Resonance Exchange Scattering in Er|Tb Superlattices

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Introduction

We report on resonance x-ray magnetic scattering (RXMS) experiments of Er|Tb superlattices, depending on the growth conditions. Interest in such systems is caused by concurring interactions in magnetic multilayers. While the magnetism in bulk rare earth metals is fairly well understood by means of an interplay of RKKY-interaction, crystal anisotropy and magnetoelastic energies,[1] the situation in artificial superlattices is more complicated. The influence of reduced dimensionality, proximity of different crystal anisotropies, and additional strains due to the lattice mismatch changes the magnetic properties of such systems strongly. The anisotropy forces an alignment of magnetic moments in the basal plane of the hexagonal lattices in the case of bulk terbium, whereas erbium favors magnetic moment directions along the c-direction. Terbium forms a magnetic helix between 230K and 220K and is ferromagnetic below. In erbium the modulated phases persist down to lowest temperatures.

Methods and Materials

We have prepared [Er_{21}|Tb_9] multilayers and [Er_{20}|Tb_5] multilayers using different sample growth conditions leading to smoother interfaces for the second sample by molecular beam epitaxy (MBE). Surface characterization was done by means of in situ low-energy electron diffraction (LEED)-analysis. Preliminary neutron diffraction measurements have shown that helical ordered or c-axis modulated states exist at temperatures below 100K. These states have been investigated by means of resonance x-ray magnetic scattering to decide in which of the layers the magnetic order is localized.

Results

The first sample was measured in August 2000. The magnetic reflections as measured with neutrons are very broad indicating short-range magnetic order. RXMS could be detected at the Er L_{III} edge (see Fig. 1). The second sample was prepared at a slightly higher growth temperature, which leads to smoother surfaces. Neutron diffraction shows sharper peaks with a FWHM corresponding to a correlation length of 7-8 bilayers of Er|Tb. The RXMS measurements for this sample show a magnetic signal as well at the erbium L_{III} edge as at the terbium L_{II} and L_{III} edges. Figure 2 represents (0 0 l) scans at different temperatures. The stronger peak in the back is the third-order superlattice reflection due to the chemical superlattice. One sees clearly the development of the magnetic peak with decreasing temperature.

Discussion

Since the FWHM for the first sample corresponds to the thickness of one bilayer Er|Tb as measured with neutrons and to one layer of erbium as measured with RXMS, we presume a small helical ordered magnetic moment as well in the terbium layers. The data of the second sample gives clear evidence to a proximity effect, since bulk terbium is ferromagnetic at such low temperatures; while in the multilayer, we observe a magnetic structure within the terbium layers with a propagation vector corresponding to bulk erbium.

Acknowledgments

The Midwest Universities Collaborative Access Team (MU-CAT) sector at the APS is supported by the U.S. Department of Energy, Basic Energy Sciences, Office of Science, through the Ames Laboratory under Contract No. W-7405-Eng-82.

Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Basic Energy Sciences, Office of Science, under Contract No. W-31-109-Eng-38.

Reference

[1] J.Jensen and A.R.Macintosh, Rare Earth Magnetism (Oxford University Press, 1991).

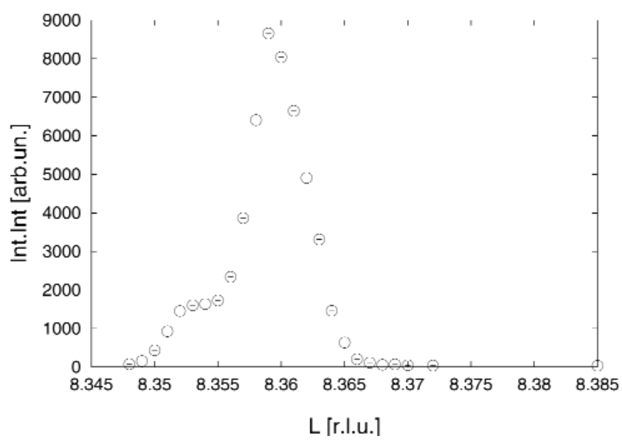

FIG. 1. Energy dependence of the (0 0 1.75) reflection at the Er L_{III} edge at 10K in the [Er_{21}|Tb_9] sample.

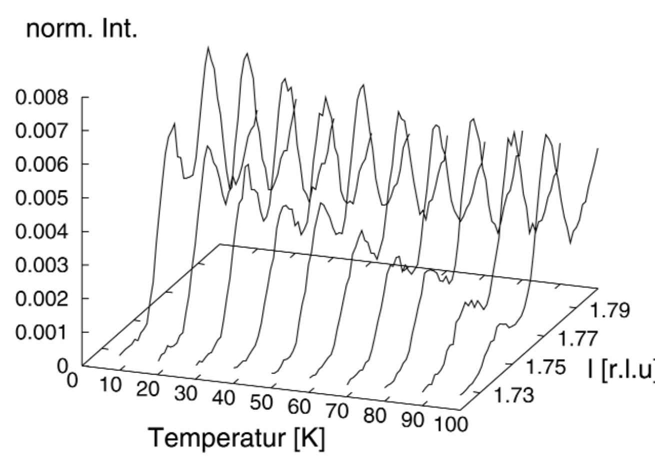

FIG. 2. (0 0 l)-scans at different temperatures at the Tb L_{III} edge. The reflection at l ≈ 1.78 is due to the chemical superlattice. The reflection at l ≈ 1.74 increases with decreasing temperature. Out of the resonances, it vanishes completely.