INL/EXT-14-33974

Magnetization measurements of uranium dioxide single crystals (P08358-E002-PF)

K. Gofryk, V. Zapf, M. Jaime

December 2014

INL/EXT-14-33974

Magnetization measurements of uranium dioxide single crystals (P08358-E002-PF)

K. Gofryk, V. Zapf, M. Jamie

December 2014

Idaho National Laboratory

Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Magnetization measurements of uranium dioxide single crystals (P08358-E002-PF)

Gofryk, K. (Idaho National Laboratory); Zapf, V. (National High Magnetic Field Laboratory LANL); Jaime, M. (National High Magnetic Field Laboratory LANL)

Introduction

Uranium dioxide is by far the most studied actinide material as it is a primary fuel used in light water nuclear reactors. UO_2 is a Mott-Hubbard insulator with an *f-f* gap due to the strong electronic correlation between uranium 5*f* electrons. When cooling below 30 K a long range antiferromagnetic ordering of the electric-quadrupole of the uranium moments is observed, forming complex non-collinear 3-***k*** magnetic structure [1]. This transition is accompanied by Jahn-Teller distortion of oxygen atoms [2].

Experimental

The magnetization has been measured on oriented high quality single crystals of uranium dioxide (magnetic fields applied along <100> and <111> crystallographic directions) using vibrating sample magnetometry. The measurements have been performed in static magnetic fields up to 14 T using a Quantum Design Physical Properties Measurement System. (NHMFL LANL)

Results and Discussion

Figure 1 shows the temperature dependence of the magnetic susceptibility (M/H) of UO_2 measured along <100> and <111> crystallographic directions. The measurements have been performed in zero-field-cooled (*zfc*) and field-cooled (*fc*) modes. In the paramagnetic state the susceptibility shows a Curie-Weiss behavior. Interestingly, below 50 K it displays some slight tendency to saturation, which is uncommon for Curie-Weiss systems. For high fields a sharp first order like anomaly is observed at about 30 K associated with antiferromagnetic phase transition and a Jahn-Teller distortion. In addition, a narrow hysteresis is observed at T_N, consistent with the first order nature of the transition. For low fields the M/H(T) behavior shows more complicated behavior that may be expected for simple antiferromagnetic systems. At the Neel transition the low field susceptibility rises instead of dropping, in a manner similar to FM systems. Interestingly, a weak ferromagnetic signal has been reported for uranium dioxide under hydrostatic pressure [3]. In addition, the magnetic anisotropy between <100> and <111> directions is small, ~ 5 %.

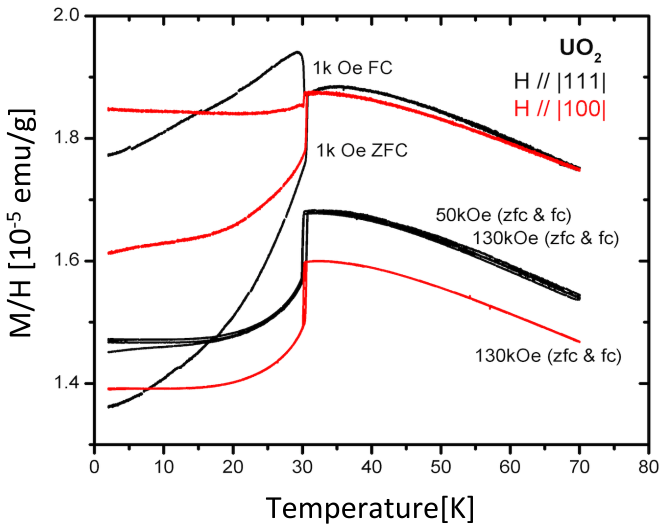

Figure 1 The temperature dependence of the magnetic susceptibility of oriented UO_2 single crystals measured along 100 and 111 directions and in *zfc* and *fc* conditions (see text).

Conclusions

Our preliminary magnetic susceptibility measurements of UO_2 point to complex nature of the magnetic ordering in this material, consistent with the proposed non-collinear 3-***k*** magnetic structure. Further extensive magnetic studies are planned to address the puzzling behavior of UO_2 in both antiferromagnetic and paramagnetic states.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy. Work at Idaho National Laboratory was partially supported by NEAMS program.

References

[1] S. Carretta, S. et al. Phys. Rev. Lett. **105**, 167201 (2010).
[2] Allen, S. J. Phys. Rev. 166, 530 (1968) and Allen, S. J. Phys. Rev. 167, 492 (1968).
[3] Sakai, H. et al. J. Phys.: Condens. Matter 15, S2035 (2003).