報告書様式(一般利用課題・成果公開利用)

MLF Experimental Report	提出日(Date of Report) 2023/2/27
課題番号(Project No.) 2022PM3004 実験課題名(Title of experiment) $R_3T_4Sn_{13}$における対称性の破れに関する構造物性研究 実験責任者名(Name of principal investigator) 岩佐和晃 所属(Affiliation) 茨城大学フロンティア応用原子科学研究センター	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) 2023/2/19-2/20

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 produce the Weyl electronic state. We focus magnetic ground state in an expected chiral-structure material $Eu_3Ir_4Sn_{13}$, which is one of the members of rare-earth-based 3–4–13 series showing centrosymmetric-to-chiral structural phase transitions. The synthesized sample exhibits the structural phase transition, and magnetic-susceptibility data suggest antiferromagnetic (AFM) ordering below the Néel temperature at 10 K [1]. To identify the magnetic ground state of $Eu_3Ir_4Sn_{13}$, 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))

Samples of $Eu_3Ir_4Sn_{13}$ were synthesized using the molten Sn-flux method at Ibaraki University. Powder sample was spread on a vanadium foil after mixed with CYTOP, and 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. Sample temperature was controlled at 3, 20 and 65 K using the closed-cycle ^{3}He refrigerator to distinguish magnetic signals from the Bragg peaks owing to nuclear diffraction. The neutron time-of-flight data, which were measured at the several detector banks, were converted into diffraction profiles as a function of *d* value for inter-atomic-planer distance.

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 conducted synchrotron X-ray diffraction measurements at BL-8A of Photon Factory, KEK to reveal the crystal structure of $Eu_3Ir_4Sn_{13}$ [2]. The low-temperature structure below 57 K is characterized by the superlattice wave vector **q** = (1/2, 1/2, 0) with respect to the high-temperature cubic structure categorized in the space group $Pm\bar{3}n$, which is a signature of chiral crystal-structure. The sample also show a tiny hysteresis behavior of magnetization in the magnetic ordered phase below 10 K, which is consistent with the chiral structure. The ND patterns between 3.4 and 20 K are shown in Fig. 1. At 20 K, only the nuclear peaks 2 0 0 and 2 2 0 were observed in addition to background intensity varying slowly with the *d* value. At 3.4 K below the Néel temperature, new peaks are enhanced at the *d* positions corresponding to **q** = (1/2, 1/2, 0), as indexed by black letters. These peaks indicate the AFM ordering with the same periodicity as that of the crystal-lattice superlattice. The strong peaks appear at the scattering vectors represented by indices of two half integers and an odd number, whereas much less intensities at those represented by indices of two half integers and an even number. The obtained experimental facts indicate that the AFM structure takes a characteristic forbidden rule for magnetic neutron diffraction. The observed ND pattern differs from those represented by **q** = (0, 0, 0) for $Nd_3T_4Sn_{13}$ (T = Co, Rh, Ir) [3, 4]; thus, the crystal structural symmetry of $Eu_3Ir_4Sn_{13}$ is also not identical to those of the Nd-based compounds. It is a further issue to establish topological electronic beahviors in the peculiar structure of $Eu_3Ir_4Sn_{13}$.

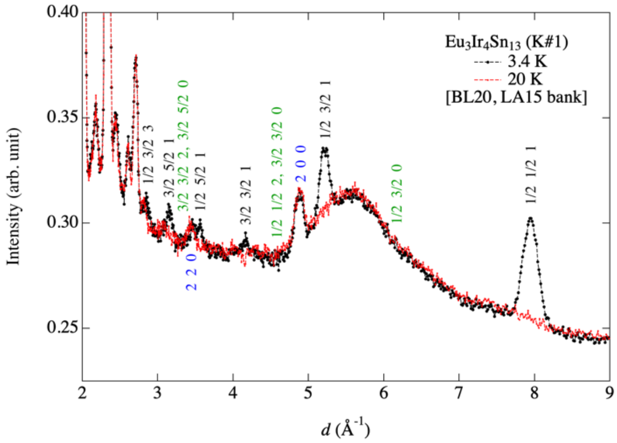

Fig. 1. ND pattern of $Eu_3Ir_4Sn_{13}$ at 3.4 and 20 K.

[1] J. R. L. Mardegan et al., IEEE Transactions on Magnetics **49**, 4652 (2013). [2] T. Kumada, Y. Suzuki, and K. Iwasa, in preparation. [3] C. W. Wang et al., J. Phys.: Condens. Matter **29**, 435801 (2017). [4] A. Shimoda, Thesis of Master Course Degree of Major of Quantum Beam, Ibaraki University (2023).

4. 結論(Conclusions)

The AFM ordered structure below 10 K in the low-temperature superlattice phase of $Eu_3Ir_4Sn_{13}$ was clearly observed using iMATERIA, despite that this compound contains the high absorption elements for thermal neutron. The 0.2-gram powder sample formed in the thin cylindrical shape is sufficient for structural investigation using neutron diffraction measurements at iMATERIA, and we will proceed the study to determine the new geometry of crystal-lattice and AFM structure in the $R_3T_4Sn_{13}$ series compounds.