Chiral Magnetic Soliton Lattice in Inorganic Chiral Materials


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The concept of chirality, meaning left- or right-handedness, plays an essential role in symmetry properties of nature at all length scales from elementary particles to cosmic science. In material sciences, it is very important to understand the chirality in molecules, crystals and magnetic structures both from theoretical and experimental viewpoints. Recently, large attention has been paid to the relationship between crystallographic chirality and that of magnetic structure, because the sense of a helical spin structure depends on the right- or left-handed chiral crystallographic structure that allows an asymmetric Dzyaloshinski-Moriya (DM) interaction due to spin-orbit interaction. Kishine et al. theoretically proposes that the chiral helimagnetic compounds form a chiral magnetic soliton lattice [1]. However, there have been few experimental results due to the difficulty to synthesize the suitable materials to realize such research. In chiral helical magnetic structures, the pitch angle, mainly determined by the ratio of exchange interaction and DM interaction, is usually very small. As a result, the helimagnetic period can be hundreds of angstroms. Therefore sometimes the angle resolution of thermal neutron diffraction experiments is not high enough to separate fundamental Bragg peaks and magnetic satellite peaks. As consequence, some compounds with chiral helimagnetic ordering may be easily misinterpreted as ferromagnetic ordering.

Firstly, we will present a unique crystallization technique to make a single crystallographic chirality in inorganic compounds. By adapting our crystallization technique, we succeeded in obtaining the mm-ordered enantiopure single crystals. Secondly, we will present neutron diffraction works performed at BL08 (Super HRPD) and BL15 (TAIKAN) in the Materials and Life Science Experimental Facility (MLF) of J-PARC. By means of super high-resolution powder neutron diffraction in Super HRPD, we observed very long periodical magnetic satellite peaks in some of ferromagnetic $T_{1/3}MS_2$ ($T =$ transition metal, $M =$ Nb and Ta) compounds. Magnetic structure analysis indicates the magnetic structure forms helimagnetic structure. We performed small and wide angle polarized neutron scattering in TAIKAN, and observed chiral incommensurate magnetic structures in MnSi, which is a chiral magnet with cubic symmetry, and YbNi3Al5, which is a new rare earth based chiral magnetic compound. The difference in magnetic satellite intensity between up- and down-spin neutron indicates that chiral helimagnetic ordering Moreover, under an applied magnetic field, we succeeded in observing higher harmonics as an evidence of the chiral magnetic soliton lattice.

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