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Synthesis and Characterization of Metastable Tetragonal UTe_2 at Ambient Conditions

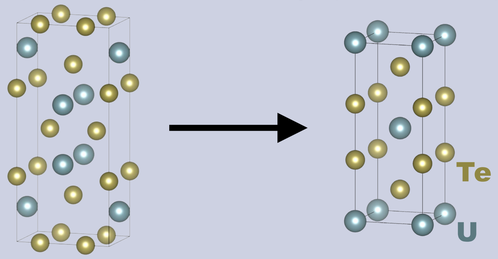
Matthew C. Brennan*, Blake T. Sturtevant, Pedro M. T. Vianez, Joe D. Thompson, Eric D. Bauer

Los Alamos National Laboratory, *mcbrennan@lanl.gov

Background

- The low-*P* (α) phase of UTe_2 is a heavy fermion superconductor with unusual *P*-dependent properties [1,2]
- A metastable superconducting phase (β) forms at high *P*, but it has not been studied at ambient conditions
  - Samples from previous studies [3,4,5] were either too small for ex-situ analysis or quickly reverted to α

α (*Immm*) → β (*I4/mmm*)

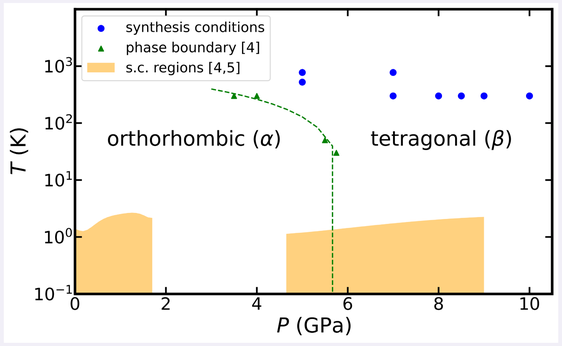


Tetragonal β-UTe_2 forms near 5 GPa

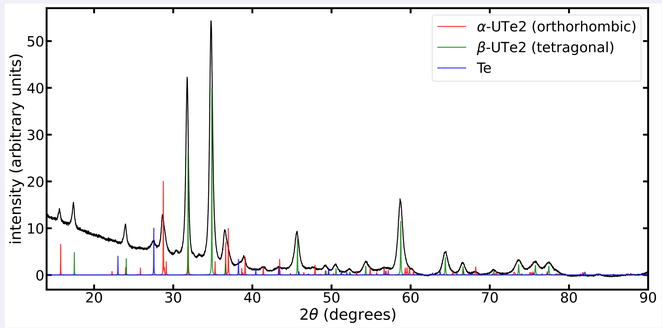
The α→β change involves an 11% volume collapse and a 40% increase in stiffness [3]

Experiments

We compressed and heated 1 mm^3 powder samples (30 mg) up to 10 GPa and 500 °C in a Paris-Edinburgh press.

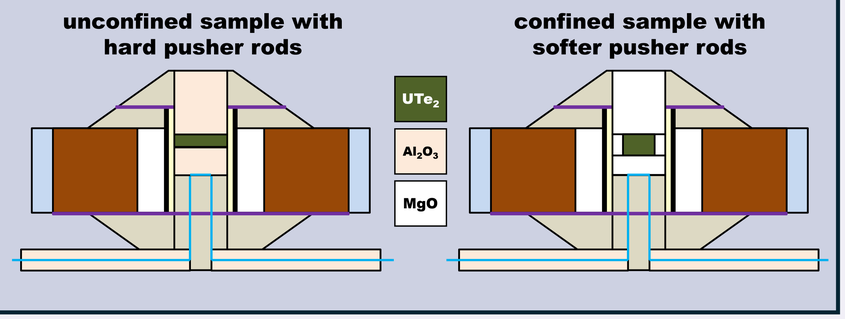


Recovered Phases



- Recovered samples contained both the α and β phases, with proportions varying depending on synthesis conditions
  - Some samples also had minor Te, as seen previously [3]
- Maximum applied *P* was a stronger control on α/β ratios than applied *T*, time spent at high *P*, or decompression strategy
  - Our purest sample (80% β) was held at 10 GPa and ambient *T* for 2 hours

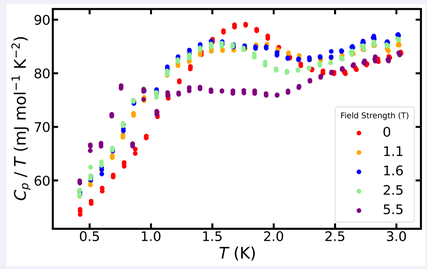
Our samples were optimized for high *P* (**left**), but a more hydrostatic setup (**right**) may improve the α/β ratio [3,5]

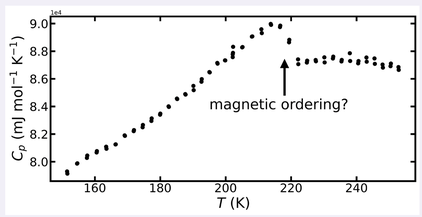


Characterization

Heat Capacity (PPMS)

- Low *T* data show a broad feature that may be a mixture of α & β superconducting transitions
  - $\gamma = 71 \frac{mJ}{mol\ K^2}$, $\beta = 1.393 \frac{mJ}{mol\ K^4}$, $\theta_D = 161$ K, $T_c = 2$ K

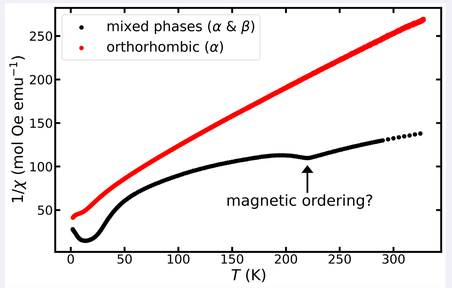




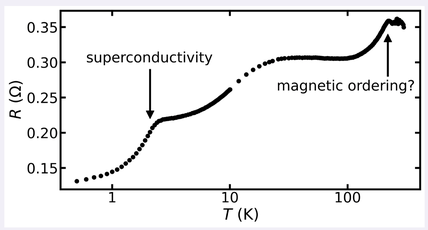
- Higher *T* data show a discontinuity at 220 K that may be due to magnetic ordering [4, 5]
  - This feature is unique to the β structure

Magnetic Susceptibility (SQUID)

- Susceptibility is higher in β than α at all *T*
- The feature at 20 K may be a crystal field excitation
  - The 220 K feature is also visible



Electrical Resistance (PPMS)



- Zero-field resistivity shows features at 220 K, 20 K, and 2 K, but does not go to *R* = 0
  - This may indicate either filamentary superconductivity in β-UTe_2 or the influence of impurities like Te

References & Funding

1. Ran et al. (2019) *Science* 365: 6454
2. Aoki et al. (2022) *JoP:CM* 34: 24
3. Huston et al. (2022) *PRM* 6: 114801
4. Honda et al. (2023) *JPS Jap.* 92: 044702
5. Thebault et al. (2024) *PRB* 109: 214420

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Summary

- We have recovered samples of tetragonal β-UTe_2 to ambient conditions
- β-UTe_2 appears to demonstrate magnetic ordering, which does not occur in α-UTe_2
- Increased sample purity may be needed to determine superconducting properties