（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。）

CROSS TOKAI **Experimental Report** J-PARC	承認日 Date of Approval 2017/1/4 承認者 Approver Takashi Ohhara 提出日 Date of Report 2017/1/4
課題番号 Project No. 2016A0254 実験課題名 Title of experiment Spin-density-wave state of 1D frustrated chain compound NaCuMoO4(OH) 実験責任者名 Name of principal investigator Shinichiro Asai 所属 Affiliation ISSP, the Univ. of Tokyo	装置責任者 Name of Instrument scientist Takashi Ohhara 装置名 Name of Instrument/（BL No.） SENJU(BL18) 実施日 Date of Experiment 24/10/2017 - 28/10/2017

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.

$NaCuMoO_4(OH)$

Form: Single crystal

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.

In S = 1/2 one-dimensional frustrated chain with nearest-neighbor ferromagnetic interaction and next-nearest-neighbor antiferromagnetic interaction, the ground state exhibits various quantum phases depending on the ratio between J_1 and J_2 [1]. Theoretical study predicted that applying magnetic field induces unconventional magnetic state such as the spin multipole order in the vicinity of the saturation field [2]. Meanwhile, such a state has not been well identified in experimental researches because of too high saturation field and/or difficulty of obtaining a large crystal for the existing model compounds.

Recently a new model compound $NaCuMoO_4(OH)$ was reported [3]. Figure 1(a) shows the crystal structure [4, 5]. Cu^{2+} ions carrying S = 1/2 spin form one-dimensional chain along the crystallographic b axis. The magnetic transition and saturation field are 0.6 K and 26 T, respectively [3]. The synthesis of a single crystal were reported [3]. Thus this compound is a good candidate for studying the quantum phases in the magnetic field. Our recent neutron diffraction study at zero field indicates that the proper-screw magnetic structure is realized below 0.6 K. When the magnetic field is applied, the transition to the spin-density-wave (SDW) state is

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

theoretically predicted [2]. The magnetic phase diagram is shown in Figure 2, which suggests the transition around 1.7 T [6]. However, no neutron diffraction study has not been carried out.

In order to investigate the SDW state for $NaCuMoO_4(OH)$, we carried out the neutron diffraction experiment. The measuring temperature was 0.1 K, which was achieved by the dilution cryostat. .We used the superconducting magnet for applying the magnetic field. Applied magnetic field is 0, 1, 2.5, 3.5, 4.5 T. 1.03 mg of single crystal was used. The sample size is 1.0*0.5*0.5 mm^3.

We observed the (0δ0) magnetic peak ($\delta \sim 0.48$) at H = 0 T, which is consistent with the previous result. The value of δ is independent of the magnetic field below 1 T. Meanwhile, the value of δ decreases with increasing the magnetic field above 2.5 T. This behavior is consistent with the theoretical prediction for the SDW_2 state with the ferromagnetic J_1 [7]. The intensity of the (0δ0) peak decreases with increasing H below 1 T, and is almost independent of H above 2.5 T. When we assume that the magnetic state above 2.5 T is SDW state where the spin direction is parallel to the magnetic field (the crystallographic a axis), we can evaluate the amplitude of the magnetic moment m_{SDW} to be 0.24 μ_B at 4.5 T. The ratio of m_{SDW} to the ordered moment of the spiral phase a H = 0 T m_{SP} for $NaCuMoO_4(OH)$ is bigger than that for $LiCuVO_4$ [8].

[1] S. Furukawa *et al.*, Phys. Rev. Lett. **105**, 257205 (2010). [2] T. Hikihara *et al.*, Phys. Rev. B **78**, 144404 (2008). [3] K. Nawa *et al.*, J. Phys. Soc. Jpn. **83**, 103702 (2014). [4] A. Moini *et al.*, Inorg. Chem. **25**, (1986) 3782. [5] S. Asai *et al*, J. Phys.: Conf. Series **828**, 01206 (2017). [6] K. Nawa *et al.*, 70th JPS meeting 22aAH-1. [7] M. Sato *et al.*, Phys. Rev. B **79**, 060406 (2009). [8] T. Masuda *et al.*, J. Phys. Soc. Jpn. **8**, 113705 (2011).

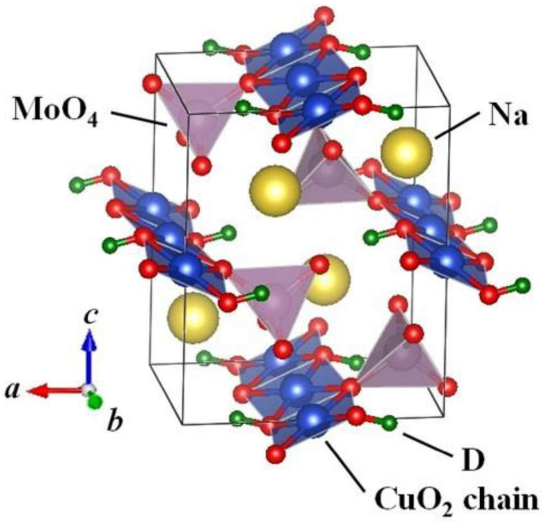

Figure 1. Crystal structure of $NaCuMoO_4(OH)$

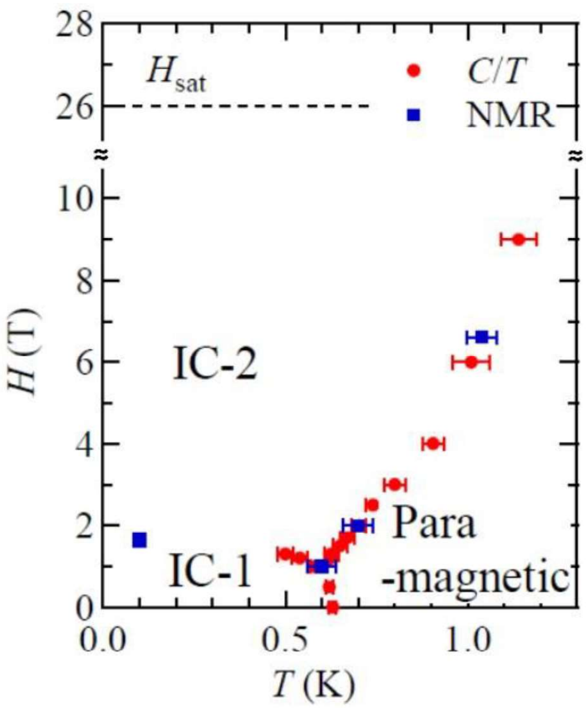

Figure 2. Magnetic phase diagram for $NaCuMoO_4(OH)$ [6].