High tunability of helimagnetic phases to uniaxial stress in $EuAl_4$

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The centrosymmetric tetragonal itinerant magnet $EuAl_4$ has garnered increasing attention as a platform for various intriguing physical phenomena, such as the emergence of charge density wave (CDW) [1] and magnetic skyrmions [2]. In zero field, a multi-step phase transition occurs from the paramagnetic phase to the double-**Q** vortex phase (VII), double-**Q** meron/antimeron phase (VI), and single-**Q** spiral phases (V and I) as the temperature decreases. During this process, the **Q**-vector changes from **Q** = (0.085, ±0.085, 0) in phases VI and VII to **Q** = (0.17, 0, 0) in phase V, and eventually **Q** = (0.194, 0, 0) in phase I at 5 K. Furthermore, the phase transition from phase VI to V accompanies a tetragonal-to-orthorhombic structural transition characterized by a B_{1g}-type distortion of ~0.2%, highlighting the importance of spin-lattice coupling. Our previous resonant x-ray scattering experiment revealed that the magnetic modulation propagates along the elongated *b*-axis in phases I and V, as shown in Fig. 1(a) [3]. These characteristics suggest the potential for controlling the versatile magnetic phases in $EuAl_4$ using uniaxial stress.

To investigate this, we performed single-crystal neutron scattering experiments under applied uniaxial stress. The experiments were carried out using a triple-axis spectrometer at PONTA(5G) in JRR-3. The sample with the dimension of 2.0×1.8×0.5 mm^3 was mounted in a clamp-type uniaxial-stress cell, with the (*H*, 0, *L*) horizontal scattering plane, as depicted in Fig. 1(b). Compressive stress was applied along the [010] direction. Based on the relationship between the **Q** vector and lattice distortion [Fig. 1(a)], we expected the **Q** vector to align within the scattering plane under uniaxial stress in this geometry. The spectrometer was operated in the two-axis mode, with an incident neutron beam energy of 30.5 meV. The sample was cooled to 2 K using an orange cryostat.

Figure 1(c) summarizes the zero-field magnetic phase diagram under various strengths of uniaxial stress, σ. The data at 0 MPa, 20 MPa, and 50 MPa were obtained in 2023. In 2024, we additionally performed the experiments at 80 MPa. As the stress increases, a systematic increase in the q value in phase I, as well as an increase in the transition temperature between phases V (or I) and VI, was observed. Notably, phases I and V coexist at σ = 20 MPa, and phase V disappears at σ = 50 MPa. Eventually, phase I persists up to 14.6 K at σ = 80 MPa, highlighting the high sensitivity of the magnetic phase transition against uniaxial stress.

[1] A. Nakamura *et al.*, J. Phys. Soc. Jpn. **84**, 124711 (2015).
[2] R. Takagi *et al.*, Nat. Commun. **13**, 1472 (2022).
[3] M. Gen *et al.*, Phys. Rev. B **107**, L020410 (2023).

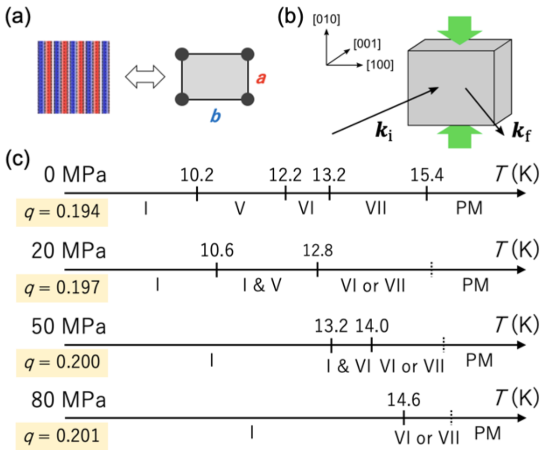

Fig. 1. (a) Relationship between the magnetic structure and orthorhombic lattice distortion in the single-**Q** spiral phases (I and V) [3]. (b) Geometry of the neutron scattering experiments under uniaxial stress. (c) Stress dependence of the magnetic phase diagram of $EuAl_4$ in zero field revealed in this study.