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Interaction in double layered ME tapes

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Abstract

A series of experimental double layered ME tapes with different oxygen concentrations were produced using an experimental mini-rollcoater set-up. δM measurements on these tapes indicate a negative (magnetostatic) interaction between the individual layers.

1. Introduction

Commercially produced double layered metal evaporated (ME) tapes (e.g. TDK) have better recording characteristics over a wider frequency range and less media noise compared to single layer tapes [1]. The reason for better recording performance might be a decrease in intrinsic domain width in the double layer compared to a single layer of the same thickness. The magnetostatic interaction range due to stray fields is in the order of the domain size (hundreds of nanometers). In common with previous authors [1] magnetostatic interaction is expected to be present in double layered tape. Since δM measurements [2] can be used to indicate magnetic interaction, these measurements were done on a series of experimental double layered evaporated tapes.

2. Experimental procedure

The evaporated tapes mentioned above, were produced using an experimental mini-rollcoater set-up. A schematical drawing of this set-up is given in Fig. 1 and the experimental procedure is described in Ref. [3]. An 11 μm PET base film is used as a substrate (Toray Q68S). The localised oxygen supply was at the opening angle of 60° and the background pressure during evaporation was always in the order of 5×10^{-6} mbar. All samples were evaporated with an average rate of 12 nm/s.

Using this set-up three double layers were evaporated, with variation in the oxygen flow. Each double layer was prepared in a two step deposition run. In the first step the bottom layer is deposited on the first two thirds of the total length of evaporation (420 mm). By remounting the drum in the opposite direction and subsequently evaporating the top layer, we obtain the coated area profile as schematically shown in Fig. 2.

The overlap of the single layers should result in a double layer morphology, which is schematically shown in Fig. 3.

For each layer the thickness was determined by SEM and also by a surface profiler (DEKTAK) using Si samples which were mounted on the drum (see Fig. 1). These results were confirmed by an additional check which was made by comparing the saturation magnetisation of the double layer and the sum of the separate single layers.

The structure of the evaporated layers was observed by SEM. Auger analyses have been undertaken to reveal the thickness-dependent composition. These Auger sputter profiles were taken using $E_p = 10$ kV, $I_p = 0.1$ μA, $\Delta E/E = 0.6\%$ and the measurement area is 120×150 μm^2. The sputter etching was done with an argon ion beam with an ion energy of 3.5 kV, 25 mA.

The extrinsic hysteresis behaviour of the samples was measured with a biaxial VSM, model DMS 1660, after the samples had been ac demagnetised in-plane by rotating the samples in a decreasing dc field (13 kA/ms). The error margin in the measured coercivities is 2 kA/m.

3. Results and discussion

The important parameters of the prepared films are shown in Table 1.

From this it can be seen that double layer A consists of a highly oxidised top layer (oxygen flow equals 10.0 ± 0.3 SCCM) and a less oxidised bottom layer (oxygen flow equals 2.50 ± 0.03 SCCM). In double layer B both layers have been interchanged and finally in sample C the same oxygen flow (2.50 ± 0.03 SCCM) was chosen for both layers.

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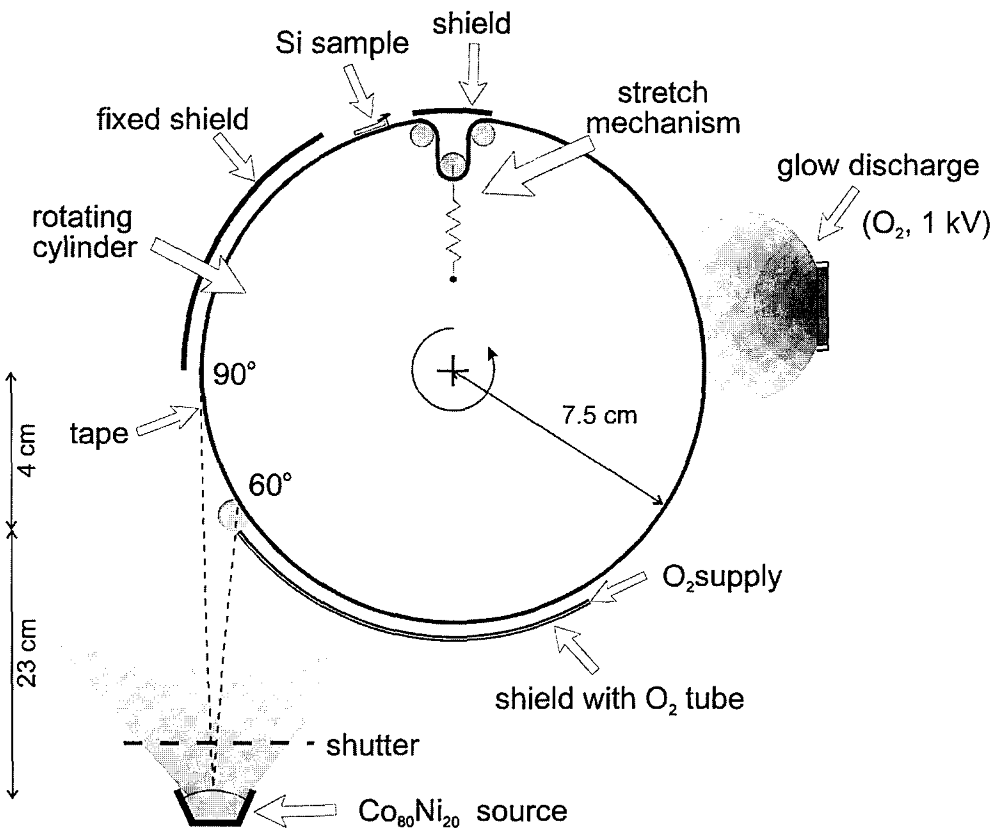

Fig. 1. Schematical drawing of the mini-rollcoater.

A SEM cross-section of for example double layer B, as shown in Fig. 4, confirms the schematical drawing of Fig. 3.

The photograph shows a reasonably defined columnar structure of the bottom layer, whereas the structure of the top layer seems to be much less defined. This could be due to a much larger roughness of the substrate of the top layer, i.e. the bottom layer, but also due to the lower O_2 concentration which increases surface diffusion [4]. Another indication for the influence of the surface roughness can be found in comparing the coercivities of both single layers (18 ± 2 kA/m) and the double layer (33 ± 2 kA/m) of tape C. However, the banana-shaped columnar direction still corresponds to the film morphology given in Fig. 3.

Auger analysis of the elements C, Co, Ni and O, was performed on all double layered samples. As an example the Auger depth profile of sample B is given in Fig. 5, which confirms the same trend as was found in Ref. [1]; the oxygen depth profile reveals two distinctive peaks which can be contributed to the different layers. Also the width of these peaks correlates with the chosen oxygen flow of the individual layers.

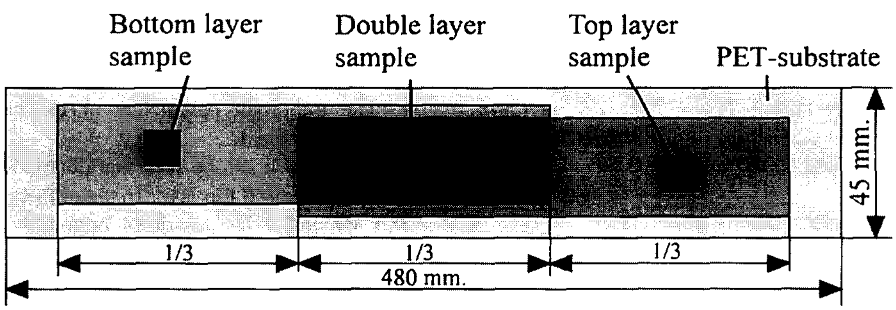

Fig. 2. Schematical drawing of the coated area profile resulting in the single and double layers.

Table 1
Thickness and magnetic parameters of the prepared tapes.

Sample #		δ (nm)	M_s (kA/m)	$H_{c,long}$ (kA/m)
A	Top	110 ± 20	211 ± 22	66
	Bottom	160 ± 25	356 ± 48	22
	Double	270 ± 35	286 ± 30	23
B	Top	110 ± 20	409 ± 38	29
	Bottom	125 ± 21	187 ± 24	76
	Double	250 ± 33	313 ± 38	57
C	Top	123 ± 21	485 ± 48	19
	Bottom	110 ± 20	591 ± 75	17
	Double	250 ± 33	456 ± 54	33

The second peak, as indicated in Fig. 5 indicates an enhanced oxide concentration around the interface between both layers. This interfacial oxide layer, probably composed of CoO and NiO, is estimated to be around 70 (nm). Therefore, it is likely that the exchange coupling between both layers is strongly reduced.

To investigate the possibility of magnetostatic interaction, δM curves were measured. All the layers showed a large negative δM peak, which can be expected by the fact that the samples have an out-of-plane anisotropy axis. As an example, δM curves of both single layers and the double layer of sample B are given in Fig. 6.

There clearly is a significant difference between the

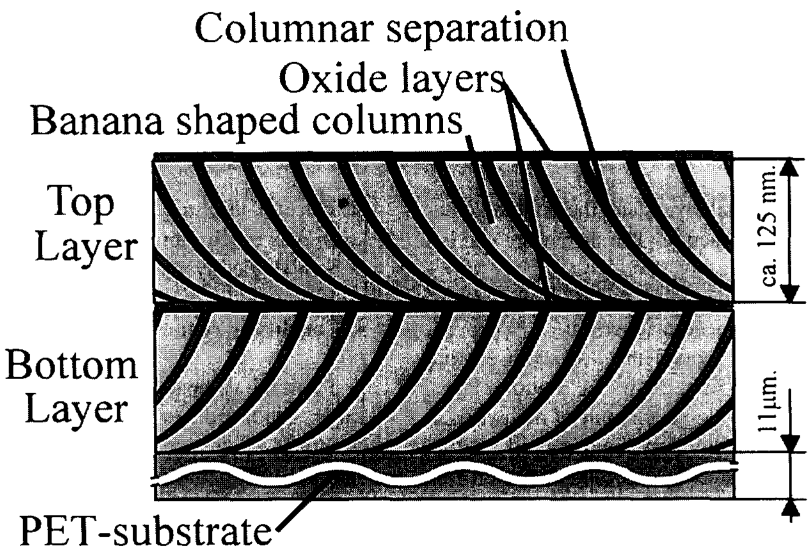

Fig. 3. Schematical drawing of the double layered ME structure.

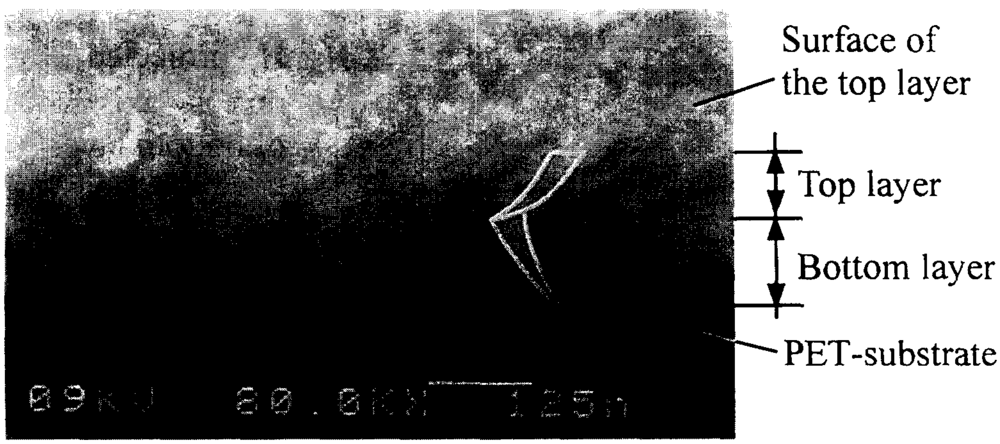

Fig. 4. SEM cross section of double layer B.

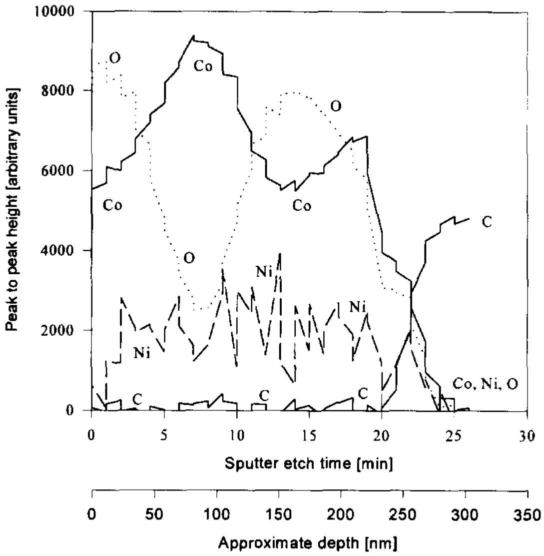

Fig. 5. Auger depth profile of double layer B.

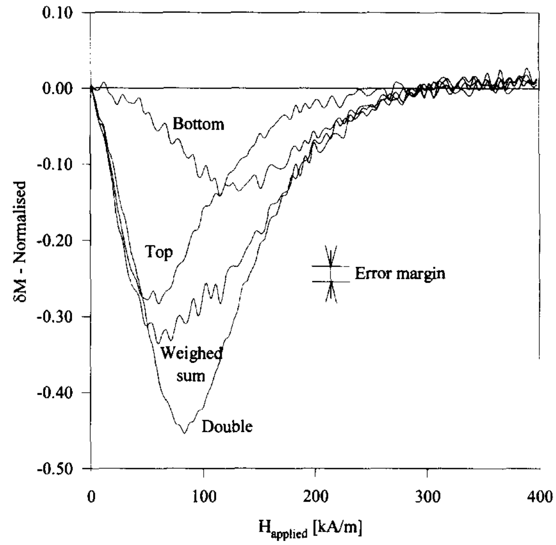

Fig. 6. δM curves of double and single layers of sample B.

weighed sum of the individual layers and the double layer, which strongly suggests interaction. The difference can be explained as follows:

In the initial state the double layer sample is ac demagnetised and shows no remanent magnetisation. When an external increasing field is applied the less oxidised top layer becomes magnetised first. Now the bottom layer experiences a field which is the vector sum of the external applied field (H_{applied}) and the stray field caused by the already magnetised top layer (H_{tb}). This is shown in the schematical picture of Fig. 7.

The effective applied field (the projection of H_{tot} on the easy axis of the bottom layer) is reduced by the presence of this stray field. Therefore, the peak of double layer B is much more negative than the weighed addition of both single layers.

4. Conclusive remarks

From the comparison of the SEM cross section and the Auger depth profiles with those from Ref. [1] it becomes clear that our experimental double layers resemble commercially available tapes. Considering the oxygen interlayer it seems not likely that exchange interaction is present between the layers. However, it can be concluded that the measured δM curves can be explained by a

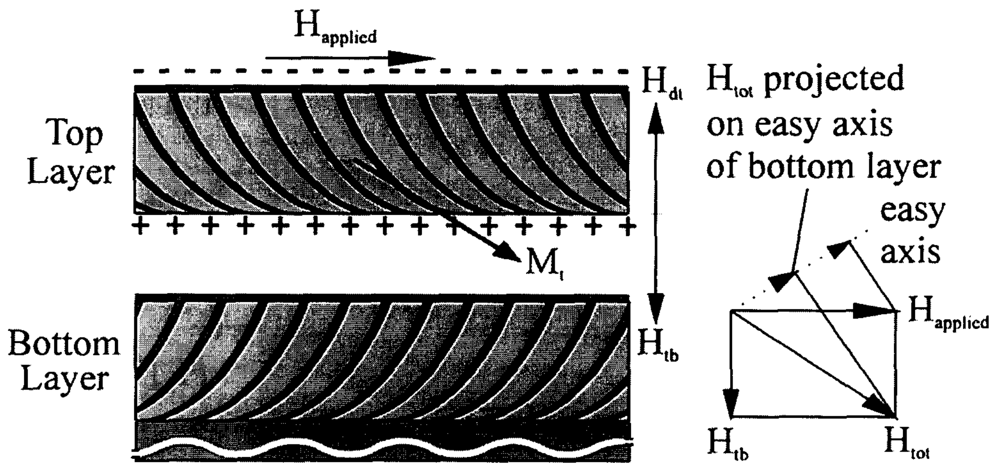

Fig. 7. Vector addition of the applied field and the stray field of the first layer that is switched.

magnetostatic interaction between the individual layers. Therefore, magnetostatic interaction should also be considered when explaining the better recording performance of double layered tape.

The accuracy of this measurement method can be improved by compensating the large demagnetising field perpendicular to the thin film plane as is done in e.g. Ref. [5].

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