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Introduction

Uranium dioxide is known to be a Mott insulator and to develop a first order antiferromagnetic ordering of uranium magnetic moments below 30 K. Strong spin-lattice interactions based on Jahn-Teller interactions have been proposed to account for these behaviors [1-3]. Despite huge theoretical and experimental efforts the nature of the strong spin-lattice coupling and how the coupling affects the thermal properties of UO_2 are still unclear.

Experimental

The magnetostriction has been measured on oriented high quality single crystals of uranium dioxide using optical fiber Bragg grating (FBG) dilatometry. The measurements have been performed in pulsed magnetic fields up to 65 T (NHMFL LANL).

Results and Discussion

Figure 1a shows the temperature dependence of the thermal expansion ΔL/L and thermal expansion coefficient α of UO_2 crystal measured along <100> direction. A sharp first order like anomaly is observed at about 30 K associated with antiferromagnetic phase transition and simultaneous Jahn-Teller distortion. In Figure 1b selected representative isothermal magnetostriction curves are presented for <100> and <111> directions. As seen, in paramagnetic state the magnetostriction is negative and much stronger for <111> axis. In the magnetic state a positive magnetostriction is observed together with irreversible behavior at low fields. This behavior has only been observed in zero-field-cooled conditions. At higher fields the magnetostriction forms a broad maximum. Solid arrows in Figure 1b mark position of these anomalies and by tracking the evolution of these features, a phase diagram can be constructed as presented in Figure 1c for <111> direction. At the present time we are unable to construct a similar diagram for the <100> direction. For several magnetostriction measurement attempts performed so far below the Neel temperature in this orientation the sample has detached off the optical fiber at about 45 T.

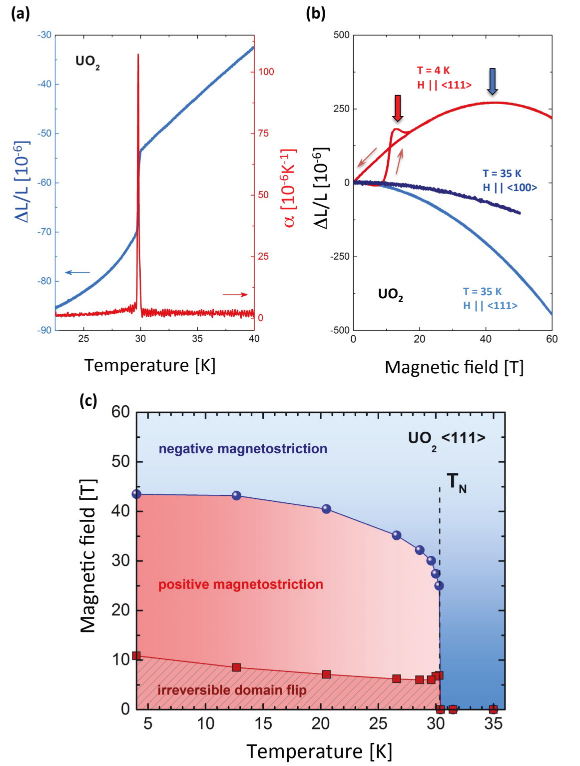

Figure 1. (a) The temperature dependence of the thermal expansion (left axis) and thermal expansion coefficient (right axis) of UO_2 single crystal. (b) Isothermal magnetostriction measured above and below T_N. Solid arrows mark positions of anomalies used to construct the phase diagram. (c) The phase diagram of uranium dioxide obtained for <111> direction (see text).

Conclusions

Our preliminary magnetostriction measurements have already shown a strong interplay of lattice dynamic and magnetism in both antiferromagnetic and paramagnetic states, and give unambiguous evidence of strong spin-phonon coupling in uranium dioxide. Further studies are planned to address the puzzling behavior of UO_2 in magnetic and paramagnetic states and details of the spin-phonon coupling.

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