Magnetic ordering in the Tb-Co-Sn compounds

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The $Ln_3Co_4Sn_{13}$ class of materials show various electronic states accompanied with structural transformations [1, 2]. The *Ln* = Ce compound shows a Weyl–Kondo semimetal behavior [3], and the *Ln* = La compound is a superconductor below 2.7 K [4]. The electronic properties are caused by the topological electrons produced from the asymmetric spin–orbit effect under the chiral symmetry (the $I2_13$ space group). Recently, a heavy-rare-earth-based compound $Tb_3Co_4Sn_{13}$ was reported for structural and magnetic ordering [5]. The compound shows a structural phase transition at 89.4 K and an antiferromagnetic ordering at 11.3 K. However, various composition ratios were suggested for the ternary *Ln*-Co-Sn materials. In present study, we investigated magnetic behaviors in Tb-Co-Sn, which was synthesized using a molten-Sn flux method with a starting composition Tb : Co : Sn = 1 : 1 : 20 and 30-hour heating for reaction [4].

Neutron scattering experiment for the polycrystalline sample were performed at the cold-neutron triple-axis spectrometers PONTA (5G). Measurements were conducted with final neutron energy at 14.7 meV, respectively, chosen by the focusing PG analyzer. Sample temperature was controlled using a closed-helium cryostat.

Figure 1 shows neutron diffraction data measured at chosen temperatures between 6 and 12.5 K. Below approximately 11 K, several peaks emerge, which are attributed to magnetic ordering. However, the peaks are not explained by a single-phase structure. Actually, the nuclear scattering intensity pattern (not shown here) is consistent with a mixture of $Tb_3Co_4Sn_{13}$ and $Tb_7Co_6Sn_{23}$ [7]. The latter material was newly identified to crystallize in a rhombohedral structure revealed using synchrotron x-ray diffraction analysis. Therefore, the synthesis condition used for previous $Ln_3Co_4Sn_{13}$ class of materials are not optimized for $Tb_3Co_4Sn_{13}$.

The emergent magnetic peaks are indexed by (0, 0, 0) for $Tb_3Co_4Sn_{13}$ and (1/2, 0, 0) for $Tb_7Co_6Sn_{23}$. These magnetic ordering temperatures were evaluated to be 10.7 and 11.8 K, respectively.

Recently, we confirmed that the starting composition Tb : Co : Sn = 1 : 2 : 50 is much better for providing a pure $Tb_3Co_4Sn_{13}$, as proposed in previous study [5]. In addition, we succeeded in synthesizing pure $Tb_7Co_6Sn_{23}$ by a longer time reaction at high temperatures. Therefore, it is a further issue to identify the magnetic structures of both compounds precisely.

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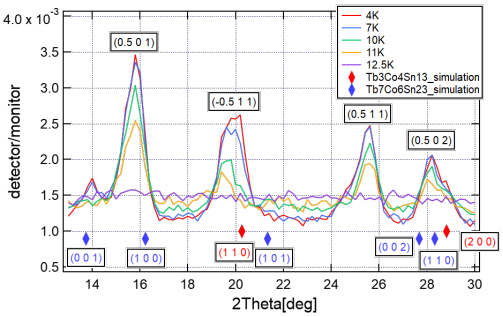

Fig. 1. Neutron diffraction data of the mixture sample of $La_3Co_4Sn_{13}$ and $Tb_7Co_6Sn_{23}$ between 6 and 12.5 K.

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