Magnetism in Reduced Dimensions – Nanoscaled Wires

In the following chapter we want to consider the magnetic properties of nanoscaled wires. They are characterized by a large aspect ratio of their length to their width and height. We will distinguish between wires with a width in the sub-micrometer regime on the one hand and those which a built up by only single atoms on the other hand. It is obvious that such systems exhibit a pronounced anisotropic behavior due to its shape.

13.1 Wires Exhibiting a Width in the Sub-Micrometer Regime

Let us assume that the height and the width of the wire is in the sub-micrometer regime whereas the length is significantly larger. This implies a high aspect ratio. One example of such a system is presented in Fig. 13.1. The sample is a thin Fe film of 13 nm thickness which has been transformed into a periodic nanoscaled wire array by an anisotropic plasma etching process after film deposition. The Fe film was grown on an Al$_2$O$_3$(1102) substrate onto a 150 nm thick Nb buffer layer which has a (001)-orientation as can be derived from the three-dimensional epitaxial relationship between niobium and sapphire. Finally, an array of well separated Fe wires on top of a Nb buffer is obtained. The measurement confirms the regularity of the Fe nanoscaled wires having a width of 150 nm and a periodicity of 300 nm as well as that the wires are completely separated from each other. The stripes have a sinusoidal shape.

Due to the shape anisotropy the magnetization is expected to be oriented along the wire. The upper part of Fig. 13.2 shows the remanent Kerr signal $\theta_{\text{rem}}^K$ normalized to the Kerr signal at saturation $\theta_{\text{sat}}^K$ as a function of the angle of rotation $\chi$ about the surface normal of the Fe film which yields information about the squareness of the hysteresis loops. The signal $\theta_K$ represents the rotation of linearly polarized monochromatic light due to the reflection on a
ferromagnetic surface. This experimental technique is known as the magneto-optical Kerr effect (MOKE). According to Fig. 13.2 the remanent Kerr signal is significantly reduced at certain angles $\chi$ without reaching zero-values signifying the hard axis orientations (around $90^\circ$ and $270^\circ$). For the corresponding angles $\chi$ along the easy axis orientations ($0^\circ$ and $180^\circ$) the ratio $\theta_{K\text{rem}}/\theta_{K\text{sat}}$

![Graph](image)

**Fig. 13.2.** The upper panel shows results from hysteresis loop measurements at different angles of rotation $\chi$ for the nanowire array as measured at remanence normalized to the Kerr rotation as measured at saturation. The lower panel depicts the results of MOKE hysteresis loop measurements as a function of the angle of rotation of the unpatterned sample where $\theta_{K\text{rem}}$ as measured at remanence is normalized to $\theta_{K\text{sat}}$ as measured at saturation and plotted as a function of the angle of rotation $\chi$ which is a measure of the magnetic anisotropy. (Adapted from [40] with permission of IOP)