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Helical magnetic structure in cubic chiral crystal $Pr_5Ru_3Al_2$

Daisuke Okuyama[1], Koya Makino[1], Maxim Avdeev[2], Kazuki Ohishi[3], Kunihiko Yamauchi[4], Tamio Oguchi[4], Taku J Sato[1]
[1]IMRAM, Tohoku University, Sendai, Japan, [2]Bragg Institute, Australian Nuclear Science and Technology Organisation, NSW, Australia, [3]Comprehensive Research Organization for Science and Society (CROSS), Tokai, Japan, [4]The Institute of Scientific and Industrial Research, Osaka University, Suita, Osaka, Japan
E-mail: okudaisu@tagen.tohoku.ac.jp

Helical magnetic structure has recently attracted intrests because of the discovery of novel topological spin textures, for example magnetic skyrmions and chiral magnetic soliton lattices. For such spin textures, a finite antisymmetric Dzyaloshinsky–Moriya-type (cross product) interaction is crucial, activated in noncentrosymmetric crystals. Such antisymmetric interactions have been studied mainly in 3d magnets. For example, in B20 compound (Mn,Fe,Co)Ge, the antisymmetric interaction is well investigated by the theoretical first principle calculation and found that the observed sign inversion of the helicity of the helical magnetic structure by the magnetic ion substitution is quantitatively explained [1]. In contrast, there are few studies investigating the antisymmetric interaction in 4f rare-earth based noncentrosymmetric materials. Murashova et al. reported the rare-earth based chiral compounds Re5Ru3Al2 with the space group I213 (Re = La, Pr) [2]. Nonetheless, their low temperature magnetism was largely unexplored.
Powder Pr5Ru3Al2 was synthesized by the arc melting and high-frequency induction heating methods. The powder samples were annealed using muffle furnace and the high quality powder sample and single crystal were grown. In the magnetization measurement using obtained Pr5Ru3Al2, the temperature dependence of the magnetic susceptibility is fitted by Curie-Weiss law and the obtained Curie constant is close to the value for a free Pr3+ ion. At 4K, the antiferromagnetic transition is observed [3]. To clarify the magnetic structure of Pr5Ru3Al2, we performed powder neutron diffraction using ECHIDNA in ANSTO and single crystal small angle neutron scattering (SANS) using TAIKAN in J-PARC. The powder diffraction pattern at 10 K is explained by the nuclear scattering of Pr5Ru3Al2. At 3 K, additional incommensurate magnetic peaks with the propagation vector (q q q): q ~ 0.066 [r. l. u.] are observed. More noteworthy are the integrated intensities of the equivalent magnetic reflections around the nuclear 1 1 0 are not the same value. To explain the difference of the intensities between equivalent reflections, it is reasonable to conclude that the helical magnetic ordering takes place and the sign of its helicity is determined by the sign of the crystal chirality. The magnetic structure determined by the magnetic representation and Rietveld analyses is shown in Fig. 1 (a). The composite magnetic structure obtained by adding the magnetic moments of Pr1, Pr2, Pr3, and Pr4 layers is the typical helical, as shown in Fig. 1 (b). In the SANS experiment using single crystal Pr5Ru3Al2, the (q q q)-type magnetic reflection is also observed below 3.3 K. The band structure near Fermi energy is calculated by the first principle calculation to determine the conduction band mediating RKKY interaction. From these experimental and theoretical results, the origin of the helical magnetic structure in Pr5Ru3Al2 will be discussed.

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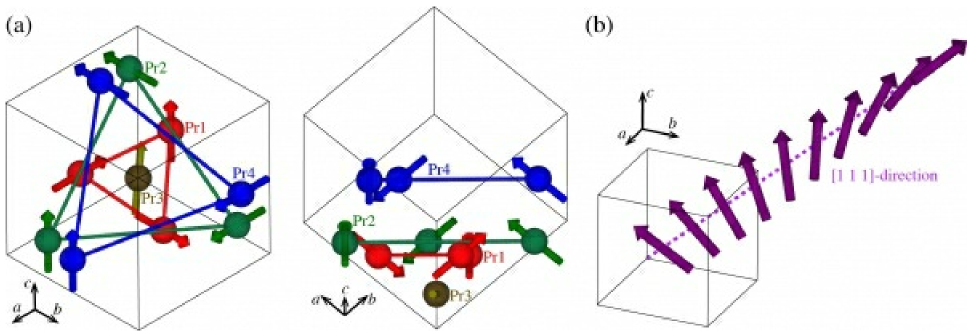

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