Signature of superconducting onset in presence of large magnetoresistance in type-II Dirac semimetal candidate Ir$_2$In$_8$S

Pallavi Malavi$^{1,**}$, Prakash Kumar$^2$, Navita Jakhar$^2$, Surjeet Singh$^2$$^*$ and S Karmakar$^1$

$^1$ High Pressure and Synchrotron Radiation Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400085, India
$^2$ Department of Physics, Indian Institute of Science Education and Research (IISER), Pune 411008, India

$^*$ Author to whom any correspondence should be addressed.
E-mail: spallavi@barc.gov.in

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Abstract

Since the discovery of type-II Dirac semimetal (DSM) as the potential candidate for topological superconductor, magneto-transport studies on diverse type-II DSMs have been of tremendous research interest. Here we report the structural and magneto-transport properties of type-II DSM candidate Ir$_2$In$_8$S under high pressure. With increasing pressure, this shows dramatic suppression of its characteristic large magneto-resistance, which is however partially regained upon release of pressure. No superconductivity has emerged with increasing pressures up to $\sim$20 GPa. However, in the pressure-released sample a significant resistivity drop below $\sim$4 K has been detected. The field dependent resistivity and dc magnetization measurements confirm this as superconducting onset. Ir$_2$In$_8$S thus becomes a unique system exhibiting large MR above the superconducting transition. X-ray diffraction results show that the ambient tetragonal structure ($P4_{2}mnm$) remains stable up to $\sim$7 GPa, above which this undergoes a reversible structural transition into an orthorhombic structure ($Pnnm$). The observed enhanced residual resistivity and concurrent increase in carrier density of the normal metal state of the pressure-cycled sample indicate that the enhanced impurity scattering plays a significant role in the emergence of superconductivity.

1. Introduction

Three dimensional Dirac semimetals (DSM) are new states of topological quantum matter, characterized by symmetry-protected linear band crossing at the four-fold degenerate Dirac point near the Fermi level [1, 2]. The massless Dirac fermions arising from Dirac points are often considered responsible for the remarkable transport properties, including ultrahigh carrier mobility and extremely large and unusual field- and angle-dependent magneto-resistance (MR) in 3D materials like Cd$_3$As$_2$ [3, 4], Na$_3$Bi [5, 6], TlBiSeS [7] and PtBi$_2$ [8]. Understanding the extremely large MR (XMR) in terms of nontrivial band topology is often debated. While electron–hole compensation mechanism is considered a necessary ingredient for the emergence of the XMR in multiband semimetals [9–13], the possible origin of the ultrahigh mobility (the essential criteria) is discussed in terms of either topological protection [4, 5, 14–16] or spin–orbit coupling (SOC)-induced orbital texture on Fermi surface [12, 17–20]. Lorentz invariance-broken (type-II) DSM state, as has been predicted and experimentally verified in the 1T-PtSe$_2$ family [21, 22] and VAl$_3$ family [23], has become of tremendous current research interest due to the observed finite density of states around the Dirac point, that may help emerge topological superconductivity (SC) and host Majorana modes with possible applications in quantum computations. The non-trivial topology has indeed been established in the SC phases of PdT$_2$ and Ir$_{1-x}$Pt$_x$Te$_2$ [24–26]. As the Dirac points in these systems are situated below the Fermi level, carrier doping often helps tune the Fermi level through the Dirac point in order to probe the surface states carriers [26]. However, the normal
state MR and so the carrier mobility is much reduced, implying non-involvement of the massless Dirac fermions in their transport phenomena [24]. On the other hand, in the newly synthesized type-II DSM candidate Ir2In8S exhibiting significantly large and anisotropic MR (qualifying the ultrahigh mobility criteria) and possessing non-trivial electron pockets, theory predicts two Dirac crossings at 25 and 40 MeV above the Fermi level [31, 32]. In this case, pressure-induced band broadening may shift the Fermi level upward by enhancing the carrier density and help tune the Fermi level towards the Dirac points, thus possibly exhibiting exotic transport signatures. Pressure being a cleaner way to tune the band structure without inducing disorder, P-induced SC in presence of large MR is highly sought after in diverse types of DSMs as possible platform to explore topological SC [27, 28, 50]. It is noteworthy that the observed SC in the type-I DSM Cd3As2 at high P is accompanied by a structural transition [27] and SC in WTe2 and PtBi2 emerge at high P with complete suppression of MR [28, 29, 50], suggesting possible non-coexistence of the SC state and the topological surface states.

Sub-chalcogenide compounds with diverse structural motifs have recently been found to be promising topological semimetal candidates [2, 30–32]. The sub-valent metallic character in related compounds leads to competing electronic phases like charge density wave and SC [33, 34]. Sub-chalcogenide Ir2In8Q (Q = S, Se, Te) compounds crystallize in tetragonal P42/mmm space group with 3D framework of IrIn8 polyhedra with chalcogen atoms in the channels along the c-axis [31, 32]. No SC has been reported in this series of compounds. But an increased chalcogen atom radii leads to lattice instability with commensurately modulated structures due to enhanced polyhedral distortions at intermediate temperatures. This also reduces the low temperature MR [32]. As the effect of pressure is expected to be similar to that of decreasing atomic radii, high pressure study on these compounds may reveal competing electronic phases including SC.

2. Experimental

High quality single crystal Ir2In8S (see figures 1(a) and (b)) has been synthesized using indium metal flux method [32] and characterized by x-ray diffraction, EDX and HRTEM measurements. High-pressure resistance measurements at low temperatures have been performed on a freshly cleaved ~20 μm thick microcrystal of ~100 μm lateral dimensions having cleaved plane in arbitrary crystallographic orientation. A Stuttgart version diamond anvil cell (DAC) was used for measurements under quasi-hydrostatic pressures up to 20 GPa using NaCl as the pressure medium. The resistance was measured in the van der Pauw square geometry using standard four probe method with 1 mA current excitation and in the ac lock-in detection technique. For measurements down to 1.4 K, the DAC was placed inside a KONTI-IT (Cryovac) cryostat. A nonmagnetic Cu–Be DAC (Easylab) was prepared with identical sample size for high-field measurements under pressures up to 7.5 GPa and was inserted into a S700X SQUID magnetometer (Cryogenic Ltd) to study transverse MR and Hall resistance up to 7 T field and also for the low-field dc magnetization measurements. Pressures were measured by conventional ruby luminescence method. High-pressure x-ray diffraction measurements at room temperature have been performed at the XPRESS beam line (λ = 0.4957 Å) of the Elettra synchrotron, Trieste. Finely powdered sample was loaded in a DAC with methanol-ethanol-water mixture (16:3:1) as the pressure medium and Cu as the x-ray pressure marker.

3. Results and discussion

Figures 1(c) and (e) show the temperature dependent in-plane resistivity ρxx(T) plots at various pressures. No sign of SC has been observed down to 1.4 K with increasing pressures up to 20 GPa. At 0.2 GPa, ρxx(T) displays an overall metallic behavior with anomalous kink feature at T∗ ~ 230 K associated with the emergence of local structural disorder at high T [32]. The presence of noticeable hysteresis in ρxx(T) above T∗ (shown as inset in figure 1(c)) supports the structural origin of this resistivity anomaly. In the ordered phase (T < T∗), the resistivity above 30 K follows the Bloch–Grüneisen (BG) resistivity model [35].

\[
ρ(T) = ρ_0 + C \left( \frac{T}{Θ_D} \right)^k \int_0^{Θ_D/T} \frac{x^k}{(e^x - 1)(1 - e^{-x})} dx
\]

where ρ0 is the residual resistivity and ΘD is the Debye temperature. The ρxx(T) data for pressures up to 5 GPa can be fit well with k = 5, indicating phonon dominated scattering mechanism. At 0.2 GPa, ΘD = 214 K, in reasonable agreement with the reported value [32]. The ρxx(T) curve at 8 GPa when fitted with the BG equation gives k = 4.1 with ΘD = 120 K, indicating significant electronic structural modifications that can be associated with the observed structural phase transition, as discussed later. With increasing pressure the residual resistivity ρ0 decreases systematically up to ~8 GPa, beyond which it starts
increasing (see inset in figure 1(c)). Also, the residual resistivity ratio (RRR) and so the metallic character remains mostly unchanged in the low-\(P\) phase (see inset in figure 1(e)). An order of magnitude low RRR value in our DAC-based measurement, compared to the value for the ab-plane resistivity of a bare sample [31], can be due to the arbitrary crystallographic orientation of the measurement plane. The metallicity, as seen from the RRR values, marginally increases at 8 GPa, but decreases more rapidly at higher pressures. In figure 1(b) are shown the \(d\rho_{xx}/dT\) plots at various pressures. The characteristic temperature (\(T^*\)) down to which the IrIn\(_8\) polyhedral local disorder persists in the tetragonal structure [31], as indicated by the peak position, systematically decreases at higher pressures due to enhanced intrinsic disorder in the system. At high pressures (\(P > 6.2\) GPa), the resistivity anomaly disappears, indicating ordered polyhedral arrangements in the high \(P\) phase.

Figures 2(a)–(c) show in-plane resistivity \(\rho_{xx}(T)\) measured on Ir\(_2\)In\(_8\)S crystal at three pressure conditions (initial 0.2 GPa, pressurized at 7.5 GPa and at 0.2 GPa released) with zero field and 7 T field applied perpendicular to the current plane. At low pressure, the field-induced upturn at low temperature (\(T < 50\) K) is the signature of large magneto-resistance (LMR) in this compound, in agreement with the reported results [31]. At 7.5 GPa, the field-induced resistivity upturn disappears, with dramatic suppression of MR (see figure 2(c)). Upon release of pressure to 0.2 GPa, resistivity upturn is partially regained (see figure 2(b)). Although the field-induced resistivity change (\(\Delta\rho\)) is mostly unchanged after \(P\)-release, a reduced LMR is apparently due to the increased residual resistivity (\(\rho_0\)). More surprisingly, for the \(P\)-released sample a sharp decrease in resistivity is observed below \(\sim 4\) K in zero field measurement.
Figure 2. In-plane resistivity $\rho_{xx}(T)$ at zero field and at 7 T field measured (a) at initial 0.2 GPa, (b) at 0.2 GPa released pressure, marked with $R$, and (c) at 7.5 GPa. Resistivity drop below $\sim 4$ K in (b) is shown by blue circle. The enlarged view of the resistivity drop under various magnetic fields up to 0.6 T is shown as inset. (d) Temperature dependent zero-field-cooled (ZFC) dc magnetic moment measured at 5 mT field on two $P$-released samples, having volumes $2 \times 10^{-7}$ cm$^3$ (S1) and $32 \times 10^{-7}$ cm$^3$ (S2) and (e) $H_c^2-T_c$ plots and the Ginzburg–Landau fit.

(see figure 2(b)). With increasing magnetic field the resistivity drop gradually smears out (see inset in figure 2(b)), indicating possible onset of SC in the $P$-released sample. This also gets support from the observed change in resistivity drop by current variation (shown in supplementary information). As the SC transition width is significantly broad, zero resistance is not reached down to 1.4 K, the lowest $T$ of this measurement. DC magnetization measurement on a $P$-released sample of larger volume (see curve S2 in figure 2(d)) show significant diamagnetic signal below $\sim 3$ K confirming bulk superconducting nature, with estimated SC shielding fraction $\sim 5\%$ at 2 K. These observations make $P$-released Ir$_2$In$_8$S a unique system, where a large MR persists above SC $T_c$. The enhanced residual resistivity ($\rho_0$) in the $P$-released sample (figure 2(b)) indicates increased defect/impurity scattering. The impurity scattering-induced enhancement of SC $T_c$ has earlier been reported in In-doped SnTe [46]. Moreover, SC persisting upon $P$-cycling with enhanced $T_c$ in layered chalcogenides has earlier been discussed in terms of subtle structural modification of irreversible nature [47, 48]. It can be noted that the resistivity anomaly reappears with unchanged $T^*$ (figure 2(b)), suggesting that SC emerges in the tetragonal structure in absence of local disorder.

The onset $T_c$, taken as the temperature with 1\% resistance drop from the normal state (shown by dashed line in inset of figure 2(b)), decreases systematically with increasing magnetic field in temperature-scanning and in field-scanning mode (not shown here). The $T_c-H_c^2$ plot (shown in figure 2(e)), when fitted with the Ginzburg–Landau (GL) equation $H_c^2 = H_c^2(0)\left[\frac{1 - t^2}{1 + t^2}\right]$ with $t = T/T_c$, estimates an upper critical field $H_c(0) \sim 0.75$ T, which is an order smaller than the Pauli limit of 1.84$T_c \sim 7.5$ T. The estimated GL coherence length ($\xi_{GL} \sim 10$ nm) is much less than the transport mean free path ($l_m \sim 100$ nm), suggesting the phonon mediated SC in the clean limit.

At low pressures, the field-induced large resistivity upturn at low temperature follows the typical trend of known extreme MR materials [8, 9, 14, 17, 20, 36–38]. In figure 3(a) is shown the in-plane resistivity
Resistivity $\rho_{xx}(T)$ of Ir$_2$In$_8$S at 0.5 GPa at different magnetic fields. With large magnetic field, $\rho_{xx}(T)$ shows a large upturn which saturates below $\sim 20$ K. This is consistent with the power-law $T$-dependence ($\rho_{xx}(T) = \rho_0 + A_1 T^\alpha$) of zero field $\rho_{xx}(T)$ below $\sim 20$ K (see figure 3(b)), as discussed in detail in references [10, 12]. The obtained $\alpha \sim 2.5$ indicates electron–electron dominated scattering along with interband electron–phonon scattering [35]. Based on the field variation of $d\rho_{xx}/dT$ curves (figure 3(c)), we plot the $T - H$ phase diagram (inset in figure 3(a)), where $T_m$ and $T_i$ are taken as the sign change point and the minimum in $d\rho_{xx}/dT$ respectively. The phase diagram is consistent with the known LMR materials [20]. $\alpha$ decreases gradually with increasing $P$ and approaches the Fermi liquid behavior ($\alpha = 2$) at $P \sim 6$ GPa, with opposite trend following above this pressure (see inset in figure 3(b)). In case of $P$-released sample resistivity upturn in 7 T field, although much reduced, is observed below $T_m \sim 27$ K. This is consistent with the increased value of $A_1$ for the zero-field $\rho_{xx}(T)$ as per the semi-classical analysis [12].

In order to understand the pressure variation of the MR and possible origin of SC in the DSM candidate Ir$_2$In$_8$S, we have investigated detailed transport properties by transverse MR and Hall measurements at high pressures and also on the $P$-released sample. Figures 4(a) and (b) show the plots of the field dependence of magneto-resistance MR($\%) = [R(H) - R(0)] \times 100/R(0)$ and the Hall resistivity ($\rho_{xy}$) at various temperatures at 0.5 GPa. The observed asymmetry of the MR curves originates from the in-plane Hall contribution that is separated by symmetrizing the MR curves, $MR_{sym}(H) = [MR(H) + (MR(-H))]/2$ [49]. An order of magnitude reduced transverse MR, as compared to the reported value for the ambient sample [31], can be due to the arbitrary crystallographic plane in this measurement. Moreover, a small pressure can also lead to drastic reduction of MR due to Fermi surface modification [39]. With increasing temperature, MR decreases rapidly. A highly non-linear field dependent Hall resistivity indicates multi-carrier transport behavior in Ir$_2$In$_8$S (figure 4(b)). At low $T$ large negative $\rho_{xy}$ indicates electron dominated transport. At high $T$ above 50 K, $\rho_{xy}$ becomes positive overall, showing hole dominated transport. This is also apparent in the $T$-dependent Hall resistivity measured at 5 T field (see inset of figure 4(b)). The presence of multiple Fermi surfaces in the tetragonal Ir$_2$In$_8$S has been previously reported by quantum oscillation measurements and band structure calculations [31].

Field-induced low $T$ resistivity upturn in the LMR materials can be explained by semi-classical multi-carrier model in systems obeying modified Kohler’s rule $MR = F[H/\rho_0] = A[H/\rho_0]^m$ [10, 12]. In case of perfect electron–hole resonance condition, $m = 2$ [11]. For systems where Kohler’s rule [40] is nearly obeyed ($m \approx 2$ and $T$-independent), MR is found to scale with $A$ [17]. As shown in figure 4(c), both $A$ and $m$ vary rapidly with $T$ causing systematic deviation from Kohler’s rule at high $T$. At 2.5 K, $m = 1.58$ (see inset in figure 4(d)), a value similar to other type-II topological semimetals [17, 41]; deviation from the
Transverse MR (a) and Hall resistance (b) at 0.5 GPa as a function of applied magnetic field at various temperatures. Inset in (b) is the $T$-dependent Hall resistivity at 5 T field. (c) Field-induced normalized resistivity-change ($\Delta \rho$) plotted as a function of $T$. The coefficient of the Kohler’s fit is found to scale with $\Delta \rho$ (d) $T$-variation of the exponent $m$. Inset, Kohler’s law fit for the MR plot at 2.5 K (e) and (f) $T$-variation of the carrier density $n_e, h$ and mobility $\mu_e, h$, as obtained from the two-band model fit.

Variation of $A$ with temperature, when compared with field-induced resistivity change $\Delta \rho_{xx}$ (shown in figure 4(c)), indicates a rapid change of carrier transport behavior below 50 K. This is further verified by the observed variation of the exponent $m$ as a function of $T$ (figure 4(d)) indicating electronic structural modification at low $T$. The carrier density and mobility have been calculated by analyzing the Hall conductivity, $\sigma_{xy} = \rho_{xy}/(\rho_{xx}^2 + \rho_{yx}^2)$, using the two-band model [45]

$$\sigma_{xy} = eB \left( \frac{n_e \mu_{eh}}{1 + \mu_{eh}^2 B^2} + \frac{n_h \mu_{he}}{1 + \mu_{he}^2 B^2} \right)$$

where $n_e (n_h)$ and $\mu_e (\mu_h)$ are electron(hole) density and mobility respectively. As shown in figures 4(e) and (f), at low $T$ the electron density is an order of magnitude higher than the hole density and therefore dominate the transport. But the hole mobility is 4 times higher than the electron mobility at this $T$. The results of our measurements at 0.5 GPa are slightly different than the ambient pressure measurements [31], possibly due to the effect of pressure or sample quality. The large carrier mobility mismatch and a rapid decrease of hole mobility with increasing $T$ are responsible for the systematic violation of the Kohler’s rule.

Figure 5(a) shows the transverse MR plots at 2.5 K at high pressures and at 5 K (above SC $T_c$) upon $P$-release. The MR value decreases rapidly with increasing $P$ (upper inset in figure 5(a)). The power-law

quadratic field dependence ($m < 2$) can be due to uncompensated carriers or anisotropic Fermi surface or field-induced Fermi surface modification [38, 42]. In case of anisotropic multi-band materials, the relative contributions of different FS pockets vary with strength and orientation of the magnetic field [43, 44].
Figure 5. (a) Transverse MR measured at 2.5 K at various pressures and upon decompression. Upper inset, MR at 6.5 T field plotted as a function of pressure; lower inset, the plot of the exponent \(m\) as a function of pressure. (b) Hall resistivity plotted as a function of magnetic field at various pressures. Inset shows an expanded view at lower field. (c) carrier density \(n_{e,h}\) and (d) mobility \(\mu_{e,h}\) in the low \(T\) normal metal state. In upper inset in (a), the simulated MR is also plotted based on these carrier density and mobility values (see text). The solid circles in various plots correspond to the \(P\)-released sample.

Field dependence (MR \(\propto (\mu_e H)^m\), \(m = 1.58\) at 0.5 GPa) is found to change gradually with increasing \(P\) (lower inset in figure 5(a)), showing \(P\)-induced change of the Fermi surface anisotropy. Anomalous change in \(m\) at 7.5 GPa may be associated with the phase transition, as discussed above (see figure 1). Upon release of \(P\), \(m\) returns to the initial value. The field variations of the Hall resistivity at various pressures are shown in figure 5(b). At low pressures, high field Hall resistivity clearly indicate electron dominated transport, but strong non-linearity and positive Hall resistivity at low field (see inset in figure 5(b)) indicates significant high mobility hole contributions. In figures 5(c) and (d) are plotted the \(P\)-variation of the carrier densities \((n_{e,h})\) and mobilities \((\mu_{e,h})\) at 2.5 K. With increasing \(P\) both carrier densities systematically increase. At low \(P\), the hole density is an order of magnitude less than the electron density, but become roughly of same order above 2 GPa. The hole mobility at low \(P\) is a factor of 4 higher than electron mobility, but decreases rapidly at 2 GPa where hole mobility becomes a factor of 1.5 higher than the electron mobility. An enhanced field dependence exponent \(m \sim 1.72\) above 2 GPa can thus be corroborated from the carrier density approaching the same order and also systematic reduction of their mobility mismatch (compensated semimetal criteria). The systematic suppression of MR at high pressures can be attributed to the reduced average carrier mobility. In case of \(P\)-released sample, the carrier densities remain at an order of magnitude high value and the carrier mobility remains at a relatively low value as compared to those values at the initial \(P\), indicating the irreversible modification of the Fermi surface pockets in the \(P\)-cycled sample.

We have calculated the MR at 2.5 K using the values of carrier density and mobility and have compared with the measured values (see upper inset of figure 5(a)). The observed MR values at all increasing pressures (except at initial 0.2 GPa) and also upon \(P\)-release, are consistent with the semi-classical two-band model. So the Dirac points have little influence on the mobility at high \(P\). At low pressure, a significant deviation exhibiting large MR and high hole mobility may have an origin beyond the classical description. A topological origin or the role of SOC-coupled orbital texture in enhancing the transport mobility at low \(P\) cannot be ruled out, which demands further theoretical and experimental investigations. Although the MR in the \(P\)-released sample shows LMR-like feature, its transport behavior follows the simple two-band model.

In order to understand the structural evolution at high pressures, powder x-ray diffraction measurements have been performed on the Ir2In8S crystals from the same batch. Diffraction patterns at various high pressures are shown in figure 6(a). The ambient tetragonal structure (SG: \(P4_2/mnm\)) is found to be stable up to \(\sim 7\) GPa. Structural analyses at various high \(P\) have been performed by Le-Bail profile fitting, using the reported atomic coordinates [32]. Above 7 GPa, the system undergoes a subtle structural
Figure 6. (a) Powder x-ray diffraction patterns of Ir$_2$In$_8$S at various high pressures. Patterns in red correspond to the orthorhombic structures above 7 GPa. Released pattern at 0.1 GPa (marked with R) is shown in green. Inset shows the polyhedral arrangement in the tetragonal unit cell. Variations of (b) lattice parameters and (c) volume per formula unit at various pressures, solid circles are for releasing $P$. (d) Diffraction patterns at initial 0.2 GPa and $P$-released 0.1 GPa without background subtraction. (e) $P$–$T$ structural phase diagram of Ir$_2$In$_8$S based on resistivity and x-ray diffraction studies.

transition to a low symmetric orthorhombic structure ($Pnmm$), as determined by the group-subgroup analysis. Therefore, the electronic structural changes near 8.1 GPa as discussed from resistivity results can be associated with this structural phase transition. As the four-fold screw $4_2$ symmetry that protects Dirac point crossing in the tetragonal structure is lost in the high $P$ orthorhombic structure ($Pnmm$), a possible quantum topological transition is expected at this pressure. In figures 6(b) and (c) are plotted the lattice parameters and the unit cell volume with pressure, showing first order nature of the phase transition. $P$–$V$ data when fitted with the 3rd order Birch–Murnaghan equation of state gives bulk moduli 85(4) GPa ($B' = 4.1$) and 104(5) GPa ($B' = 5$) in the tetragonal and orthorhombic phases respectively. Upon release of $P$, the orthorhombic phase transforms back completely to the ambient tetragonal structure and the Bragg peaks regain the initial width (see figure 6(d)). It is worth mentioning that any In precipitation upon $P$-cycling causing the observed SC is unlikely, as no additional Bragg peaks corresponding to elemental In have been detected in the XRD pattern upon $P$-release. Also the observed broad SC transition width and much higher upper-critical field ($H_{c2}$) are in contrast to that of bulk In SC. Our resistivity measurements upon repeated $P$-cycling further verify that SC occurs in the tetragonal Ir$_2$In$_8$S and rules out the possibility of SC originating in small regions undergoing structural transition or local plastic deformation or sample decomposition (see supplementary information). As the system returns to the initial crystal structure upon $P$-release, it is expected to retain the Dirac-like band crossings near the
Fermi level even in the presence of the enhanced bulk defects. The observed enhanced carrier density of the $P$-released sample indicates SC onset may be driven by the enhanced DOS at the Fermi level. The increased carrier density can also shift the Fermi level towards the Dirac point, suggesting possible coexistence of SC and Dirac points. The results thus call for direct investigations on the $P$-released Ir$_2$In$_8$S for possible Dirac band crossing.

4. Conclusions

Type-II DSM candidate Ir$_2$In$_8$S has been investigated by resistivity, magneto-transport and x-ray diffraction measurements under high pressure. This undergoes a phase transition near 8 GPa with modified electronic structure as revealed by resistivity measurements. This is supported by the observed structural transition at this pressure. With increasing $P$ the characteristic large MR gets suppressed rapidly and is partially regained upon decompression. No SC has emerged with increasing $P$ up to 20 GPa. However, in the $P$-released sample a significant resistivity drop below $\sim$4 K has been detected and this has been verified as the signature of superconducting onset. An increased normal state residual resistivity suggests possible role of impurity scattering in the emergence of SC. Magneto-transport measurements show irreversible changes of the carrier density and mobility upon $P$-cycling, suggesting a subtle electronic structural modification that favors SC onset. $P$-released Ir$_2$In$_8$S is thus a unique system, where a large MR persists above SC $T_c$. The $P$-released tetragonal structured Ir$_2$In$_8$S is believed to be in the DSM state, which however needs further investigations. Present results will invite more investigations on other topological semimetals to explore possible emergence of SC by $P$-cycling, while retaining the topological band structure.

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Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

ORCID iDs

Pallavi Malavi https://orcid.org/0000-0001-9832-000X
Surjeet Singh https://orcid.org/0000-0001-7990-9994
S Karmakar https://orcid.org/0000-0002-7039-0839

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