Effect of uniaxial pressure on magnetic structure of a frustrated triangular antiferromagnet.

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We report results of neutron diffraction studies of triangular antiferromagnetic metal $PdCrO_2$ under uniaxial pressure. Neutron scattering experiments under uniaxial pressure are rarely reported owing to great technical challenges. Here we present details of a new compact uniaxial pressure device, which can be easily accommodated at most neutron scattering instruments at temperatures as low as 1.5 K, Figure 1 [1]. A plate-like shape of a sample is compatible with application of high uniaxial pressure with high-pressure homogeneity. Samples are held in detachable holders, which allows for a rapid sample change during an experiment. The sample holder contains flexures, which protect a sample from transverse and twisting forces, which is necessary since the samples are thin and fragile. The sample holder slots into a spring holder, which holds either a compression or a tension spring to apply force to a sample. A set screw is used to adjust the force, which is determined by multiplying the spring constant of the spring with the applied displacement. One of us (C. W. H) has also developed a version of the device with built-in piezoelectric actuators, so that a pressure can be changed in situ. Such a setup minimizes beamtime lost during multiple cooldowns and allows a much higher pressure to be applied at low temperatures.

$PdCrO_2$ is a rare example of a magnetically frustrated metal. It crystallises in the delafossite structure which consists of alternate stacks of a conductive triangular lattice of Pd atoms and a magnetic triangular lattice of edge-shared CrO_6 octahedra [2]. Below the Neel temperature, $T_N = 38$ K, the Heisenberg Cr^{3+} ($S = 3/2$) spins order in a commensurate non-collinear structure which involves two magnetic propagation vectors unrelated by symmetry [2].

Figure 1. The overall appearance of the uniaxial pressure device for neutron diffraction experiments. The shown configuration of the device is for applying a compressive load. Force is applied to a moving part of the sample holder, whose motion is constrained by flexures to be longitudinal with respect to the sample. This protect the sample from inadvertent transverse or twisting forces. Each end of the sample is secured with epoxy between 2 Ti sample plates.

Recently, we have performed neutron diffraction measurements on single crystals of $PdCrO_2$ using WISH beamline at ISIS spallation neutron source with both compression and tension applied along (1-10). The experiment clearly demonstrated the presence of three magnetic domains (Figure 2a) and confirmed that each domain involved two propagation vectors combined in the following way: domain 1 ($\boldsymbol{k_1}$=1/3,1/3,0 + $\boldsymbol{K_1}$=1/3,1/3,3/2), domain 2 ($\boldsymbol{k_2}$=-2/3,1/3,0 + $\boldsymbol{K_2}$=-2/3,1/3,3/2) and domain 3 ($\boldsymbol{k_3}$=1/3,-2/3,0 + $\boldsymbol{K_2}$=1/3,-2/3,3/2).

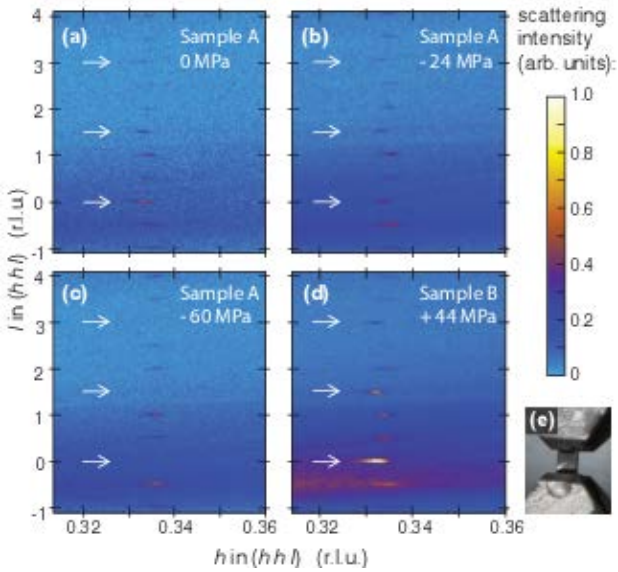

Figure 2. (a-d) Magnetic reflections at various uniaxial stresses applied along (1-10) direction. Negative values indicate compression. All measurements were performed at 2 K. The l = 0, 3/2, and 3 reflections are indicated by white arrows: under compression these reflections fade together, and under tension they are strengthened together. (e) Typical sample is 0.97 mm wide and 0.11 mm thick.

The orientation of the domains 2 and 3 is degenerate with respect to the direction of compression, which populates the domains 2 and 3 and depopulated domain 1. We show that magnetic reflections, which belong to the domain 1 (1/3,1/3,L) where L=0, 3/2, 3 disappear under compression of only 60 MPa, Figure 2c. Conversely, under tensile stress of 44 MPa, the reflection from the domain 1 become stronger, whereas the reflections from the domains 2 and 3 become weaker, Figure 2d. More generally, the uniaxial pressure offers a direct way to turn a sample monodomain, which greatly simplifies a magnetic structure refinement.

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