High-Frequency Conductance in the *p*-type Si/SiGe Heterostructures in Parallel Magnetic Field: Acoustic Study

I.L. Drichko, I.Yu. Smirnov (Ioffe PTI); A.V. Suslov (NHMFL); M. Mironov (Musashi Institute of Technology); O.A. Mironov (Warwick SEMINANO R&D Centre)

Introduction

Among the interesting issues in transport properties of dilute 2D electron/hole systems is the observed giant magnetoresistance (GMR) in strong parallel (to the 2D layer) magnetic field. The parallel field induced GMR is attributed usually to a spin effect because the orbital motion does not couple to a field parallel to the 2D plane. However, in such systems like *p*-Si/SiGe heterostructures spin effects couldn't be considered as responsible for observed in-plane magnetoresistance [1]. Really, in this system the heavy hole–light hole degeneracy is split due to a strain in SiGe. Due to this splitting, heavy holes only are responsible for conductivity. Wave functions of the heavy holes have the quantum number (j=l+s) j=3/2, and angular momentum projection m=±3/2. In this case the Zeeman splitting is completely determined by normal component of field. Sarma et al [2] don't consider spin as playing a role in the GMR in quasi-2D systems, and explain it as arising from the coupling of the parallel field to the carrier orbital motion due to the finite thickness and the low density of the layer. There is predicted anisotropy of resistivity in the 2D plane. To discriminate between the possible mechanisms one needs to know how AC conductance depends on frequency and temperature at different orientation against in-plane field. Here we report on high parallel field acoustic study of AC conductance in low density *p*-type Si/SiGe systems.

Experimental and Results

Acoustoelectric effects – the Surface Acoustic Wave (SAW) attenuation coefficient Γ and the velocity change ΔV/V have been studied in the frequency range f=17-150 MHz in the temperature interval 0.3-1.6 K and *in-plane* fields of up to B=18 T in the heterostructures Si/SiGe (density $p=8\times10^{10}$ cm^{-2}, mobility $\mu=1\times10^4$ cm^2/Vs). AC measurements were conducted in two configurations: SAW wave vector $k_{SAW}\|B$ and $k_{SAW}\perp B$. Fig. 1 illustrates the field dependence of Γ and ΔV/V at f =17MHz at T=0.3 K. By simultaneously measuring Γ and ΔV/V both the real σ_1 and imaginary σ_2 components of the complex conductance $\sigma_{xx}(\omega)=\sigma_1(\omega)-i\sigma_2(\omega)$ were determined as functions of field, temperature, frequency. Fig. 2 illustrates the real component of the AC conductivity σ_1 (17MHz) for cases $k_{SAW}\|B$ and $k_{SAW}\perp B$. In the both configurations $\sigma_1>\sigma_2$.

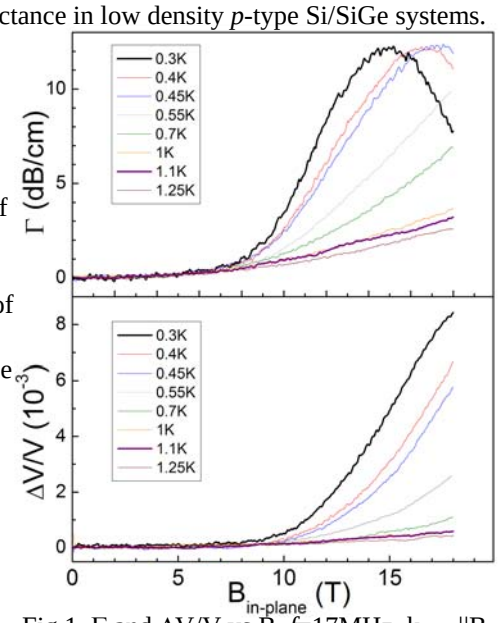

Fig.1. Γ and ΔV/V vs B, f=17MHz, $k_{SAW}\|B$.

Discussion and Conclusion

One can see that σ_1 is a decreasing function of the in-plane field. In the two orientations it's essentially the same at low fields, while at B >10 T $\sigma_1^{\|}<<\sigma_1^{\perp}$. Our preliminary analysis shows that there is a weak frequency dispersion for $\sigma_1^{\perp}$; while $\sigma_1^{\|}$ is practically frequency independent. The ratio $\sigma_1>\sigma_2$ evidences a low localization degree. The anisotropy of the AC conductivity supports the idea that coupling of the parallel field to the orbital motion of the 2D carriers is responsible for GMR. Moreover, such an orbital coupling could be strong when $l_B<z$ ($l_B=(\hbar c/eB)^{1/2}$ is the magnetic length, z is the 2D thickness, being of the order of 300 Å which is the case.

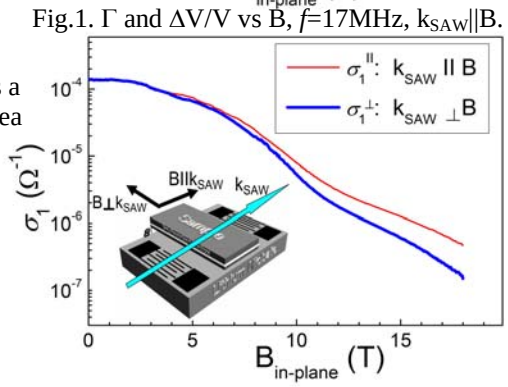

Fig.2. Real part of AC conductivity σ_1 at f=17MHz for two orientations; T=0.3K.

References

[1] Dorozhkin, S.I., *et al*, Phys. Rev. B **52**, 11638-11641 (1995).
[2] Das Sarma, S. and Hwang, E. H., Phys. Rev. Lett. **84**, 5596-5599 (2000).