ORIENTED CrO_2 DISK SURFACES FOR MAGNETIC RECORDING

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INTRODUCTION

The objective of this program is to develop a disk coating with CrO_2 particles oriented circumferentially in the direction of the recorded tracks and to determine if the surface has any advantages for magnetic recording. The expected advantages of oriented CrO_2 particulate surfaces over conventional unoriented γFe_2O_3 surfaces are larger output due to increased remanence magnetization and possibly less noise due to more uniform particle size and volume distribution. In the following report is discussed the coating formulation, orientation procedure, magnetic hysteresis measurements and magnetic recording results for the disk coatings developed in this program.

COATING FORMULATION

The CrO_2 particles were obtained from the E. I. DuPont Company and had the following characteristics:

H_c = 370 Oe
σ_s = 84 emu/gram
aspect ratio = 8:1.

In order to utilize the magnetic properties of CrO_2 particles, it is necessary to apply the pigment in an organic binder. Chromium dioxide is a vigorous oxidizing agent and will destroy many organic binders: resins containing reactive groups susceptible to free radicle polymerization are rapidly catalyzed by chromium dioxide and pose considerable manufacturing problems. Such resins include acrylics, epoxies and polyesters. Initially, it was found that polymers of methyl methacrylate are inert to chromium dioxide and can be used as excellent binders for the pigment. In order to allow orientation of the particles, the viscosity of the medium must be low enough that the applied magnetic field can orient the particles and high enough to keep them oriented and dispersed until the film loses its liquid character. Additionally, the viscosity must be such as to result in the desired thickness with spin coating. It was found that a solution of polymethyl methacrylate which would dry by solvent evaporation at a controlled rate formed an ideal binder for orientation purposes. The preferred solvent was found to be a mixture of cyclohexanone and isophorone with composition 15% cyclohexanone and 85% isophorone by weight. The coating material consisted of the following:

chromium dioxide particles	24% wt/wt wet coating
polymer	20%
solvent (15% cyclohexanone 85% isophorone)	56%
pigment volume concentration	22%
coating viscosity (for 300 μin. coating)	3 poise

ORIENTATION PROCEDURE AND MAGNETIC MEASUREMENTS

The technique used for orienting the CrO_2 particles was to apply an in-plane magnetic field perpendicular to a radius of the disk while the coating was still wet (see Fig. 1). The magnets used had a spacing between poles of 1/4 inch, a gap of 2 mm and a maximum field of 2 kOe. An analysis has been done of the dynamics of the magnetic orientation of a two-dimensional random array of acicular particles in a Newtonian fluid.(1) The analysis predicts the magnetic properties of the particulate array in the direction of the orienting field as a function of time. Magnetic properties of a particulate array for one set of parameters is shown in Fig. 2. In the low-field mode single-domain particles initially magnetized in the quadrant directed away from the field do not switch, while in the high-field mode they do. The orienting time is approximately inversely proportional to magnetic field and exactly proportional to viscosity. The experiments on orientation to be described are better explained by the low-field mode since the initial remanence ratio (M_{ir}/M_s) is different than the squareness ratio (M_r/M_s). Coatings which dry by solvent evaporation have time dependent viscosity and the coating used was not Newtonian and therefore the above analysis is not directly applicable to our experiments. However, the prediction that orientation should take place in times much less than a second with the assumed parameters is of interest in understanding the limits on the rate of solvent evaporation.

MERLIN substrates and 3" substrates cut from them were spin coated with the CrO_2/MMA coating with the magnetic field applied until the coating was dry (2 to 3 minutes). With the magnetic field in the 2 mm magnet gap applied at a disk radius of 5 in. for 2 minutes, each particle in the oriented band is subjected to the orienting field for 0.3 sec. Experimental hysteresis curves measured with a vibrating sample magnetometer on a sample cut from a 14" CrO_2/MMA coated disk are shown in Fig. 3. Measurements were made with the magnetization along the orientation field direction (easy axis), perpendicular to the orientation field direction (hard axis) and with an unoriented coating. The branch of the hysteresis curves starting from H = 0 was measured first; after saturation, this branch is no longer accessible. The orientation ratios (.853, .650, .454) are comparable to those obtained on CrO_2 tape.

The spin-coated and oriented surfaces made with this binder were approximately 300 μin thick. Subsequent polishing with lapping tape reduced this thickness to approximately 100 μin. before the coating no longer adhered to the substrate. Experiments are in progress to reduce the coating viscosity with the same PVC to result in thinner coatings.

MAGNETIC RECORDING EXPERIMENTS

An advantage of an oriented CrO_2 disk coating over the present unoriented γFe_2O_3 coating is its larger remanent magnetization. This larger remanent magnetization is expected to result in larger read-back amplitude from an isolated transition in digital recording. However, some question remains as to the effect of this increased remanence on the pulse width and hence peak shift.

Recording experiments were done on both 14 in. and 3 in. CrO_2/MMA coated disks. The 3 in. recording system using a MERLIN head (50 μin. gap flying near 50 μin.) is described in the paper on magnetite disks. Frequency response curves measured on 3 in. oriented CrO_2/MMA and MERLIN coatings are shown in Fig. 4. The larger amplitude of the CrO_2 coating is due both to its larger remanence and larger thickness. Similar measurements with oriented and unoriented CrO_2 coatings of the same thickness showed the expected linear dependence of output at low fci with remanence.

Peak shift measurements were made on a 14 in. disk using a MERLIN recording system. The measurements used techniques developed by San Jose Product Test. A 10 bit character (0101001111) was recorded at 6.45 Mt/sec in a region of the track in which amplitude variations were at a minimum, as shown in Fig. 5. The read-back signal was plotted on a chart recorder using the output from a sampling oscilloscope. Peak shift was measured as the variation from 156 nanoseconds of the last two 1's in the above character. Typical experimental results are tabulated in Table 1. The difference in peak shift observed with the two surfaces is difficult to interpret because of the difference in surface thickness. However, the difference in peak shift between the oriented and unoriented regions with the CrO_2/MMA coating is significant because the oriented region is near the ID of the disk where the MERLIN head is known to fly closer to the surface and narrower pulse width would be expected. The larger peak shift actually observed is therefore indicitive that peak shift is increased with the increased squareness resulting from orientation. This result is in agreement with predictions from theoretical models of magnetization distributions in recording media(2).

TABLE I

Peak Shift from CrO_2/MMA and Merlin Recording Surfaces

Surface	Thickness μ in	Peak Shift n sec	% Peak Shift
CrO_2/MMA	85 ± 10		
Oriented		16	10.3
Unoriented		8	5.1
MERLIN	50 + 10	4	2.6

ACKNOWLEDGEMENT

Mr. R. T. Muto made significant contribution in all phases of this work - including measurements and suggestions on orientation procedure. Mr. Tom Fugate and Mr. Mel Kahl helped carry out the peak shift measurements.

FIGURE CAPTIONS

Fig. 1 -- Experimental technique for orienting the particles in a band of a disk surface. The magnetic field is applied while the disk with wet coating is rotated.

Fig. 2 -- Theoretical magnetic properties of particulate array in an orienting magnetic field of 1000 Oe and a binder with viscosity of 100 poise. In the calculation, it was assumed that the particles had $M_s = 300$ emu cm^{-3}, uniaxial anisotropy $K_u = 10^6$ erg cm^{-3} and acicularity k = 15:1.

Fig. 3 -- Measured hysteresis curves for CrO_2/MMA coating. In (a) the magnetization was along the oriented direction, in (b) the magnetization was perpendicular to the orientation direction and in (c) the coating was unoriented.

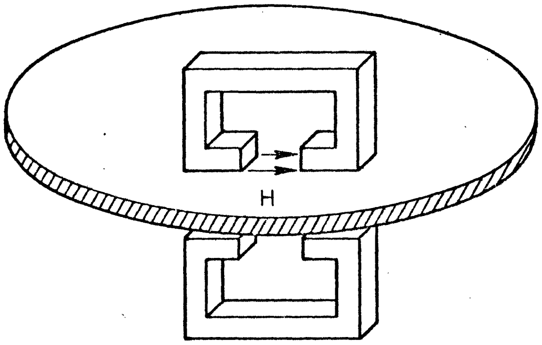
Fig. 4 -- Frequency response curves of CrO_2/MMA and MERLIN coatings measured with a 3 in. recording system. The drive currents were adjusted for saturation for both surfaces.

Fig. 5 -- In (a) is shown a photograph of a track recorded with the 10 bit character shown in (b). Peak shift was measured by the shift in the two 1's shown in (b) recorded in the relatively uniform part of the track shown in (a).

REFERENCES

1. P. H. Lissberger and R. L. Comstock, "Orientation of Acicular Particles in a Recording Medium", to be presented at 1970 INTERMAG Conference

2. S. Iwasaki and T. Suzuki, "Dynamical Interpretation of Magnetic Recording Process", IEEE Trans. Magnetics, MAG-4, 26a (1968).



ORIENTATION EXPERIMENT

FIG. 1

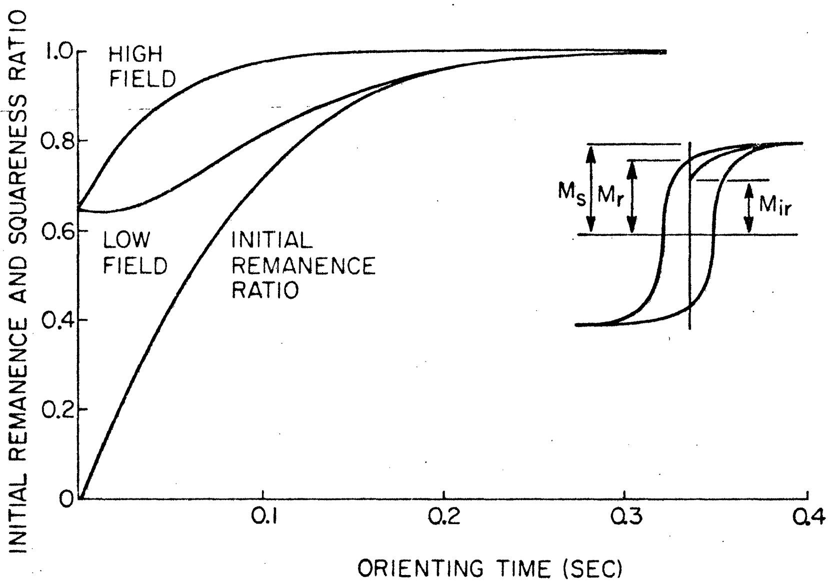
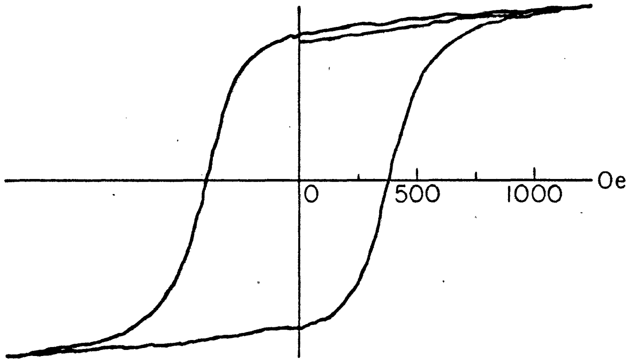
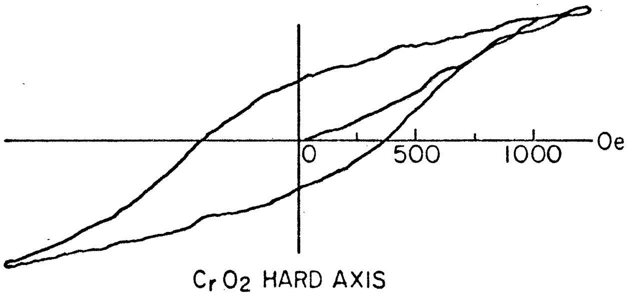

INITIAL REMANENCE AND SQUARENESS RATIO
1.0
0.8
0.6
0.4
0.2
0
0.1
0.2
0.3
0.4
ORIENTING TIME (SEC)
HIGH FIELD
LOW FIELD
INITIAL REMANENCE RATIO
M_s
M_r
M_{ir}

FIG. 2



C_rO_2 ORIENTED–EASY AXIS

FIG. 3a



CrO_2 HARD AXIS

FIG. 3b

Fig3b

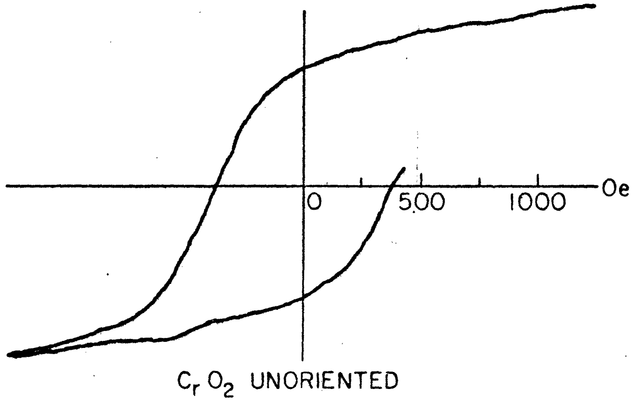
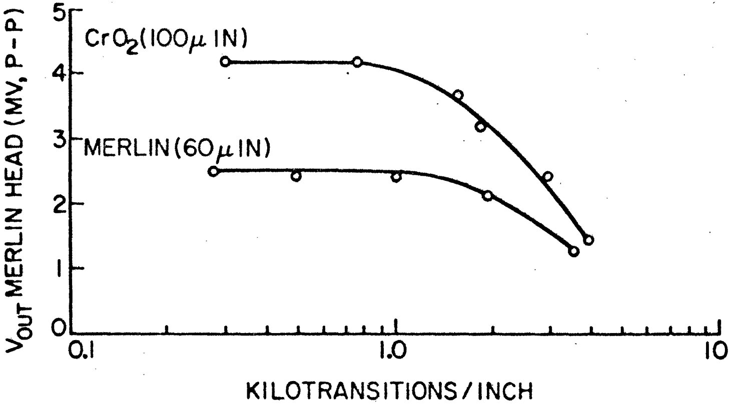
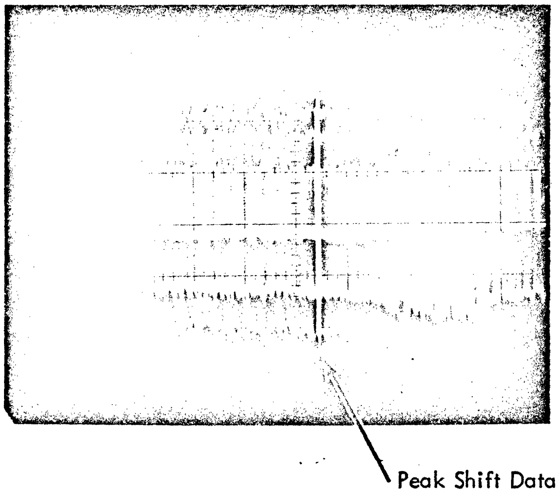


FIG. 3c



V_{OUT} MERLIN HEAD (MV, P-P)
5
4
3
2
1
0
CrO_2(100μ IN)
MERLIN(60μ IN)
0.1
1.0
10
KILOTRANSITIONS / INCH

FIG. 4



RECORDED TRACK-ORIENTED CrO_2 DISK

FIG. 5a

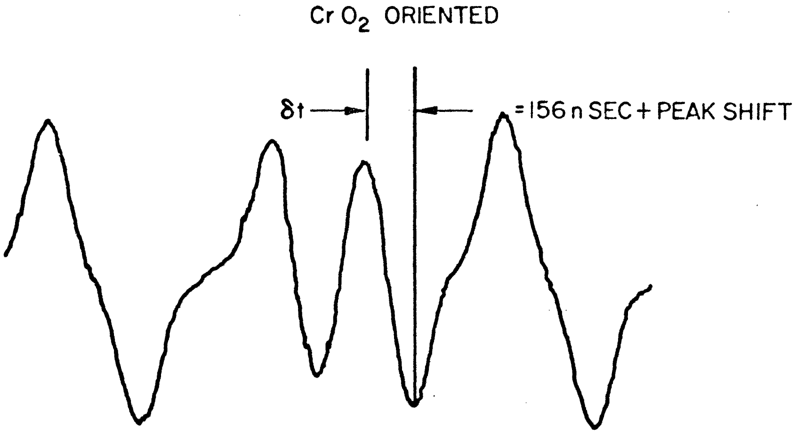


FIG. 5b