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MEASUREMENT OF MAGNETIC TEXTURE IN COBALT-PHOSPHORUS THIN FILMS

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Abstract. — In this work we report on a range of magnetic studies of cobalt-phosphorus thin films prepared by electroless deposition. From these measurements we have derived the distribution of easy axes within the film and attempted to correlate the results with the Interaction Field Factor for the films.

Introduction

Electroless plated thin films of magnetic alloys are widely accepted as the potential high density recording media for the next decade. The preparation technique commonly used for the deposition of cobalt-phosphorus films is due to Morton et al. [1]. The films are deposited on a nickel-phosphorus substrate previously coated by a similar process onto an aluminium disc for use as rigid recording media [2]. The films contain a small percentage of phosphorus to bring the magnetic properties to the specification required. The films are in the region of 100 nm thick with a grain size of about 40 nm [3].

In the absence of dipolar interactions between the grains, the films would be expected to be isotropic Stoner-Wohlfarth materials having a squareness ($I_r$) of 0.5. However it is commonly found that $I_r$ for these materials lies between 0.7 and 0.9 due to the strong interactions between the grains, which have an aligning effect on the moments.

The Ni-P substrate has grooves cut into it ($<0.5 \mu m$) with a fine diamond slurry. This seems to introduce anisotropic magnetic properties (known as textures in multiparticle systems) and there is an effective anisotropic distribution of easy axes induced in the plane of the film.

In this paper we report on measurements made by the often disregarded method of Shtrikman and Treves [4] in which the easy axis distribution $f(\alpha)$ is derived from the measurement of the remanence, in the plane of the film, perpendicular to the applied saturating field. We have attempted to correlate the results with the Interaction Field Factor (IFF) due to Corradi and Wohlfarth [5].

Experimental

In this study we have measured the properties of a range of commercially produced [2] samples. These were cut from 5" rigid discs and were themselves circular with a diameter of 1 cm. The direction of the grooves were marked on the samples.

All magnetic measurements were made using a PAR 155 Vibrating Sample Magnetometer with a resolution of $5 \times 10^{-5}$ emu. Field measurement was made using a Bell-Gauss Hall Probe calibrated with a Proton Magnetometer giving an accuracy of better than 0.05 % on measured values.

For each sample examined, the hysteresis loop, the DC demagnetisation remanence and isothermal remanent magnetisation (IRM) curves were measured in the direction parallel to the grooves. From these the IFF was calculated:

$$\text{IFF} = \frac{H'_r - H_r}{H_e} \times 100 \%$$

where $H'_r$ is the field required to produce half of the maximum remanence on the IRM curve and $H_r$ is the reverse field required to reduce the remanence of a saturated sample to zero.

According to [4] $f(\alpha)$ is given by:

$$f(\alpha) = 1 - \sum_{n=1}^{\infty} \frac{(4n+1)}{2n} \frac{(-1)^{n+1}}{(2n+1)} \frac{P_{2n}(\cos \alpha)}{2n+1}$$

$$\times \int_{-\pi}^{\pi} \frac{I_{r+}(\beta)}{I_s} \frac{P_{2n}'(\cos \beta)}{P_{2n}(\cos \beta)} \sin \beta \, d\beta$$

where $P_{2n}$ are the associated Legendre Polynomials, $\beta$ is the angle between the symmetry axis (i.e. the direction of the grooves) and the applied field and $I_{r+}(\beta)$ is the remanence perpendicular to the applied field. Thus the saturation remanence of the film was measured parallel ($I_{rP}$) and perpendicular ($I_{rt}$) to the applied field, using the sample rotation facility of the VSM.

Results and discussion

Figure 1a shows the hysteresis loop for a typical sample of the films we examined. The field direction was...
parallel to the symmetry axis. Superimposed on this are the IRM (b), and DC demagnetisation (c) curves, from which the IFF was determined. Data for other samples derived from results similar to figure 1 are shown in table I.

![Fig. 1. - Magnetic properties of Co-P thin films.](image1)

Table I. - Magnetic properties of cobalt-phosphorus thin films.

<table>
<thead>
<tr>
<th>Sample</th>
<th>( I_r )</th>
<th>( H'_r )</th>
<th>( H_r )</th>
<th>( H_e )</th>
<th>IFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.91</td>
<td>566</td>
<td>638</td>
<td>535</td>
<td>-13</td>
</tr>
<tr>
<td>2</td>
<td>0.83</td>
<td>860</td>
<td>890</td>
<td>835</td>
<td>-3.6</td>
</tr>
<tr>
<td>3</td>
<td>0.90</td>
<td>705</td>
<td>740</td>
<td>715</td>
<td>-4.9</td>
</tr>
<tr>
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<td>0.81</td>
<td>710</td>
<td>725</td>
<td>730</td>
<td>-2.0</td>
</tr>
<tr>
<td>5</td>
<td>0.76</td>
<td>631</td>
<td>635</td>
<td>599</td>
<td>-0.7</td>
</tr>
<tr>
<td>6</td>
<td>0.80</td>
<td>668</td>
<td>694</td>
<td>670</td>
<td>-4.0</td>
</tr>
</tbody>
</table>

Figure 2 shows the variation of \( I_{rp} \) and \( I_{rt} \) with angle for the samples to be considered. Figure 3 shows \( f(\alpha) \), the easy axis distribution.

The values of IFF measured along the symmetry axis are always negative. This implies that the samples are easier to magnetise than demagnetise. In general the average steepness of the \( I_{rt} (\beta) \) curve correlates with the size of the IFF. This would suggest that the anisotropic magnetic properties of the film are due to

![Fig. 2. - The angular dependence of remanence in Co-P thin films.](image2)

the interactions of grains with each other in the direction of the grooves. This would be because the grains that have grown in the grooves are slightly out of plane.

However, the IFF does not correlate with the average steepness of \( f(\alpha) \), which depends on the area under \( I_{rt} (\beta) \) as well as the shape.

**Conclusion**

From our results we concluded that the enhanced remanence arises from the dipolar interactions but that the magnetic texture had its origin in the presence of the grooves in the substrate, in which we get out of plane grains which interact with each other.

![Fig. 3. - The easy axis distribution \( f(\alpha) \).](image3)