Drastic pressure effect on the extremely large magnetoresistance in WTe_2: a quantum oscillation study

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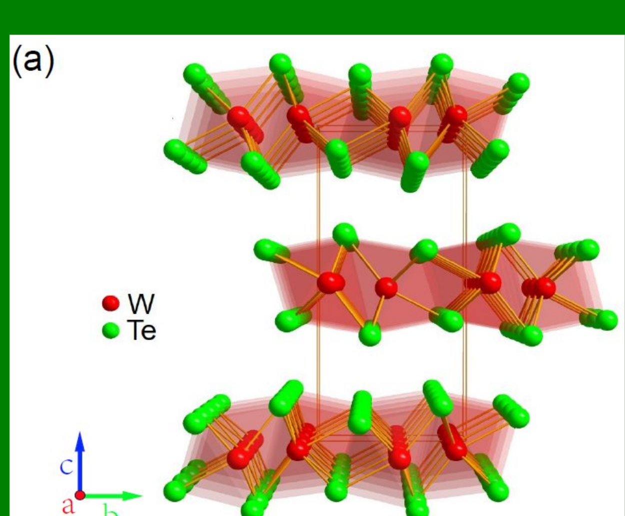
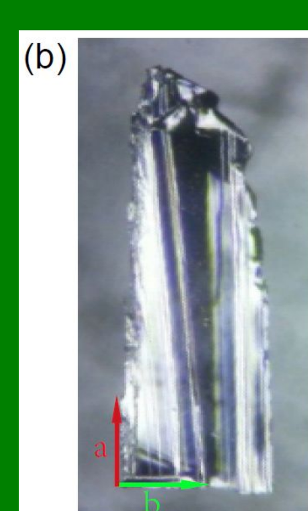
Introduction

The very recent discovery of XMR in WTe_2 is of particular interest [1]. WTe_2 is a layered transition-metal dichalcogenide, with the crystal structure shown in Fig. 1(a). In the dichalcogenide layers, W chains are formed along the *a* axis. An XMR of 4.5×10^5% in 14.7 T at 4.5 K was found when the current is along the a axis and magnetic field is applied along the c axis [1]. More remarkably, it increases to as high as 1.3×10^7% in 60 T at 0.53 K, without any sign of saturation [1].

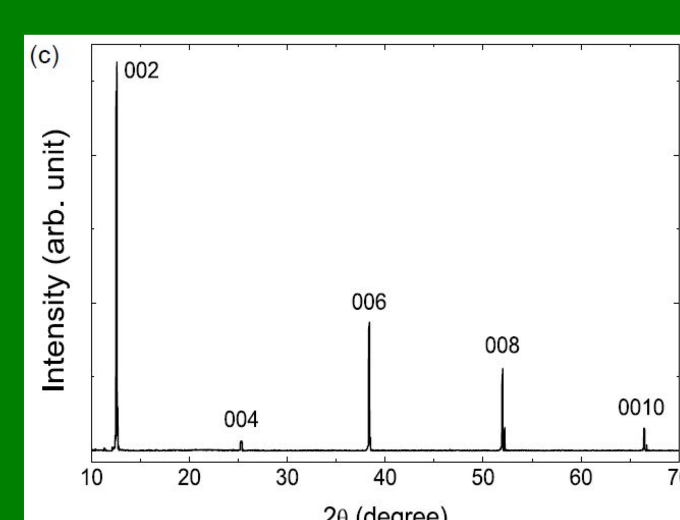
We present the quantum oscillation study of the magnetoresistance for WTe_2 single crystals under ambient and high pressure. By analyzing the Shubnikov-de Haas oscillations of magnetoresistance at low temperature, four Fermi surfaces are revealed, which should correspond to the two pairs of hole and electron pockets later probed by ARPES experiments [3]. A drastic suppression of the XMR with increasing pressure is observed, which is accompanied by a change of the Fermi surface topology. The correlation between them provides support for the mechanism that the XMR of WTe_2 originates from the electron hole compensation.



Crystal structure of WTe_2



Cleaved WTe_2 sample



X-ray diffraction pattern of single crystal

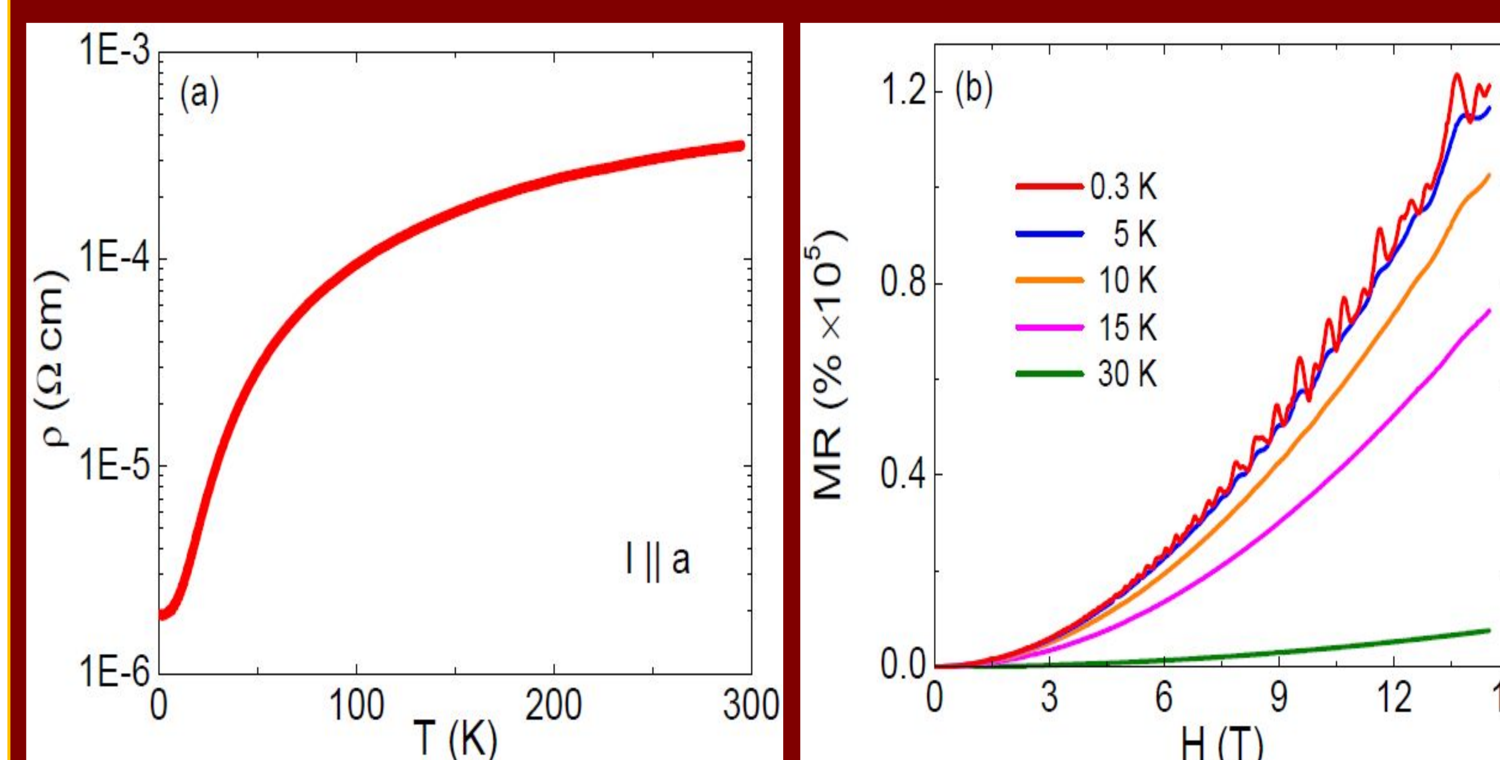
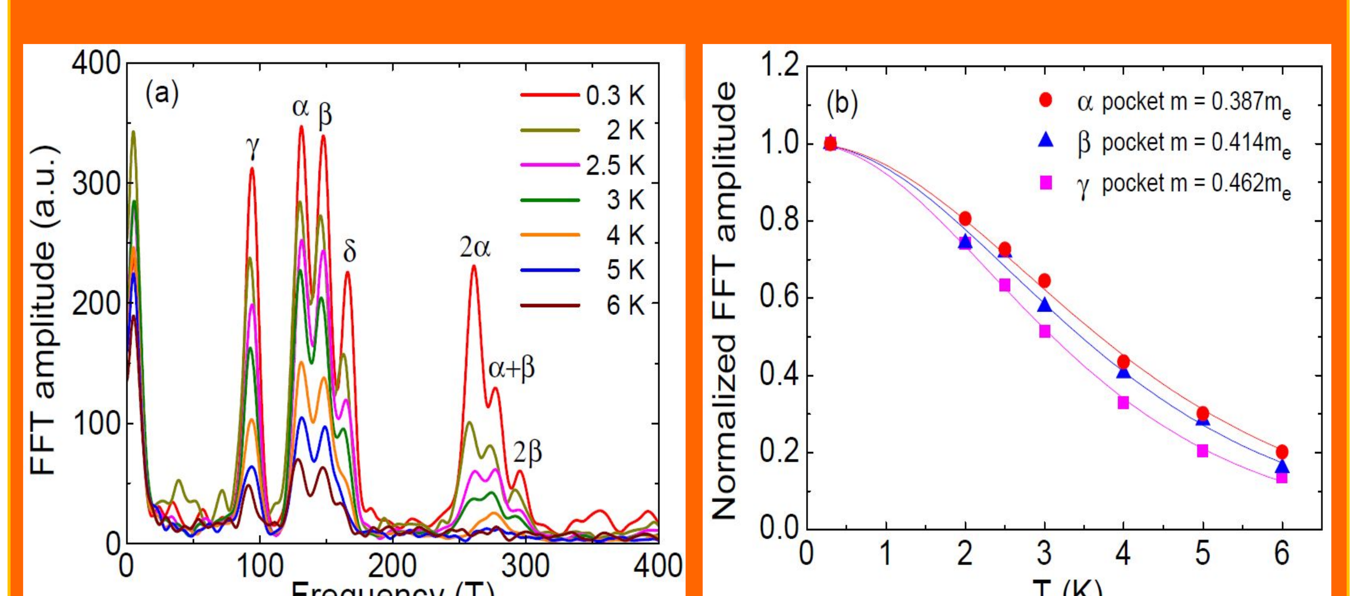


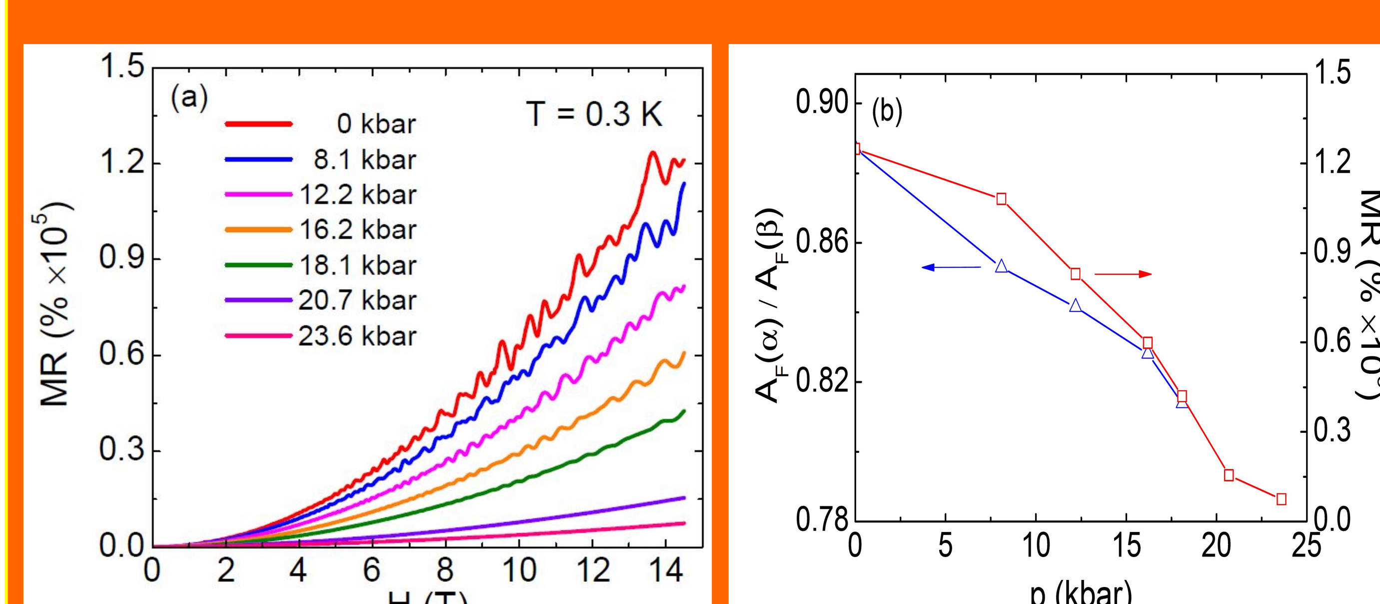
Fig. (a) Temperature dependence of resistivity in zero field, with current along the *a* axis. It has ρ (295 K) = 355 μΩ cm and ρ (2K) = 1.93 μΩ cm, with the residual resistivity ratio RRR = ρ (295 K) / ρ (2 K) = 184.

In Fig. (b), the magnetoresistance of WTe_2 single crystal up to 14.5 T at various temperatures, with magnetic field applied along the *c*-axis direction. There are clear Shubnikov-de Haas oscillations below 5 K.



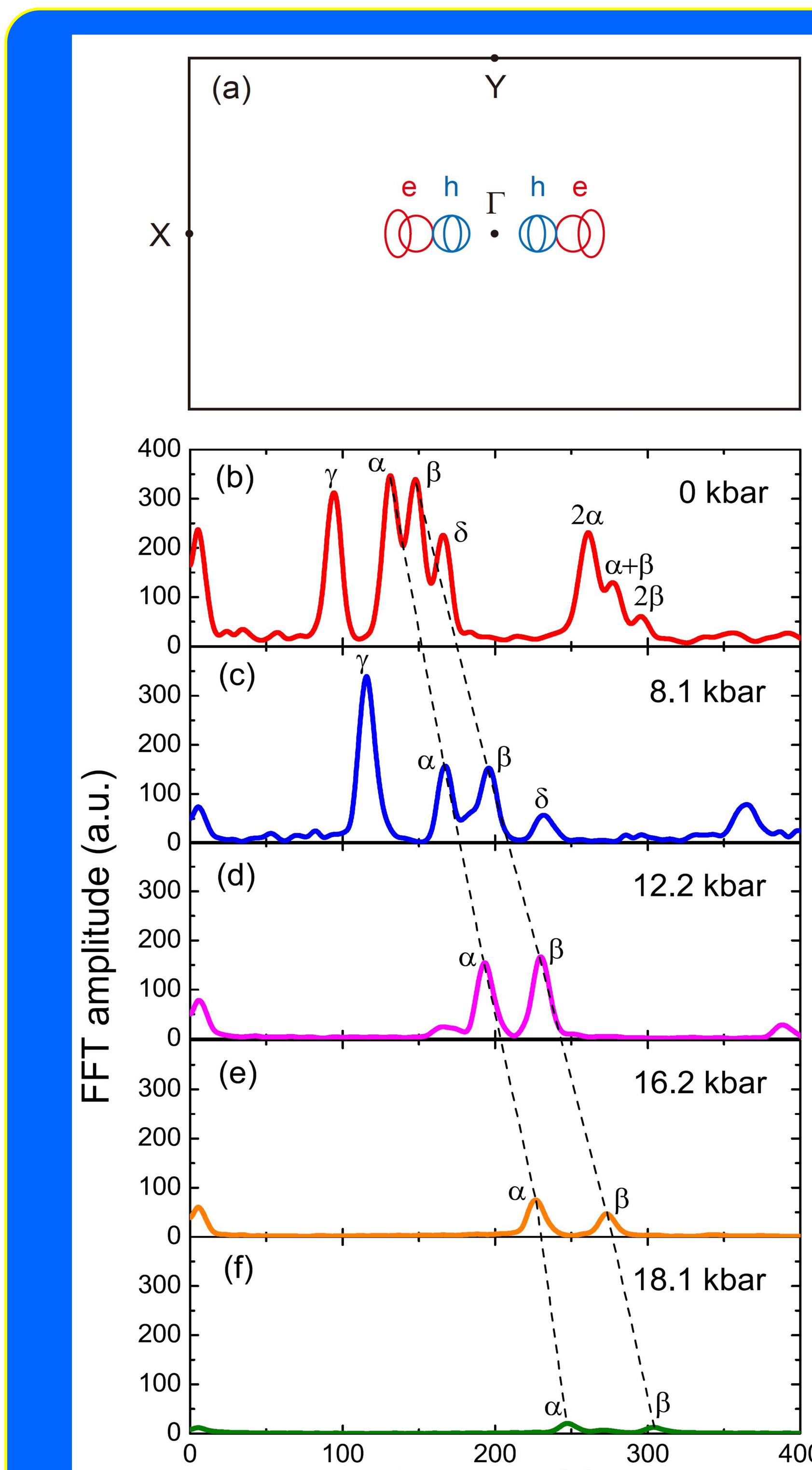
(a) The Fast Fourier Transform (FFT) of the oscillatory magnetoresistance shows four major peaks, labeled as α, β, γ and δ. The second harmonics 2α and 2β, and the sum of α and β are also observed.

(b) The temperature dependence of FFT amplitude of α, β and γ peaks, normalized by their 0.3 K values. The solid lines are the fit using the Lifshitz-Kosevich formula, which give the effective mass $m^* = 0.387m_e$, $0.414m_e$, and $0.462m_e$, for α, β and γ pockets, respectively.



(a) The magnetoresistance of WTe_2 single crystal under various pressures up to 23.6 kbar, measured at T = 0.3 K.

(b) The pressure dependence of the magnetoresistance at T = 0.3 K and in H = 14.5 T. The data points are taken from the smooth background of each curve in (a). The magnetoresistance decreases from 1.25×10^5% under ambient pressure to 7.47×10^3% under p = 23.6 kbar. For the pair of electron and hole pockets α and β, the ratio of their area $A_F(\alpha)/A_F(\beta)$ manifests similar pressure evolution.



(a) Sketch of two pairs of hole and electron pockets along the Γ - X direction in the Brillouin zone of WTe_2, as observed by ARPES experiments [3]. (b)-(f) The FFT spectrum of the oscillatory magnetoresistance under various pressures up to 18.1 kbar. The α and β peaks persist to high pressure, which are identified as the pair of electron and hole pockets in (a). From (b) to (f), the dash lines are guide to the eye to show that the sizes of electron and hole pockets become increasingly different.

Conclusions

- By analyzing the SdH oscillations, four Fermi surfaces are found in WTe_2, which should correspond the two pairs of electron and hole pockets.
- The MR of WTe_2 is strongly suppressed by pressure. One pair of electron and hole pockets (γ and δ) disappear first. The other pair (α and β) shows increasing different size, which may cause the suppression of MR.
- Our results support the scenario that the perfect balance between the electron and hole populations is the origin of the XMR in WTe_2.

References

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