MLF Experimental Report

課題番号 Project No. 2015A0016 実験課題名 Title of experiment Magnetic excitations in the spin-3/2 antiferromagnetic alternating chain substance $HoCrGeO_5$ 実験責任者名 Name of principal investigator Masashi Hase 所属 Affiliation National Institute for Materials Science (NIMS)	提出日 Date of Report Jan. 7, 2016 装置責任者 Name of responsible person Shin-ichi Itoh 装置名 Name of Instrument/（BL No.） BL12 HRC 実施日 Date of Experiment Nov. 17 to 20, 2015

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

Holmium chromium germanate, $HoCrGeO_5$, powders and Erbium chromium germanate, $^{166}ErCrGeO_5$, powders.

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）

Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

An interesting phenomenon in quantum spin systems is the appearance of a spin-singlet ground state with a spin gap (singlet - triplet excitation). When the spin value is larger than 1, existence of a spin-singlet ground state with a spin gap was not confirmed experimentally. We expected antiferromagnetic (AF) alternating spin-3/2 chains of Cr^{3+} in $RCrGeO_5$ (R = Y or rare earth) [1] and a spin-singlet ground state with a spin gap. We performed inelastic neutron scattering (INS) experiments on $YCrGeO_5$, $^{154}ErSmCrGeO_5$, and $NdCrGeO_5$ powders using the HRC spectrometer at BL12 [2]. We observed magnetic excitations of Cr^{3+} spins and obtained the dispersion relation of the magnetic excitations parallel to the spin chain using the conversion method developed by Tomiyasu et al. [3]. We confirmed experimentally the spin gap. The dispersion relation can be explained by the AF alternating spin chain model. The energy range of the dispersive first-excited triplet states is 10 to 23 meV and 18 to 23 meV for Y and Sm, respectively.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

The ground state is a dimer state with a strong bond alternation (SD state) and a dimer state with a weak bond alternation (WD state) for $0 \leq \alpha < 0.41$ and $0.41 < \alpha < 1$, respectively. Here, α is the ratio of two exchange interaction values in the chain. The value of α is 0.14 and 0.05 for Y and Sm, respectively. The ratio depends on rare earth. In order to find $RCrGeO_5$ having a WD state, we performed INS experiments on $HoCrGeO_5$ and $^{166}ErCrGeO_5$ powders using the HRC spectrometer at BL12. The incident neutron energy Ei was 51.0 or 92.1 meV.

Figure 1(a) shows INS results of $HoCrGeO_5$ powders at 3.8 K using Ei = 51.0 meV. Magnetic excitations are apparent around 13 meV. The Q dependence of the intensity shows a maximum around $Q = 1.3\text{Å}^{-1}$, indicating that Cr^{3+} spins generate the 13 meV excitations. The value of 13 meV corresponds to the spin gap. The 13 meV excitations remain at high Q. Therefore, crystal-field excitations of Ho (total angular momentum J = 8) may overlap. We can see excitations around 22 meV that probably correspond to the highest energy of the dispersive first-excited triplet states. We can see other dispersionless excitations, for example around 34 meV. They may be also crystal-field excitations of Ho.

Figure 1(b) shows INS results of $^{166}ErCrGeO_5$ powders at 2.5 K using Ei = 51.0 meV. Magnetic excitations are apparent around 10.5 and 13.5 meV. The Q dependence of the intensity shows a maximum around $Q = 1.3\text{Å}^{-1}$, indicating that Cr^{3+} spins generate the 10.5 and 13.5 meV excitations. These excitations remain at high Q. Therefore, crystal-field excitations of Er (total angular momentum J = 15/2) may overlap. We can see weak excitations up to 26 meV that probably correspond to the highest energy of the dispersive first-excited triplet states. We can see other dispersionless excitations, for example around 33 meV. They may be crystal-field excitations of Er. We will perform further quantitative analyses.

[1] R. V. Shpanchenko et al., J. Solid State Chem. 181, 2433 (2008).

[2] M. Hase et al., Phys. Rev. B 90, 024416 (2014).

[3] K. Tomiyasu et al., Appl. Phys. Lett. 94, 092502 (2009).

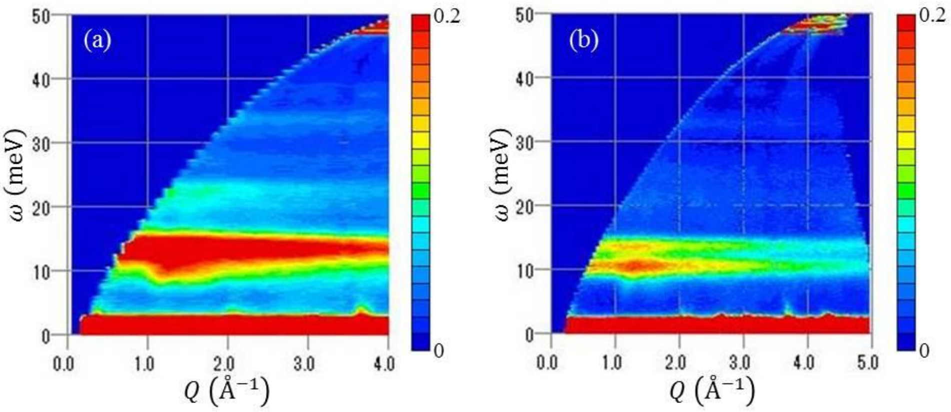

Fig. 1 The INS intensity map in the $Q - \omega$ plane obtained using $E_i = 51.0$ meV. (a) The results of $HoCrGeO_5$ at 3.8 K. (b) The results of $^{166}ErCrGeO_5$ at 2.5 K.