Magnetotransport of High-Mobility Strained α-Sn Layers Grown on Insulating (001)-oriented CdTe/GaAs Substrates

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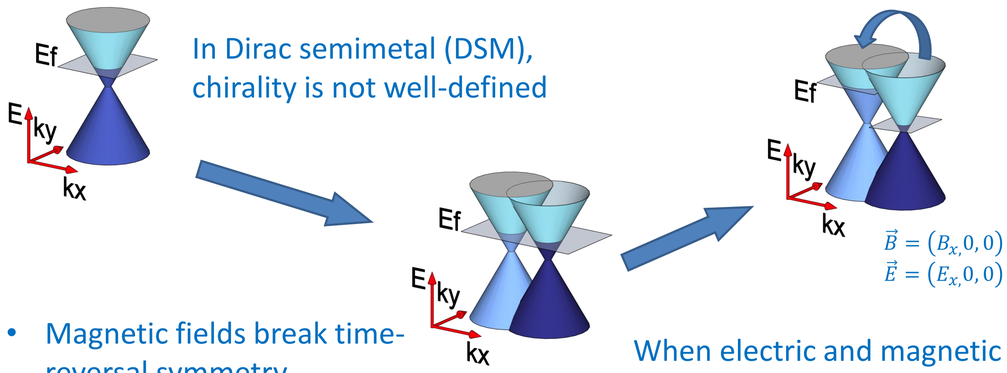
MOTIVATION: CHIRAL ANOMALY IN TOPOLOGICAL MATERIALS



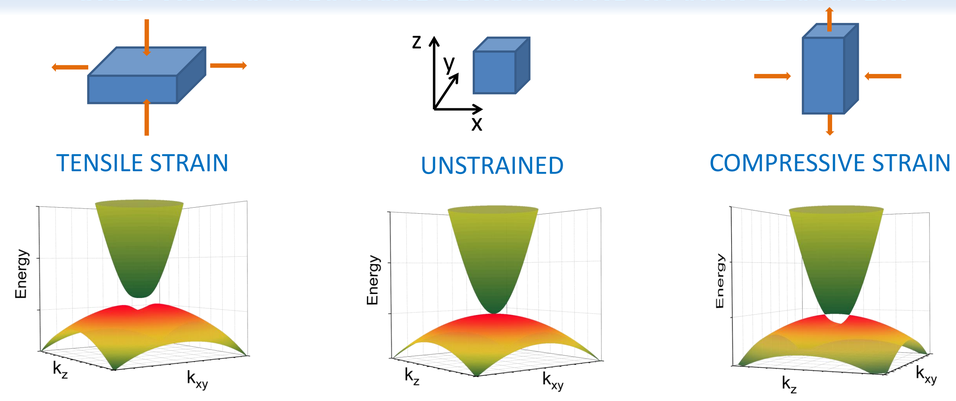
In Dirac semimetal (DSM), chirality is not well-defined

- Magnetic fields break time-reversal symmetry
- Chiral degeneracy is lifted
- Dirac cone splits into Weyl cones – Weyl semimetal (WSM) is produced

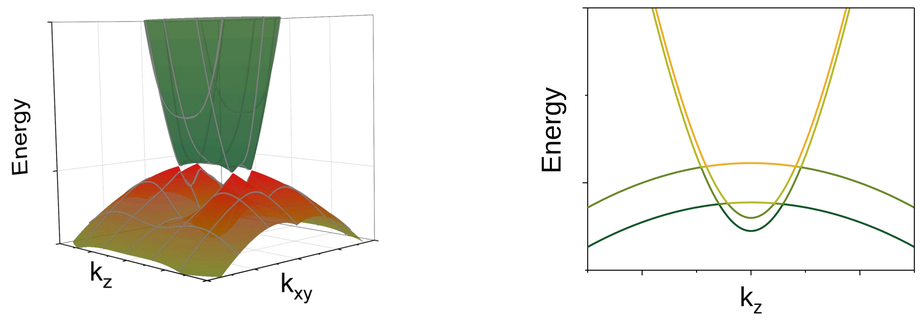
When electric and magnetic fields are parallel, $\vec{E} \cdot \vec{B} \neq 0$ which results in chiral-charge pumping between the cones

Anomaly-related conductivity is given by [1]: $\sigma_{xx} = \frac{e^4 v^3 \tau_a}{4\pi^2 c^2 E_F^2 \hbar} B^2 \quad (1)$

GREY TIN: TOPOLOGICAL PLAYGROUND IN SIMPLE SYSTEM

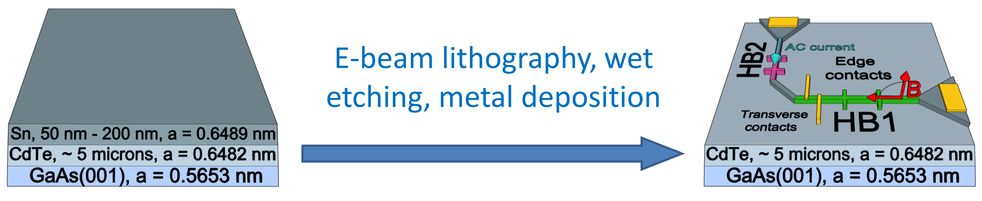


COMPRESSIVE STRAIN, EFFECT OF MAGNETIC FIELD



Solutions of $k \cdot p$ Hamiltonian [2] with experimentally-defined parameters*

OUR SAMPLES



MBE-grown epilayers

Micro-device for magnetotransport studies

The role of the substrate:
- Stabilizes crystal structure
- Introduces **compressive strain** of 0.1%

We use hybrid, **insulating** substrates
No special treatment needed

Experimental details:
- *B* = +/- 14.5 T
- *T* = 300 mK – 100 K (He-3 refrigerator)
- *In-situ* sample rotation
- AC current, *f* < 50 Hz, *I* < 500 nA

Literature and acknowledgments

[1] D. T. Son, B. Z. Spivak, *Phys. Rev. B* **88**, 104412 (2013)
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[3] M. M. Parish, P. B. Littlewood, *Nature* **426**, 162 (2003)
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[6] A. B. Pippard, Magnetoresistance in metals, Cambridge University Press, New York (2009)
[7] A. Kawabata, *Solid State Comm.* **34**, 431 (1980)

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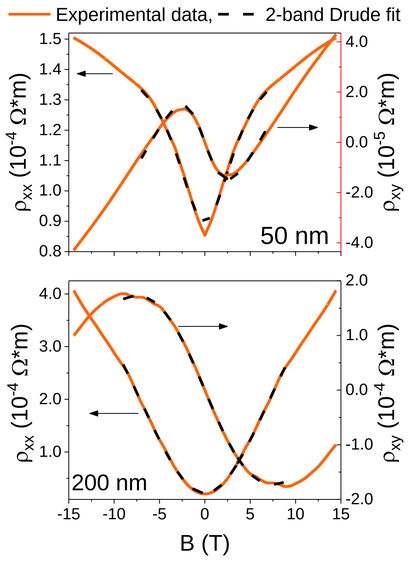
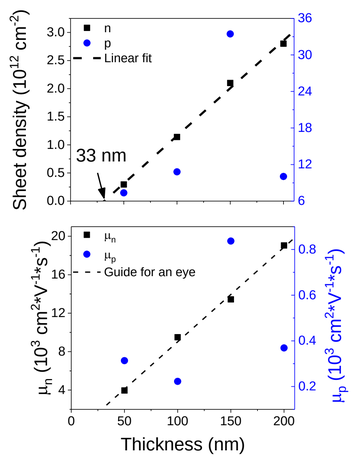
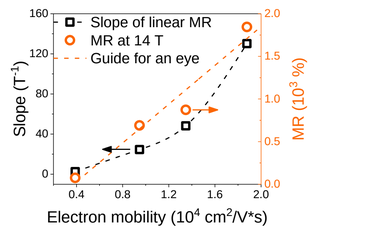
MAGNETOTRANSPORT: OUT-OF-PLANE MAGNETIC FIELD



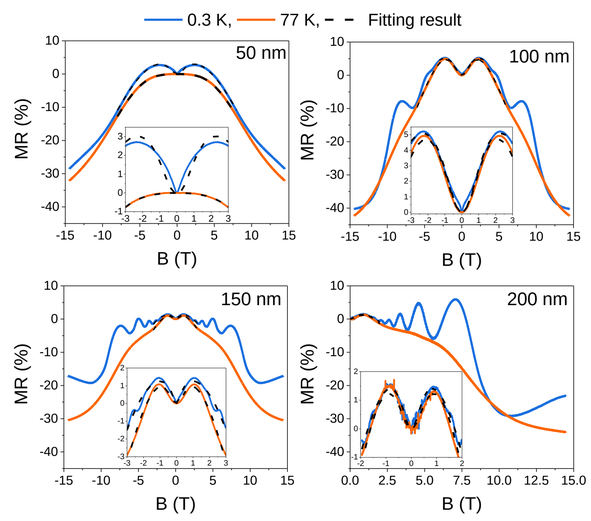
Parameters from fitting of 2-band Drude model



- High-field **linear MR** is dominated by mobility fluctuations [3]
- Conditions for reaching **quantum limit** are fulfilled [4]



NEGATIVE LONGITUDINAL MAGNETORESISTANCE IN IN-PLANE MAGNETIC FIELD



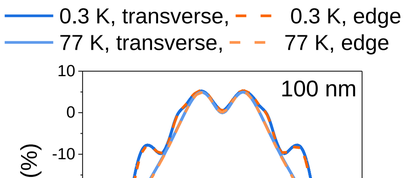
Experimental data can be described by adding weak antilocalization-related conductivity [5] to eq. 1:

$$\sigma_{WAL}(B) = C_{WAL}\left(\sqrt{B}\frac{B^2}{B^2 + B_C^2} + \gamma B^2 \frac{B_C^2}{B^2 + B_C^2}\right) \quad (2)$$

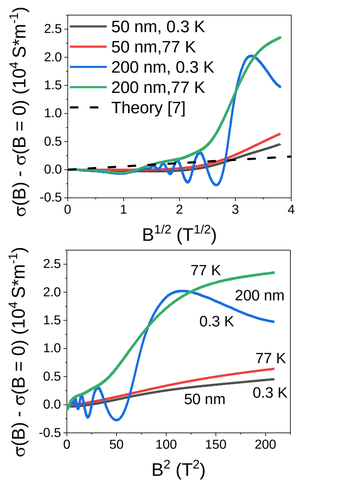
It accounts for low-field positive MR. However, different origin of this positive contribution is expected in 50 nm thick layer and the rest of samples due to their different temperature dependence.

ALTERNATIVE SOURCES OF NEGATIVE MAGNETORESISTANCE

Current jetting [6]: excluded by comparison of transverse and edge contacts

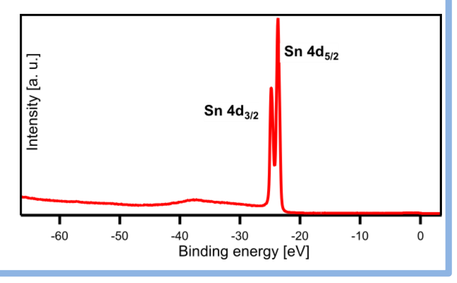


Weak localization (WL): inconsistent with theory [7]

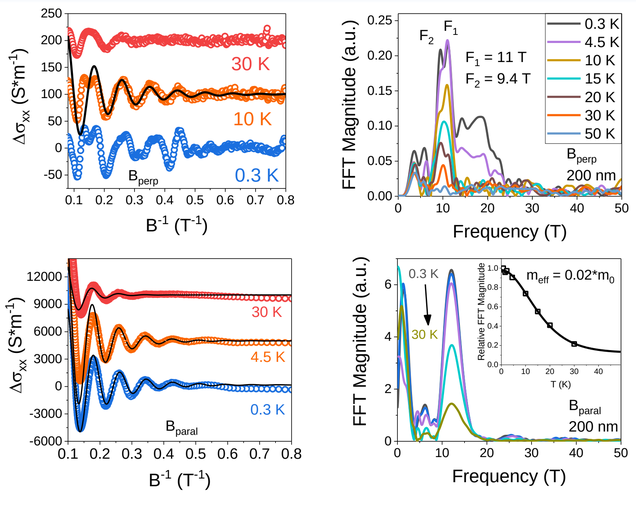


Reaching quantum limit: inconsistent with field dependence of NLMR

Magnetic doping: only Sn detected by core level spectroscopy



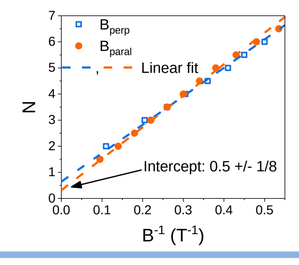
SHUBNIKOV - de HASS OSCILLATIONS: NON-TRIVIAL BERRY PHASE



Fitting with single-frequency Lifshitz-Kosevitch formula (black, solid lines):

$$\Delta\sigma_{xx} \propto \sqrt{\frac{B}{2F}} \cos\left[2\pi\left(\frac{F}{B} - \frac{1}{2} + \beta \pm \gamma\right)\right] \quad (3)$$

Intercept $\frac{1}{2} \pm \frac{1}{8}$ suggests **non-trivial Berry phase**



CONCLUSIONS

Our results are consistent with the existence of Weyl semimetal phase in α-Sn:
- Band structure calculations predict WSM phase
- Negative longitudinal magnetoresistance consistent with chiral anomaly
- Non-trivial Berry phase from Shubnikov – de Haas oscillations

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