Magnetic Torque in Uranium Dioxide

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Introduction

Uranium dioxide (UO_2) is one of the most studied actinide compounds due to its fundamental and applied importance. Recently, we have completed the first low-temperature magnetostriction study of UO_2 in magnetic fields up to 92.5 T (NHMFL LANL), and uncovered the abrupt appearance of positive linear magnetostriction, leading to a trigonal distortion. Upon reversal of the field the linear term also reverses sign, a hallmark of piezomagnetism [1]. A switching phenomenon occurs at ±16 T that makes uranium dioxide the hardest piezomagnet known. The new findings are related to complex magneto-elastic properties important for both applied and fundamental aspects [2]. The non-collinear 3**k** magnetic order that breaks time-reversal symmetry in a non-trivial way is the cause of piezomagnetism in UO_2, but details of this phenomena are still unclear.

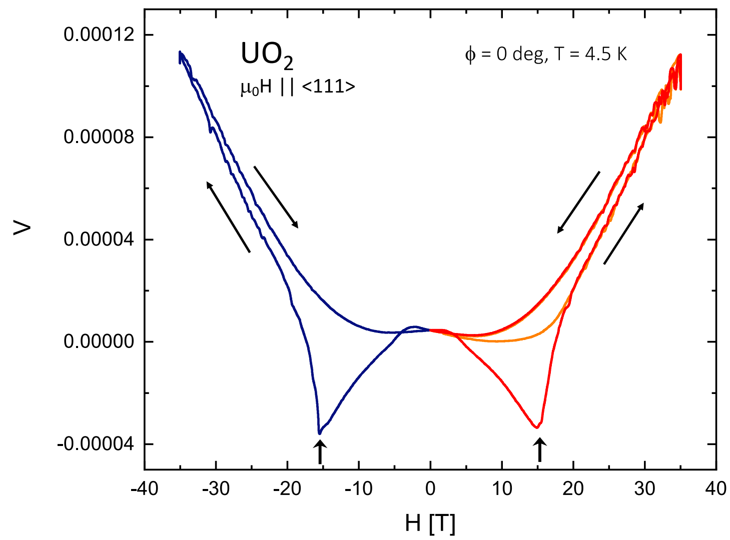

Figure 1. The magnetic torque of UO_2 single crystal measured in applied magnetic field along <111> crystallographic direction. The measurement sequence is explained in the text. Thick arrows mark the transition at ±16 T.

Experimental

We performed a detailed magnetic torque measurement of UO_2 (NHMFL in Tallahassee). These studies are important in understanding of magnetic properties and their relationship to piezomagnetism in this material. In addition, the proposed experiment was crucial in understanding the nature of the transition at ~16 T (previously observed in high field magnetostriction measurements) and its relationship to piezomagnetic ground state. The magnetic torque measurements were performed on oriented single crystals of UO_2 using a piezo-resistive torque magnetometer. The high-quality single crystals of uranium dioxide were prepared and oriented by Dr. Baumbach's group (NHMFL/FSU).

Results and Discussion

The torque measurements of UO_2 crystals have been performed (also under rotation) in temperatures above and below Neel temperature, T_N = 30 K. Figure 1 shows the magnetic field dependence of magnetic torque of UO_2 (in Volt units). We see in trace 1 (orange curve) that torque increases with magnetic field and shows ~H^2, characteristic of linear magnetization. Trace 2 (dark blue) was measured in a subsequent negative field, and torque was observed to turn negative, displaying sharp minimum and a rapid change to positive values at approximately 16 T. Again, a monotonic decrease to zero torque with no remanence is observed during the field down-sweep. When the field direction is changed once again, trace 3 (red) is obtained, displaying a minimum at 16 T and a rapid switch to positive values, with a monotonic decrease to zero as H is swept back to zero. All the studies demonstrate that the high-field torque measurements are powerful methods to investigate the magneto-structural coupling in UO_2, especially its piezomagnetic ground state [3].

Acknowledgements

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References

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