Transport and magnetic properties of the topological (Weyl) semimetal: Hexagonal - $(Mn_{1-\alpha}Fe_{\alpha})_3Ge$ (α = 0 -0.3)

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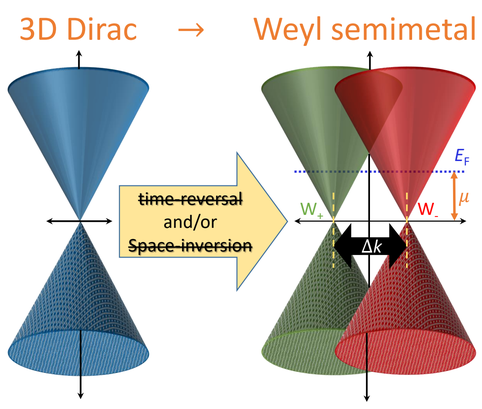
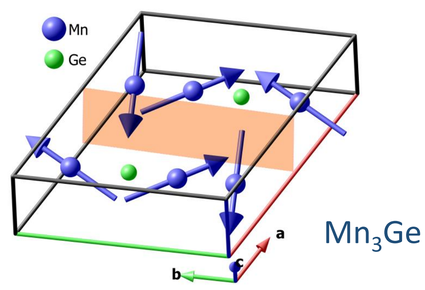
Introduction:

Weyl semimetals host Weyl fermions, which act as a source and sink to the non-zero Berry curvature, giving rise to the fictitious magnetic field in phase space.

Large anomalous Hall effect can be observed in chiral *antiferromagnetic* Weyl systems. **Best example: Hex.-Mn_3Ge.**

Magnetic and transport properties of Fe-doped Mn_3Ge were studied to examine the evolution of Weyl parameters ($\Delta k, \mu$) with: (i) *magnetization* (ii) *magnetic symmetry*, and (iii) *impurity.*

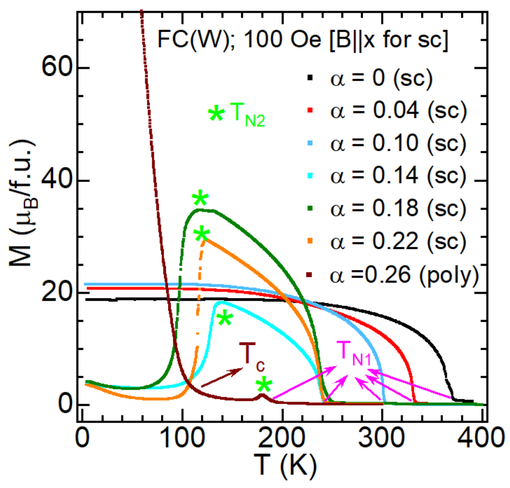


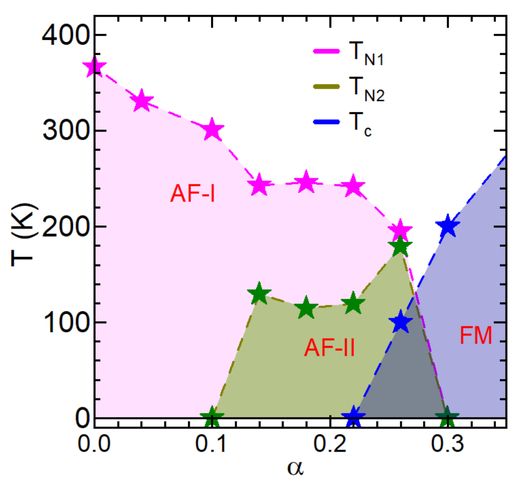


Mn_3Ge

Sample characterization:

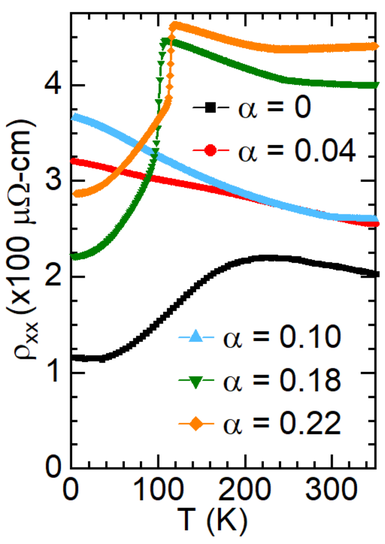
- Single crystal (sc) **Hex- $(Mn_{1-\alpha}Fe_{\alpha})_3Ge$ (α = 0-0.22)** were synthesized.
- X-ray powder diffraction analysis confirms the pure hexagonal phase ($P6_3/mmc$) for all the compounds.
- Magnetization and resistivity measurements show magnetic phase tansitions at 240 K (T_{N1}) and 110 K (T_{N2}).



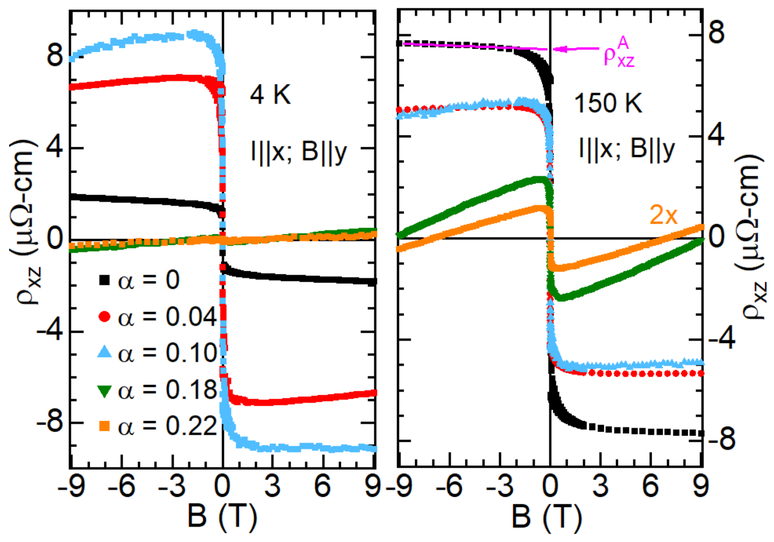


Resistivity and anomalous Hall effect (AHE):

Long. resistivity

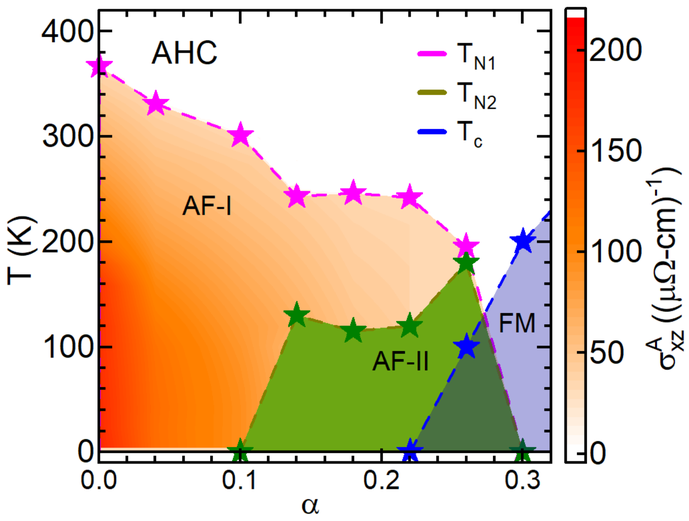


Hall resistivity



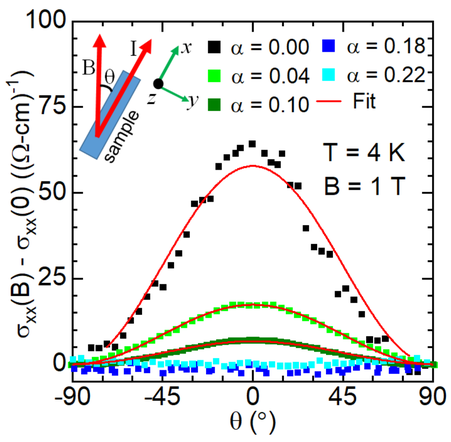
- Anomalous Hall resistivity (ρ_{xz}^{A}) is observed in AF-I regime.
- Anomalous Hall conductivity (AHC): $\sigma_{xz}^{A} = \rho_{xz}^{A}/(\rho_{xx}\rho_{zz})$.
- AHE is present within AF-I regime only.

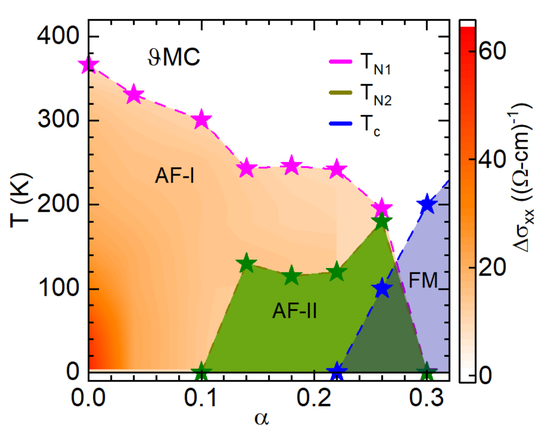
- Origin of AHE in AFM? Non-zero Berry curvature.
- Weyl points are likely to exist within the entire AF-I region.



Angular magneto-conductivity (ϑMC):

- Positive ϑMC is observed within the AF-I regime only (below T_{N1}, and above T_{N2}).
- Fitting: $\sigma_{xx}(B) - \sigma_{xx}(0) = \Delta\sigma_{xx}\cos^2\theta;\ [\Delta\sigma_{xx} = \sigma_{xx}(0^o) - \sigma_{xx}(90^o)]$.



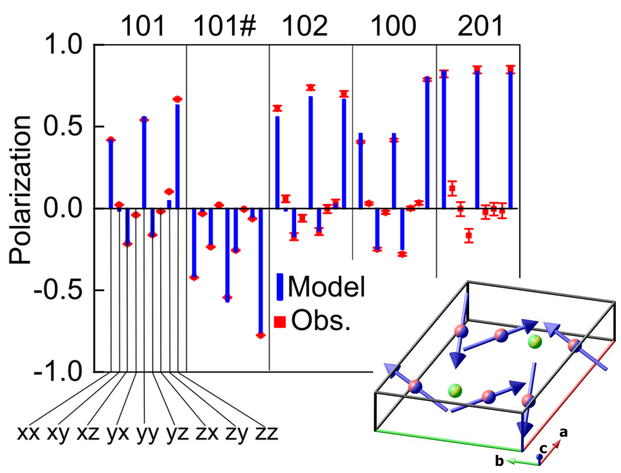


- AF-I region: Positive ϑMC is small compared to the Mn_3Ge.
- AF-II region: Positive ϑMC *vanishes*.
- Origin of positive ϑMC in AF-I region? (possibly) *chiral anomaly effect.*
- Why $\Delta\sigma_{xx}$ decreases with an increase in α? Weyl points move far from E_F

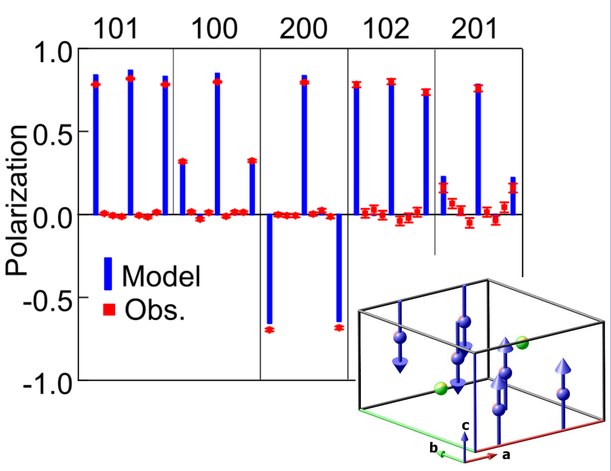
Single-crystal neutron diffraction (@ ILL):

- Polarized neutron (CRYOPAD, D3), Unpolarized neutron (D23) diffraction techniques were used to determine the magnetic structure (mag. srt.) of the $(Mn_{(0.78)}Fe_{0.22})_3Ge$.

T = 130 K



T = 4 K



- AF-I region: mag. Str. remains same as Mn_3Ge (in-plane AFM).
- AF-II region: mag. str. become collinear AFM along the *z* axis.

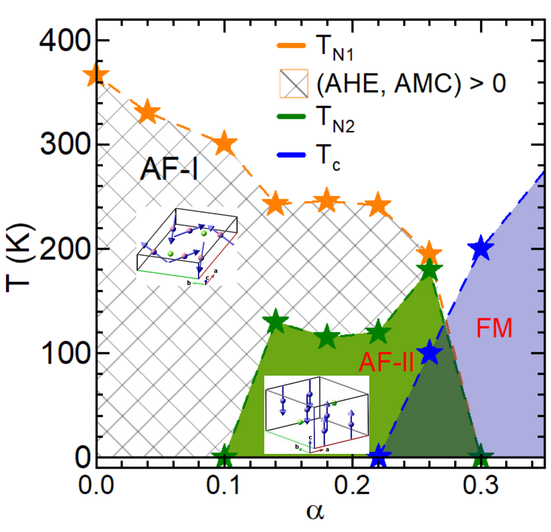
Conclusion:

AHE and ϑMC are present in AF-I regime only, where mag. str. is same as Mn_3Ge.

- *Weyl points are robust, and most likely exist in $(Mn_{1-\alpha}Fe_{\alpha})_3Ge$ (α = 0-0.22).*
- *Magnetic symmetry and Weyl points are intimately connected.*

AHE and ϑMC, in the AF-I regime, weaken significantly.

- *Δk decreases, and μ increases with Fe doping. So, Weyl parameters ($\Delta k, \mu$) can be tuned by doping of the parent Weyl semimetal.*



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