Strain-engineered topological Dirac fermions in epitaxial α-Sn

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Breaking the symmetry, e.g. by applying strains, makes it possible to create various topological phases in α-Sn (a.k.a. grey tin), nominally a zero-gap semiconductor with an inverted band structure [1]. In particular, in-plane compressive strain in epitaxial grey tin layers leads to the formation of Dirac semimetal (DSM). The external magnetic field additionally breaks time-reversal symmetry and creates Weyl semimetal (WSM). This tunability of topological properties makes α-Sn an attractive material platform for studying the physics of Dirac fermions [2].

Here, we present a comprehensive study of grey tin layers grown by molecular beam epitaxy. The CdTe/GaAs (001) hybrid substrates used for the growth introduce a compressive in-plane strain of 0.13%, as determined from X-ray diffraction. According to the results of **k·p** calculations, this value is large enough to create the DSM phase, which we characterize by low-temperature magnetotransport ($T \geq 300$ mK, $B \leq 14.5$ T). Significantly, a non-saturating negative longitudinal magnetoresistance (NLMR) occurs in magnetic fields parallel to the current for all samples studied. After ruling out alternative mechanisms, such as current jetting and weak localization, we associate this feature with a chiral anomaly – the WSM signature. To our knowledge, this is the first detailed study of NLMR in α-Sn. The non-trivial nature of our samples is supported by the π Berry phase extracted from Shubnikov-de Haas oscillations. Their presence in various orientations of magnetic field indicates the 3D character of observed carriers. Our results are consistent over a wide thickness range (50 nm – 200 nm) and provide a comprehensive description of grey tin in agreement with the predicted Dirac and Weyl semimetal phases [2].

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References

[1] Liang Fu and Charles Kane, Phys. Rev. B **76** (2007), 045302
[2] Huaquing Huang and Feng Liu, Phys. Rev. B **95** (2017), 201101(R)

Figures

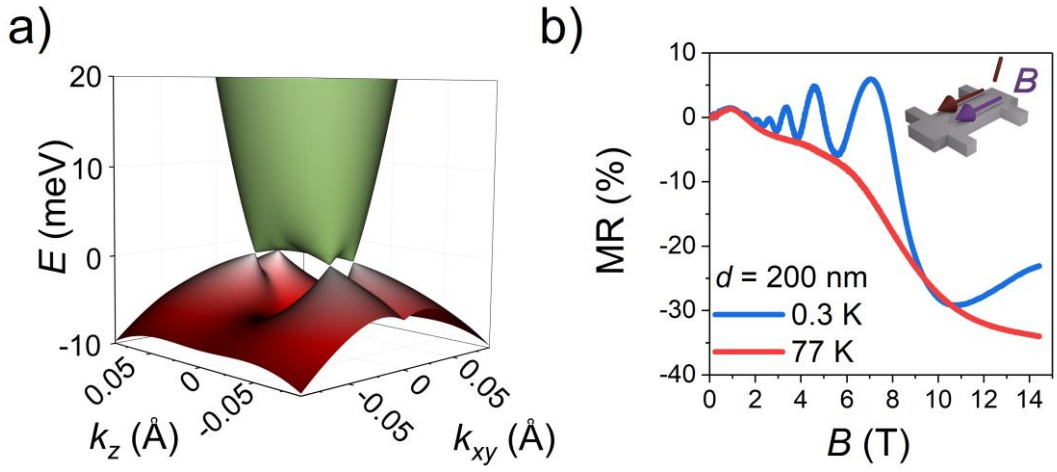

Figure 1: a) Band structure of compressively strained α-Sn in in-plane magnetic field $B = 10$ T. b) Example of NLMR in grey tin in magnetic field parallel to the current, measured for two temperatures.