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Recording characteristics as a result of the special morphology of ME tape

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Abstract

The performance of ME tape has been studied by assuming a certain morphology of the magnetic layer. The effects of a non-uniform magnetization throughout the depth and an easy-axis out-of-plane are studied and their influence on the recording behavior are investigated. For this purpose a self-consistent recording model is used, in which a Moving-Preisach Stoner–Wohlfarth hysteresis model is implemented. Decreasing the magnetization from the top to the bottom layer could possibly improve the recording characteristics. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Tape recording; ME tape; Moving-Preisach Stoner–Wohlfarth model

1. Introduction

Metal evaporated tape has a relatively small remanent coercivity (H_r) and large saturation magnetization (M_s) with respect to MP tape. This would suggest a bad high-frequency response for ME tape. The contrary turns out to be true. To investigate this phenomenon the particular details of the internal structure of the ME tape, consisting of Co–Ni–O, have been studied [1,2]. Due to the continuously varying angle of vapor incidence (CVI), from grazing incidence to 30°–50° with the normal and the localized oxygen supply in the production process a banana-shaped columnar structure is observed. This morphology is due to the shadowing effect during nucleation and the CVI technology. Moreover, a larger structure of clustered columns appears. These columns (diameter < 10 nm) are separated by virtue of the shadowing effect. The columns consist of ferromagnetic and non-ferromagnetic grains (3–5 nm). According to [3] the magnetization distribution in the tape depth direction is not uniform. In the upper sublayers it can be 50% larger than the VSM measured value and in the back sublayers it decreases. In this paper the effects of a non-uniform magnetization profile and different easy-axes are studied to understand the effect of the large M_s and the small H_r of ME tape with respect to MP tape.

2. Simulation model

The well-known moving-Preisach and Stoner–Wohlfarth hysteresis models have been combined to model accurately the magnetic hysteresis process [4]. The combination of these models can reproduce the hysteresis loops of different recording media very well. This hysteresis model is implemented in a self-consistent two-dimensional recording model and predicts within 2 dB the output of recording media with different magnetic properties. Macroscopic tape parameters are used as input for the simulated hysteresis loop, such as e.g. M_s, H_r, switching field distribution and orientation. AC-erased and modulation noise studies [5] indicate that ME tape shows a more particulate behavior instead of that of a continuous thin film. The magnetic correlation through the depth is also taken into account [6]. Thus although this model is a particle assembly model, it is still useful in the case of ME tape with its columnar structure. For the head field the Karlqvist approximation is used.

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The tape used to model is a single layer Hi8 metal evaporated tape, which has a thickness of 0.2 μm, an M_s of 365 kA/m, an H_r of 100 kA/m, a squareness of 0.97 and a switching field distribution of 0.22. The macroscopic measured intrinsic easy-axis angle is 35° with respect to the substrate. MP tape on the other hand has a thickness of 0.2 μm, an M_s of 365 kA/m, an H_r of 195 kA/m, a squareness of 0.89 and a switching field distribution of 0.22.

3. Results and discussion

Calculation of the signal output for four cases (M_s is 100 and 200 kA/m combined with an easy-axis of 10° and 35°.) are shown in Fig. 1. Here the signal output is given with respect to the inverse wavelength. It shows that increasing the easy-axis angle does not bring about a larger signal output. In fact it is decreasing. In the same graph it can be noted that the most likely way to improve the signal output is to increase the magnetization. This could mean that ME tape has a smaller output performance than its capability due to the oblique easy-axis. On the other hand it is a necessity for this tape because of the use of the shadowing effect during the evaporating process for column separation. In the high-frequency region the primary parameters which determine the fall of the curve are the head-medium spacing which is taken to be a constant (35 nm), the gap loss factor (which is the same for all simulations) and the transition parameter. In Fig. 2 a calculated transition is shown. Here the tape is subdivided into 12 sublayers to follow the transition through the depth. One arrow corresponds with a magnetization of about 10 columns and has an easy-axis of 35°. The space between the outermost curves gives the transition length through the depth. The curve in-between shows the transition center through the depth. In Fig. 3 the transition length is calculated through the depth for different magnetizations (100, 250, 380, 500 kA/m) with an easy-axis of 35°. It shows that the transition length for increasing magnetization has values which are close together with a slight decreasing trend (mainly in the upper layers) when the magnetization is increased. In the arctangent model the transition parameter is proportional to M_r/H_r. This suggests that an increase in the M_r would increase the transition length. H_r however, is also changed when the magnetization is increased. In the model used this brings about more positive magnetizing effect. In a micromagnetic study of

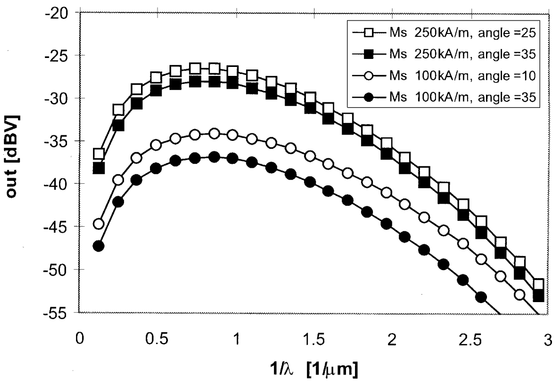

Fig. 1. Simulation of the output as a function of inverse wavelength for different M_s and easy-axes.

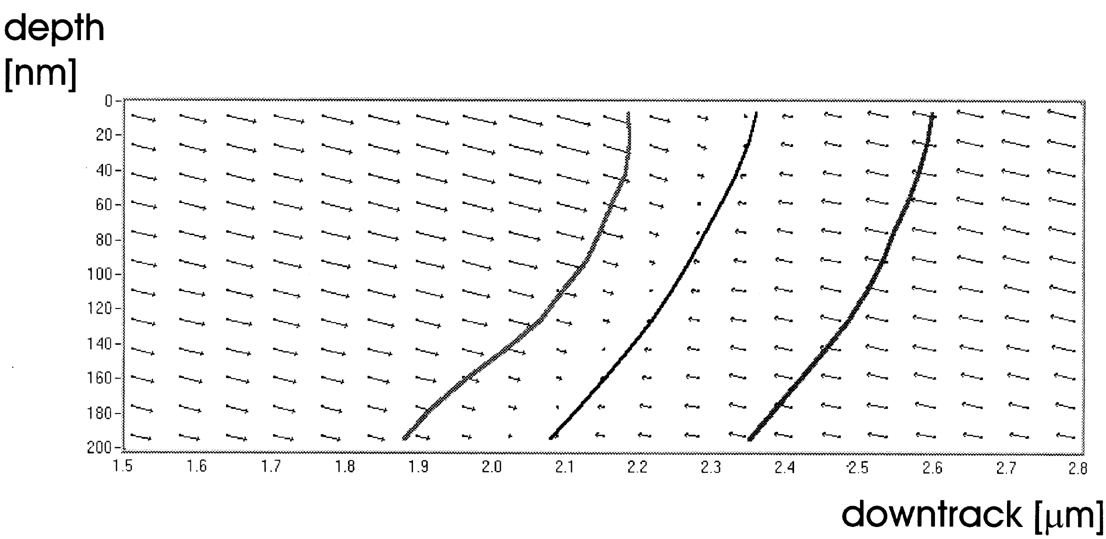

Fig. 2. Simulation of a transition in a tape with an easy-axis angle of 35°. The transition length in each sublayer (the length between the two outermost curves) throughout the depth. The middle curve indicates the transition center.

an isolated column of ME tape [7] it was shown that high exchange coupling acts to keep moments aligned, resulting in higher values of H_r. This is especially true in the case of high alignment of the easy-axis of the grains along the column axis (which results in a higher squareness). Another reason for increase in H_r during recording is due to the large angle between the applied field and the easy-axis in ME tape (in the good direction). H_r is known to follow the inverse cosine behavior. This is also measured by Ref. [8] for a single layer ME tape and it shows similar behavior (Fig. 4). Here H_r is given as a function of the extrinsic angles of the applied fields. The extrinsic easy-axis angle is 160° out-of-plane. It is seen that the maximum occurs at an angle of about 70°, which is in the hard direction of the columns.

The simulation also shows an increase of the phasing effect in the deeper layers when the magnetization is increased. In the case of a non-uniform magnetization distribution in the depth direction, the magnetization profile is decreasing with depth. The transitions are then more synchronized throughout the depth. This results in a higher output.

Decrease of the magnetization in deeper layers is also important for the overwrite behavior. No cooperative reversal will take place and the H_r will be reduced [7] in these back sublayers. This results in a better overwrite behavior [9].

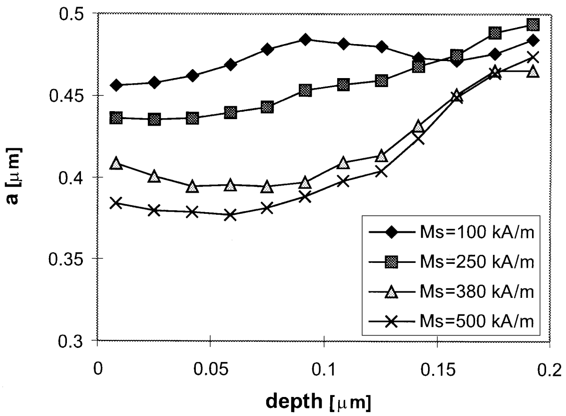

Fig. 3. The transition length as a function of the tape depth for different M_s with an easy-axis angle of 35°.

4. Conclusion

The numerical model showed that the increase of the magnetization is necessary for attaining a high output by a recording medium with an oblique easy-axis. This explains the large M_s value in ME tape. It has a non-uniform magnetization profile. The large magnetization at the surface is reduced in the back sublayers. This is advantageous for the output, since the phasing effect in the back sublayers will be removed. In the back sublayers H_r becomes smaller. This changes the reversal mechanism in such a way that the overwrite behavior becomes better as shown in [9]. M_s in the tape is linked with H_r through the interactions of the particles. In the model a large M_s will induce a large H_r (because of the cooperative reversal mechanism). It is understandable that thin film medium designers choose a low remanent coercivity medium to be compatible with the existing heads. MP tape has no output reduction due to an oblique easy-axis, which makes the large M_s not necessary. On the other hand its interparticle interactions are not comparable with ME tape, thus to write sharp transitions its H_r must be increased.

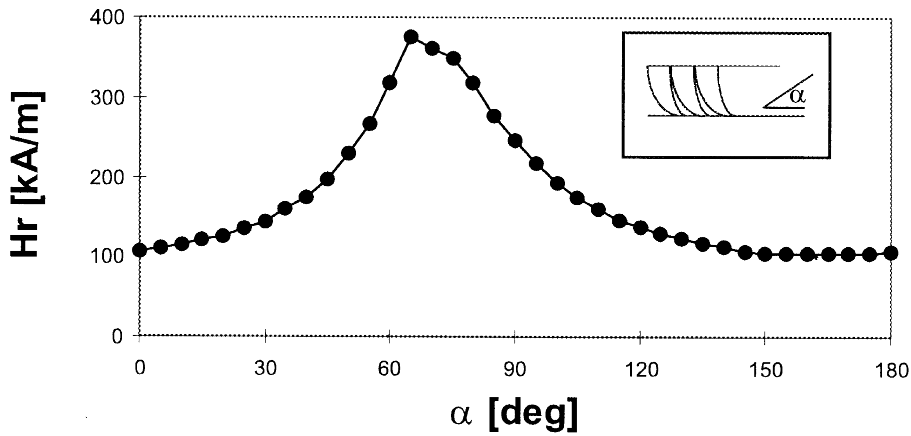

Fig. 4. Angular dependence (out-of-plane) of the H_r of a single layer ME tape [8].

Acknowledgements

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