Polarized neutron diffraction experiment on HoB_2 single crystal

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Recently, HoB_2 was discovered to undergo gigantic magnetic entropy change; one of the largest, $|\Delta S_M|$ = 40.1 J kg^{-1} K^{-1} at 15 K by a magnetic field change of 5 T, in all the magnetocaloric effect (MCE) materials that have been studied for hydrogen liquefaction.[1] HoB_2 exhibits two phase transitions at 15 K and 11 K.[2] Since both two phase transitions contribute the giant MCE, it is essential to clarify the origins of these phase transitions for understanding such the large MCE in HoB_2. Although the higher temperature phase transition is associated with a ferromagnetic-paramagnetic phase transition, the origin of the lower transition has not been understood thus far.

In order to investigate the details of magnetic structure change for the phase transitions, we have performed the polarized neutron diffraction experiment with using the single crystal of $Ho^{11}B_2$ on PONTA in JRR-3. The vertical polarization mode was employed. We used the vertical field electromagnet to align the ferromagnetic domain. The scattering plane of hexagonal (H0L) was used. We employed two horizontal alignments to observe Bragg reflections closely parallel to a* and c* directions, due to existence of large blind region in the electromagnet. We could observed 001, 002, 100, 200 and 201 reflections.

Figure 1 shows the typical temperature dependence of the neutron intensity on spin-flip (SF) and non-spin-flip (NSF) channels. The experimental data points are well fitted with the calculated curves. The calculation values are taken account of with neutron spin depolarization by emergence of horizontal spin components of the sample below the lower phase transition temperature 11 K. The neutron spin depolarization probabilities were doubly considered before and after scattering process. We therefore found that the spin canting from hexagonal ab-plane toward the c-axis happens below 11 K, which was consistent with previous powder experiment.[2]

Recently, our x-ray diffraction experiment with the single crystal of HoB_2 revealed that the lattice distortion occurs at the spin-canting temperature at 11 K. It is probably associated with the quadrupole ordering below 11 K. We are now analyzing the data obtained in the present neutron experiment and x-ray diffraction experiment.

[1] P. Baptista de Castro, K. Terashima, T. D. Yamamoto, Z. Hou, S. Iwasaki, R. Matsumoto, S. Adachi, Y. Saito, P. Song, H. Takeya, and Y. Takano, NPG Asia Mater. 12, 35 (2020).
[2] N. Terada, K. Terashima, P. Baptista de Castro, C. V. Colin, H. Mamiya, T. Yamamoto, H. Takeya, O. Sakai, Y. Takano, and H. Kitazawa Phys. Rev. B 102 094435 (2020)

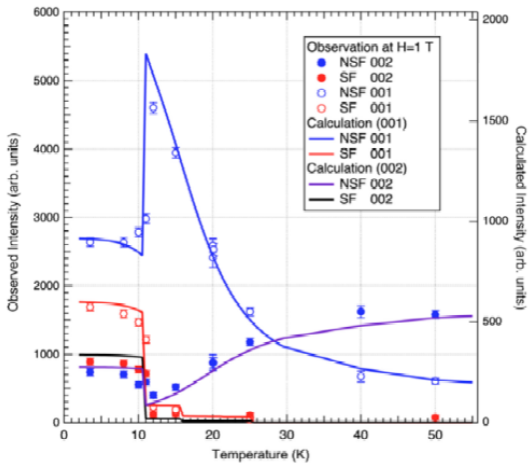

Fig. 1. Temperature dependence of integrated intensity of 001 and 002 reflections (observed and calculated) of $Ho^{11}B_2$ single crystal for SNF and SF channels in the experiment on PONTA (No. 23802).