Verification of magnetic structure of ferrimagnetic NdAlSi by neutron scattering

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Emergent inductor, an inductor realized in magnetic materials, attracts significant attentions due to its potential application and the relevant physics of emergent electrodynamics [1, 2]. Especially, the inducting response of the magnetic domain walls has not been fully explored. We focus on the inductance response in the ferrimagnetic NdAlSi, however, the magnetic structure and origin of magnetism is complex and needs to be clarified to discuss the origin of the inductive response [3]. Therefore, we aim to detect the Fourier component of the spin perpendicular to the uniform magnetization by polarized neutron scattering for the ferrimagnet NdAlSi and to reveal the details of the magnetic structure in the commensurate ($T < 3.3$ K) and incommensurate ($3.3 < T < 7$ K) phases in this experiment.

We prepared a millimeter-sized single crystalline sample of NdAlSi by using Al-flux method. (H,K,0) is chosen as the horizontal scattering plane and fixed to an aluminum plate with varnish. Since the sample is ferrimagnetic with magnetization in the c direction at low temperatures, polarized neutron scattering experiments cannot be performed if the spontaneous magnetization inside the sample is randomly arranged. Therefore, a special sample cell with permanent magnets on the top and bottom of the sample is used. The sample cell is mounted on a GM refrigerator for cooling. The sample cell is mounted on the GM refrigerator and cooled down to 2.3 K.

The experiment is performed in the P_{zz} polarization analysis mode with the neutron spin direction fixed in the z direction. Spin-flip (SF) and non-spin-flip (NSF) scattering of magnetic Bragg peaks appearing mainly at (2/3+δ, 2/3+δ,0) are observed. The former corresponds to the spin component perpendicular to the c-axis and the latter to the c-axis direction. At the lowest temperature of 2.3 K, we observed only the SF component of magnetic diffractions at (2/3, 2/3,0). Furthermore, we also observe weak magnetic intensities with both SF and NSF contributions at (1/3, 1/3,0). By investigating the NSF scattering at several q = 1/3 peaks, we deduce that the magnetic structure is likely spiral-type. These results are consistent with the previous work [1]. Furthermore, we investigate the incommensurate phase at 5 K, which was not studied carefully in the previous report [1]. At 5 K, we observed an incommensurate magnetic peak at (2/3+δ, 2/3+δ,0) only with the SF component and a weak peak at (1/3+δ, 1/3+δ,0) only with the NSF component (see Fig. 1). These results indicate that the magnetic structure in the incommensurate phase is similar to that in the commensurate phase.

In summary, we confirmed that the magnetic order of NdAlSi is likely spiral-type through the polarized neutron diffraction measurement. This result suggests that Bloch-type domain walls is stabilized between two ferrimagnetic domains, which is an important information to interpret inductive responses of NdAlSi in the future.

[1] N. Nagaosa, JPSJ **58**, 120909 (2019)
[2] T. Yokouchi *et al*., Nature **586**, 232 (2020)
[3] J. Gaudet *et al*., Nat. Mater. **20**, 1650 (2021)

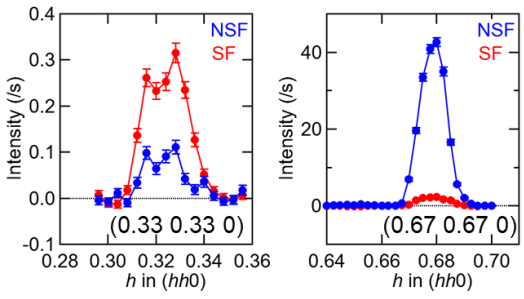

Fig. 1. Polarized analysis of magnetic diffraction peaks of NdAlSi at 5 K (incommensurate phase) in neutron diffraction measurements. This result indicates that the magnetic moment has only c-component and the incommensurate magnetic order is sinusoidal-type.