Magnetic structure of Spin S=1/2 linear trimer system Na2Cu3Ge4O12

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Low dimensional quantum spin systems attract much attention. In particularly, the frustrated quantum spin systems due to geometrical arrangement or competing interactions are expected to exhibit various interesting properties. Na2Cu3Ge4O12 has a Cu3O8 trimer formed of edge-sharing three CuO4 square planes [1]. For Cu2+ spins (S=1/2) within the Cu3O8 trimer, the second-neighbor exchange interaction J2 is antiferromagnetic (J2 >0) ,and the nearest-neighbor exchange interaction J1 is weak ferromagnetic or antiferromagnetic (AF). Such competing interactions between J1 and J2 can lead to novel quantum magnetic phenomena.

The T-dependence of magnetic susceptibility χ of Na2Cu3Ge4O12 in the T-region 70 K $<$ T $<$ 650 K can be explained by the isolated S = 1/2 Heisenberg trimer model, and it is obtained J2/kB = 340 $\pm$ 20 K (AF), and J1/kB = 30 $\pm$ 20K. [2] On the other hand, T-dependence of χ of Na2Cu3Ge4O12 in the T-region 4 K $<$ T $<$ 70 K can be explained by the S = 1/2 uniform Heisenberg chain model called as Bonner-Fisher model [3], and it is obtained J3/kB = 18 $\pm$ 1 K where J3 is an inter-trimer exchange interaction.[2] The ground state of the isolated S = 1/2 trimer is found that two spins of the edge in the Cu3O8 trimers form a nonmagnetic singlet state by strong AF interaction J2. The center spin of the Cu3O8 trimer only survives in low T-region T $<$ 70K. The behavior of the specific heat in the T-region 4 K $<$ T $<$ 70 K can also be explained by the S = 1/2 uniform Heisenberg chain model. As results of measurements of magnetic susceptibility, specific heat, and dielectric constant, the center spin of the Cu3O8 trimer of Na2Cu3Ge4O12 exhibits an antiferromagnetic transition at TN = 2 K accompanied with a ferroelectricity (called multiferroic phenomenon). From the detailed magnetization measurements, we found the existence of dM/dH anomaly at Hc = 0.37 T at T = 1.9 K ($<$ TN). It is indicating that the magnetic structure changes at Hc. The determination of the magnetic structure at H = 0 and H = 1T ($>$ Hc) give us important information to understand the magnetic behavior of the S = 1/2 linear trimer system.

We investigated the magnetic structure of Na2Cu3Ge4O12 below TN through powder neutron diffraction experiments using cold neutron powder diffractometer DMC at PSI. We used amount of 15 g of powder for Na2Cu3Ge4O12. The superconducting magnet and the dilution refrigerator waer used to reach down to 0.1 K and up to 1 T.

We obtained powder neutron diffraction patterns at T = 0.1 K, 3K, and 12 K, respectively, in H = 0 as well as that of T = 0.1 K applied the magnetic field H = 1T. The figure (a) show the diffraction patterns at T=0.1 K and 12 K, respectively. We can clearly observe the super-lattice magnetic Bragg peaks below TN assigned by the arrows. The figure (b) show the intensity profile of difference between at T = 0.1 K and 12 K, I (0.1K) ? I (12K). We also found the possible magnetic Bragg peaks assigned by the short arrows. By applied the magnetic field H = 1T, no difference found the magnetic Bragg intensities at T = 0.1 K in the error bar. Then, changing the magnetic structure at Hc seems to be small. Recently, the aligned powder of Na2Cu3Ge4O12 can be obtained in the magnetic field H = 9T. For determination of the magnetic structure of Na2Cu3Ge4O12, the results of the various measurements of the aligned powder give us important information. We are analyzing the neutron diffraction data and various measurements data.

[1] X. Mo et al.: Inorg. Chem. 45 3478 (2006).
[2] Y. Yasui et al.: J. Appl. Phys. 115 17E125

(2014).
[3] J. C. Bonner et al.: Phys. Rev. 135 A640 (1964).

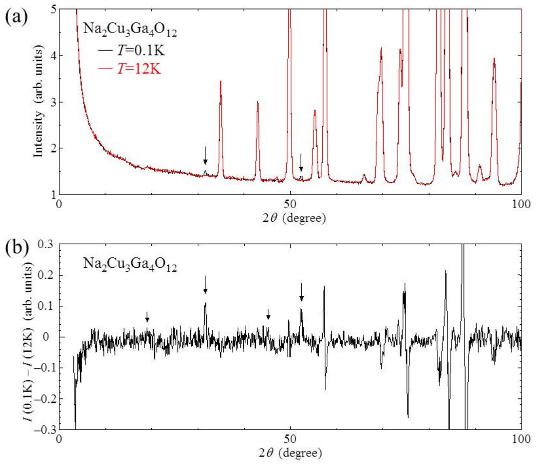

Fig. 1. (a). Neutron powder diffraction patterns measured at 0.1 K and 12 K. The arrows indicate the magnetic Bragg peaks. (b). Intensity profile of difference between at T = 0.1 K and 12 K.