High-Resolution High-Energy X-ray Scattering for Materials Research at High Magnetic-Fields

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Introduction

The availability of synchrotron photons generated in high flux and with energies greater than 60 keV has significantly advanced the field of materials research because of the great penetration and low absorption of high-energy x-rays. The ability of obtaining high angular resolution for high-energy x-ray scattering provides further research opportunities, especially in the study of bulk samples for both fundamental research and practical applications. Magnetic interaction is one of the most fundamental forces affecting the physical properties and function of materials and devices.

Methods and Materials

It is increasingly realized that magneto-lattice coupling plays a crucial role, especially in the vicinity of competing phases, where many intriguing properties come to play. Recently, a user facility for high-resolution, high-energy x-ray scattering studies of materials under high magnetic fields has been developed at the APS beamline 11-ID-C. This facility combines all the advantages of high-energy photons (high penetration, low absorption, small scattering angle, and greater access to the reciprocal space) with the high-Q resolution of the triple-axis diffractometer at 11-ID-C. This instrument has been used for different research efforts, ranging from the fundamental study of correlated electronic systems to in-situ characterization of applied materials.

Results

The geometrically frustrated triangular lattice antiferromagnet $CuFeO_2$ has been studied. On cooling from room temperature, it undergoes two magnetic phase transitions with incommensurate and commensurate magnetic order at T_{N1} = 14 K and T_{N2} = 11 K, respectively, associated with structural phase transitions (Fig. 1).

Discussion

The occurrence of these two magnetic transitions is accompanied by second- and first-order structural phase transitions from a hexagonal to a monoclinic structure. Application of a magnetic field induces an additional structural modulation in the temperature region where the field-driven ferroelectricity occurs. These results suggest that a strong magneto-elastic coupling is intimately related to the multiferroic effect.

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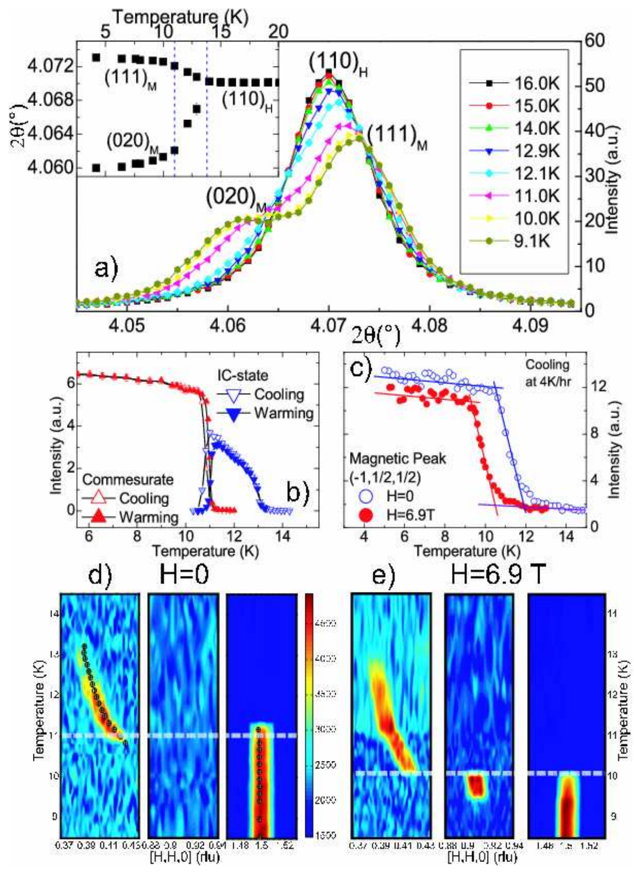

Fig. 1: (a) Synchrotron X-ray diffraction patterns showing the hexagonal (110) peak splitting to two peaks with decreasing temperature. The inset shows the temperature dependence of the peak splitting. (b) temperature dependence of the integrated intensities of the incommensurate (q; q; 1:5) and the commensurate (1/4,1/4,1.5) magnetic peaks respectively, from neutron scattering. (c) magnetic intensities as a function of temperature in zero field (open) and H=6.9 T (solid). Temperature dependence of selected structural modulations in (d) zero-field and (e) H=6.9 T. Solids circles show the lattice modulation wave vector, predicted from the magnetic modulation wave vector.