Butterfly-Like Anisotropic magnetoresistance in frustrated half Heusler semimetal, TbAuPb

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In condensed matter physics, the last decade has been dedicated to the search for non-trivial topological materials. Significant progress has been made in characterizing different intermetallic families, where non-trivial topological properties such as topological insulators, Weyl semimetals, Dirac semimetals, and Skyrmion structures have been realized. The rare-earth-based half-Heusler (HH) family is one such group[1]. Despite their relatively simple face-centred cubic (FCC) crystal structure, these compounds exhibit non-trivial topological properties. For example, GdPtBi, a member of the RPtBi (R = rare earth) series, hosts field-induced Weyl nodes[2]. Similarly, other HH families like RPdBi, RPtSb, RPdSn have also been extensively studied[3]. Recently, GdAuPb, a member of the RAuPb family, was reported by Yonglai Liu et al. GdAuPb shows large magnetoresistance (800 % at 1.5 K) and also exhibits an anomalous Hall effect[4]. We have extended this series by preparing single crystals of TbAuPb. Terbium (Tb) is next to Gadolinium (Gd) in the periodic table, but unlike Gd, which has zero total orbital angular momentum (**L**), Tb has a non-zero (**L**). Single crystals of TbAuPb were synthesized using the self-flux method. Magnetic measurements were performed between 300 K and 2 K in magnetic fields up to 7 T. The susceptibility data reveal that the compound orders antiferromagnetically (AFM) at 4.5 K. The Tb^{3+} ions form a frustrated FCC lattice, as indicated by the high frustration parameter (f $\approx$ 7.6). Below the Néel temperature T_N, TbAuPb undergoes metamagnetic transitions around 5 T, clearly visible in the phase diagram. Resistivity measurements indicate a semi-metallic nature, with a kink around 4 K, confirming a second-order transition from the paramagnetic state to the AFM phase. Magneto-transport measurements reveal interesting features: below T_N the magnetoresistance (MR) is positive and increases with field up to 5 T, after which it starts to decrease. Above T_N, the material exhibits negative MR in both longitudinal and transverse geometries, with the magnitude of MR decreasing as the temperature increases. Hall resistivity data show a curvilinear dependence on magnetic field at high temperatures (above 50 K), suggesting multi-band contributions. The positive slope of the Hall resistivity and its temperature dependence confirm that the charge carriers are holes, and the carrier concentration varies with temperature. The AFM transition is also confirmed by a sharp lambda anomaly in the heat capacity C_P measurements. Additionally, angular magnetoresistance (AMR) measurements reveal butterfly-like features in high magnetic fields. At 5 T, we observed a valley inversion in the AMR, which may be related to the meta-magnetic transition. These AMR measurements clearly show the influence of the magnetic field on the Fermi surface below T_N. TbAuPb needs further experimental and theoretical investigation to explore the origin of its metamagnetic transition, frustrated ground state, and anisotropic, field-induced butterfly-like AMR. This compound demonstrates that there is still ample room for further experimental studies in this family of materials.

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References

[1] Yan et.al. https://doi.org/10.1146/annurev-conmatphys-031016-025458

[2] Liang et.al. doi: https://doi.org/10.1103/PhysRevX.8.031002

[3] Singh et.al. APL Mater. 8, 060903 (2020); doi: 10.1063/5.0006118

[4] Lai et.al. Appl. Phys. Lett. 124, 033102 (2024); doi: 10.1063/5.0181680