Investigation of Terbium with X-ray Resonance Exchange Scattering

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Introduction

First studies on terbium with x-ray resonance exchange scattering (XRES) have been performed by Perry et al.[1] They observed a splitting in the energy dependence of the intensity diffracted by XRES at the L_{II}-edge but no such splitting at the L_{III}-edge. The aim of the series of experiments we conducted first at HASYLAB and then at BESSRC-CAT and MU-CAT at the Advanced Photon Source (APS) at Argonne National Laboratory was to investigate the reason for this splitting in the energy dependence. Instead of measuring the full diffracted signal, we performed a polarization analysis of the diffracted XRES signal. This allows us to distinguish between a contribution of elastic dipolar and quadrupolar transitions.[2]

Methods and Materials

Terbium has a hexagonal structure and undergoes a transition from a paramagnetic phase to a basal-plane spiral antiferromagnetic phase at T_N ~230K. At T_C ~220K, a second phase transition to a ferromagnetic phase occurs. Due to the modulation wave vector τ in the antiferromagnetic phase incommensurate satellite reflections appear at positions (0 0 2n±τ). The terbium single crystal had a mosaicity of 0.18° after being etched with concentrated HNO_3. For cooling, a closed-cycle He-gas cryostat was used. A resonance enhancement of the magnetic signal is observed at the L_{II}- and L_{III}-edges of terbium at 8252 eV and 7514 eV, respectively. The polarization analysis at the L_{II}-edge was done using a pyrolitic graphite crystal. Here the elastic scattering for the (0 0 6) reflection occurs at an angle of 84.5°. We performed polarization analysis in the σ-π-channel to be able to make definite statements about the nature of the scattered intensity.

Results

According to the form of the resonant cross section, the contribution of intensity scattered by quadrupolar excitation should be zero for the (0 0 4+τ)-satellite reflection.[1] Therefore, it is possible to conclude from the outcome of the experiment on the nature of the scattered intensity, since the dipole scattering at ± t is purely σ-π-polarized. The energy dependencies of the magnetic satellites around the (0 0 2), (0 0 4) and (0 0 6) reciprocal lattice positions have been measured at the L_{III}-edge as well as at the L_{II}-edge. In Fig. 1 the energy dependence of the magnetic intensity at the L_{II}-edge is shown. The energy dependence of the magnetic intensity at the L_{II}-edge is shown in Fig. 2. Both energy dependencies are clearly different. At the L_{II}-edge, there are two peaks of a similar intensity, where one is just below the white line and one just above. At the L_{III}-edge, there is no peak above the white line. Instead, a peak is growing out with larger momentum transfer 5 eV below the main peak.

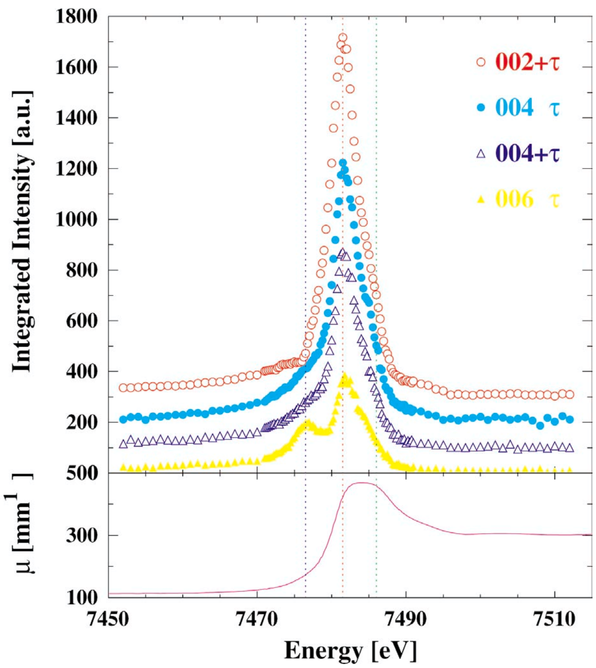

FIG.1. Absorption-corrected energy dependence at the L_{III}-edge of terbium of the magnetic (0 0 2+τ), (0 0 4-τ), (0 0 4+τ), and (0 0 6-τ) reflections. The graph at the bottom shows the absorption coefficient.

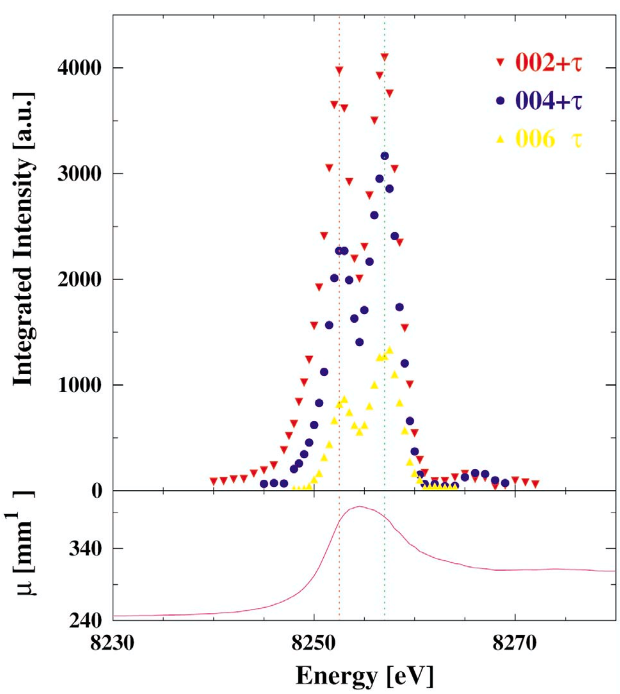

FIG. 2. Absorption corrected energy dependence at the L_{II}-edge of terbium of the magnetic (0 0 2+τ), (0 0 4+τ), and (0 0 6-τ) reflections.

Discussion

Based on the calculations provided by Perry et al.,[1] we can conclude that there is no contribution of a quadrupolar transition to the scattering at the L_{II}-edge, and that the structure we see in the energy dependence of the intensity may stem from the 5d-band. Although there is no clear peak above the white line at the L_{III}-edge, there still is a pronounced slope, which suggests also a small signal here. The second peak below the white line at the L_{III}-edge might be of quadrupolar nature.

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