ANALYSIS OF TORQUE MEASUREMENTS ON FILMS WITH OBLIQUE ANISOTROPY

Leon Abelmann, Cock Lodder

MESA, University of Twente, Box 217, 7500 AE, Enschede, NL

When an anistropy axis is oblique to the film plane the analysis of torque curves becomes complex because measurements in several planes are necessary [1]. To analyse the anistropy in these films the common approach is to assume a physical model based on a priori assumptions like the type of crystal structure or the direction of columns. When one includes second order anistropy this is not a trivial task and a universal model is needed. Using spherical harmonics it is possible to give a general description of the anisotropy without assuming an a priori physical model. With torque measurements in five different planes we can describe the magnetic anisotropy in second and fourth order for any arbitrary sample.

Theory

Assume that we only have anistropy axis and no anisotropy directions (like frozen-in fields) than we can desribe the energy E in the sample up to the fourth harmonic by:

$$E(\theta,\varphi)=\sum_{n=1}^{2}\sum_{m=-2n}^{2n}k_{2n,m}Y_{2n,m}(\theta,\varphi) \quad [J] \qquad (1)$$

Where θ and φ indicate the direction of magnetization (fig 1); $Y_{2n,m}(\theta,\varphi)$ are the spherical harmonics [2] and the $k_{2n,m}$ the anisotropy coeficients.

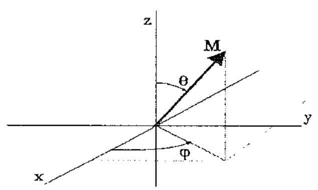

Figure 1: Definition of coordinate system

Table 1: Measurement planes

Labc	θ [°]	φ [°]
L001	90	-90 to 90
L010	-90 to 90	0
L100	-90 to 90	90
L1-10	-90 to 90	45
L110	-90 to 90	-45

To determine the 14 anisotropy coeficients $k_{n,m}$ we need to measure in 5 different planes L_{abc} (table 1). We describe the torque measurements in rectangular (P,Q) or polar (L,α) coordinates.

$$L_{abc}(\gamma)=\sum_{n=1}^{2}P_{2n,abc}\cos(2n\gamma)+Q_{2n,abc}\sin(2n\gamma)=\sum_{n=1}^{2}L_{2n,abc}\cos[2n(\varphi+\alpha_{2n,abc})] \quad [Nm] \qquad (2)$$

With index abc as in table 1 and γ the measurement angle (either θ or φ). These five measurement result in 20 fourier coeficients of which a number are mutually dependent. The relation between the 20 fourier coefficients and the 14 anisotropy coeficients was solved analytically using Mathematica software.

Experiment

To illustrate this method we measured an obliquely evaporated 1.1 μm thick $Co_{80}Ni_{20}$ film. The film plane was taken to be the xz plane. In each measurent plane five field values between 1000 and 1600 kAm^{-1} were taken. To correct for the finite field error the modulus L was plotted against $1/H^2$ or $1/H$ for the 2nd and 4th order coefficients respectively. This gives a better estimation of the torque at infinite field than extrapolating P and Q coeficients independently since the argument α is field-independent. Figure 2 gives the torque curves corrected for finite field error. Table 2 gives the resulting anistropy coefficients. We will show how the anisotropy coeficients in table 2 can be related to a physical model including shape anisotropy, crystal anistropy etc.

Table 2: Measured anistropy coeficients of an obliquely evaporated CoNi film [kJm^{-3}]

k[n,m]	m=-4	m=-3	m=-2	m=-1	m=0	m=1	m=2	m=3	m=4
n=2			29.6	16.2	-71.1	-12.5	-62		
n=4	-0.098	-0.091	-0.33	-0.54	6.00	-0.22	0.27	0.016	0.08

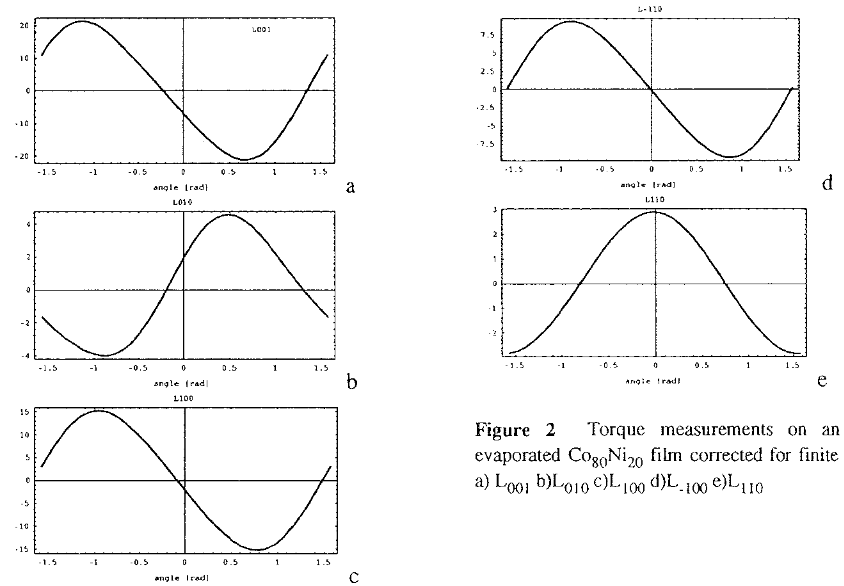

Figure 2 Torque measurements on an obliquely evaporated $Co_{80}Ni_{20}$ film corrected for finite field error a) L_{001} b)L_{010} c)L_{100} d)L_{-100} e)L_{110}

[1] S. Swaving; G.J. Gerritsma, J.C. Lodder, Th.J.A Popma *J. Magn.Magn. Mat.* vol 67 (1987) p155-64
[2] Robert R. Birrs *Symmetry and Magnetism* North-Holland, Amsterdam, 1964.