Magnetic and Dielectric Properties of One-Dimensional Array of S=1/2 Linear Trimer System $Na_2Cu_3Ge_4O_{12}$

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Magnetic and dielectric properties have been studied for quantum spin linear trimer system $Na_2Cu_3Ge_4O_{12}$ which has the one-dimensional array of Cu_3O_8 trimers formed of edge-sharing three CuO_4 square planes. Figure 1shows the schematic structure of $Na_2Cu_3Ge_4O_{12}$ cut in a cross section parallel to three CuO_4 square planes [1]. The shaded area and circles represent the Cu_3O_8 trimes and Ge^{4+} ions, respectively. Measurements of the magnetic susceptibility χ, the specific heat C, the dielectric constant ε, and ^{23}Na-NMR have been carried out on polycrystalline samples of $Na_2Cu_3Ge_4O_{12}$. Figure 2 shows the temperature (T) dependence of χ of $Na_2Cu_3Ge_4O_{12}$, and the inset of Fig.2 shows the data at magnified scales. We analyzed the χ data to clarify the interactions between the Cu^{2+} (S=1/2) spins, and were able to understand the magnetic behavior by employing the following model. The exchange couplings J_1, J_2, and J_3 are defined in Fig. 1. At first, two spins of the edge in the Cu_3O_8 clusters form a nonmagnetic dimer by strong antiferromagnetic interaction J_2 (~400 K). The spin left in the center of the Cu_3O_8 clusters forms one-dimensional chains by the antiferromagnetic interaction J_3 (~20 K) between the clusters. Anomalous behavior has been found in the T-dependence of χ, C, and ε at T_N=2 K of $Na_2Cu_3Ge_4O_{12}$, indicating that the spin system exhibits antiferromagnetic and ferroelectric transitions, simultaneously (called multiferroic). ^{23}Na NMR spectra have characteristics of the modulated magnetic structure below T_N, which is considered to induce the ferroelectric transition.

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Figure captions

Fig.1 :Schematic structure of $Na_2Cu_3Ge_4O_{12}$ cut in a cross section parallel to three CuO_4 square planes. The exchange couplings J_1, J_2, and J_3 are defined.

Fig. 2. Temperature dependence of the magnetic susceptibility of $Na_2Cu_3Ge_4O_{12}$. The inset shows the data at magnified scales.