Magneto-elastic phenomena of uranium dioxide in high magnetic fields

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ABSTRACT

The magneto-elastic properties of actinide materials remain an unsolved puzzle resulting from the lack of a thorough understanding of strong coupling between 5*f*-electron magnetism and lattice vibrations. During the talk, we demonstrate how high-field experiments such as magnetostriction, x-ray diffraction, and magnetic torque can be used to study these interactions in uranium dioxide. It is a Mott-Hubbard insulator with well-localized 5*f*-electrons and its magnetic state is characterized by a non-collinear antiferromagnetic structure and multidomain Jahn-Teller distortions. In the magnetic state a UO_2 single crystal subjected to strong magnetic fields (up to 95 T) exhibits the abrupt appearance of positive linear magnetostriction leading to a trigonal distortion. Upon reversal of the field the linear term also reverses sign, which is a hallmark of piezomagnetism. A piezomagnetism is a rare phenomenon observed in antiferromagnetic crystals that breaks time reversal symmetry in non-trivial way and it's characterized by a linear coupling between the system's magnetic polarization and mechanical strain. In UO_2, the switching phenomenon persists during subsequent field reversals, demonstrating robust magneto-elastic memory. This is the first example of piezomagnetism in an actinide spin system and the magneto-elastic memory loop here is nearly an order of magnitude wider in field than those previously observed, making UO_2 the hardest piezomagnet known. The unusually strong correlations between the magnetic moments in U-atoms and lattice distortions are a direct consequence of the non-collinear symmetry of the magnetic state. Changing the oxygen content in UO_{2+x} leads to drastic change in the Jahn-Teller interactions and symmetry, and ultimately to disappearance of the piezomagnetism. We will also show some recent magnetic torque measurements (up to 35 T) and we will discuss implications of these results in the context of piezomagnetic ground state in this material. All the studies demonstrate that these high fields measurements are powerful methods to investigate the magneto-structural coupling in actinide materials.