Chapter 7

Summary and Outlook

In this work the magneto-optical Kerr effect in the soft x-ray region (XMOKE) is compared to its well known counterpart in the visible-light region. MOKE in the visible is widely accepted to monitor the average sample magnetization and therefore serves as reference technique. In the x-ray region magnetooptics in reflectivity can provide huge magnetic signals which do not require lock-in technique for detection, but can be measured just with a simple photo-diode and a hand multimeter.

The temperature dependence of the visible-light MOKE signal was found to reveal the magnetostrictive contributions to the magnetization. It can be used as an alternative approach for investigating magnetostriction in thin films grown on thick substrates, a combination which does not permit direct stress measurements. In order to compare the optical signal with known magnetostrictive properties, it will be interesting to combine the new method with traditional stress measurements.

It is shown that magnetooptics in the x-ray region (XMOKE) is a suitable tool for element-specific investigations. Compared to absorption measurements the XMOKE method has the advantage that element-specific hysteresis in external magnetic fields can be measured. An experimental example of element-specificity is given for a system consisting of two magnetic layers (Gd and Tb) separated by a non-magnetic buffer (Y). At the $4d \rightarrow 4f$ absorption threshold, element-specific hysteresis loops can only be obtained by forming appropriate linear combinations of the MO signals, taken at different photon energies. Much purer element-specific experimental results were obtained at the $3d \rightarrow 4f$ thresholds, where the transition energies for the different elements are well separated.

In the soft-x-ray region, interference effects may become important, and calculated reflection spectra are useful for the discussion of experimental results. Kramers-Kronig transformation was employed to calculate the dispersive part of the (complex) refractive index from experimental absorption spectra at the $M_{4,5}$ and $N_{4,5}$ thresholds of Gd and Tb. The optical constants permit to calculate the energy-dependent reflectivities (Fresnel), including interference effects with the substrate. Good agreement with experimental XMOKE spectra is obtained at the $M_{4,5}$ absorption thresholds.

The shorter wave length and huge dichroic effects at the $N_{4,5}$ absorption threshold of lanthanides makes XMOKE in 10-nm thick samples sensitive to inhomogeneities during the magnetization reversal process. The MO-signal becomes sensitive to domain-wall movements, which is reflected in the shape of the hysteresis loop. A comparison of experimental and model-dependent hysteresis loops shows that in a thin Tb film on W(110) the magnetization reverses by domain walls propagating downwards from the topmost layer (vacuum) to the interface with the substrate. In a thin Gd-film, by contrast, it is found that the magnetization reversal starts from the bottom layer (substrate).

In the visible light region, MO measurements in the submonolayer range suffer from a lack of signal intensity, and the signal-to-noise ratio becomes unfavorable. This is not the case with MO-signals in the soft-x-ray region: The signal is intense enough to obtain a good signal-to-noise ratio even from submonolayer thin films. XMOKE is especially suitable for studies of submonolayer systems, which usually are difficult to access in the visible-light region. It will be a challange to re-investigate with XMOKE topics of nanomagnetism where visible-light MOKE failed because the signal was too weak. Furthermore, XMOKE could provide magnetic contrast in future x-ray microscopes, where magnetic samples are scanned in order to obtain a space- and element-resolved magnetic map of the sample.