAW propagates along the surface of a piezoelectric LiNbO$_3$ while the sample is pressed onto the niobate.

Fig. 1 illustrates the field dependence of $\Gamma$ and $\Delta V/V$ at different temperatures (sample 1). For relatively low magnetic fields $\Gamma$ and $\Delta V/V$ both undergo Shubnikov-de Haas type oscillations: the field position of minima in $\Gamma$ and maxima in $\Delta V/V$ corresponds to the center of the $\nu=1$ IQHE plateau observed in DC measurements. In higher fields at low temperatures (the extreme quantum limit) both $\Gamma$ and $\Delta V/V$ saturate. By simultaneously measuring $\Gamma$ and $\Delta V/V$ both the real $\sigma_1$ and imaginary $\sigma_2$ components of the complex hf conductance were determined as functions of magnetic field, temperature and SAW power. From these dependences as well as from relation between $\sigma_1(\omega)$ and $\sigma_2(\omega)$ one can judge the hf conductivity mechanisms. In ultra-quantum limit temperature dependence of the hf conductivity in both samples could be associated with the holes activation from the localized states under the Fermi level to the delocalized states band, corresponding to $0$-Landau level. Conductivity maximum in this band occurs at the filling factor $\nu=0.756$ ($H=4.5$ T) and $\nu=0.716$ ($H=9.5$ T) for samples 1 and 2 respectively. The imaginary component of the hf conductivity tends to zero with magnetic field increase. Temperature dependence of $\sigma_1$ in the fields above 14 T shows a sharp increase by more than an order of magnitude at $T=1$K which resembles a phase transition (Fig. 2). This increase could be attributed to melting of a Wigner crystal, which formation at low temperatures in the quantum limit was discussed for such materials as GaAs/AlGaAs heterostructures and Si MOSFETs [2].

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References