Superconductivity at 2.5 K in new transition-metal chalcogenide Ta_2PdSe_5

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Abstract

We report the synthesis and superconducting properties of a new transition-metal chalcogenide Ta_2PdSe_5. The measurements of resistivity, magnetization, and specific heat reveal that Ta_2PdSe_5 is a bulk superconductor with $T_c \sim 2.5$ K. The zero-field electronic specific heat in the superconducting state can be fitted with a two-gap BCS model. The upper critical field H_{c2} shows a linear temperature dependence, and the value of $H_{c2}(0)$ is much higher than the estimated Pauli limiting field H_{c2}^{p} and orbital limiting field H_{c2}^{orb}. All these results of specific heat and upper critical field suggest that Ta_2PdSe_5 is a multi-band superconductor.

Introduction

	T_c (K)	$H_{c2}(0)$ (T)	$H_{c2}(0)/T_c$ (T/K)
$Nb_2Pd_{0.81}S_5$	6.6	37	5.6
$Nb_2Pd_{0.74}Se_5$	5.0	35	5.9
$Ta_2Pd_xS_5$	5.4	31	5.7
Ta_2PdSe_5	?	?	?

Recently, a new quasi-one-dimentional (Q1D) transition-metal chalcogenide $Nb_2Pd_{0.81}S_5$ was synthesized, in the monoclinic space group C2/m. It becomes a superconductor below the transition temperature $T_c \sim 6.6$ K. Later, the two existing compounds Ta_2PdS_5 and Nb_2PdSe_5 with the same crystal structure, were also found to be superconducting below 6 K and 5.5 K, respectively. All these three compounds display extremely high and anisotropic H_{c2}, suggesting a new family of exotic superconductors T_2PdCh_5 (T = Nb or Ta, Ch = S or Se).

Synthesis

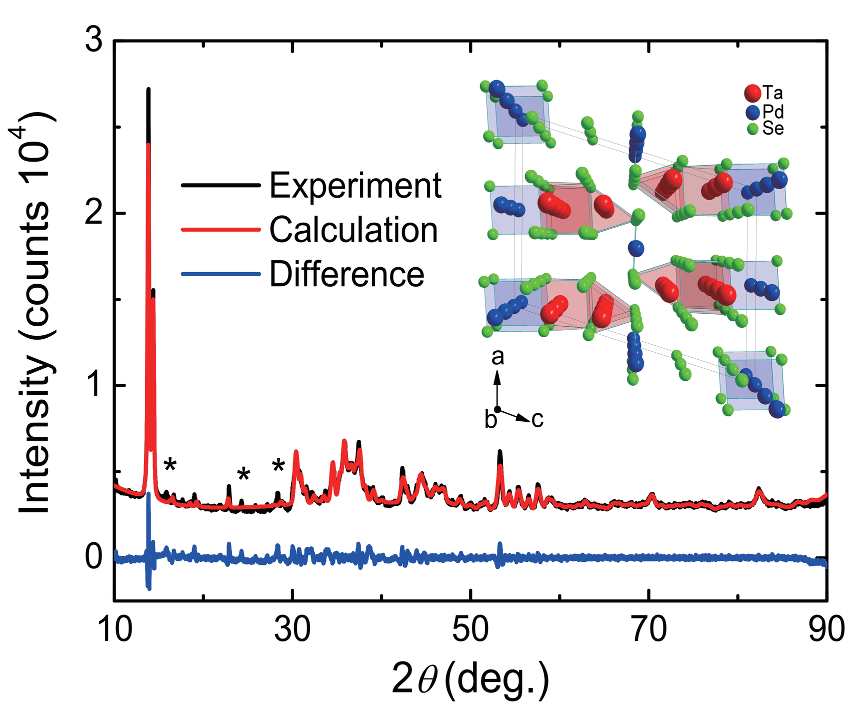

Fig. 1: X-ray diffraction pattern of a Ta_2PdSe_5 polycrystalline sample measured at room temperature.

The polycrystalline samples of Ta_2PdSe_5 were synthesized by a conventional solid state reaction method with the starting materials of Ta, Pd, and Se powders.

Figure 1 shows the powder X-ray diffraction (XRD) pattern of Ta_2PdSe_5, in which most of the peaks can be well indexed to a monoclinic structure with space group *C2/m*. From the refinement, Ta_2PdSe_5 is recognized as the main phase, with a small amount of Pd_7Se_4 impurity. A perspective view of the Ta_2PdSe_5 crystal structure along b-axis direction is shown in the inset of Fig. 1.

Results

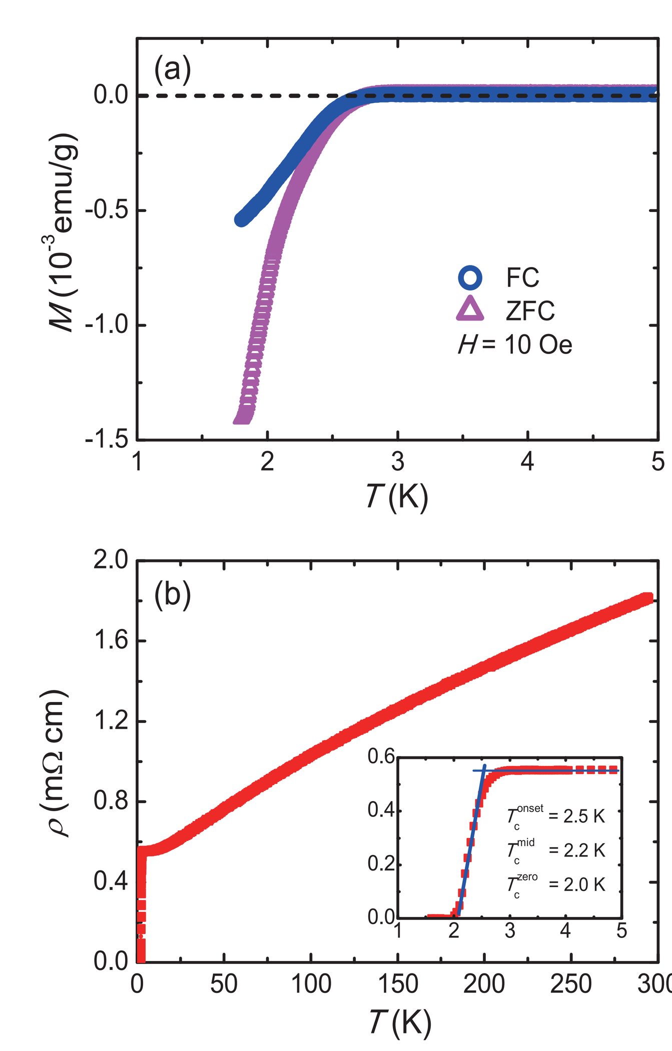

Fig. 2: (a) Low-temperature dc magnetization of Ta_2PdSe_5. (b) Temperature dependence of the resistivity. The inset shows the superconducting transition at low temperature.

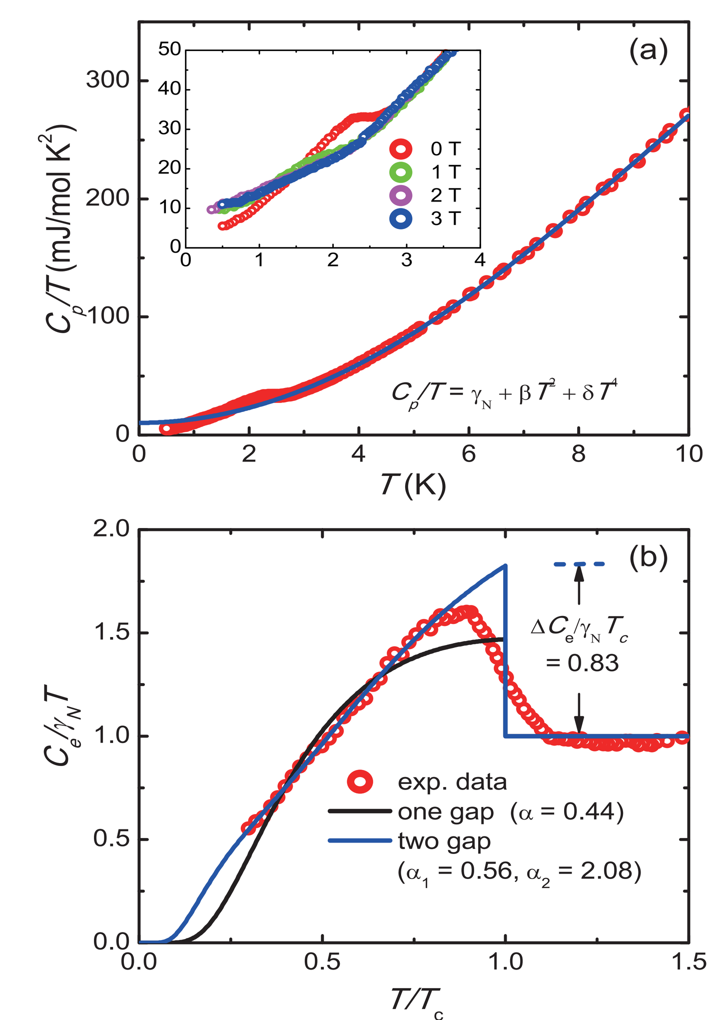

Fig. 3: (a) Temperature dependence of specific heat divided by temperature C_p/T. (b) Reduced temperature T/T_c dependence of electronic specific heat divided by temperature C_e/T.

The diamagnetic signal reveals a superconducting transition with the onset T_c at about 2.6 K. ρ(T) displays metallic behavior with a residual resistivity ratio RRR ~ 3.3. A clear drop of resistivity is observed, corresponding to the superconducting transition.

C_p/T shows an anomaly around 2.5 K in zero field and the zero-field electronic specific heat C_e/T obtained by subtracting the lattice terms from C_p. The bulk nature of the superconductivity in Ta_2PdSe_5 is confirmed by the significant jump of C_e/T. We fit C_e/T in the superconducting state with the BCS two-gap model with $\alpha_1 = 0.56$ and $\alpha_2 = 2.08$. This result is consistent with the band structure calculation of T_2PdCh_5

Discussion & Summary

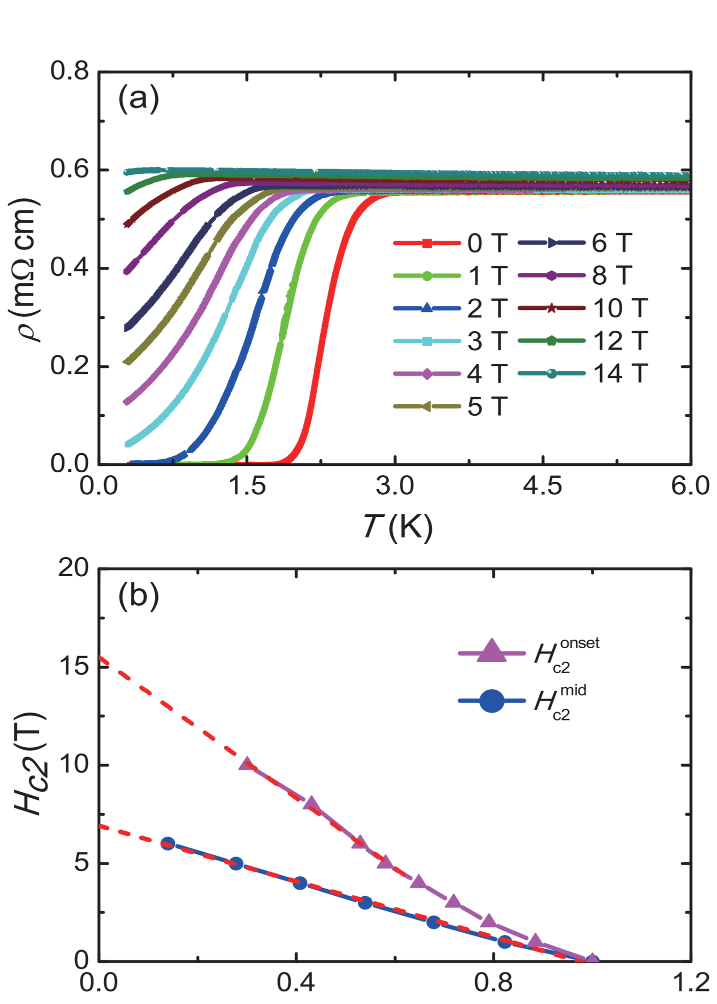

Fig. 4:(a) Low-temperature resistivity ρ(T) of Ta_2PdSe_5 in various magnetic fields up to 14 T. (b) Reduced temperature T/T_c dependence of the upper critical field H_{c2}(T).

As the magnetic field increases, T_c decreases and the superconducting transition broadens. H_{c2}(T) versus T/T_c is shown in Fig. 4(b). The linear temperature dependence of H_{c2}(T) was previously observed in two-band superconductor MgB_2. Therefore, we ascribe the linear temperature dependence of H_{c2}(T) observed to the multi-band effect.

Summary:

In summary, a new transition-metal chalcogenide compound Ta_2PdSe_5 was first synthesized. Measurements of resistivity, magnetization and specific heat revealed that Ta_2PdSe_5 is a superconducting material with $T_c \sim 2.5$ K. This compound displays a remarkably high $H_{c2}(0)$ relative to its T_c. Both the fit of C_e/T and the linear temperature dependence of H_{c2} indicate multi-band superconductivity in Ta_2PdSe_5.

Reference

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