5–1 Magnetic-Structure Analysis of a Highly Neutron-Absorbent Material with Pulsed-Neutron Diffraction

— Magnetic Structure of $EuGa_4$ Studied by Single-Crystal Neutron Diffraction —

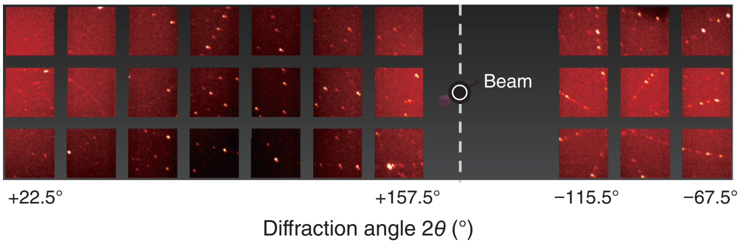

Fig.5-3 Neutron-diffraction pattern from an $EuGa_4$ single crystal
Diffraction spots were observed clearly though the shadow due to the high neutron-absorption ratio of Eu.

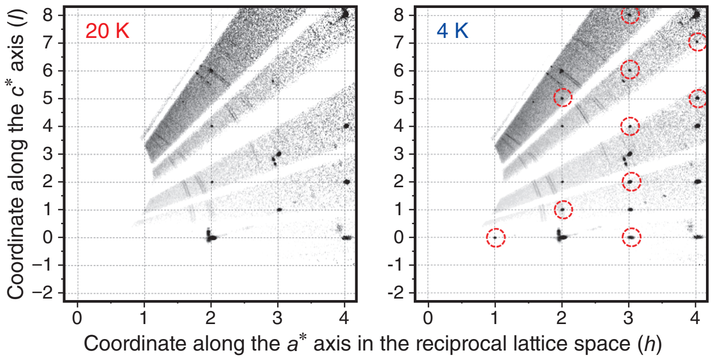

Fig.5-4 Neutron-diffraction intensities on particular planes at 20 K and 4 K
Magnetic reflections (red-dotted circles) were observed below 16 K, which is the magnetic-transition temperature.

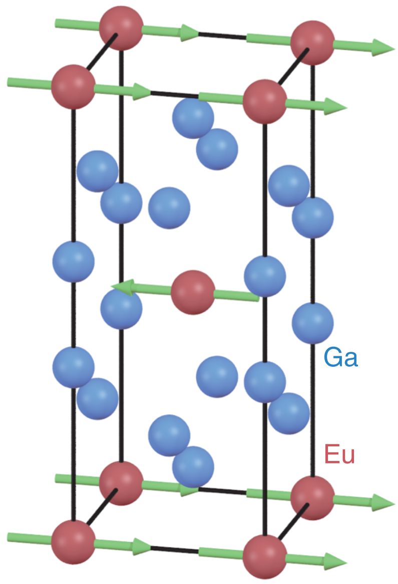

Fig.5-5 Crystal and magnetic structures of $EuGa_4$ at 4 K based on analysis of pulsed-neutron-diffraction data
Eu atoms, Ga atoms, and magnetic moments are shown by red circles, blue circles, and green arrows, respectively.

Magnetic-structure analysis by single-crystal neutron diffraction is an essential tool for studying the magnetic properties of materials. However, analysis of materials containing rare-earth elements such as Europium (Eu), Samarium (Sm), and Gadolinium (Gd) is not easy. As these elements show extremely high neutron absorption and non-monotonic neutron-energy dependence of absorption, the correct diffraction intensity cannot be obtained directly from the measured data. A correction method for such data is required.

In the present study, we developed an absorption-correction method for the single-crystal neutron-diffraction data from materials with high and complicated neutron absorption. By adopting this method for analyzing the high-quality neutron-diffraction data measured using the Extreme Environment Single Crystal Neutron Diffractometer SENJU, the magnetic structure of $EuGa_4$ was successfully obtained.

Fig.5-3 shows the diffraction pattern from the $EuGa_4$ single crystal measured by the detectors of SENJU. Although a shadow appeared due to the high neutron absorptivity of the sample, each diffraction spot was clearly observed. In general, the arrangements of the atoms and spins in materials can be obtained from the intensities of the spots. However, in the present case, the intensities extracted from the data must be corrected to suppress the effect of absorption before quantitative analysis of the structures. Therefore, an intensity correction based on the neutron-energy dependence of absorption for elements in the nuclear database was adopted for this analysis. The positions of the diffraction spots are as important as their intensities. Fig.5-4 shows the intensity distribution in the particular plane that reflects the tetragonal crystal lattice of $EuGa_4$. The possible spin arrangements can be estimated from the positions of the spots appearing below 16 K, the ordering temperature of the spins in $EuGa_4$. From these data, we conclude that the spins in $EuGa_4$ are arranged alternately, as shown in Fig.5-5, and that the magnitude of the magnetic moment is ideal for divalent Eu.

We will develop the present analytical method of neutron-diffraction data more extensively, together with instruments for understanding the structure and properties of rare-earth compounds.

Reference
Kawasaki, T. et al., Magnetic Structure of Divalent Europium Compound $EuGa_4$ Studied by Single-Crystal Time-of-Flight Neutron Diffraction, Journal of the Physical Society of Japan, vol.85, no.11, 2016, p.114711-1-114711-5.