COMPOSITION AND TEMPERATURE DEPENDENCE OF MAGNETIC TRANSITIONS IN SPUTTERED GdCo FILMS FOR MAGNETO-OPTIC DATA STORAGE

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COMPOSITION AND TEMPERATURE DEPENDENCE OF MAGNETIC TRANSITIONS IN SPUTTERED GdCo FILMS FOR MAGNETO-OPTIC DATA STORAGE

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Résumé - Le retournement de l'aimantation dans plusieurs couches minces Gd-Co de composition entre 20 et 46 % Gd, déposées par pulvérisation r.f., a été étudié par effet Kerr polaire à λ = 633 mm, sous des champs jusqu'à ± 10 kOe. Les observations à température ambiante montrent que certaines compositions, qui ne correspondent pas à celle pour laquelle une compensation de l'aimantation est attendue ($\sim$ 20/80), présentent une forte coercivité inhabituelle, jusqu'à 6 kOe, et des cycles d'hystérésis très carrés qui indiquent une anisotropie perpendiculaire intrinsèque significative. Le tracé de la coercivité en fonction de la composition met donc en évidence des maxima très marqués qui sont attribués à des transitions de structure du sous-réseau magnétique dominant dans le film, et semblent également se manifester par des maxima dans l'aimantation à saturation.

Des transitions magnétiques pour des compositions choisies sont aussi produites facilement par des variations thermiques. La dépendance en température de la coercivité des films correspond bien à celle requise pour un milieu magnéto-optique de stockage piloté par un faisceau.

Abstract - Magnetization reversal in a number of r.f. sputtered GdCo films with compositions in the range 20-46 at.% Gd has been studied using the polar Kerr effect at λ = 633 nm and drive fields up to ± 10 kOe. Room temperature observations show that some compositions other than that expected to achieve room temperatue magnetization compensation ($\sim$ 20/80) have unusually large coercivities, up to 6 kOe, and very square hysteresis loops indicative of significant inherent perpendicular anisotropy. The coercivity versus composition plot therefore shows some extremely sharp coercivity maxima which are thought to be associated with transitions in the magnetic dominance of the film subnetwork structure and also seem to relate to maxima in the saturation magnetization.

Magnetic transitions at selected compositions are also easily produced by a change in film temperature. The temperature dependent coercivity of these films is well suited to that required by beam addressable magneto-optic storage media.

INTRODUCTION

We report the existence of previously unknown magnetic transitions in GdCo. The sign of the polar Kerr effect at 633 nm in GdCo films has been observed to be an oscillatory function of film composition. Abrupt reversals have been recorded at Gd contents of 34 and 41.5 at.%. Sharp peaks in coercivity (H_c) measured along the film normal also occur at these compositions. Moreover, films with compositions immediately adjacent to both 36 and 41.5 at.% Gd may also be driven through the transition by varying their temperatures.

Lachowicz has noted that the Kerr rotation in GdCo originates principally from the

Co subnetwork and that consequently its sign may be used to determine which of the two subnetworks is dominant at any particular composition and temperature.

In GdCo the saturation magnetization (M_s) has a strong compositional and temperature dependence. It is well known that at room temperature M_s passes through zero at some composition between 18 and 22 at.% Gd as the magnetic contributions from the anti-ferromagnetically coupled Co and Gd subnetworks compensate. Compensation is accompanied by a peak in coercivity as well as a change of sign in the polar Kerr effect as the Gd subnetwork assumes dominance from the previously dominant Co subnetwork. Compensated or near compensated films also exhibit a characteristic perpendicular anisotropy with easy axis along the film normal. Films with compositions such that their behaviour is Co-dominant at room temperature require cooling to achieve compensation, their compensation temperature (T_{comp}) is below room temperature. Conversely, T_{comp} is above room temperature for Gd-dominant films with compositions on the high Gd side of the room temperature compensation point. Such films may be heated through compensation.

Implicit in most of the published literature on GdCo is the understanding that once the Gd-network establishes dominance at room temperature (i.e. when the Gd content reaches $\simeq$ 20 at.%) it thereafter remains dominant at all compositions with higher Gd content. All such compositions should therefore attain compensation at temperatures above room temperature. The further transitions in dominance, implied by the polar Kerr effect reversing sign at compositions well removed from the room temperature compensation point, are not anticipated in any existing literature.

PREPARATION AND MEASUREMENT TECHNIQUES

A Nordiko 2000M r.f. sputtering system running at an argon pressure of 10 mtorr was used to prepare a selection of films with compositions in the range 22-46 at.% Gd. Compositional variation was achieved by the use of mosaic targets of Co on Gd or Gd on Co augmented as necessary by negative substrate bias for fine tuning. The deposited composition was determined from the actual sample using a Philips 9100/60 energy dispersive X-ray analysis unit. All films were deposited to a thickness of 1 µm on their glass substrates and coated with a protective layer of SiO_2 before removal from the system.

Polar Kerr rotations were measured at normal incidence using a He-Ne laser source in a Newport A-type electromagnet producing fields up to ± 10 kOe. The hysteresis loops were obtained by plotting the rotation as a function of applied field. During these measurements the samples were mounted on either a Peltier stage permitting temperature excursions between -20°C to +50°C or on an electrically heated aluminium block to achieve temperatures up to +200°C.

RESULTS

Table I lists the sign and magnitude of the polar Kerr rotation measured at 633 nm for films with different compositions. When this is examined in conjunction with Fig.(1) it can be seen that these reversals in sign coincide with peaks in coercivity.

Gd content at.%	polar Kerr rotation min
22.0	- 15.01
23.1	- 12.43
25.5	- 11.01
30.6	- 11.50
33.7	- 13.86
34.6	+ 13.70
37.0	+ 11.91
37.7	- 10.55
39.0	- 9.10
40.9	+ 9.10
43.0	+ 7.11
45.3	+ 7.82
45.9	+ 7.98

Table I: The variation of polar Kerr rotation with film composition.

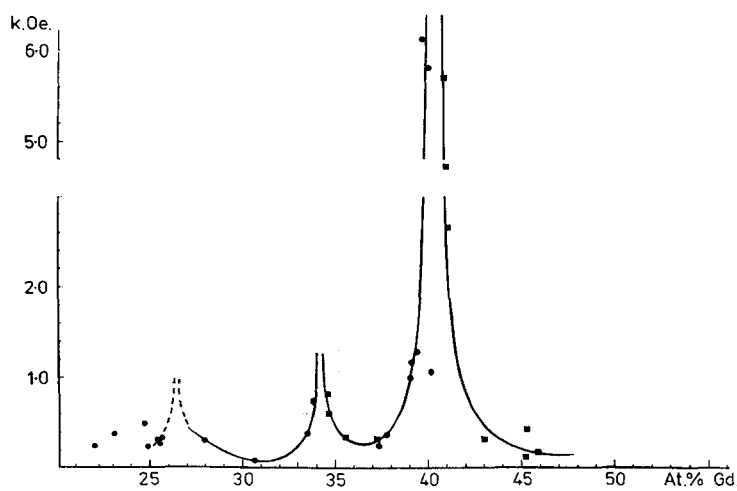

Fig.(1) The compositional variation of coercivity in GdCo films.

Hysteresis loops showing (A) Co and (B) Gd dominated behaviour observed immediately either side the peak centred at 34 at.% are shown in Fig.(2). The sequence of loops depicted in Fig.(3) shows the change in behaviour that occurs for only a 2% increase in Gd content across the transition at approximately 41 at.% Gd.

The thermomagnetic properties of the films are illustrated in Figs.(4) through (6). Sample (B) of Fig.(2) has a composition of 36.4 at.% Gd. Its hysteretic behaviour as a function of temperature is shown in Fig.(4). The coercivity of this sample shows a clear peak as it executes a transition in subnetwork dominance at approximately 47°C, see Fig.(5). Sample (A) of Fig.(2) shows similar behaviour, but being Co dominant at room temperature, has a transition temperature of $\simeq$ - 5.5°C, see also Fig.(5).

Films with compositions close to the coercivity peak at 41 at.% Gd show much the same behaviour. Fig.(6) shows a transition occurring at approximately 36°C in a film Gd dominant at room temperature.

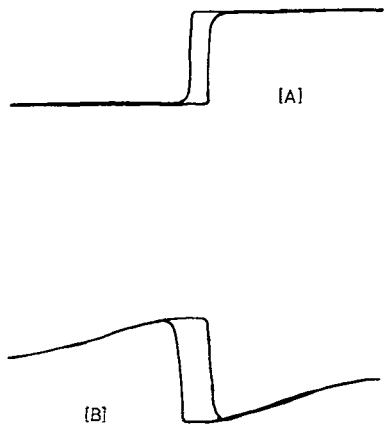

Fig.(2) Square hysteresis loops obtained either side the peak in coercivity at ≃ 34 at.% Gd. (A) Co dominated (B) Gd dominated. Drive fields ± 10 kOe.

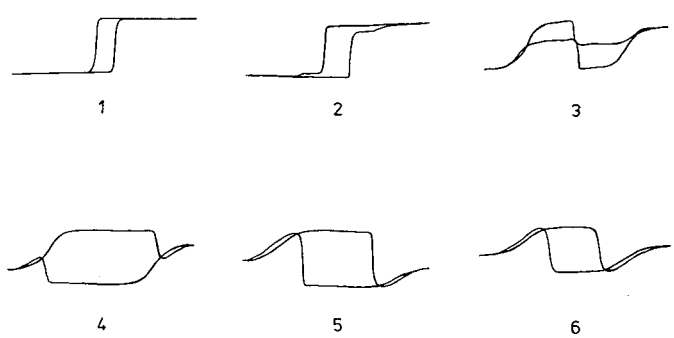

Fig.(3) The compositional dependence of the hysteresis loops across the coercivity peak at 40 at.% Gd. The Gd content increases by 2 at.% between 1 and 6. Drive fields ± 10 kOe.

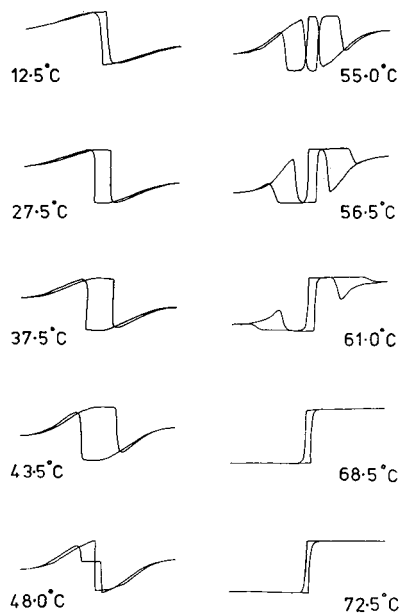

Fig.(4) The hysteretic behaviour of a film with a Gd content of 36.4 at.% as a function of temperature.

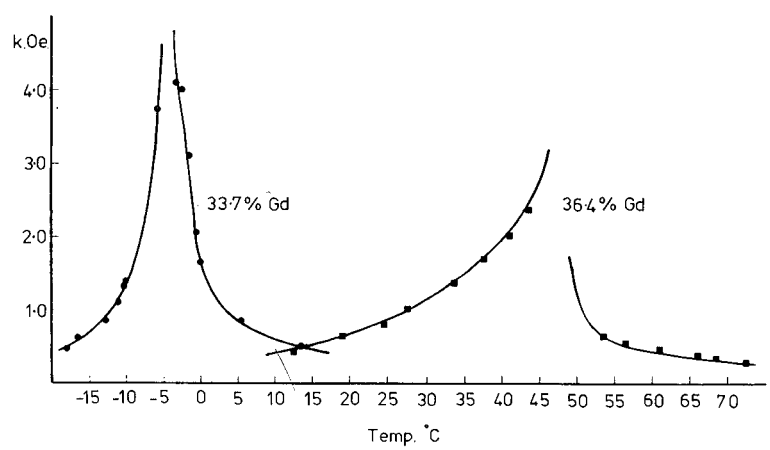

Fig.(5) The temperature dependence of the coercivity for films with compositions either side the peak in coercivity at a Gd content of 34 at.%.

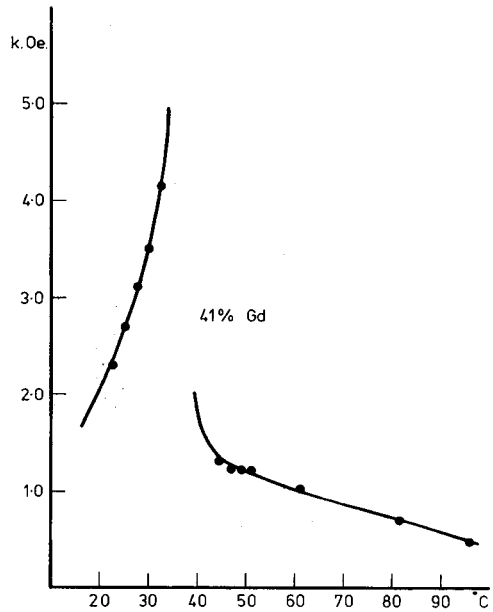

Fig.(6) The variation of coercivity with temperature for a film with 41 at.% Gd.

DISCUSSION

Apparent transitions in magnetic subnetwork dominance have been observed in GdCo films at compositions close to 34 and 41 at.% Gd. A change in subnetwork dominance is usually taken to indicate compensation. However, although the magnetic and thermomagnetic behaviour illustrated in Figs.(2) through (6) is analogous to that observed at the room temperature compensation point, it is not likely that compensation is occurring at these compositions. The temperatures at which these transiditions occur are incompatable with the compensation temperatures predicted in published work. According to Chaudhari[2] compositions with Gd contents around 30 to 40 at.% should have compensation temperatures between 200 and 250°C. Moreover, compensation temperatures below room temperature should not be observed at these or any other composition above approximately 20 at.% Gd. Secondly, at the room temperature compensation point $|M_s|$ is a minimum (zero) with respect to composition and temperature. At the compositionswhere we observe these new transitions, $|M_s|$ is close to a maximum as a function of composition[3] with a value ≃ 25% that of pure cobalt

The precise origin of these new transitions in GdCo films remains the subject of further investigation.

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