Quantum Transport in 2D Tellurene thin films

Qiu, G. (Purdue); Niu, C. (Purdue); Ye, P.D. (Purdue)

Introduction

Tellurium (Te) is a p-type semiconductor with narrow band gap and high mobility. It has unique crystal structure of 1D helical Te-Te covalent bonds along chain direction and van der Waals force between each chain. The solution-grown Tellurene[1] provide a suitable platform to the investigation of Te in two dimensional limit.

The research on two-dimensional electron gas (2DEG) is an important task in condensed-matter physics[2]. 2DEG under low temperature and high magnetic field with high mobility leads to the observation of Shubnikov-de Haas(SdH) oscillations and quantum Hall effect. Here we report a new type of 2DEG in Tellurene thin films achieved by field-effect confinement with high mobility. SdH oscillations of low Landau levels are observed.

Experiment

Tellurene thin films were synthesized using hydrothermal method and dispensed onto 90 nm SiO_2/Si substrate[1,3]. The field effect transistors were fabricated with electron-beam lithography and electron-beam evaporator in Purdue University. Magneto-transport measurements were performed using DC Field Cell 9 and SCM2 facility at NHMFL, Tallahassee, FL.

Results and Discussion

Shubnikov-de-Haas (SdH) oscillations are observed in n-type Tellurene thin film for the first time. Both gate dependent (Fig.1) and temperature dependent (Fig.2) SdH oscillations are measured. The Hall mobility of the device is around 3,700 $cm^2V^{-1}s^{-1}$ and the onset of the oscillations are around 3 T in high gate bias, which gives the quantum mobility comparable to Hall mobility. With the increase of gate voltage the oscillation features are stronger as shown in Fig.1, indicating stronger field induced 2D confinement. Higher magnetic field reveals lower landau level and possible Zeeman splitting.

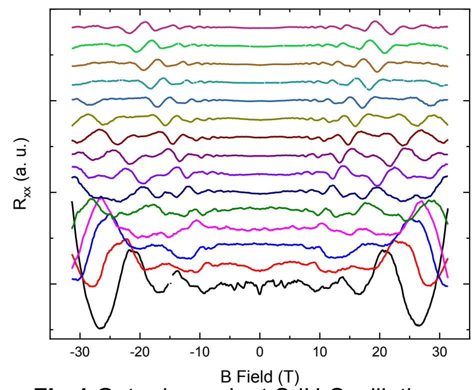

Fig.1 Gate dependent SdH Oscillations measured at 300mK

We extracted SdH oscillation amplitudes from temperature dependent data shown in Fig.2 after subtracting magneto-resistance and fit the amplitude as a function of temperature using Lifshitz-Kosevich equation:

$$\Delta R_{xx} \sim \frac{2\pi^2 k_B m^* T/\hbar eB}{\sinh(2\pi^2 k_B m^* T/\hbar eB)} \quad [1]$$

The effective mass of electrons is calculated to be 0.13 m_0. (m_0 is free electron mass)

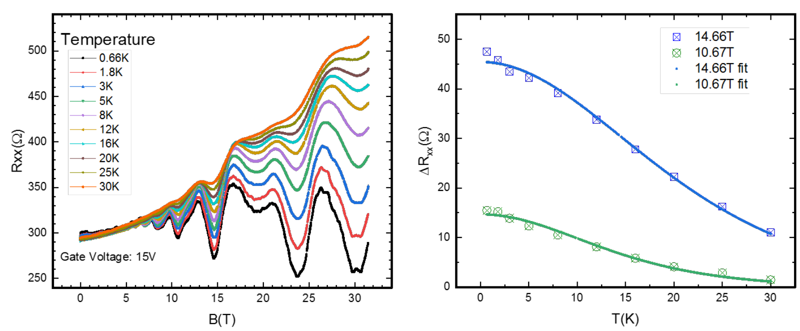

Fig.2 Temperature dependent SdH Oscillations measured at 15V gate bias. Inset shows the fitting of SdH oscillations amplitude as a function of temperature.

Conclusions

We achieved high mobility Two-dimensional electron gases in n-type 2D tellurene thin films. Quantum oscillations show evidences of the observation of lower landau level. Our 2D tellurene films provide an ideal platform to study quantized electron and even many-body behavior in high mobility 2D quantum limit.

Acknowledgements

The work was supported by AFOSR/NSF EFRI 2-DARE Grant No. 1433459-EFMA and SRC GRC program. A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490 and the State of Florida.

References

[1] Wang, Y., *et al.*, Nat. Electron., 2018, 1(4), 228.
[2] Zhang, Y., *et al.*, Nature, 2005, 438(7065), 201.
[3] Qiu, G., *et al.*, Nano Lett., 2018, 18(9), 5760.