g-factor in Very High-mobility p-SiGe/Ge/SiGe Heterostructures in a Tilted Magnetic Field: Acoustic Studies

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Introduction

High frequency (ac) conductivity in a single quantum well LEPECVD grown p-$Ge_{0.7}Si_{0.3}$/Ge/$Ge_{0.7}Si_{0.3}$ heterostructure with the concentration of $p=6\times10^{11}$ cm^{-2} with very high hole mobility $\mu\approx7\times10^4$ cm^2/Vs was studied by acoustic methods in the integer quantum Hall effect regime in perpendicular and tilted magnetic fields of up to B=18 T and temperatures down to 0.3 K. We studied the dependence of the ac conductivity on temperature and the magnetic field tilt angle. The effective g-factor and its dependence on the tilt angle were determined.

Experimental Results and Discussion

Spin-dependent effects in Si-Ge based heterostructures were intensively studied by us earlier. E.g., the experiments in p-Si/SiGe/Si have shown the quantum Hall ferromagnetic-paramagnetic transition to occur in a tilted magnetic field [1]. In this work we continue our studies being focused now on Ge-channel systems. The so-called "hybrid" configuration of the contactless acoustic method was used in our experiments: a guide of the surface acoustic wave (SAW), a plate of lithium niobate, was located in the vicinity of the 2D channel. The electric field produced by the SAW interacts with the carriers. Thus, the attenuation and the velocity of the acoustic wave are affected by the conductivity of the 2DEG. The real part of the complex ac conductivity σ_1 was calculated from the attenuation and the velocity of the SAW measured in the experiment, performed in the temperature range (0.3-5.8) K at frequencies f=30 and 85 MHz. We also measured the acoustic effects at T=0.3 K as a function of angle θ of tilting the magnetic field with respect to the 2D channel normal.

First, we determined the value of the effective g-factor from the slope of the field dependence of the activation energy associated with the spin gap at θ=0, $g\cong5$. Then, we applied the coincidence technique to the acoustics.

In th~~is sort of~~ ese systems the threefold degeneracy of valence band is lifted by a strain and spin-orbit coupling. The band splits into 3 subbands, the top of which is occupied by heavy holes (HHs). The g-factor then is highly anisotropic [2], and spin splitting of the HHs band is governed merely by the magnetic field component normal to the 2D interface. As a result, the oscillations amplitude should be independent of the tilt angle which is not the case here for $\nu\geq5$ and $\theta>60^o$, **Figure 1**.

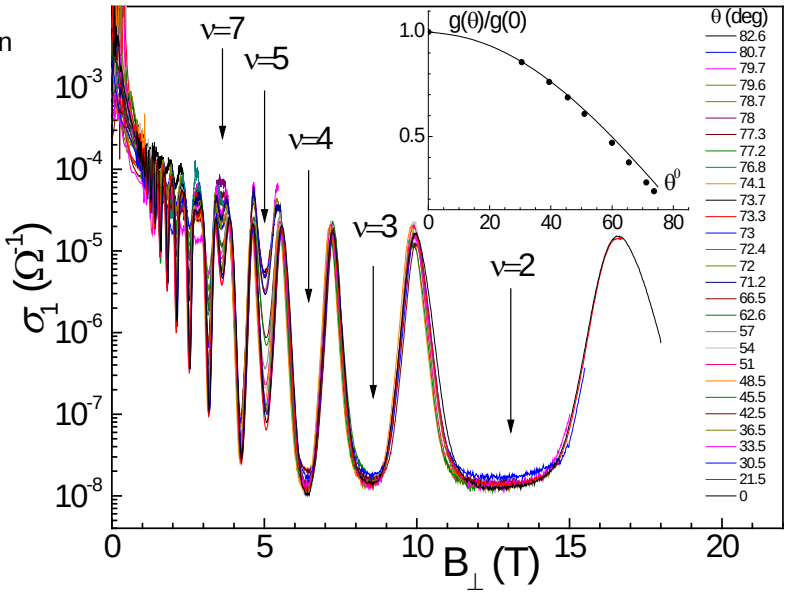

Figure 1. Real part of ac conductivity σ_1 vs $B_\perp$ at different tilt angles. T=0.3 K, f=30 MHz. Inset: reduced g-factor g(θ)/g(θ=0) vs tilt angle θ.

The tilt evolution of the oscillation pattern enables us to determine the g-factor and its dependence on the angle θ. The coincidence technique gives $g\cong9$ for ν=7. It turned out that in the range of θ=0-60° the functional form of dependence g(θ)/g(θ=0) is cos(θ), while at $\theta>60^o$ it deviates from cos(θ), yelding to stronger dependence (see the inset to Fig.1). The reason for that is probably the fact that the magnetic length l_B becomes comparable with the quantum well width Z=200 nm at relatively low fields, resulting in a modification of the quantization condition. With increase of the field's parallel component, induced by rotation, and at $l_B << Z$ a quantization in the plane normal to the 2D channel could occur.

References

[1] Drichko, I.L., *et al.,* JETP **115**, 480-484 (2012).
[2] Dorozhkin, S.I., Phys. Rev. B **61**, 7803-7805 (2000).