

CoCr/NiFe DOUBLE LAYERS STUDIED BY FMR AND VSM

M.T.H.C.W. Stam, G.J. Gerritsma, J.C. Lodder, Th.J.A. Pogna
Twente University of Technology, P.O. Box 217, 7500 AE, Enschede, The Netherlands

ABSTRACT

CoCr/NiFe double layers were investigated by FMR and VSM. The FMR linewidth of NiFe of the double layer is about twice that of a single NiFe layer. The resonance field is the same in both cases. Using the VSM the coercive field of the CoCr layer of the double layer was obtained. It is approximately equal to the coercivity of a single CoCr layer. The initial susceptibility $\chi_i = [dM/dH]_{H=0}$ of the MH curve of CoCr on top of NiFe however differs from that of a single CoCr layer.

INTRODUCTION

A double layer medium consisting of a CoCr perpendicular anisotropy film with a soft magnetic NiFe film underneath was reported by Iwasaki to have a high recording sensitivity [1]. The back layer enhances the interaction with the head [2]. However for a back layer (NiFe) with a coercive force H_{cn} below 80 A/m there are large noise pulses in the reproducing process. This noise decreases with increasing H_{cn} , which should therefore range from 240-560A/m [2]. In our study of double layers we were especially interested in the possible interaction mechanism between the two layers.

EXPERIMENTAL TECHNIQUES

The NiFe was RF-sputtered on Si using a 82/18 at% alloy target. Sputtering parameters were: argon pressure (P_{ar}) = $2.5 \cdot 10^{-2}$ mbar, bias voltage = 0.1kV, sputter voltage (V_{RF}) = 1.0kV, target distance (d) = 38mm. A magnet of field strength 7.5 kA/m was placed around the substrate holder during sputtering to introduce a magnetic anisotropy axis. The CoCr layer was RF magnetron sputtered using a 81/19 at% alloy target using the following sputter parameters: P_{ar} = $6 \cdot 10^{-3}$ mbar, V_{RF} = 200V, d = 32 mm. For both cases a Leybold Heraeus 2400 was used and the background pressure was less than $3 \cdot 10^{-7}$ mbar. The composition and thickness of the samples were checked using X-ray fluorescence. The thickness of the CoCr layer ranged from 35 to 1350 nm. The NiFe layer thickness was chosen at 500 nm as this is the optimal value for reading [3]. The saturation magnetization M_s and the coercive force H_{cn} were measured using a vibrating sample magnetometer (VSM) and an inductive hysteresis loop tracer. We found H_{cn} = 32-60 A/m (0.4-0.75 Oe) for a single NiFe layer and H_{cn} = 88-199 A/m (1.1-2.2 Oe) for the NiFe of the double layer. The plasma effects of the sputtering of the CoCr on top of the NiFe could cause defects and stresses. These would be introduced by the different sputtering effects such as temperature, damage etc which might give rise to higher H_{cn} .

FERROMAGNETIC RESONANCE

The ferromagnetic resonance (FMR) apparatus contained a magnet producing a maximum DC-field of 640 kA/m (8 kOe). The resonance frequency $\omega/2\pi$ was 9.44 GHz. The sample was placed on the side of the rectangular cavity, operating in the TE₁₀₂ mode, the RF-field being in the film plane. The DC-field could be rotated in a plane perpendicular to the RF-field. The resonance field H_r of the NiFe layer was measured as a function of the angle β between the external applied field and the normal to the film. For the NiFe of the double layer $H_r(\beta)$ is approximately equal to that of a single NiFe film. (see fig.1). It is of the same form as that found for evaporated NiFe by [4]. By solving the Landau-Lifshitz equation of motion (1) $H_r(\beta)$ can be determined theoretically.

$$\frac{d\vec{M}}{dt} = -\gamma(\vec{M} \times \vec{H}) - \frac{\gamma\alpha}{M}(\vec{M} \times (\vec{M} \times \vec{H})) \quad (1)$$

where γ is the gyromagnetic ratio, α is the damping parameter, M the magnetization and H the field. The solution may be expressed in terms of the second derivatives of the free energy F [5].

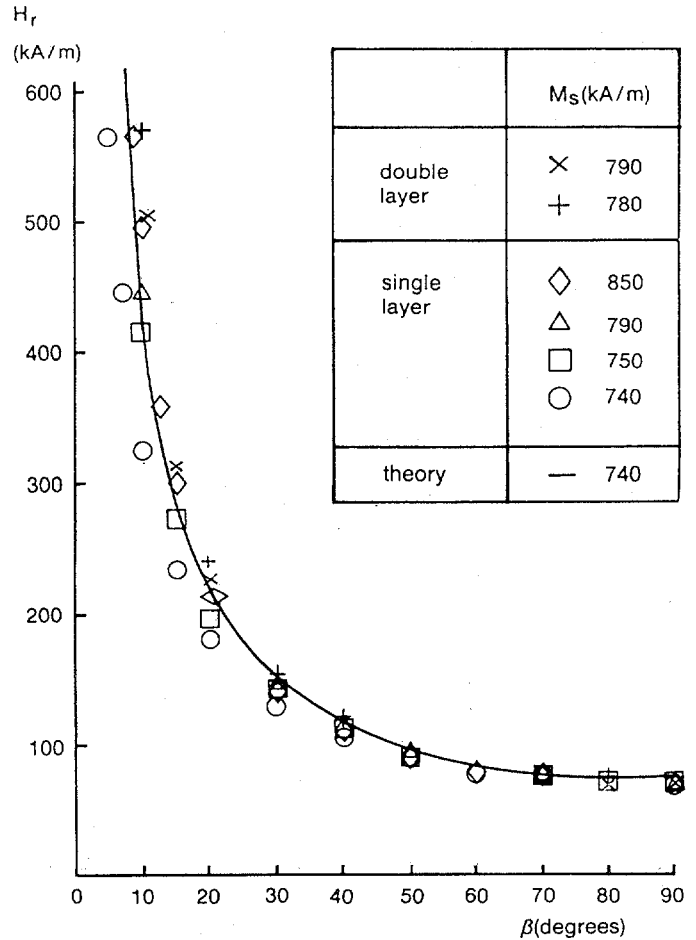


Fig.1 Experimental values of $H_r(\beta)$ for single and double layers with different values of M_s compared with the theoretical curve.

$$\omega = \frac{\gamma(1+\alpha^2)^{1/2}}{M_s \sin\theta} \{ F_{\theta\theta} F_{\varphi\varphi} - F_{\theta\varphi}^2 \}^{1/2} \quad (2)$$

where θ is the angle between M and the normal to the film and φ the angle between M and a plane normal to the film. For NiFe the F can be expressed as

$$F = 1/2 \mu_0 M_s^2 \cos^2\theta - \mu_0 M_s H_r (\sin\beta \cos\varphi \sin\theta + \cos\beta \cos\theta) \quad (3)$$

We can now form an implicit equation (4) for H_r .

$$\omega = \gamma\mu_0 (1+\alpha^2)^{1/2} \cdot (\sin\beta/\sin\theta)^{1/2} \cdot \{-M_s H_r \cos 2\theta + H_r^2 \cos^2(\beta-\theta)\}^{1/2} \quad (4)$$

Imposing the equilibrium conditions $F_{\theta} = F_{\varphi} = 0$ one obtains a relation between θ and H_r .

$$M_s \sin 2\theta = 2H_r \sin(\theta - \beta) \quad (5)$$

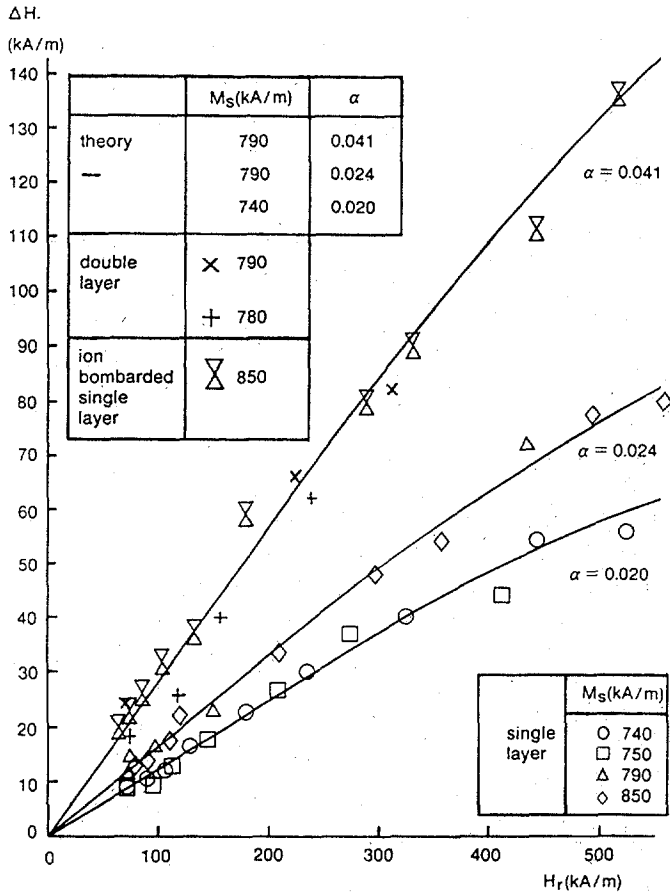


Fig.2 Experimental values of $\Delta H(H_r)$ for single and double layers and theoretical lines for different values of M_s and α .

Using equations (4) and (5) theoretical values of H_r are obtained as a function of the material parameters M_s and γ . When M_s increases H_r also increases and this is more important for high fields when the applied field is almost perpendicular to the film. When γ decreases H_r increases and this is noticeable for low as well as high fields. The theoretical values of H_r coincide with the experimental values of H_r for single and double layers (see fig 1). The experimental curves give a value of $\gamma = 1.93 \cdot 10^{11} \text{ Hz/T}$ ($g = 2.2 \pm 0.1$). The full width at half the maximum height ΔH of the resonance curves was also measured (figs 2 and 3). In this case different results were obtained for single NiFe films and NiFe under a CoCr for low as well as high fields. The width of the resonant absorption line $\Delta \omega$ can be expressed as [5].

$$\Delta \omega = \left(\frac{d\omega}{dH} \right) \cdot \Delta H = \frac{\alpha \gamma}{M} \{ F_{\theta\theta} + F_{\varphi\varphi} / \sin^2 \theta \} \quad (6)$$

We calculated ΔH using a low frequency, low field approximation

$$\Delta H = \frac{4 \alpha}{(1 + \alpha^2)^{1/2}} \frac{H_r}{\mu_0 M_s} \left\{ \frac{\epsilon^{-1} + \epsilon}{4} - \frac{\epsilon^3}{16} + \frac{\epsilon^5}{64} \left(\frac{5 - 3}{\sin^2 \theta} \right) \right\} \quad (7)$$

where $\epsilon = \frac{2\omega}{\gamma(1 + \alpha^2)^{1/2} \mu_0 M_s}$

The calculated (solid) lines for $\Delta H(H_r)$ (see fig 2) and for $\Delta H(\beta)$ (see fig 3) are shown for various damping parameters α . The experimental results are in agreement with the theory. In fig 2 it can be seen that there is some variation in ΔH for single layers, but that the ΔH of double layers is much higher. Part of the difference may be due to the influence of M_s , but most comes from the influence of α . This difference in α could be caused by either: a) interaction between the two layers or b) the glow discharge effects of the magnetron sputtering during the deposition of CoCr on NiFe.

The latter could be due to i) the heating of the NiFe ii) the physical damage and the defects caused by the ion bombardment of the sputtering plasma. Therefore two additional experiments were performed. In order to simulate the heating effect a NiFe sample was annealed during two hours at 440°C. We found almost the same ΔH and H_r as before annealing. In order to obtain information on the bombardment a number of NiFe samples were subjected to argon ion bombardment during 10 seconds. ($P_{ar} = 2.5 \cdot 10^{-2} \text{ mbar}$, $V_{RF} = 1.0 \text{ kV}$, $d = 38 \text{ nm}$). A bombarded sample shows the same $H_r(\beta)$ dependence as an untreated NiFe sample. However $\Delta H(\beta)$ and $\Delta H(H_r)$ are very different from an untreated sample and coincide with that of the NiFe layer under a CoCr layer. Nevertheless both treated and untreated samples do have a similar H_c while NiFe of a double layer has a larger H_c than a single NiFe layer. This could be due to the extra stresses which are caused by the CoCr on top of the NiFe.

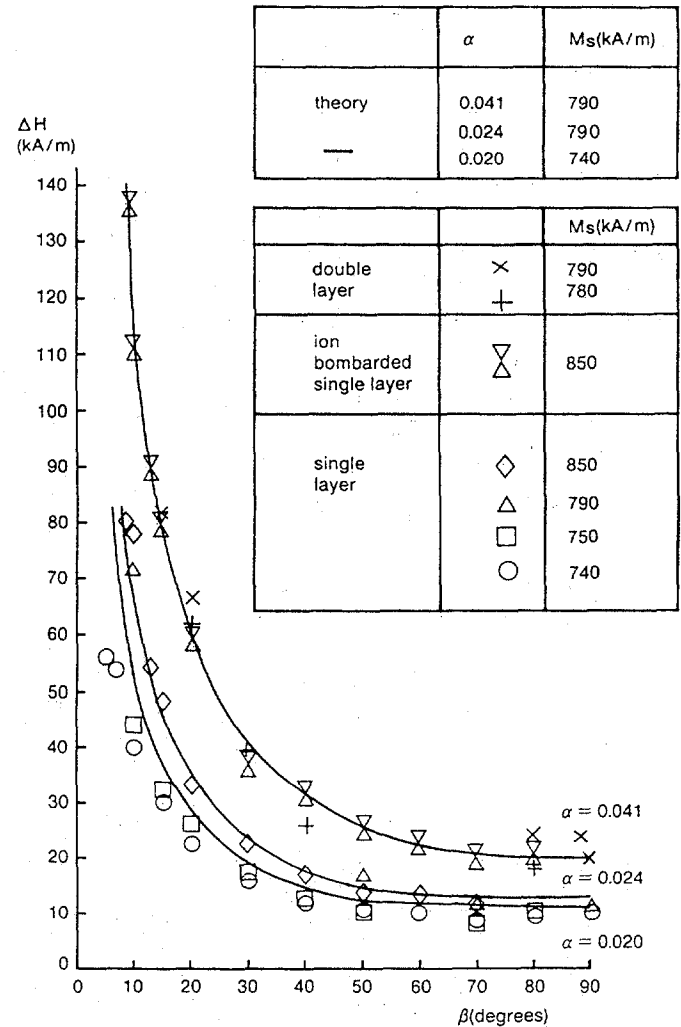


Fig.3 Experimental values of $\Delta H(\beta)$ and theoretical lines for different values of M_s and α .

COERCIVITY AND INITIAL SUSCEPTIBILITY

The perpendicular coercivity of both single CoCr layers (H_c) and double layers (H_{cd}) was measured using the VSM. In both cases the coercivity shows a maximum value at about 800 nm. The H_{cd} is lower than H_c . Bloomberg [6] proposes a model based on the non-interaction of the two layers which can be used to calculate the coercivity of the CoCr layer of the double layer (H_{cc}).

If the two layers are not coupled the response of the film can be considered as the superposition of the response of each layer to the applied field and neglecting the coercivity of the NiFe layer then H_{CC} is given by:

$$H_{CC} = (1 + t_n/t_c) H_{cd} \quad (8)$$

where t_n and t_c are the thicknesses of the NiFe and CoCr layers respectively. Fig. 4 shows that H_{CC} and H_C are similar. Differences between them will be due to the different nucleation and growing process of CoCr on NiFe and on Si. Nevertheless using (8) H_{cd} can be estimated knowing the corresponding H_C . These predictions agree with the experimental results.

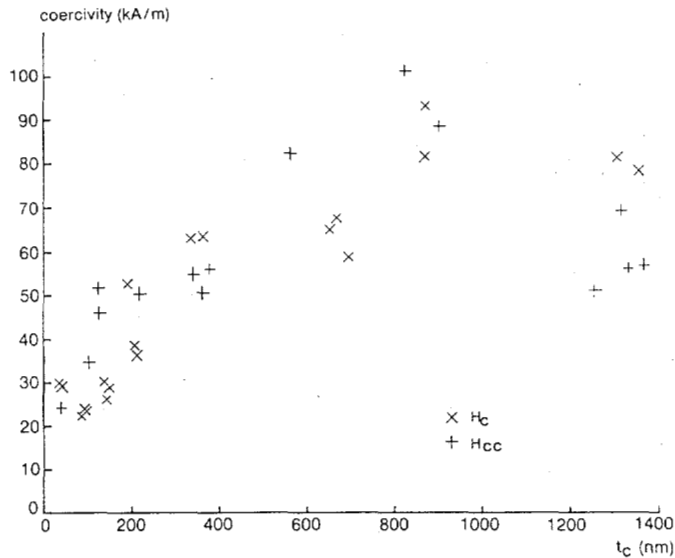


Fig.4 H_C and H_{CC} as a function of t_c .

The initial perpendicular susceptibility χ_i of the hysteresis curve of a single CoCr layer could be explained by the stripe domain model of Kooy and Enz [7]. We measured χ_i and found that it is different for CoCr in a double layer and CoCr in a single layer. Fig 5 shows these results together with those of the RF sputtered single CoCr layer of Wielinga [8]. Presumably there is a magnetostatic interaction between the magnetic domains in CoCr and the NiFe layer, but we have not yet been able to calculate its effect on χ_i .

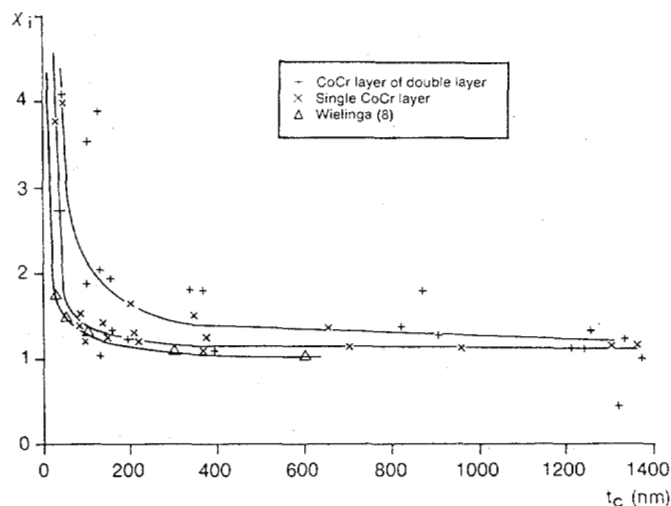


Fig.5 χ_i of CoCr in single and double layers versus t_c compared with RF sputtered layers from [8]

CONCLUSIONS

FMR measurements were performed on double layers consisting of CoCr on NiFe and single NiFe layers. The resonance field belonging to a resonance in the NiFe layers, is the same for both cases. ΔH is different for single and double layers. This is due to the bombardment of the NiFe layer due to the plasma effect of sputtering of the CoCr layer on top of it. VSM measurements indicate that H_{CC} is similar to H_C , using a model which assumes that there is no interaction between the two layers. However there is a difference in χ_i of the CoCr of the double layer and of single CoCr layer. Presumably the difference may be explained by assuming a magnetostatic interaction between the domains in CoCr and the NiFe. This is not necessarily in contradiction with the VSM results. It could be that the coercivity is not directly dependent on the layer thickness but on a factor such as column diameter which in turn depends on the thickness of the grown layer in single layers. The magnetostatic interaction would not change this factor and therefore H_{CC} would not suffer from this effect. If we assume that this interaction is confined to a thin surface layer of NiFe it will not affect the FMR results which mainly result from the bulk of the NiFe layer.

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