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Spin form factors of Pr and Dy in the dialuminides

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Introduction

Spin is one of the basic attributes of the electron as well as its electric charge. The technological application such as spin electronics has been also studied in recent years. Different from the case of the electric-charge distribution, the spatial distribution of the spin in materials is difficult to measure. We have recently developed a concrete method to approach the spin distribution using the x-ray diffraction[1,2]. We have applied this method to the ferromagnetic Laves phase compounds $PrAl_2$ and $DyAl_2$. Here we report the results of the experiments.

Experimental

Sample

The single crystal samples of $PrAl_2$ and $DyAl_2$ were prepared at the Institute for Solid State Physics, the University of Tokyo, by the Bridgeman method using sealed tungsten cruicibles. Preliminarily to the experiments, the magnetic properties were examined with a SQUID magnetometer at the Cryogenic Center of the University of Tokyo.

Method

The experiments were done at the 3C3 station. The incident x rays were elliptically polarized white x rays emitted from a bending-magnet light source. The diffraction angle was fixed to be 90 degrees. The sample was set such that the easy direction of magnetization, <100>, should be parallel to the scattering vector, and several reflections of <*h*00> were simultaneously measured by a Ge SSD. The sample magnetization was switched every ten seconds by a magnetic field of 8.4 kOe generated by an electromagnet. The spin form factors of a magnetic ion can be obtained from a change in diffraction intensity concomitant with a reversal of the magnetization. The measurements were made at some temperatures lower than the Curie temperatures. Data accumulation lasted for about 2 days at each temperature.

Results

Figure 1 shows the spin form factors f_s multiplied by the spin magnetic moments μ_s for Pr and Dy in the dialuminides, which were obtained from the measurements at 14 K. The data on the lower-$\sin\theta/\lambda$ side have negative and positive values for Pr and Dy, respectively. These polarities correspond to those of the spin magnetic moments with respect to the total magnetic moments, being consistent with the fact that Pr is a light rare-earth element and Dy is a heavy one.

The smooth lines are the theoretical estimates of the contributions from the *4f* electrons, which are analyzed to be $\mu_s(\langle j_0\rangle+c_2\langle j_2\rangle+c_4\langle j_4\rangle+c_6\langle j_6\rangle)$. Here, $\langle j_n\rangle$ are the expectation values of the spherical Bessel functions of the *n*th order with respect to the *4f* radial wave function; $\langle j_0\rangle$ and $\langle j_n\rangle$(n=2, 4, 6) represent the spherical component and the *n*th-order asphericities, respectively. The angular distribution is reflected in the coefficients c_n, which were estimated in the *LS*-coupling scheme characterized by *SLJM*[1, 2]. As can be seen from the figure, an agreement between the experiments and the theoretical results thus estimated is fairly good, indicating that this method properly approaches the spin density distribution. Discussion about the thermal variation is found in Ref. 3.

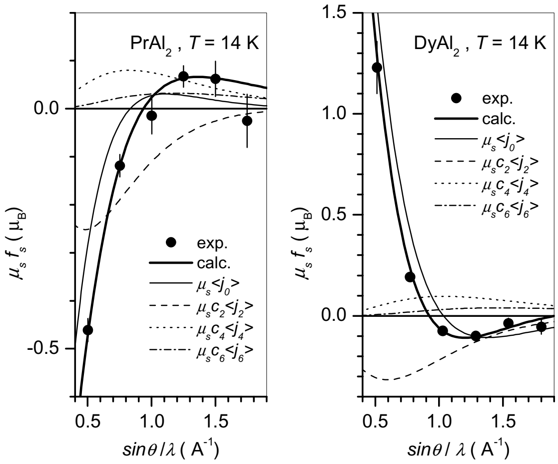

Fig. 1 The spin form factors f_s multiplied by the spin magnetic moment μ_s for Pr and Dy in the dialuminides. Displayed are the data for <*h*00>(*h*=8, 12, 16, 20, 24, and 28), which are crystallographically allowed reflections.

References

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