ANOMALOUS FIELD DEPENDENCE OF TORQUE CURVES.

Hans te Lintelo, Leon Abelmann, Vladimir Kambersky, Cock Lodder
Mesa Research Institute, University of Twente, P.O. Box 217, 7500 AE Enschede, the Netherlands.

The nature of the effective uniaxial magnetic anisotropy ($K_{eff}=K_1-\frac{1}{2}\,\mu_0 M_s^2$) is of interest in magnetic storage media, and can be determined from torque measurements. The first order fourier coefficient of the torque curves is field dependent and is given in a first order approximation by [1]:

$$L_1 = K_{eff}\left(1-\frac{1}{2}\varepsilon^2\right) \qquad (1) \qquad \text{where } \varepsilon \text{ is given by:} \quad \varepsilon = \frac{K_{eff}}{\mu_0 MH} \qquad (2)$$

This relation is often used to correct measured torque values for finite field error. We will show however torque measurements which are inconsistent with this relation. The inconsistency will be explained in terms of second order anisotropy effects and a dispersion in direction and magnitude of the uniaxial anisotropy.

Results

In figure 1 the field dependence of the first order Fourier coefficient is shown for different types of materials. Their slopes are listed in table 1 and compared to the slope as calculated by equation 1, using VSM data and the K_{eff} extrapolated to infinite field. Only the permalloy sample exhibits an agreement. Note that the measured slope can even reverse its sign.

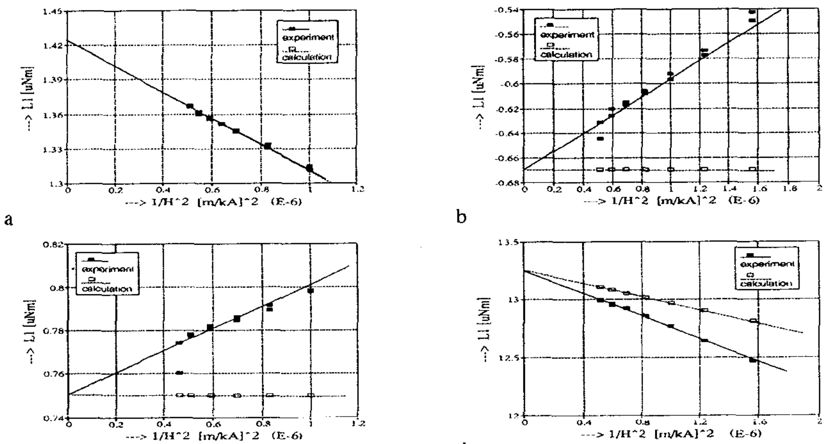

Figure 1. The field dependence of the 1st order Fourier coefficient for a).NiFe, b). Co-Cr evaporated, c). Co-Cr sputtered 1 and d) Fe 1 alumite.

Influence of K_2

The influence of the second order anisotropy constant K_2 is often neglected because it is only a few percent of K_1. However for most perpendicular storage media K_{eff} is around zero and therefore the influence of K_2 can be considerable. In table 1 this is expressed in column 3 which shows that the agreement between theory and experiment for the alumite samples increased. For the Co-Cr samples the slope even reversed its sign. It can be concluded that with taking K_2 into account the agreement increased for the sample with a negative K_{eff}. For positive K_{eff} the agreement between experiment and theory decreases.

Table 1

Sample type	Experimental slope [μNm (kA/m)^2]	Slope calculated with only K_1 [μNm (kA/m)^2]	Slope calculated with K_1 and K_2 [μNm (kA/m)^2]	MsV [μAm^2]	L1 (∞) [μNm]	L2(∞) [μNm]
NiFe	-1.17 10^5	-1.13 10^5	-1.13 10^5	2.84	1.425	0
CoCr evaporated	7.84 10^4	0.0689 10^4	-0.27 10^4	11.68	-0.67	0.13
CoCr sputtered 1	5.1 10^3	-0.1 10^3	1.0 10^3	34.59	0.73	0.12
CoCr sputtered 2	2.0 10^5	-0.2 10^3	-1.6 10^3	44.17	-1.12	0.16
Fe alumite 1	-4.2 10^5	-2.8 10^5	-3.3 10^5	51.1	13.25	-0.4
Fe alumite 2	-8.8 10^4	-4.4 10^4	-6.3 10^4	60.6	8.0	-0.3

Inhomogeneity

In relation (1) it is assumed that the film is homogeneous. In an inhomogeneous film K_{eff} varies in direction and magnitude. When we neglect interaction it can be seen from relation (1) that K_{eff} is determined by a weighted average value $\langle K_{eff}\rangle$, whereas the slope is determined by $\langle K_{eff}^3\rangle$. This can explain some anomalies of figure 1 and table 1. For a further analysis however information about the inhomogeneities is needed which cannot be obtained from torque measurement alone. Additional knowledge on the microstructure and morphology of the film is necessary.

A second effect of inhomogeneity is that the samples are not in a completely saturated state. This is illustrated in figure 2 where the maximum torque (normalized) is plotted against the applied field. For a saturated sample the maximum torque should be field independent for $H>0.7H_k$. For the CoCr samples, which are known to be inhomogeneous, this is apparently not true.

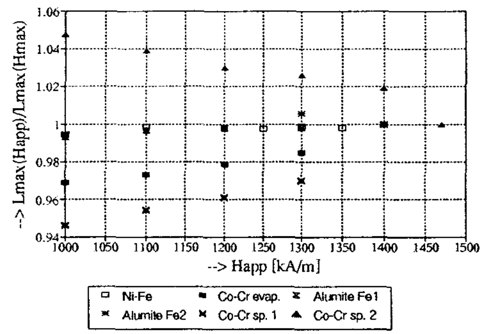

figure2 Field dependence of maximum torque.

Conclusion.

The field dependence of torque curves is often not in agreement with theory. Correction of torque curves for the finite field error should preferably be performed by extrapolation of measurements at different fields values to infinite field. To explain the anomalous behaviour of field dependencies we have to consider the influence of second order anistropy, non-saturation and inhomogeneity in magnitude and distribution of anistropy. We will show simulations to illustrate the effect of inhomogeneity.

[1]. G. Pastor; A. Ferreiro, M. Torres *J. Magn.& Magn. Mat.* vol 53 (1986) p 349-53.