SdH Oscillations and Quantum Hall Effect in 2D Te nanofilms

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Introduction

Tellurium (Te) is a p-type narrow-bandgap high-mobility semiconductor with one-dimensional van der Waals (vdW) structure. It has a unique chiral-chain crystal lattice in which individual helical chains of Te atoms are stacked together by vdW type bonds and spiral around axes parallel to the [0001] direction at the center and corners of the hexagonal elementary cell. Recently we made a breakthrough in developing a substrate-free solution phase process [1] to synthesize a new type of large-area, high-quality 2D single crystal Te films, which exhibits process-dependent thickness ranging from a few to tens of nanometers. Here we report for the first time the observation of quantum oscillations and quantum Hall effect in Te nanofilms.

Experimental

Tellurium thin films were synthesized using recently reported hydrothermal method and dispensed onto a silicon wafer with 300 nm SiO_2 capping layer. Six-terminal Hall bar device was fabricated with electron-beam lithography and electron-beam evaporator in Purdue University. Magneto-transport measurements were performed using DC Field SCM2 facility at NHMFL, Tallahassee, FL.

Results and Discussion

Well-developed Shubnikov-de-Haas oscillations and quantum Hall effect was observed at 300 mK and -85V gate bias(Fig. 1(a)). The Hall mobility of the sample reaches over 2640 cm^2/Vs and the onset of the oscillations is around 6 Tesla. A degeneracy factor of 4 was observed, 2 arising from spin degeneracy and 2 from valley degeneracy. We measured the oscillation peaks with different tilted angle and the maxima and minima field is proportional to 1/cos(α) (shown in fig. 1(b)), which is the signature of 2D Fermi surface, indicating our nanofilm sample is in 2D quantum limit. Oscillation amplitude is also measured under different temperature as shown in Figure 1(c). Oscillation amplitude versus temperature at different B-fields (Fig. 1(d)) are fitted by Lifshitz−Kosevich equation:

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

And the effective mass is derived accordingly to be ~ 0.26 free electron mass.

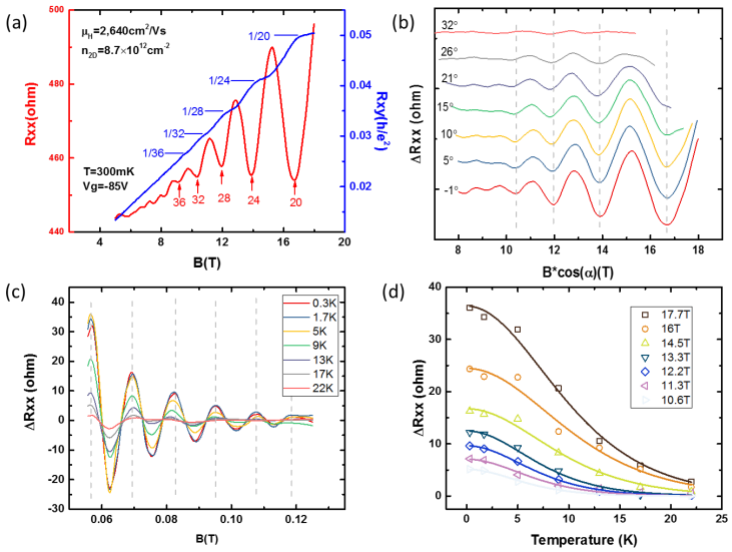

Fig.1 (a) SdH oscillations and quantum Hall effect of Te nanofilms measured at 300 Mk and -85V gate bias; (b) Angle dependence of SdH oscillations; (c) temperature dependence of SdH oscillation amplitude; (d) Extraction of effective mass using SdH oscillations amplitude.

Conclusions

In this year's experiment in NHMFL, we managed to reach 2D quantum limit novel van der Waals material Te nanofilms. Well-developed SdH oscillations and quantum Hall was observed in high quality samples.

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References

[1] Wang, Y., *et al.*, arXiv preprint. arXiv:1704.06202 (2017).