Observation of the Magic Angle Effect in the Angular Dependence of $ZrTe_5$ Magnetoresistance in the Quantum Limit

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Introduction

We investigate sharp, anomalous dips in the angular dependence of the magnetoresistance of $ZrTe_5$ single crystals. These dips occur at fixed "magic angles" once the magnetic field passes the quantum limit. The magic angles correspond to commensurate angles where the field direction connects neighboring atoms in the lattice, reminiscent of "Lebed's Magic Angles" found in the organic Bechgaard salts $(TMTSF)_2X$. Unlike the Bechgaard salts, a quasi-1D open fermi surface is absent in $ZrTe_5$. Instead, $ZrTe_5$ has an extremely small closed ellipsoidal Fermi surface.

Experimental

High quality $ZrTe_5$ single crystals were grown using the flux technique. Additionally, $Zr_{1-x}Yb_xTe_5$ crystals were grown by the flux technique as well. The resistivity along the most conducting *a* axis is measured as magnetic field is rotated in the plane spanned by the *b* and *c* lattice directions. We measured this angular dependence of the magnetoresistance for several fixed fields for the $ZrTe_5$ crystals as well as the $Zr_{1-x}Yb_xTe_5$ crystals.

Results and Discussion

Sharp dips in the magnetoresistance were observed for angles defined by Eqn. 1,

$$\tan(\theta)=(c/b)n \qquad [1]$$

Where θ=0 points along the *b* axis, *c* and *b* are the lattice constants, and n is an integer. We observed dips for n=0, 1, and 2. For the $ZrTe_5$ crystals, we observed these dips for magnetic fields as low as 1T, all the way to 35T. For the $Zr_{1-x}Yb_xTe_5$ crystals, we observed Shubnikov-de Has (SdH) oscillations for low fields, and then a dip corresponding to n=0 at fields beyond the quantum limit. Furthermore, we extract a hall component of the resistance that diverges on either side of the magic angles, reminiscent of an orbital angular resonance hall effect found in $(TMTSF)_2ClO_4$.

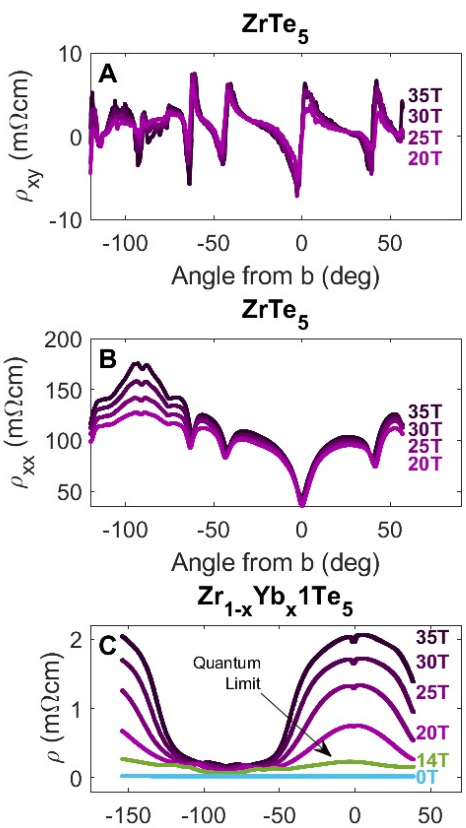

Fig.1 ρ_{xy} (A) and ρ_{xx} for ZrTe5. Sharp features at specific angles are observed. (C) ρ_{xx} for $Zr_{1-x}Yb_xTe5$. One dip is observed for fields passed the quantum limit.

Conclusions

The observed magnetoresistance dips in $ZrTe_5$ are extremely similar to the magic angles of the Bechgaard salts. Contrary to theories explaining this phenomenon for that system, $ZrTe_5$ has a small fermi surface well contained within the first Brillouin zone. Our results establish that these magic angles begin once the field passes the quantum limit, and for $ZrTe_5$ do not rely on an open fermi surface.

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida.

This work was supported by NSF MRSEC at UW (DMR1719797) as well as the Gordon and Betty Moore Foundation's EPiQS Initiative, Grant GBMF6759 to J.-H.C. We also acknowledge funding from the State of Washington funded Clean Energy Institute.

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