ESRF	**Experiment title:** Thickness dependence of magnetic properties of in-situ grown holmium films	**Experiment number:** HE-150
Beamline: Troika (ID10/A)	**Date of experiment:** from: 15.05.1997 to: 22.05.1997	**Date of report:** 20.02.1998
Shifts: 21	**Local contact(s):** Gerhard GRÜBEL	*Received at ESRF:* 11 MAR. 1998

Names and affiliations of applicants (* indicates experimentalists):

*Christoph Sutter
*Gerhard Grübel
*Eugen Weschke
*Robert Meier
*Christian Schüßler-Langeheine

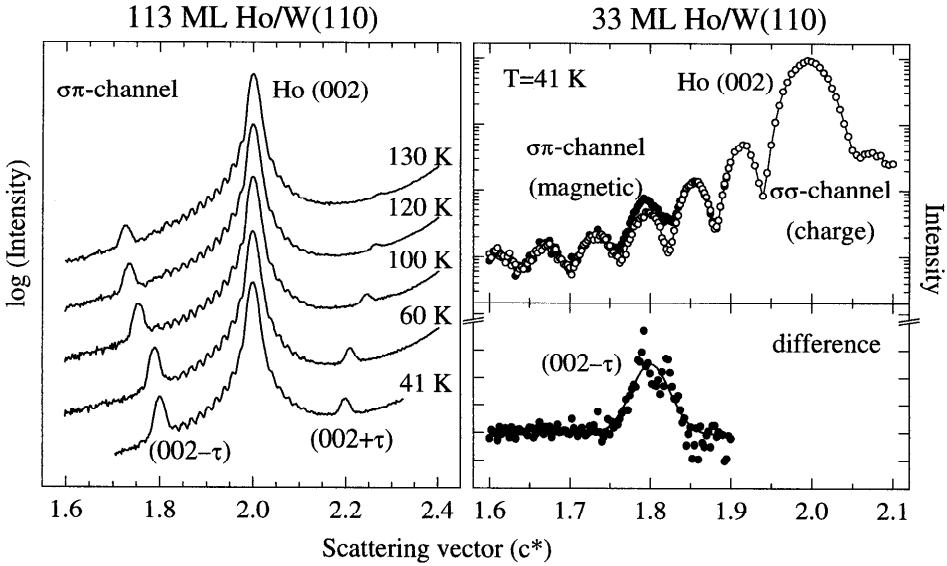
Report:

Presently, the magnetism of lanthanide films, interfaces, and superlattices is of considerable interest. Questions such as the magnetic coupling through nonmagnetic layers and the role of the conduction electrons and their exchange splitting are lively discussed.

In this context, a study of the helical magnetic structure of thin Ho films was performed using resonant magnetic x-ray scattering at the Ho L_{III}-edge as a probe. The aim of the experiment was twofold: Firstly, a test of sensitivity of magnetic x-ray scattering in the ultra thin film regime well below 1000 Å and secondly, the investigation of the influence of the film thickness on the magnetic structure in the region where the thickness is in the order of the length of the helix.

Ho(002) films were grown on W(110) in a UHV-chamber directly attached to the diffractometer. The growth characteristics could be monitored in situ in a very detailed way [l]. High quality films with rocking widths down to $<0.04°$ at the (002) Bragg reflection were obtained, for which the magnetic $(002\pm\tau)$ satellite reflections were investigated for 113, 54 and 33 monolayers (ML) thickness.

The figure displays longitudinal scans along the specular $(00L)$ rod, showing the (002) Bragg reflection and the magnetic satellites of 113 (left) and 33 (right) ML thick films. All measurements were performed with incident σ-polarization, using a graphite polarization



analyzer to record the rotated n-channel of the diffracted beam, thus enhancing the ratio of magnetic to charge scattering by a factor of about 500. In contrast to bulk samples, the charge scattering from thin films is of considerable intensity at the position of the magnetic satellite due to the Laue oscillations. These become more and more important for thinner films as the intensity is redistributed from the central maximum to the side maxima in the wings.

For 113 and 58 ML thick films the temperature dependence of the magnetic satellite position, $\tau(T)$, and its intensity could be studied between T = 41 K and 140 K. The 113 ML film shows essentially bulk-like behavior, i.e. the same Néel temperature and a similar $\tau(T)$-dependence. In the 58 ML film the z(T)-behavior is shifted by about 0.05 c* to smaller values indicating that the period of the helix becomes longer. The Néel temperature is found to be 5 K lower compared to the 113 ML thick film. Furthermore, it could be shown that the helical magnetic structure is stable down to a thickness of 33 ML, as indicated by the right panel of the figure, although a study of the temperature dependence within reasonable time is beyond feasibility in this case.

Nevertheless, our results show that the magnetic structure can be studied for even thinner films by resonant magnetic x-ray scattering, if special care is taken in suppressing the charge background of the Laue oscillations. The results obtained here are of particular importance in connection with recent photoemission data obtained from Ho films in the studied thickness range, which show an exchange splitting also in this antiferromagnetic helical phase. They will allow a comprehensive discussion of magnetic coupling in this local-moment magnetic system.

[l] E. Weschke et al., Phys. Rev. Lett. **79**, 3954 (1997).