Quantum oscillatory phenomena in $Pb_{0.6}Sn_{0.4}Te$:Cr Weyl semimetal

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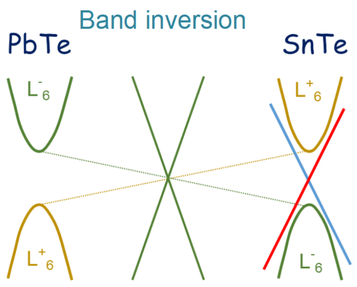
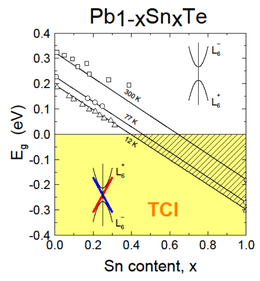
Outline

- **Introduction** – Topological phases in $Pb_{1-x}Sn_xTe$:Cr - the role of chromium impurity,
- **High field transport measurements** – perpendicular and palallel field configuration
- Shubnikov de Haas oscillations
- Aharonov-Bohm & Altshuler-Aharonov-Spivak quantum oscillations
- **Summary**

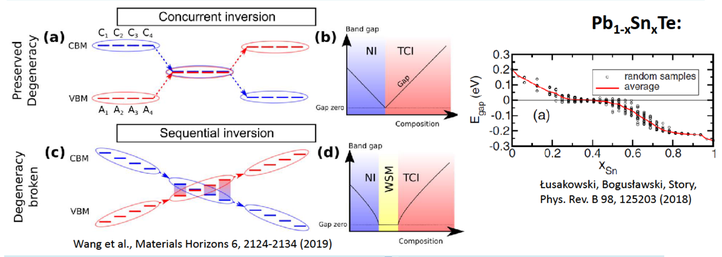
topological crystaline insulators





Disorder induced **sequential band inversion** regime

Mixed alloys e.g. $(PbTe)_{1-x}(SnTe)_x$ have always bulk Weyl points in the *sequential band inversion regime* - – transition between NI and TI phases (which drives the system to a WSM) takes place over a range of compositions.



Wang et al., Materials Horizons 6, 2124-2134 (2019)

Łusakowski, Bogusławski, Story, Phys. Rev. B 98, 125203 (2018)

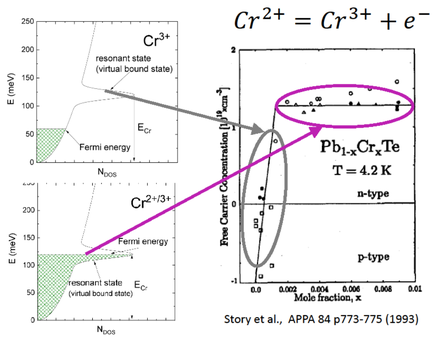
Breaking of local inversion symmetry attributed to two reasons:
- atomic potentials are different between Pb and Sn,
- atomic displacements are non-uniform.

alloy randomness splits the degenerate states

The role of chromium in obtaining the WSM phase in $Pb_{1-x}Sn_xTe$

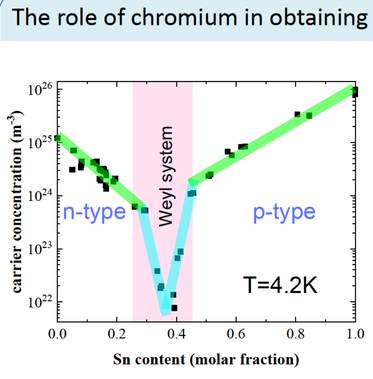
Chromium as a resonant donor in PbTe

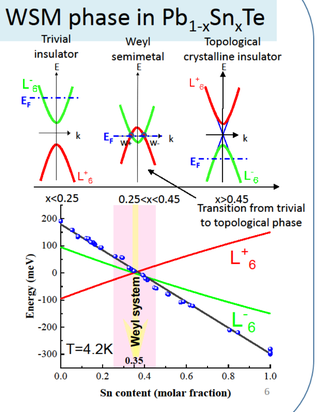
$$Cr^{2+} = Cr^{3+} + e^-$$



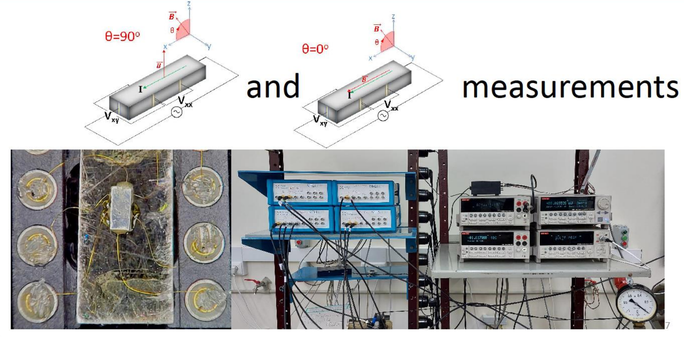
Story et al., APPA 84 p773-775 (1993)

The role of chromium in obtaining the WSM phase in $Pb_{1-x}Sn_xTe$

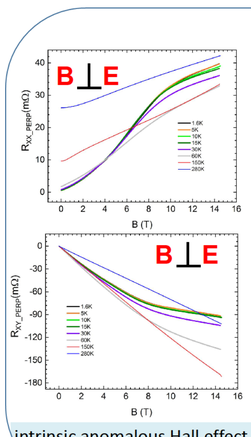




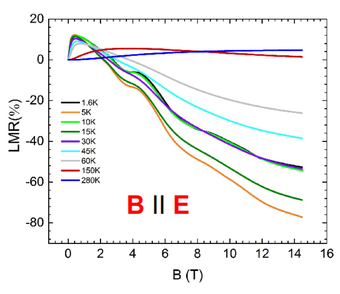
High field transport measurements (Pb,Sn)Te:Cr



The role of chromium in obtaining the WSM phase in $Pb_{1-x}Sn_xTe$



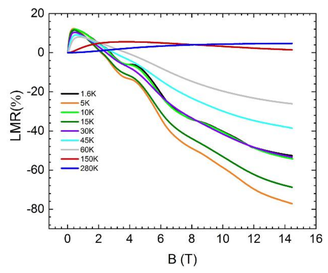
Chiral anomaly observed in $(PbTe)_{0.6}(SnTe)_{0.4}$:Cr in broad temperature range 1.6K to 60K

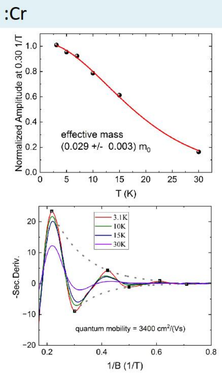


intrinsic anomalous Hall effect

parallel configuration - analysis of Shubnikov de Haas oscillations $(PbTe)_{0.6}(SnTe)_{0.4}$:Cr

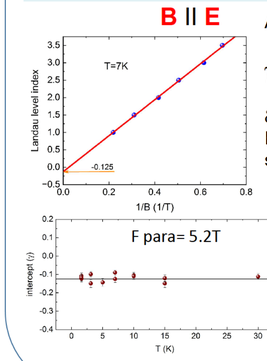
B ll E





analysis of Shubnikov de Haas oscillations - index plot intercept $(PbTe)_{0.6}(SnTe)_{0.4}$:Cr

B ll E



$A*\cos(2\pi*F/B + \gamma)$

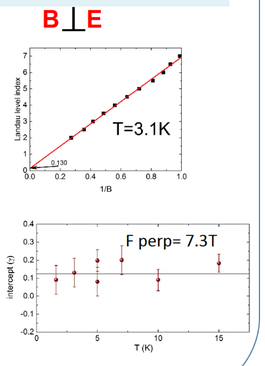
$\gamma = 1/2 - \Phi_B / 2\pi + \delta$

δ =+/- 1/8 (max, min Fermi surface cross section)

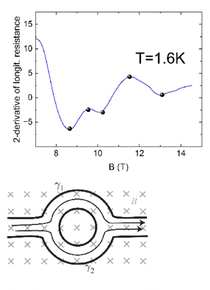
$\Phi_B = \pi$

$n_{para} = 6.7\ 10^{16} cm^{-3}$
$n_{perp} = 1.1\ 10^{17} cm^{-3}$
$n_{Hall} = 7.0\ 10^{17} cm^{-3}$

B⊥E



parallel configuration - oscillations periodic in direct magnetic field: Aharonov - Bohm and Altshuler-Aharonov-Spivak

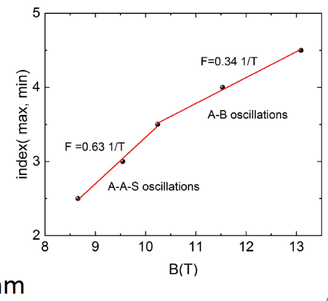


B ll E

$F_{A-B} = S/(h/e)$

$S = 3.5\ 10^{-16}\ m^2$

radius = 10.6nm



Summary

- Tuning of the Fermi energy by Cr dopant in PbSnTe crystals revealed presence of the topological phases TCI and Weyl semimetal.
- Weyl semimetal phases identified in high field magnetotransport by:
  - chiral anomaly observed (negative longitudinal magnetoresistance),
  - Shubnikov de Haas oscillations : observed in both paralel and perpendicular configurations, quantum limit at 6 Tesla, Pi Berry phase, 3 dimensionality confirmed, anisotropy of Fermi surface detected
- Additionally quantum interference oscillations observed in high magnetic fields: Aharonov - Bohm and Altshuler-Aharonov-Spivak

Acknowledgments

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