ION MIXING EFFECT ON THE STRUCTURAL AND MAGNETIC PROPERTIES OF CoCr FILMS FOR PERPENDICULAR RECORDING

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Abstract. – Influence of mass, energy and dose of bombarding ions are considered. The trends are: 1) a better c axis orientation; 2) a progressive disappearance of the transition layer and 3) a way of controlling the saturation magnetization M_s and the perpendicular coercive field $H_{c\perp}$.

Introduction

The properties of sputter deposited CoCr are sensitive to polycrystalline structure, composition and deposition parameters [1]. Moreover there are heterogeneous properties along the film thickness. Here is studied ion mixing (IM) i.e. rare gas ion bombardment, in sputtered CoCr films. IM can be applied either below or above a critical temperature T_c. This T_c is defined as the upper limit below which matter is made amorphous under the effect of ion irradiation. Up to now IM experiments in ferromagnetic materials were made below T_c. Here, IM is considered above T_c. Then, the ion perturbation produced in the sample is annihilated by simultaneous thermally induced rearrangements of atoms. Therefore, in this regime, if matter is inclined to a specific crystal growth along a definite direction, this tendency will be sped up under the influence of radiation enhanced diffusion of point defects within cascades.

Experimental procedure

The CoCr films were deposited by R.F. diode sputtering either onto silicon or glass substrates from a 22 at % Cr alloy target. The target to substrate distance, the Ar gas pressure, the input RF power and initial substrate temperature were respectively 45 mm, 5×10^{-3} mb, 700 W and 50 °C. IM has been carried out either at high energies with a Van der Graaff accelerator or at low energy with a conventional implantor. In the first case, where 300 nm thick samples were fully irradiated with Kr^+, two energies were chosen according to the average projected range R_p and the projected standard deviation ΔR_p. It is either 1.3 MeV leading to a $R_p + \Delta R_p = 300$ nm, or 2 MeV in order to have the bombarding Kr^+ ions well beyond the CoCr layer. In the second case, IM was first performed in a very thin CoCr layer (around 80 nm) with Xe^+ ions, then the sputtering deposition was completed up to the final 300 nm thickness. In consequence of preliminary investigations, room temperature IM was finally adopted for these studies with CoCr.

X-ray diffractions were used to get the degree of c orientation from $\Delta\theta$ 50 measurements and the average grain size diameter ($\emptyset$). Static magnetic properties were determined by a vibrating sample magnetometer (VSM) while X-band ferromagnetic resonance (FMR) spectra were taken with the applied field in both configurations, perpendicular and parallel to the film plane. With CoCr, these spectra at 9 GHz cannot be used to get quantitative measurements. They only give good qualitative informations on layer homogeneities and serve as sensitive comparison base between samples [2].

Results and discussion

First is considered the energy effect of the bombarding Kr^+ ions on the IM processes. In figure 1 FMR spectra are shown in both configurations for 300 nm thick samples of as-grown and ion-mixed samples at respectively 1.3 and 2 MeV *vs.* dose (i.e. 10^{14}; 6×10^{14}; 1.1×10^{15} and 5×10^{15} Kr^+ cm^{-2}). It can be seen that: 1) the spectra of the as-grown sample con-

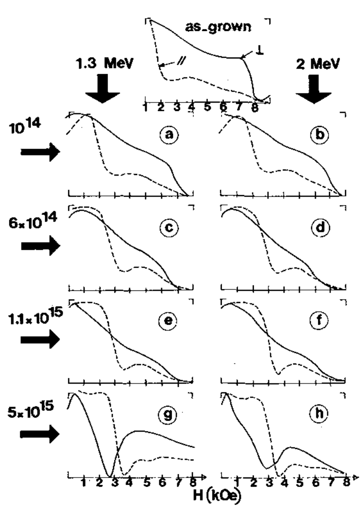

Fig. 1. – FMR spectra of CoCr films *vs.* Kr^+ dose at 1.3 MeV and 2 MeV.

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sist of only one mode in both configurations showing that the as-grown layer is already rather homogeneous [3]; 2) as the dose increases the perpendicular mode goes towards smaller while the parallel mode goes towards higher fields crossing each other above 1.1×10^{15} Kr^+ cm^{-2}. This would correspond to an increase of the effective anisotropy $\left(K_{eff} = K_u - 2\,\pi M^2\right)$ due to an increase of the magneto-crystalline anisotropy K_u or/and a saturation magnetization M_s decrease; 3) the amazing similarity of the energy effect at the same doses pointing out the likeness of IM mechanisms whether Kr^+ remains within or goes beyond the layer. Figure 2 shows the $\Delta\theta$ 50 and $\emptyset$ *vs.* doses for 2 MeV Kr^+ cm^{-2}. IM favors a progressive *c*-axis alignment along the film normal as the dose increases. On the other hand grain size increases 20 % above the as-grown value for rather low doses (3 to 4×10^{14} Kr^+ cm^{-2}) and then remains constant.

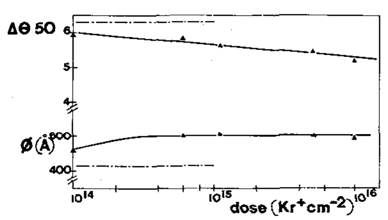

Fig. 2. – $\Delta\theta$ 50 and $\emptyset$ *vs.* Kr^+ dose at 2 MeV. (·—·) as-grown value.

In figure 3 are displayed $H_{c\perp}$, M_s and in-plane relative remanence $m_{r\parallel}$, values as a function of dose. Apart from $H_{c\perp}$, which seems to decrease systematically a little faster with dose for 1.3 than for 2 MeV Kr^+ ions, there are no discernible variations of M_s and $m_{r\parallel}$ for the two chosen energies. The latter observation backs up the remark 3 above referring to figure 1. The straightforward interpretation of the $H_{c\perp}$ and M_s reduction with dose would be the atomic scale redistribution in CoCr of segregated Cr. The decrease of $m_{r\parallel}$ could be explained through a better grain size distribution and crystalline orientation along the film thickness.

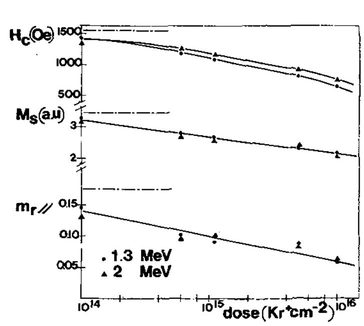

Fig. 3. – $H_{c\perp}$, M_s and $m_{r\parallel}$ *vs.* Kr^+ dose. (·—·) as-grown value.

Perpendicular hysteresis loops of highly ion-mixed CoCr as compared to the as-grown layer, besides the $H_{c\perp}$ and M_s decreases, are characterized by shoulders which features are typical of continuous media [4]. It has also been shown that IM effects in CoCr films are not substrate dependent and that it can suppress the high field mode of FMR spectra in perpendicular configuration, corresponding to the " $4\,\pi M_s$ " resonance due to a "soft" transition layer [3]. A second deposition onto this ion-mixed layer does not recreate a new random oriented layer.

Conclusion

A new means of modifying CoCr properties through IM is presented. The structural homogeneity along the film normal is improved by suppressing the transition layer and by reducing the dispersion of the hcp *c*-axis perpendicular to the film plane. The reason put forward is radiation induced diffusion enhancing a natural thermally activated growth process along a certain crystallographic direction.

The $H_{c\perp}$, M_s and $m_{r\parallel}$ are reduced at will by conveniently choosing the dose. Segregated Cr at grain boundaries is redistributed within the alloy, reducing $H_{c\perp}$ and M_s. The change in $m_{r\parallel}$ is correlated with the structural realignment. The effective anisotropy change for the better is displayed by the evolution of FMR spectra with dose. K_{eff} is directly correlated to the reduction of $\Delta\theta$ 50 and of M_s leading respectively to a K_u increase and a demagnetizing energy decrease. Whether the ion chosen ends its trajectory at the bottom or beyond the layer has almost no effect on the final properties. This would seem to prove that stresses have little action on IM processes so far as the crystalline growth and orientation are concerned. Substrates have no determining effects on the ion-mixed CoCr layers. A last argument acting in favor of IM is that a thin ion-mixed layer can be used as seeding underlayer to make thick CoCr films with no transition layer.

Acknowledgments

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