Magnetic structure of the quasicrystal approximant $Au_{72}Si_{12.5}Eu_{13.5}$

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Quasicrystals and approximants are expected to exhibit non-collinear magnetic structures due to the formation of magnetic clusters and competing interactions within clusters. This expectation is confirmed by recent neutron diffraction experiments on Tsai-type 1/1 approximants, Au-Al-Tb [1], Au-Ga-Tb [2], Au-Si-Tb [3,4], and Au-Si-Ho [4]. For example, in Au-Al-Tb and Au-Ga-Tb, the whirling antiferromagnetic structure is realized as the ground state where magnetic moments are aligned tangential to the cluster surface with preserving the threefold rotation symmetry along the 111 and its equivalent directions. Inelastic neutron scattering experiments have indicated the strong uniaxial anisotropy of Tb^{3+} ions, whose orientation roughly coincides with that of the magnetic moment. This coincidence suggests that the contributions from magnetic anisotropy of rare earth elements are significant for the stabilization of the non-collinear magnetic structure.

On the other hand, noncollinear magnetic structures could be also induced from competing magnetic interactions between magnetic moments with little magnetic anisotropy [5]. To verify this point, we performed neutron diffraction experiments on Au-Si-Eu 1/1 approximants, where Eu^{2+} (S = 7/2) is responsible for the magnetism. The Au-Si-Eu 1/1 approximant crystallizes in the space ground pf *I*m-3. The polycrystalline sample with the nominal composition of $Au_{72}Si_{14.5}Eu_{13.5}$ (2.05 g) was prepared by an arc-melting method. Its transition temperature was estimated to be 4.2 K from the magnetic susceptibility and specific heat measurements. To reveal the magnetic structure of this compound, neutron diffraction experiments were performed using a high-resolution neutron powder diffractometer HERMES with a wavelength of 2.195 Å. The temperature was set to 0.7 and 5 K by using ^{3}He refrigerator. The polycrystalline sample was set in an aluminum can with the double cylindrical geometry to suppress absorption of neutrons. A diameter of the can and the thickness of the sample were 10 mm and 0.25 mm, respectively. Neutron diffraction patterns at the two temperatures are compared in Fig. 1. The occurrence of the magnetic reflections at H+K+L=(odd) indices indicates that body-centered symmetry is broken by the magnetic order. In addition, we found that magnetic reflections those were absent in the powder diffraction patterns in Au-Al-Tb [1] and Au-Ga-Tb [2], such as 111, were observed, indicating that threefold rotation symmetry is broken in the antiferromagnetic phase. This indicates that the magnetic structure has different symmetries from those discovered in Au-Al-Tb [1] and Au-Ga-Tb [2]. The refinement based on the irreducible representation theory suggests that a single irreducible representation consists of 4 × 3 dimensional basis vectors can represent the magnetic structure. However, the magnetic structure was not solved completely because of 12 parameters necessary for the refinement and magnetic domains allowed in this structure. Further single crystalline neutron diffraction experiments would be necessary to complete the determination of the magnetic structure.

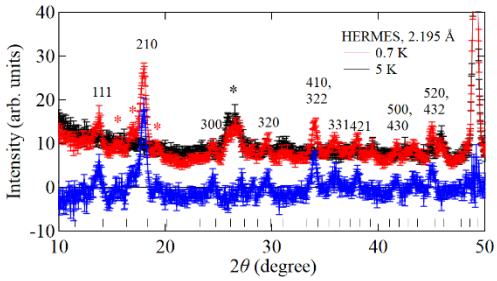

Fig. 1. Neutron diffraction patterns of $Au_{72}Si_{12.5}Eu_{13.5}$ measured at 0.7 and 5 K.

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