Topological nodal-line semimetal $TaAs_2$: crystal growth, low temperature transport and ARPES study

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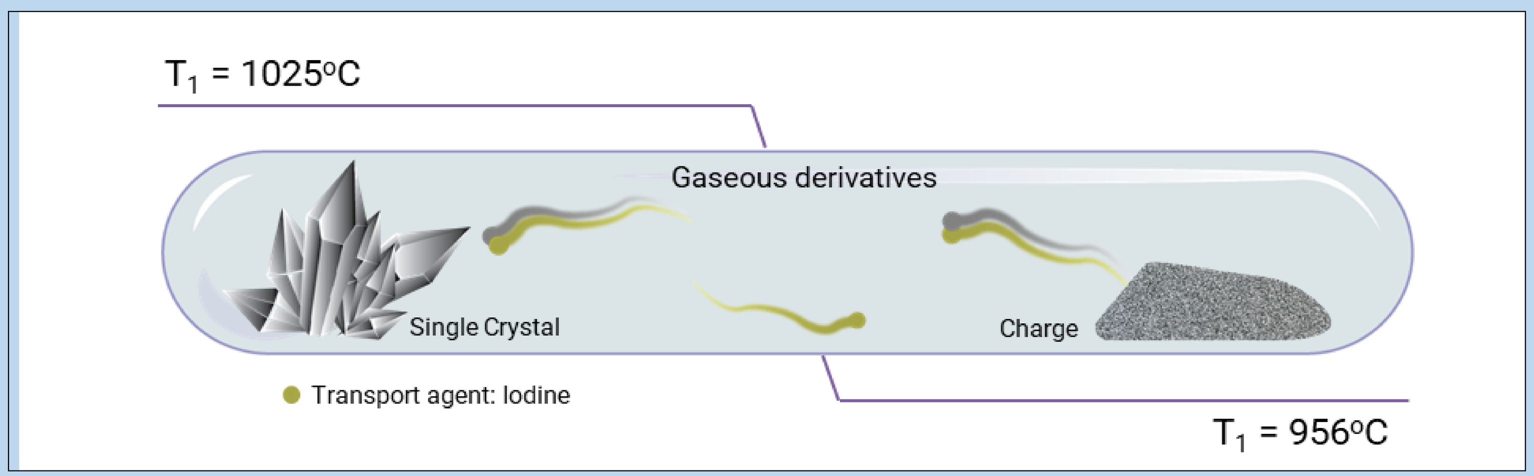
Motivation

Conducting materials with extremely large magnetoresistance are interesting from the point of view of applications in various magneto-electronic devices. Recently, it was found that non-magnetic semimetal, $TaAs_2$, exhibits non-saturated magnetoresistance as large as 10^5, in the magnetic field range up to 9 T. This is a result of nearly compensated electron-hole character of the conductance of this system [1]. We have confirmed this by using mobility spectrum analysis which is very useful tool for studies of various multi-carrier conducting systems [2]. Additionally, we observe multi-carrier Shubnikov-De Haas (SdH) oscillations whose periods shows pronounced band anisotropy. The band anisotropy is reflected in the preliminary results of ARPES studies of our $TaAs_2$ crystals and the more detailed studies are underway.

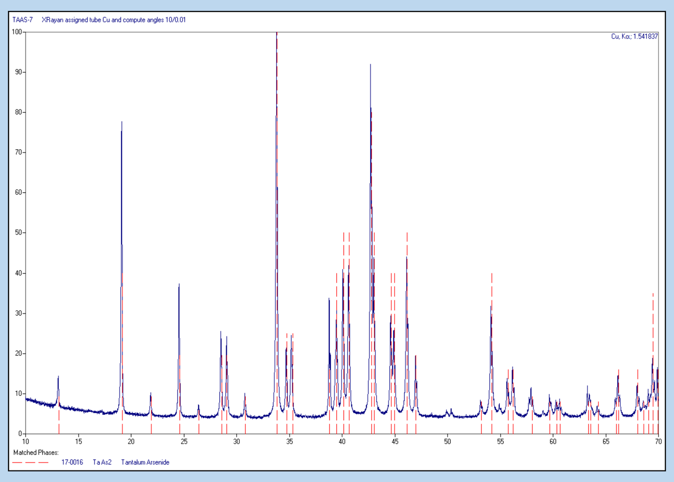
Experimental details

We have prepared single crystals of $TaAs_2$ by chemical vapor transport method and verified by X-ray diffraction and EDX analysis. a rectangular sample of $TaAs_2$ of dimensions 2.19 mm × 0.799 mm × 0.467 mm for electron transport measurement. These Ohmic contacts are prepared in a Hall bridge configuration. A four probe technique is used to obtain transverse and longitudinal resistances from temperature 1.57 K to 300 K by sweeping magnetic field from - 9 T to 9 T.

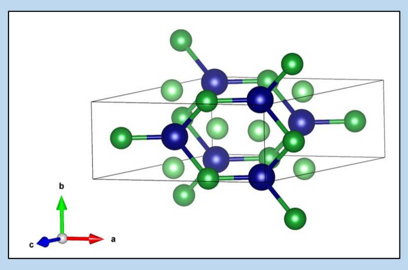
Chemical Vapor Transport



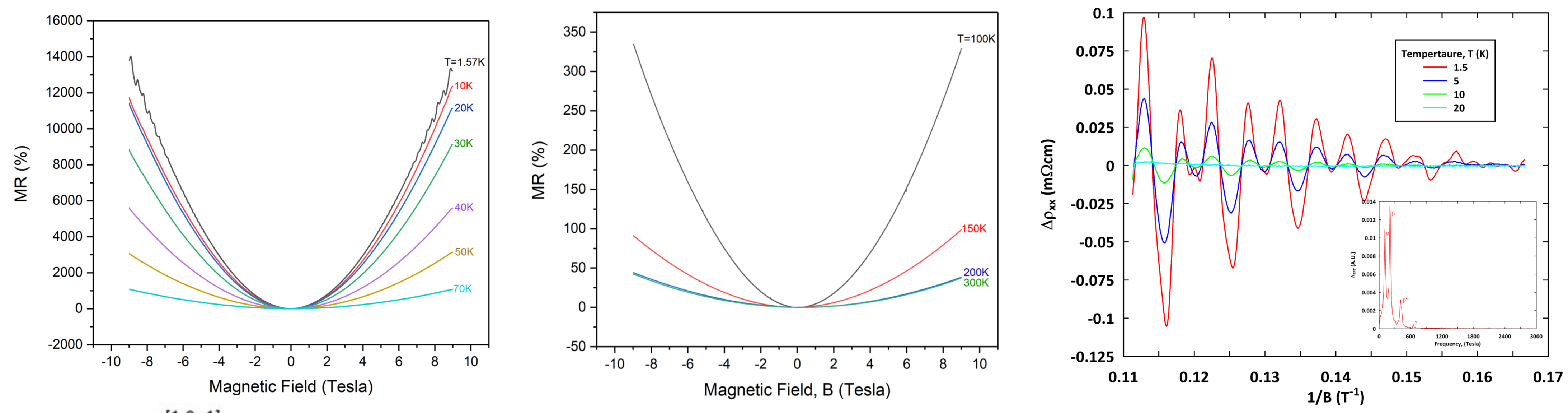
X-ray diffraction

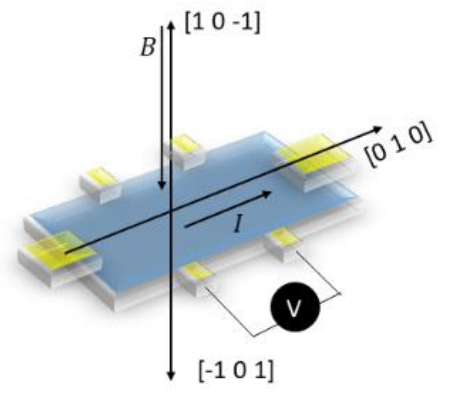


- **Crystal structure:** Monoclinic (Stoichiometry 1:2)
- **Space group:** C12/m1 (a = 7.758 Å   b = 3.392 Å   c = 8.705 Å)



Electron transport





At low temperatures and high magnetic field SdH oscillations appear with dominant frequency peaks at 109.86 T, 207.51 T, 646.97 T

Fermi surface trajectories and mobility spectrum analysis

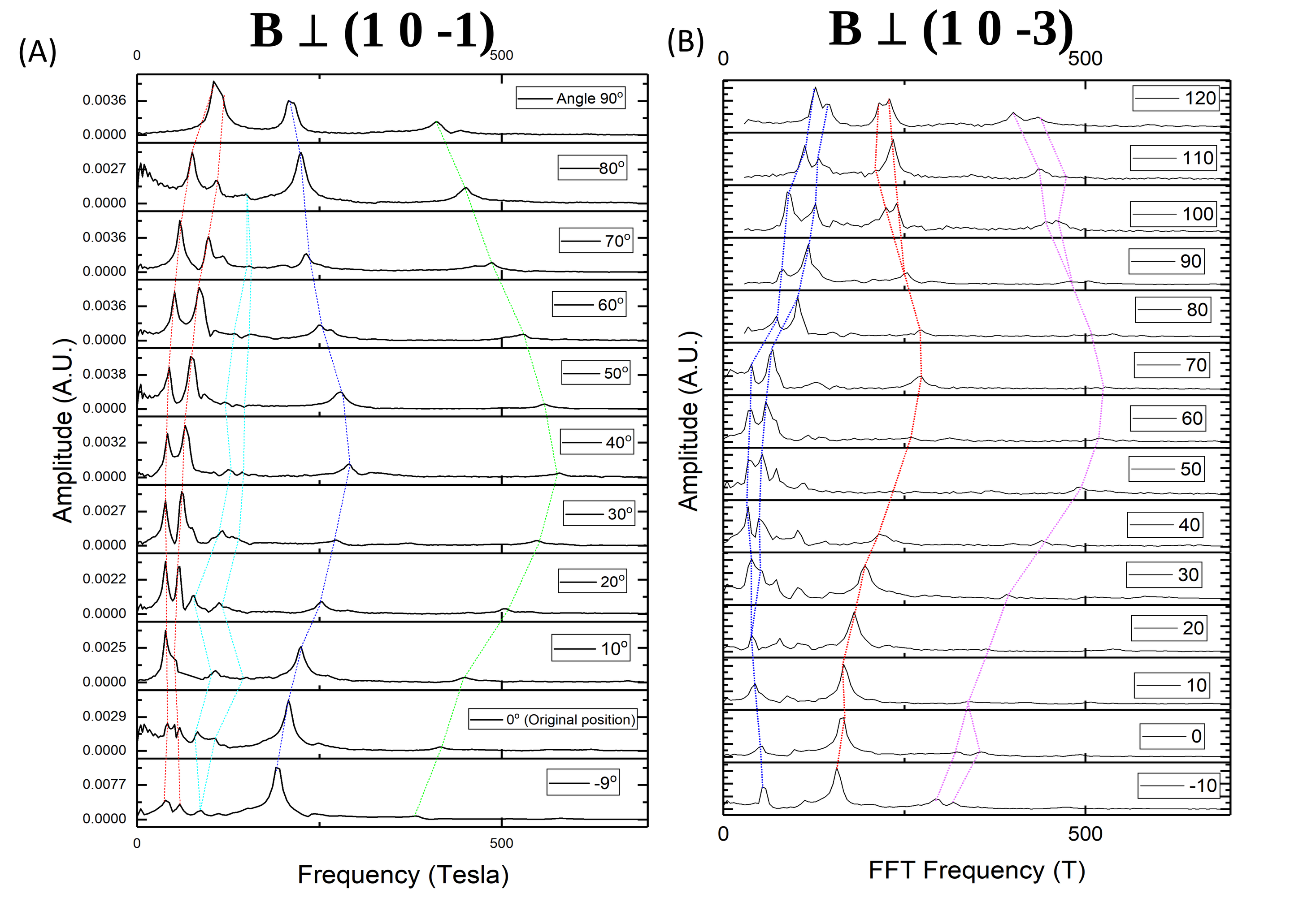


Fig.1 Angle dependence of FFT frequencies with two configurations in which mag. field (B) is perpendicular to A) (1 0 -1) plane and B) (1 0 -3) plane

Rotation probe study shows many **elliptical shape and one of the elliptical shape with two antlers attached** of Electron and Hole Fermi pockets resp.

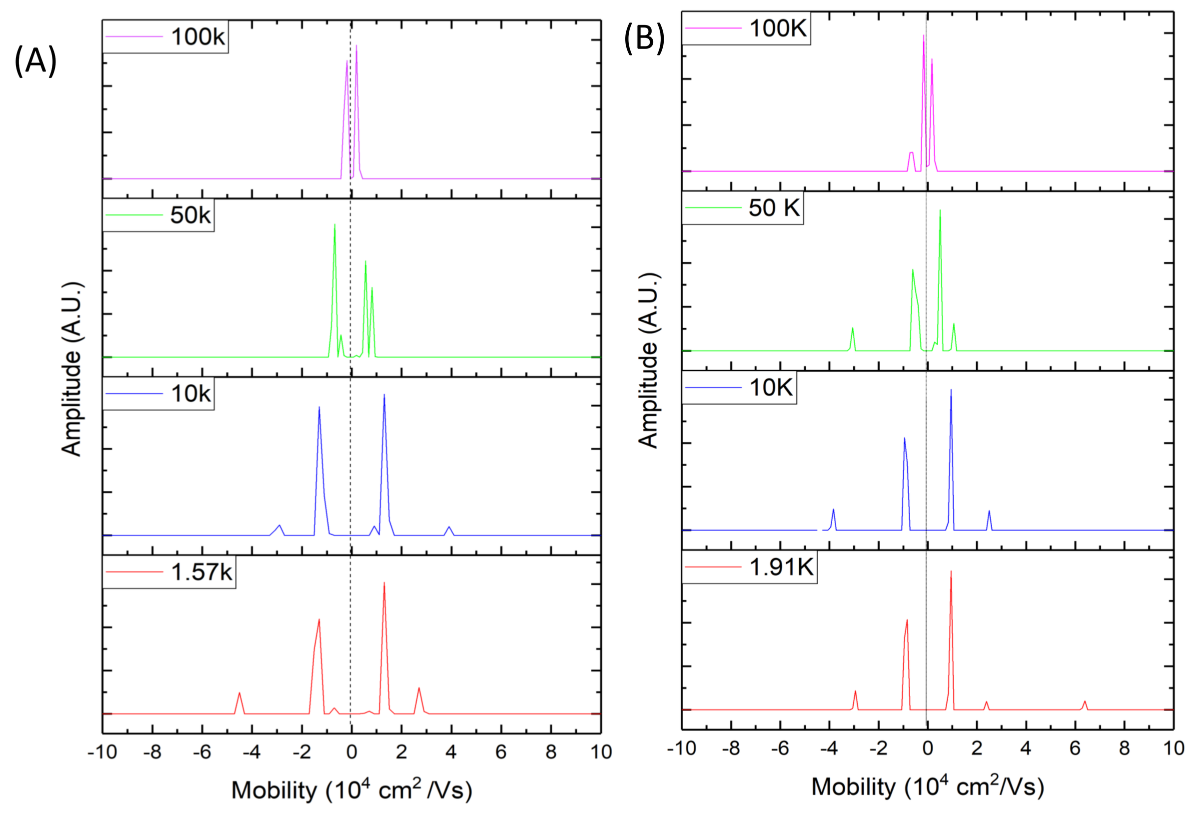


Fig2. Multicarrier mobility spectrum analysis done on two different planes A) (1 0 -1) and B) (1 0 -3) resp. which shows more than two carriers with different mobilities contributing to the electron transport.

ARPES study and mobility spectrum analysis

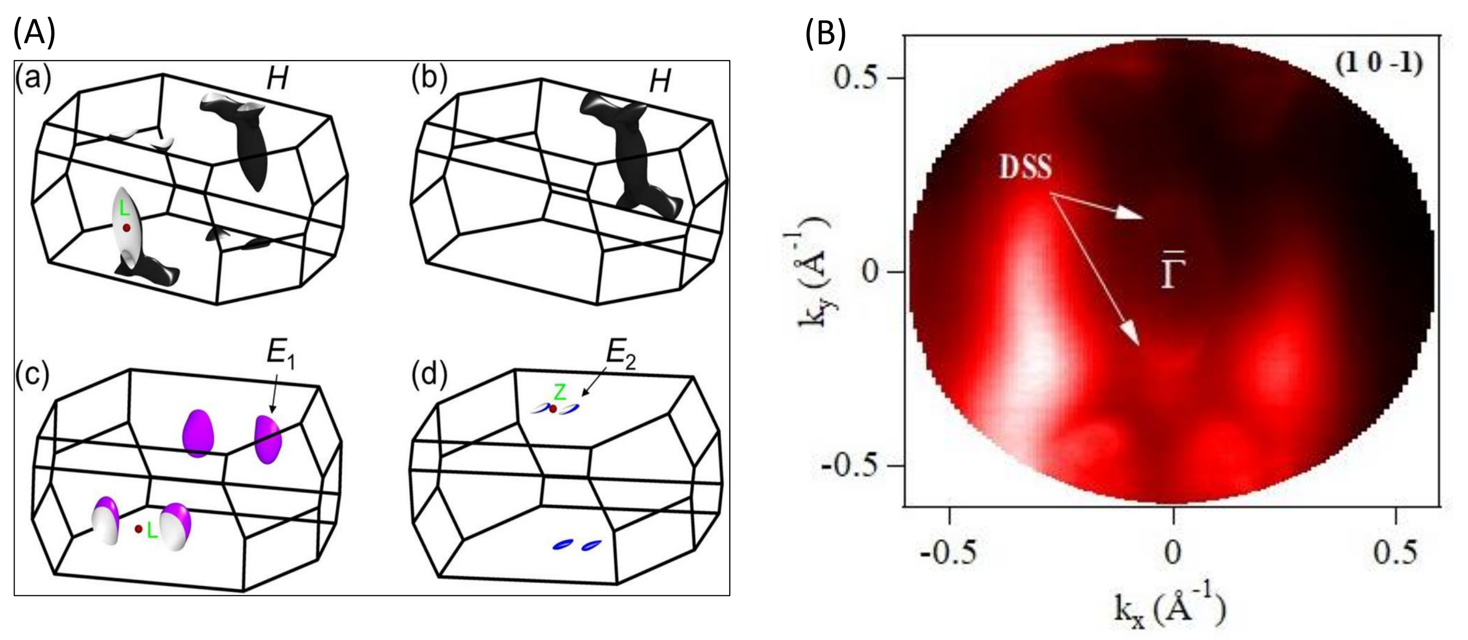


Fig. (A) Theoretical calculations of 3D Femi surface showing (a,b) Hole Pockets (c,d) Electron Pockets present in the sample taken from Ref. 1 (B) ARPES image taken on freshly cleaved (1 0 -1) surface showing **elliptical Fermi Pockets, Drumhead surface states (DSS)** which agree with Theoretical study as well as experimental study. (Theoretical work is going on in collaboration with Dr Carmine Autieri (MAGTOP))

Discussion

Table 1. Parameters extracted from Lifshitz Kosevich analysis of SdH oscillations in $TaAs_2$

FFT Frequency (Tesla)	*Effective mass (m^*)*	*Cross-section of Fermi surface ($Å^{-2}$)*	*Fermi wave-vector (Circular cross section) ($Å^{-1}$)*	*Fermi velocity (m/s)*	*Fermi Energy (meV)*
109.86	**0.245 m_0**	**0.01048**	**0.0578**	**2.719 x 10^5**	**103.13**
207.51	**0.247 m_0**	**0.0198**	**0.0794**	**3.702 x 10^5**	**192.9**
646.97	**0.598 m_0**	**0.0617**	**0.01401**	**0.2701 x 10^5**	**162.44**

At lowest temperature T = 1.57 K MR attained 14000 % and the order of magnitude is almost same up to T = 20K. At higher temperature it starts decreasing and finally reaches to 48% at room temperature. Due to complex multi-carrier nature of conductivity in $TaAs_2$, it is difficult to find mobility and carrier concentration in a usual manner. Hence we achieved a mobility spectrum by performing mobility spectrum analysis (MSA)[3]. MSA shows 5 types of carriers at T = 1.57 and finally a Fermi surface $TaAs_2$ consists of Hole and Electron Pockets. It is more anisotropic with two extra legs which is confirmed by angular dependence study performed on our sample. Angle Resolved Photoemission Spectroscopy (ARPES) performed on freshly cleaved (1 0 -1) face confirms the shape of Fermi pockets. During ARPES experiment it was very difficult to cleave the other planes of $TaAs_2$ samples.

Acknowledgement

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References

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