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Study on the resonance effect in white x-ray magnetic diffraction of $GdAl_2$

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Recently, x-ray diffraction experiments with white synchrotron radiations have been done by authors on single-crystal samples of $GdAl_2$ in order to observe the spin form factor of the gadolinium ion[1]. In this white-beam single-crystal method with a fixed geometry of 90-degree scattering, a given (*hkl*) reflection and its harmonics are diffracted in the same direction with different energies or wave lenghts and are simultaneously measured with an energy-dispersive germanium detector[2]. This means that, for a specific reflection, the energy of diffracted beam which is automatically determined from the lattice spacing and the fixed scattering angle of 90 degrees by the Bragg's law may be accidentally located in the vicinity of an absorption edge of a constituent element of the sample material. In the experiments of $GdAl_2$, it was found that the (444) reflection is considerably close to such a situation, having an energy slightly lower than the L_{II} edge of Gd. When a resonance effect is substantial, it will be difficult to properly deduce the spin form factor from the measured data with based on the non-resonant magnetic x-ray scattering theory[3]. Instead, the sensitivity to electronic spin polarization may become much higher due to the so-called resonance enhancement[4] and it may find potential application in novel experimental technique for magnetic research. From this point of view, in order to investigate if the (444) reflection measured in the previous experiments for the spin-form-factor study was more or less under the influence of resonance or not and to what extent the resonance effect, if any, can enhance the spin-dependent signal, we have done the additional experiments as described below.

The experiments were done at the beamline 3C with a bending-magnet light source and elliptically polarized off-plane beam was used as the incident one. The sample is a single crystal of $GdAl_2$ and, with the sample magnetization being parallel or anti-parallel to the scattering vector, the change rate R_{hkl} of diffraction intensity upon the magnetization reversal for the (444) reflection was measured together with those for the other (*hhh*) ones by the white-beam single-crystal method. All of these experimental conditions are the same as before. This time, however, the measurements were done in the θ-2θ scanning mode within a horizontal plane, rather than with a fixed scattering angle of 90 degrees, and R_{hkl} was obtained at each angle of the step scanning. Tracing a certain reflection with changing the Bragg angle corresponds to scanning of the x-ray energy. Thereby, we have examined the asymmetric ratio R_{444} over the whole Gd-L_{II} region and, at the same time, tried to exploit the method of measuring the resonance spectrum of magnetic diffraction using white x rays.

Figure 1 shows an example of the resonance spectrum thus obtained. Associated with the resonance, the absolute value of R_{444} reaches more than 5%. The spectral shape is roughly described by a $x/(x^2+1)$ type of function, where x is the deviation from resonance, and can be understood in terms of the so-called resonant exchange-scattering mechanism[5]. On the other hand, according to the non-resonant magnetic x-ray scattering theory[3], R_{444} should be somewhat enhanced also around 2θ=90 degrees, while no such indication is observed. This means that the value of R_{444} is not free from the resonance effect even at 2θ=90 degrees, approximately 0.2-keV far from an absorption edge.

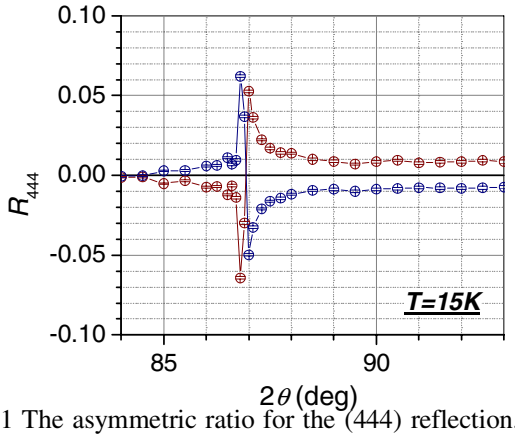

Fig. 1 The asymmetric ratio for the (444) reflection. Red and blue symbols show the data with the incident beam of opposite helicities.

References

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