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IMPROVED PROPERTIES OF Co-Cr MADE BY CO-EVAPORATION [1]

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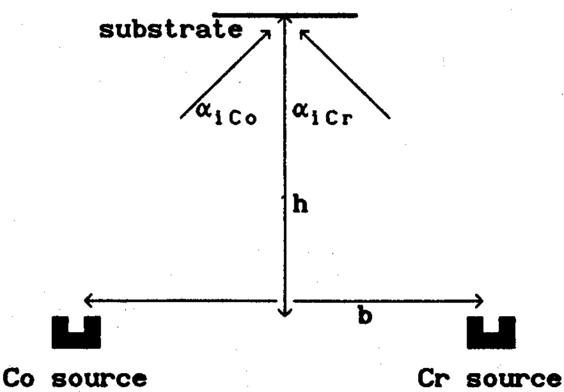
Abstract. – CoCr was made by a co-evaporation process. Good properties could be obtained by applying a Ti seedlayer. Furtheron we confirmed that "process-induced" segregation, resulting in increased perpendicular coercivity, can be controlled by angle of incidence.

1. Introduction

Previously we reported on deposition of Co-Cr by co-evaporation under intermediate oblique incidence and opposing vapour stream [1]. The present paper is on the improvement of the material and magnetic properties by applying a Ti seedlayer. We also show results which confirm our assumptions on the influence of the angle of incidence in the formation of a process-induced segregated state, which causes moderate perpendicular coercivity ($H_{c\perp}$) at low process temperatures (T_p). The experiments have been carried out using the basic configuration in our Leybold L560 vacuum system [1]. The applied geometries are shown in figure 1.



	Geo I	Geo II	Geo III
α_{iCo}	21°–31°	0°–6°	15°–21°
α_{iCr}	21°–31°	29°–35°	16°–21°
b (mm)	250	150	150
h (mm)	260	260	260

Fig. 1. – Process geometries applied in our experiments.

2. Co-deposition of Co-Cr on a Ti seedlayer

It has been shown that the structural properties and texture of the Co-Cr layers is influenced by the surface condition of the substrate [2]. In our experiments we applied Ti as a seedlayer for the Co-Cr. We used Si-wafers as a substrate. Deposition was done without etching of the surface, only rinsing by alcohol was applied. The Ti layers were deposited at $T_p = 30$ °C and a standard thickness $\delta_{Ti} = 35$ nm was applied. Geo I was used and Ti was deposited from the same position as the Cr. Also in our process we obtained an improvement of the orientation of the Co-Cr ($\Delta\theta_{50}$). A comparison between the main properties of Co-Cr and Co-Cr/Ti layers is given is table I. Investigations on the influence of δ_{Ti} (7-70 nm) showed that $\delta_{Ti} > 10$ nm, the magnetic properties were independent. In figure 2, the characteristic relation $H_{c\perp}$ *vs.* M_s is given. At low T_p it shows a tendency to lower $H_{c\perp}$ when applying the Ti. This can be understood by assuming changing substrate conditions, resulting in changes in the morphology of the layers. Related to this is the fact that we find lower H_c values in the region where domain-wall motion is the supposed magnetisation reversal mechanism (at high M_s values and in the in-plane direction).

Table I. – *Comparison between a single layer* Co-Cr *and a* Co-Cr *layer deposited on 35* nm Ti.

	Co – Cr	Co – Cr/Ti
Orientation of the hcp c–axis $\Delta\theta_{50}$	12° – 15°	4° – 6°
Perpendicular coerc. $H_{c\perp}$	similar	
In – plane coerc. $H_{c\parallel}$	24 – 35 kA/m	8 – 20 kA/m
Anisotropy constants tilt of the direction K_1, K_2, γ_a	similar	

3. Angle of incidence effects

Our most remarkable result was the appearance of higher $H_{c\perp}$ at low T_p [1]. This was explained to be attributed to the process-induced segregated state caused by shadowing effects. In order to investigate this phenomenon, we performed deposition under several process geometries (see Fig. 1). Deposition was done at $T_p = 50$ °C and $\delta_{CoCr} \sim 0.3$ μm. A Ti seedlayer was applied for Geo II and III. In figure 3 the $H_{c\perp}$ *vs.* M_s characteristic is given. Clearly the influence of the angle of incidence is shown. For decreasing angle between Co and Cr incidence direction, the $H_{c\perp}$

[1] Sponsored by European Community and Leybold AG, Alzenau, F.R.G.

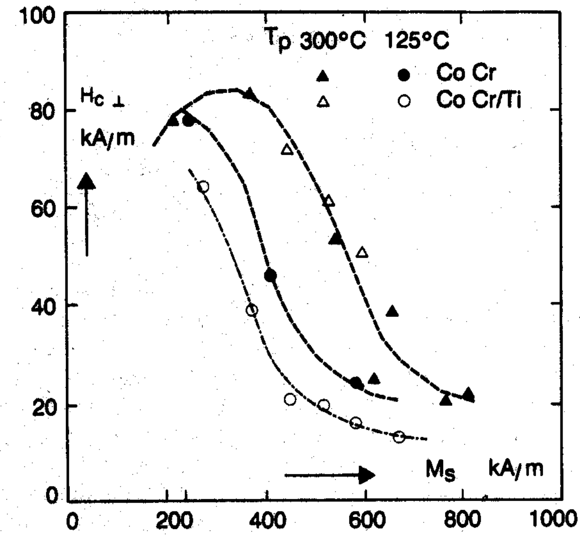


Fig. 2. – Influence of Ti seedlayer of the $H_{c\perp}$-M_s characteristic.

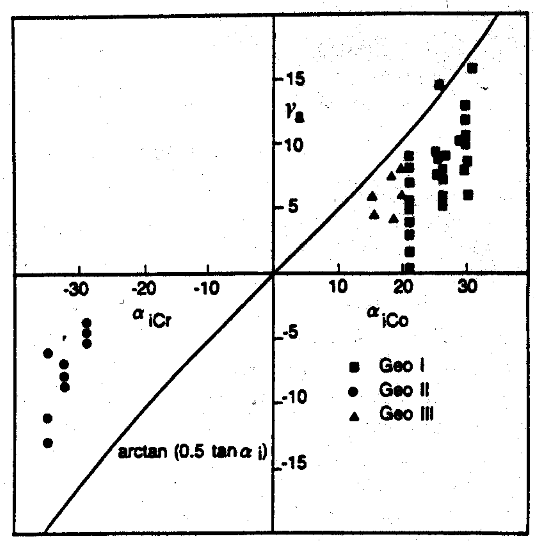


Fig. 4. – Tilting of the magnetic anisotropy axis, γ_a, as a function of the angle of incidence.

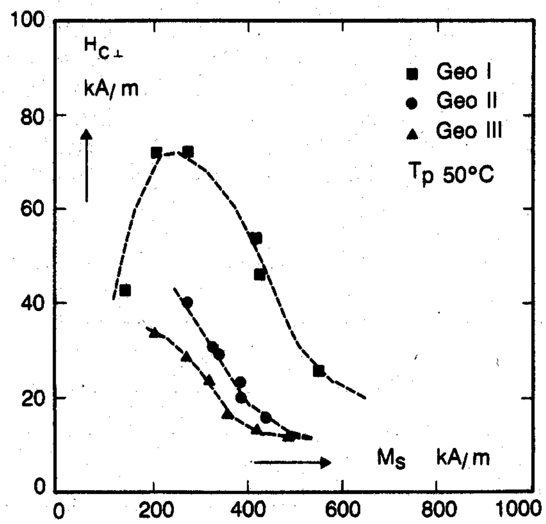


Fig. 3. – Influence of geometry on the $H_{c\perp}$-M_s characteristic.

(0.5 tan α_i) is plotted. This line gives an approxima-shows lower values, thus confirming our assumptions on the influence of shadowing effects.

We also analysed the samples by Torque-curve measurement and the model of [3]. The magnetic anisotropy constants K_1 and K_2 are similar for all geometries. More significant is the influence on the tilting of the anisotropy axis (γ_a). In figure 4 we plotted γ_a as a function of a characteristic angle of incidence. Here we take α_{iCo} for Geo I and Geo III and α_{iCr} for Geo II. In the figure we plotted most of our data from Torque-curve measurements, also from experiments in which we changed the position rates at the initial stage of film growth (low Co-rate). Also the line γ_a = arctan

(0.5 tan α_i) is plotted. This line gives an approxima-tion for tilting of columns in single source deposition [4]. The observed values of γ_a are all smaller than this calculated value, which could also be expected for our deposition process. Remarkable is the fact that for Geo II in which $\alpha_{iCo} \sim 0°$ (almost 70-80 at % of the material is Co) we find a significant tilting towards the Cr source.

4. Conclusions

Application of the seedlayer material Ti showed excellent structural properties for the Co-Cr layer ($\Delta\theta_{50} \sim 4°$). Furthermore, our experiments on angle of incidence effects gives understanding of the fundamental growth mechanism of Co-Cr. Increased $H_{c\perp}$ at higher α_i shows the relation between the shadowing effects, the "process-induced" segregated state and magnetisation reversal mechanisms [1]. The intermediate oblique incidence did not significantly influence the value of the magnetic anisotropy energy but only the direction of the anisotropy axis. Good balancing of the rates and angle of incidence of the sources will result in good material and magnetic properties for perpendicular magnetic recording.

[1] Pronk, F. A. and Lodder, J. C., *IEEE Trans. Magn.* **24** (1988) 1744.

[2] Futamoto, M., Honda, Y., Kakibayashi, H. and Yoshida, K., *IEEE Trans. Magn.* **21** (1985) 1426.

[3] Swaving, S., Gerritsma, G. J., Lodder, J. C. and Pompa, Th. J. A., *J. Magn. Magn. Mater.* **67** (1987) 155.

[4] Feuerstein, A. and Mayr, M., *IEEE Trans. Magn.* **20** (1984) 51.