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MICROMAGNETIC ANALYSIS OF THE RECORDING NOISE IN ADVANCED MAGNETIC TAPE

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A series of advanced metal particle tapes with identical particles but different magnetic coating thicknesses from 300 nm to 150 nm have been taken through a DC-demagnetisation remanent process from positive to negative saturation. Magnetization was achieved with an electromagnetic device, which produces uniform magnetization in the longitudinal direction of the tape. Spectral noise power maps have been generated for the tapes following the demagnetisation processes. The thickest tape shows characteristics similar to those of conventional thick tapes, such as video tapes, with demagnetised noise lower than the saturation noise, whereas the thinnest has characteristics of a thin film with demagnetised noise greater than that at saturation. A representation of the experimental measurement process, based on a Landau-Lifshitz-Gilbert (LLG) model of the medium and a simulation of the 'reading' process generated many of the experimental features. The changes in the noise maps with magnetic coating thickness were attributed to the increased contributions from the free surfaces of the tape as the magnetic coating thickness was reduced.

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1. Introduction

As information storage density on magnetic media is increasing, magnetic microstructure becomes more significant in determining performance. One property very much related to this is the modulation noise, which is a limiting factor in advanced metal particle media [1]. For the development of higher density formats, it is important to understand the role of magnetic components in the noise in these media so that it can be minimised. We have been investigated modulation noise in tape systems [2] and current work is focussed on the advanced double-coated MP systems. Our approach has been to use an electromagnetic magnetizer, mounted in the tape path rather than a conventional write-head, to generate a uniform magnetic state of the tape and to look at noise maps as a function of the remanent state. This ensures that the microstructural noise generated by non-uniformity of the magnetization [3] is eliminated and that observed changes are associated primarily with the changes in the magnetic microstructure. To interpret the noise maps, complementary simulation studies have been made, so that features in the maps can be associated with particular microstructures or regions of the tape i.e. bulk, surfaces and interfaces.

The experimental measurements were made on a reel-to-reel bench tester with computer controlled speed, direction and tension. The noise power spectrum was measured by passing the tape over an MR read-head at a speed of 0.5 ms^{-1}. The voltage-time series from the head was captured using a digital storage oscilloscope (DSO) and the power spectrum (0 – 2.5 MHz) was produced by using the DSO FFT software. The chosen frequency span gave an equivalent information wavelength on the tape down to 200 nm. The noise spectrum was measured for remanent states along the DC-demagnetisation curve (from positive to negative saturation) for each tape sample, and then assembled to give the full spectral noise power map.

The physical processes involved in the noise measurement have been simulated for an ensemble of up to 8000 single domain spherical particles. The dynamics of the magnetic moment of each particle were described by the Landau-Lifshitz-Gilbert equation [4]. The particles, which had a lognormal volume distribution, were arranged randomly in rectangular blocks to represent a series of tapes with thickness in the range 4 to 14 average particle radii. The particle easy axis directions were arranged to match the texture measured for the tapes under investigation. Periodic boundaries were used in the plane of the tape and magnetization states along the DC-demagnetization curve were determined. For each remanent state, the read process was simulated by determining the signal measured by a head as it tracked along the tape. Reciprocity and the Karlqvist approximation were used to take account of spacing, and then integrated across the gap to simulate an MR head. The head gap was chosen to match the characteristics of the MR head in the experimental set-up (shield to shield spacing = 0.5 μm). This produced a time series, and an FFT routine was used to produce the spectrum. A sequence of different remanent states was then assembled to produce a simulated spectral noise map. This was plotted on a log scale for comparison with experimental data dB plots.

2. Results and discussion

We describe results for a set of four commercial development samples of advanced double layer MP tape. These were produced using identical coating technology and particles, but with different magnetic coating thicknesses. These tapes have been fully characterised to measure standard magnetic properties plus magnetic coating thickness [5] and the distribution of particle easy axes [6]. Standard parameters are given in Table 1. One must note that apart from the thickness (300 nm to 150 nm) and related Mrt (remanent magnetization x thickness) values, parameters are very similar for all four samples.

Table 1. Magnetic characteristics of the four tape samples.

Tape	Mrt (memu cm^{-2})	Coercitivity H_C (kOe)	Squareness	Orientation Ratio	Thickness (t) (nm)
A	6.33	1.93	0.84	2.2	293
B	4.60	1.90	0.84	2.0	233
C	4.03	1.91	0.84	2.0	210
D	3,53	1.94	0.87	2.2	150

Fig. 1 shows the spectral noise map for the sample A, the one with the thickest magnetic coating (300 nm). Noise levels are expressed in dB relative to the mean saturation level. Note the trough like feature in the demagnetised state, which reduces the noise below the saturation level. The centre of the trough is offset from the demagnetised state towards a higher field. This is characteristic to the noise maps for conventional thick particulate media [7]. The reason for this is not clear, although it is also observed in some of our simulation studies. The reduction of noise can be interpreted as inhomogeneities of the particle distribution in the medium, such as clustering, which generates flux closures in the demagnetised state and reduces the noise field at the read-head. The trough is centred on a field above remanent coercivity and is observed in most conventional tapes. The noise map for the samples B and C show much broader and shallower troughs and a peak appearing at a lower field value. In Fig. 2 for the thinnest sample (150 nm), the trough has disappeared and the peak has become the dominant feature centred on the remanent coercivity. These noise characteristics are very similar to those for sputtered thin films [8] and to those reported for metal evaporated tape [9].

Figs. 3 and 4 present the simulated noise maps for tapes of thickness equivalent to seven and two mean particle diameters, respectively. For intermediate thicknesses, the same transition is observed as seen in the experimental results. Although the model is somewhat limited, i.e. uses spherical rather than acicular particles and it is therefore difficult to correlate model parameters to the experimental samples, the simulations show a good match to the experimental results. This allows us to draw some tentative conclusions. The model has no enhanced surface or interface roughness, only the natural roughness of fitting particles to an interface, and so the change of map features would appear to be associated solely with the change in thickness of the sample. Some initial further analysis of the simulations has been made to determine the contributions of particles from different regions of the tape. This shows that particles at the surfaces have a different contribution than those in the bulk. Bulk particles give a strong trough feature in their noise map, whereas surface particles show a dominant peak feature. The peak feature is strongest from those at the top surface, which suggests that the lower surface particle contributions are modified by a combination of the integrating effect of the head and the distance between the particle and head (the write bubble will be much wider at the lower surface than at the top surface). A likely explanation of the changing characteristics with thickness is therefore that the change in noise characteristics as the magnetic coating gets thinner is a result of the increase in the dominance of the surface contributions over those from the bulk region of the tape.

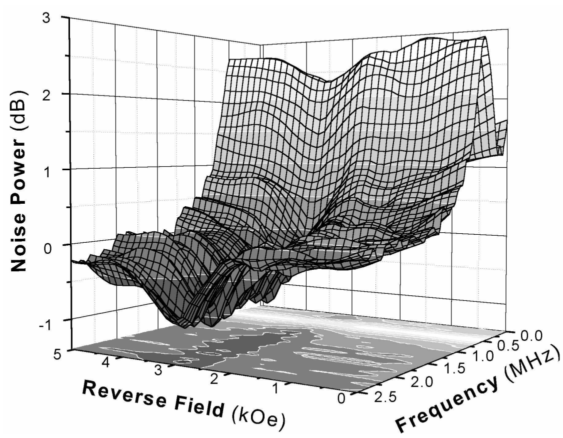

Fig. 1. Experimental spectral noise map for sample A (t = 293 nm) showing a trough around the demagnetised state characteristic of thick parti - culate media.

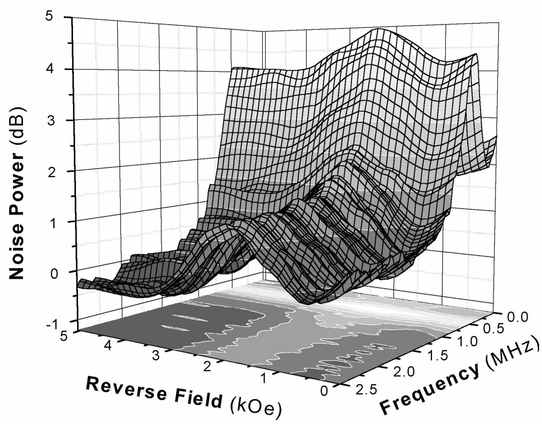

Fig. 2. Experimental spectral noise map for sample D (t = 150 nm) showing a strong peak centred on the remanent coercivity.

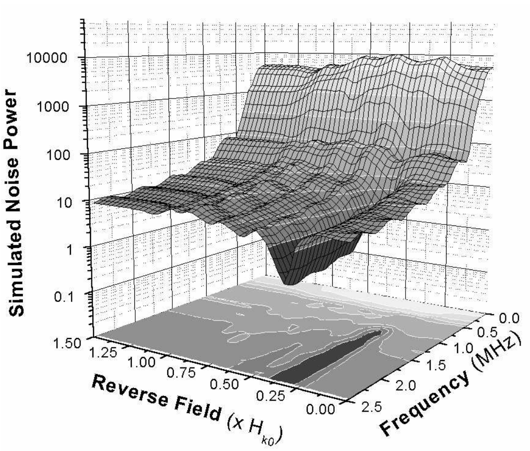

Fig. 3. A simulated spectral noise map for layer thickness equivalent to seven particle diameters.

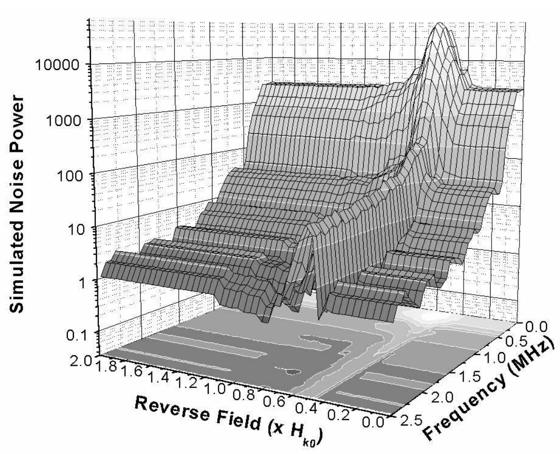

Fig. 4. A simulated spectral noise map for layer thickness equivalent to two particle diameters.

If we consider the basic difference between bulk and surface particles, the magnetostatic interactions will have a different spatial distribution of nearest neighbours in the two regimes. For particles in the bulk, the vector sum of mean interaction fields is zero due to the isotropic distribution of neighbours. However, for a particle at the surface, in a system magnetised parallel to the surface, the mean interaction field will have a finite value parallel to the surface. The inter-particle interactions at the surface therefore look more like those of a 2D thin film, which perhaps explains why they exhibit noise characteristics similar to those of thin films. These effects are the subject of an ongoing study [10].

3. Conclusion

A study of the spectral noise power maps for a series of advanced MP tape with similar characteristics but different magnetic coating thickness showed that the features changed as the tape thickness was reduced. For the thickest sample, the DC-demagnetised noise was lower than the saturated noise, but for the thinnest sample, the demagnetised noise was higher than the saturated noise. Intermediate samples showed a trend from one to the other. Simulation studies have matched the experimental observations and show that the noise contributions of particles at the surface are different from those in the bulk. This would suggest that the observed changes with thickness are the result of the increasing dominance of the surface particles as the tape becomes thinner when the bulk contributions are reduced.

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