Huge Magnetocrystalline Anisotropy in UMn_2Ge_2

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Introduction

The light actinide compounds present an astonishing range of correlated electron phenomena, including "hidden-order" and superconductivity in URu_2Si_2, correlated electron magnetism, and strongly correlated insulating behavior in UO_2. Amongst these, UMn_2Ge_2 has received little attention, although our recent calculations suggest that it should exhibit unusually large magnetocrystalline anisotropy – a property that is of great interest. In order to explore this possibility, we performed magnetization measurements, in pulsed magnetic fields up to 60 tesla, along the principal directions of single crystals of this compound.

Experimental

UMn_2Ge_2 samples were mounted for magnetization measurements using a 1500-turn compensated-coil susceptometer. The magnetization of oriented single crystals for H // c-axis and // ab-plane was measured in LANL 65 T pulse magnets at temperatures down to 0.4 K.

Results and Discussion

Magnetization measurements for H // c-axis and // ab-plane are shown in Fig.1. We find that while H // c rapidly saturates the magnetic moment to a value near 6 μ_B/f.u., the magnetization does not saturate even at the maximum fields that were measured. We compare the low field data to magnetization data that were collected in a Quantum Design SQUID magnetometer and find good agreement between the two data sets. While the anisotropy is consistent with expectations from calculation, we find a discrepancy between the experimental and predicted magnetic moments.

Conclusions

While such large anisotropies have previously been observed in certain rare-earth magnets such as $SmCo_5$, to our knowledge this is the largest value observed to date in an actinide. Our theoretical treatment shows that this behavior arises from magnetic coupling between the manganese 3d and uranium 5f states. As observed both in calculations and in the experiment, the manganese atom carries a ferromagnetic spin moment, and the coupling of this moment to the uranium atom creates a sizable uranium spin moment. The extremely strong spin-orbit coupling in uranium then induces a large orbital moment on the Uranium atom, opposite to the spin moment as a consequence of Hund's rules, leading to the observed and theoretically predicted extremely large magnetic anisotropy and large low temperature magnetization.

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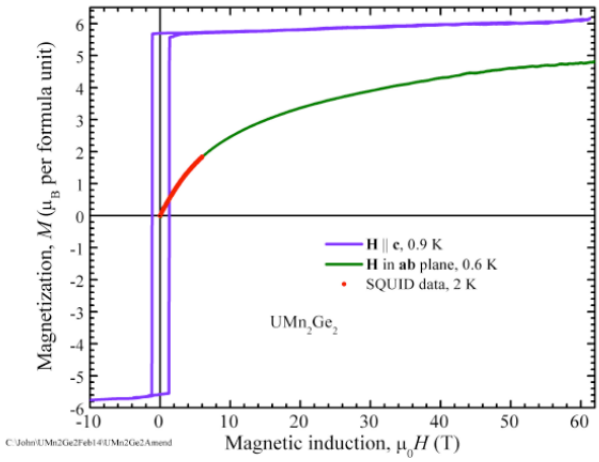

Fig. 1: The results of pulsed-field measurements of the magnetic anisotropy on axially aligned single crystals of UMn_2Ge_2. The purple lines represent the response for the field parallel to the easy axis (c-axis), and the green line for H applied in the plane. The red line shows SQUID measurements made at lower fields.