報告書様式（一般利用課題・成果公開利用）

茨城県 IBARAKI Prefectural Government **MLF Experimental Report**	提出日(Date of Report) 2022/4/4
課題番号(Project No.) 2021PM3004 実験課題名(Title of experiment) 電子物性現象の学術研究 実験責任者名(Name of principal investigator) 大山研司 所属(Affiliation) 茨城大学大学院理工学研究科	装置責任者(Name of responsible person) 石垣徹 装置名(Name of Instrument : BL No.) iMATERIA: BL20 実施日(Date of Experiment) 2022/3/28-3/30

実験目的、試料、実験方法、利用の結果得られた主なデータ、考察、及び結論を記述して下さい。
実験結果などの内容をわかりやすくするため、適宜図表添付して下さい。
Please report experimental aim, samples, experimental method, results, discussion and conclusions. Please add figures and tables for better explanation.

1. 実験目的(Objectives of experiment)

Topological effects on electronic states are attractive subjects in the recent solid state physics. The noncentrosymmetric or chiral crystal structures are expected to host the Weyl electronic state. We focus magnetic ground state in a chiral-structure material $Nd_3Ir_4Sn_{13}$. This compound is one of the members of rare-earth-based 3–4–13 series, which show centrosymmetric-to-chiral structural phase transitions. The synthesized sample exhibits the structural phase transition, and magnetic-susceptibility data suggest magnetic ordering below 2 K. To identify the magnetic ground state of $Nd_3Ir_4Sn_{13}$, we conducted neutron diffraction (ND) measurements at very low temperatures using BL20 iMATERIA, MLF, J-PARC

2. 試料及び実験方法

Sample(s), chemical compositions and experimental procedure

2.1 試料 (sample(s))

Single-crystalline samples of $Nd_3Ir_4Sn_{13}$ were synthesized using the molten Sn-flux method at Ibaraki University. Tiny crystals are crushed into a powder form, which was sealed inside an aluminum sample holder.

2.2 実験方法(Experimental procedure)

The ND measurements were conducted using the pulsed neutron diffractometer iMATERIA installed at BL20 of J-PARC MLF. Sample temperature was controlled between 0.73 and 2.02 K using the closed-cycle ^{3}He refrigerator installed at iMATERIA. The diffraction data as a function of *d* value for inter-atomic-planer distance were measured at the several detector banks (LA15, LA25, and LA35) with the neutron time-of-flight method.

3. 実験結果及び考察（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 results and discussion. If you failed to conduct experiment as planned, please describe reasons.

Prior to present ND study, we succeeded in determining the crystal structure of $Nd_3Ir_4Sn_{13}$ using the synchrotron X-ray diffraction instrument at BL-8A of Photon Factory, KEK [1]. The low-temperature structure is characterized by the chiral cubic unit cell with the lattice constant of 19.33 Å. The ND pattern between 0.73 and 2.02 K is shown in Fig. 1. Several diffraction peaks are seen in the *d*-range between 3 and 11 Å, which are indexed for the unit cell as described above. At temperatures above approximately 1.4 K, no distinct diffraction peak was observed above $d = 5$ Å, while the clear reflections appear below 1.4 K at 2 0 0, 2 2 0, and 2 2 2 points. We also observed intensity enhancements at the nuclear reflection points at higher *d*-reflections. These reflections growing in the lower temperatures indicate an antiferromagnetic ordered phase below 1.4 K that is characterized by alternative arrangement of magnetic moments at the Nd ions inside the cubic unit cell. The observed ND pattern resembles that reported in previous study on $Nd_3Co_4Sn_{13}$ [2]. However, the present data for $Nd_3Ir_4Sn_{13}$ show tiny reflections at 2 1 1 ($d = 7.93$ Å) for example, whose intensity is lower by one order of magnitude than those of the abovementioned antiferromagnetic reflections. The detailed magnetic structure should be explained by taking an additional magnetic degree of freedom owing to the chiral structure with the two inequivalent Nd-ion sites, which was not considered in the study on $Nd_3Co_4Sn_{13}$. We will perform a magnetic structure analysis to reveal the magnetic ground state.

[1] A. Shimoda et al, in preparation. [2] C. W. Wang et al., J. Phys.: Condens. Matter **29**, 435801 (2017).

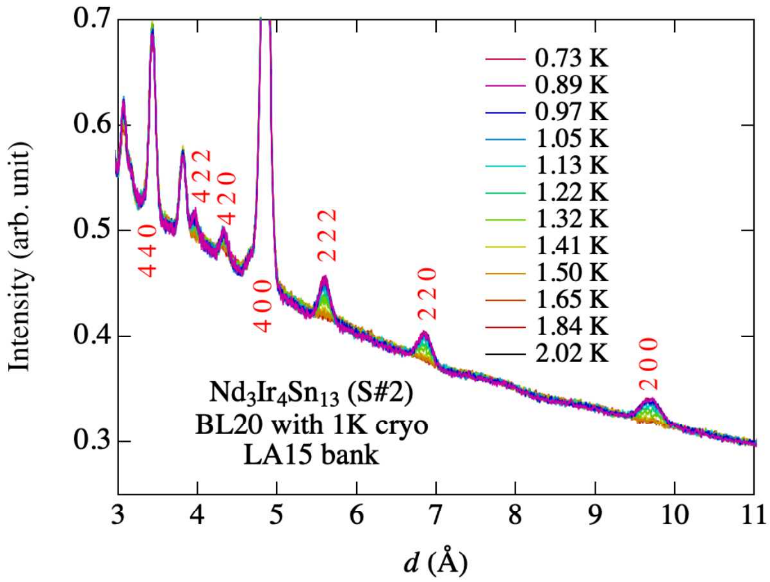

Fig. 1. ND pattern of $Nd_3Ir_4Sn_{13}$ as a function of temperature.

4. 結論(Conclusions)

The antiferromagnetic ordered structure in the chiral-structure phase of $Nd_3Ir_4Sn_{13}$ is clearly observed using iMATERIA. The ordering temperature is approximately 1.4 K. The magnetic susceptibility shows a suppression behavior above 2 K, which is far above the long-range magnetic ordering temperature 1.4 K as evidenced in the present ND study. Our previous study on the magnetic ordered state of the isomorphic compound $Nd_3Rh_4Sn_{13}$ also revealed the similar phenomenon. Such anomalous magnetic behaviors are expected to be caused by the characteristic geometry of chiral crystal lattice of $Nd_3Ir_4Sn_{13}$.