MAGNETOSTRICTION OF ANTIFERROMAGNETIC MATERIALS

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Introduction and Experimental

Magnetoelastic investigations allows proof of microscopic models and theories, including crystal electric field and magnetic exchange interaction. Because of the wide variety of magnetoelastic phenomena connected to correlation effects or phase transitions (spin order, quadrupolar transitions etc.) the investigations were focused on intermetallic compounds containing 4f- and 5f- elements.

A new miniature capacitance dilatometer (silver cell with a reduced outer diameter of 20 mm) was used. The advantage of this method for magnetoelastic investigations is its high resolution and the usability up to the highest available steady fields and lowest temperatures. By measurements of the longitudinal as well as the transversal components, the full magnetostriction tensor can be studied, and the data can be well compared to the results of model calculations. The field sweeps were done at constant temperatures between 1.2K and 20K in the NHMFL 33T or 45T magnet with a maximum sweep rate of 2T/min in order to avoid eddy current heating and errors by induced magnetic moments. One of the important experimental problems for these measurements was the noise due to mechanical vibrations. After damping these influences a resolution less than 5x10^-7 in dl/l was achieved.

Results and Discussion

The element Sm is one of the most important rare earth materials because of the partial compensation of spin and orbital momentum and because of application in hard magnets. The magnetic behavior of Sm in high magnetic field was analyzed and compared in detail to theoretical model calculations. From the striction data the phase diagram of the moments on the quasicubic sites were constructed. The magnetic transition from the afm ground state to the induced fm state is about 30 T. For an external field parallel to the c-axis the data show the occurrence of a structural distortion, associated with the transition in a spin-flop phase (see fig. top right: experiment bright colors, theory dark colors). The effects are large, in contrast to the small striction applying a field along the a- or b-axis. However, large anisotropy of the strain has been observed. The data suggest exchange striction as the dominant magnetoelastic interaction mechanism in Sm metal.

The highly symmetric monopnictide GdSb was a special candidate because it is a system with L = 0 and therefore, the crystal field influence on magnetostriction in negligible. The antiferromagnetic to ferromagnetic transition was found at about 34 T at 4 K (see fig. bottom right). The absolute striction hump in the order of 10^-4 was used to verify first principle band structure calculations and, at least, to discover new details of electronic structure of Gd-compounds.

Further basic magnetoelastic investigations were done at the pure 3d-element Pd and the 5f-systems UPd3 and U3As4. In conclusion, successful magnetoelastic measurements in the highest available magnetic fields are a strong tool to understand several basic magnetic phenomena.

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