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Magnetic ordering in Cu_6O_8TbCl probed during the μSR measurement

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The copper-oxide family of Cu_6O_8MCl (M = cation) has a caged structure (Cu_6O_8 cage) in its crystal structure (crystal system: cubic, space group: Fm-3m (No. 225)). The form of the surface of the Cu_6O_8 cage is similar to the CuO_2 plane in high-T_c cuprate superconductors. The Cu_6O_8 cage forms a three-dimensional network, sharing their face (left panel of Fig. 1).[1-3)] The Cl^- anions are located at the center of the Cu_6O_8 cage, and the M cations, which have a valence of 3+ or 4+, exist in the cuboid space located between Cu_6O_8 cages. The average valence of Cu ions in the Cu_6O_8 cage is 2.33+ for M^{3+}.

For the M = Tb^{3+} compound (Cu_6O_8TbCl), the magnetic susceptibility data indicate a weak magnetic transition at approximately 40 K. Moreover, the electrical resistivity data exhibit a metal-insulator transition at approximately 40 K (right panel of Fig. 1). The effective Bohr magneton P_{eff} is estimated to be ~6.74, which is close to the theoretical value for Tb^{3+}, indicating that a localized magnetic moment exists at the Tb^{3+} site. However, whether the origin of the magnetic ordering state is long range (static) or not and the relationship between the magnetic state and other physical properties is not yet clear. In order to clarify these points, μSR measurement was performed at the RIKEN-RAL Muon Facility in U.K. using a polycrystalline sample of Cu_6O_8TbCl.

Figure 2 (a) shows the time dependence of asymmetry of the zero field (ZF) μSR spectra, $A(t)$, of Cu_6O_8TbCl measured at various temperatures. These spectra were observed using the double-pulse muon beam. The spectra show exponential-like depolarized behaviors, and the muon-spin depolarization becomes faster with decreasing temperature above 40 K. Significant loss of initial

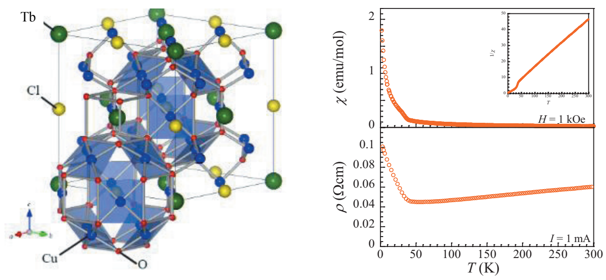

Fig. 1 (Left panel) Crystal structure of Cu_6O_8MCl (program VESTA was used. [4)]). Solid line shows the unit cell. (Right panel) Temperature dependence of magnetic susceptibility and electrical resistivity of Cu_6O_8TbCl. Inset shows the inversed magnetic susceptibility as a function of temperature.

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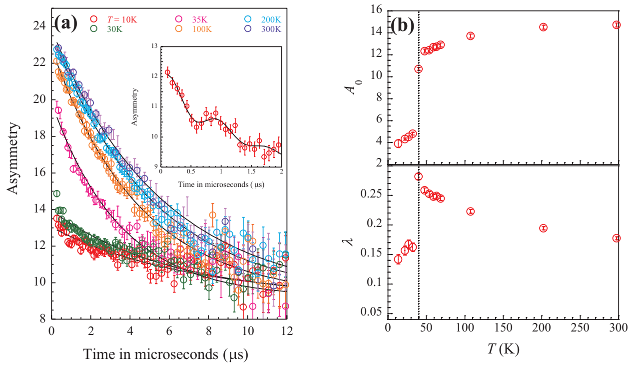

Fig. 2 (a) The time dependence of asymmetry of ZF μSR spectra of Cu_6O_8TbCl measured at various temperatures. Solid lines are fitting results using Eq. (1). (b) The temperature dependence of A_0 and λ obtained by the fitting.

asymmetry (at t = 0) is observed below 40 K. In order to observe the change of the spin dynamics in detail, all of the time spectra were analyzed using the following function:

$$A(t) = A_0\exp(-\lambda t) + A_B, \qquad (1)$$

where A_0 is the initial asymmetry, λ is the depolarization rate of the muon spins, and A_B is the background. The parameters obtained from the best fit of Eq. 1 to the data in Fig. 2(a) (solid line) are shown in Fig. 2(b). From Fig. 2(b), A_0 slightly decreases and λ increases above 40 K. Moreover, A_0 and λ values rapidly change at approximately 40 K, indicating that the spin state drastically changes at 40 K. The inset of Fig. 2(a) shows an early time region of the ZF μSR spectra at 5 K (lowest temperature of this measurement) measured using the single-pulse muon beam. Muon-spin precession behavior was observed, indicating the existence of a long-range magnetic-ordered state. Consequently, the weak magnetic transition confirmed in the magnetic susceptibility data of Cu_6O_8TbCl is generated by the development of long-range magnetic order of Tb^{3+}. Moreover, it is suggested that the conducting carrier is trapped and that the ground state changes from metallic to semiconducting with the onset of long-range magnetic order.

References

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