Capacitance of a Ge/SiGe Heterostructure Field-Effect Transistor

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Introduction

In this project we studied undoped Ge/SiGe heterostructure field-effect transistors, which had a very wide hole density range from 1×10^{10} cm^{-2} to 3.5×10^{11} cm^{-2} tunable by (negative) gate voltage. At low temperatures a reasonably high carrier mobility of about 3.4×10^{5} cm^2/Vs was achieved.

Experimental, Results and Discussion

In our recent experiments in SCM2 we studied capacitance of Ge/SiGe heterostructure field-effect transistors at various carrier concentrations tuned by gate voltage in the range from 0 V to -2 V in the magnetic field of up to 18 T at temperature 0.3 K. Measurements were performed at various frequencies from 50 Hz to 20 kHz. Results presented in Figs. 1 and 2 were collected at frequency 1 kHz. We measured the capacitance between the transistor gate and the transistor conductive channel.

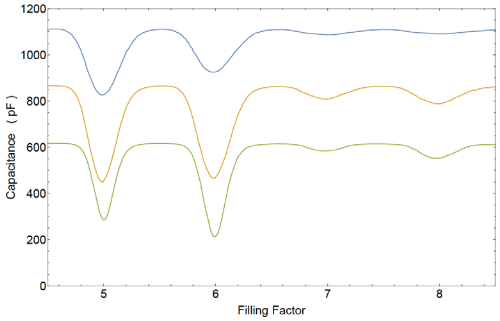

Fig. 1. Capacitance in Ge/SiGe heterostructure field-effect transistor measured at 1kHz. From top to bottom the hole density was $1.7\text{x}10^{11}$, $2.2\text{x}10^{11}$, and $2.5\text{x}10^{11}$ cm^{-2}, respectively. The curves are offset for clarity.

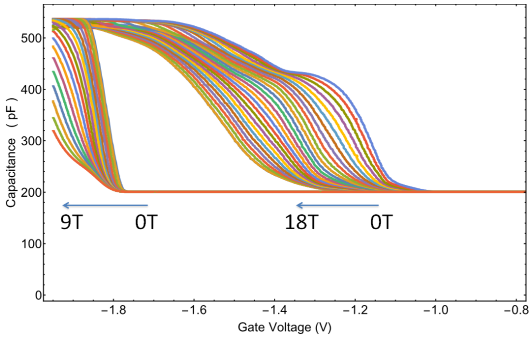

Fig. 2. Variation of the Ge/SiGe transistor capacitance dependence on the gate voltage under influence of the magnetic field. Right and left sets related to a sample cooled at gate voltage -0.8 V and -1.7 V, respectively.

Similar to the magnetoresistance measurements performed earlier on our samples [1], we observed quantum oscillations while measuring the capacitance dependence on the magnetic field at fixed gate voltage, i.e., at fixed density of carriers (Fig. 1). It is seen in Fig. 1 that in the magnetocapacitance measurements the ratio between the magnitudes of even and odd oscillations depends on the carrier density. Similar dependence of the oscillation magnitude on the carrier density was previously observed on our samples in the magnetoresistance measurements [1]. It was shown that such dependence was due to the fact that the carrier density affected the ratio between the Zeeman splitting and the cyclotron energy.

Another type of performed measurements was the dependence of the transistor capacitance on the gate voltage at a fixed magnetic field. As expected, we observed that the capacitance dependence on the gate voltage was strongly affected by the magnetic field value (Fig. 2.). Surprisingly, we found that the field effect on the capacitance versus gate voltage curves depended on the sample cooling procedure, namely on the voltage applied between the gate and the conductive channel for the in-electric-field-cooled samples (Fig. 2).

Conclusions

We present studies of magnetic filed effect on capacitance of Ge/SiGe heterostructure field-effect transistor. Further research is required for understanding how in-electric-field-cooling of these transistors affects the capacitance dependence on the gate voltage and the magnetic field.

Acknowledgements

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References

[1] Lu, T.M., *et al.*, Sci. Rep., **7**, 2468 (2017)