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Journal of Magnetism and Magnetic Materials 290–291 (2005) 82–85
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Thermal stability of magnetic properties in ternary and quaternary Co-based alloy thin-film media

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Available online 8 December 2004

Abstract

Co-based alloy thin films for longitudinal recording media are analysed. The magnetic stability of such media is studied with measurements of magnetization decay and of coercivity variation with the applied field sweep rate. The analysed films have different composition (ternary and quaternary Co alloy) and different thickness. Consequently they show different stabilities. Besides, the magnetization switching of the various films is diversified, as indicated by the rotational hysteresis analysis. The impact of such evolution on the thermal stability of the magnetic properties of the thin-film media is underlined.

PACS: 75.60.Lr; 75.50.Ss; 75.70.−i; 75.60.Jk

Keywords: Stability; Magnetic recording media; Thin films; Reversal mechanism

The magnetic layers of recording media are in most cases constituted by Co-based alloy thin films, deposited over a Cr, or Cr alloy, underlayer to control the texture and the morphology of the magnetic layer. The segregation, i.e., exchange decoupling, among the ferromagnetic grains, necessary to improve the magnetic behaviour, is obtained mainly with the addition of different elements to ferromagnetic Co, and it is the main aim of the use of alloys for the magnetic layer. The increase of linear density of informations imposes to decrease the layer thickness and the grain size of the magnetic thin film, to reduce demagnetizing field and maintain acceptable signal–noise ratios [1]. It has a negative impact on the thermal stability of the magnetic properties of the films, since it can result in heights of the energy barriers for the magnetization not very far from the thermal energy. In this work the magnetic stability of recording media whose magnetic layer is constituted of ternary (CoCrTa) and quaternary (CoCrPtTa) Co alloy thin films is studied and compared, and the effect of the magnetic layer thickness on the same stability is investigated.

The thin-film media we have analysed are industrial products. The ternary alloy magnetic layers, with composition $Co_{85}Cr_{13}Ta_2$, are deposited on a 50-nm-thick Cr underlayer over 2.5 in glass–ceramic disks. A carbon protective layer with a 5 nm thickness is deposited on the magnetic layer. The magnetic films have different thickness ranging from 10 to 30 nm. The quaternary alloy thin films have composition $Co_{71}Cr_{18}Pt_9Ta_2$. The magnetic layer is deposited on a 30 nm $Cr_{80}V_{20}$ underlayer, on top of a glass substrate, and protected with a 7 nm carbon overlayer. The analysed films have thickness of 10 and 15 nm. All depositions are by DC magnetron sputtering. Both alloys have hexagonal close-packed (HCP) structure,

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0304-8853/$ - see front matter
doi:10.1016/j.jmmm.2004.11.217

with good orientation of the grain easy axes parallel to the film plane [2]. The main properties of the media are reported in Table 1. We firstly observe that the coercivity increases when the film thickness decreases and that H_c is larger in quaternary than in ternary Co-based alloy films with the same thickness.

The energy barrier which opposes the magnetization reversal of a uniaxial anisotropy Stoner–Wohlfarth single particle is given by $\Delta E = KV(1-H/H_k)^2$, where K and H_k are the anisotropy constant and field, V the particle volume and H the applied field [3]. In a system of identical, non-interacting particles, the dynamics of the magnetization is described by

$$dM/dt = f_0 M \exp(\Delta E/kT) \tag{1}$$

(Arrenhius–Néel law). The solution of Eq. (1) is the exponential dependence of the magnetization on time, which is not frequently observed, since in real systems dispersions of size and anisotropy of the particles/grains are almost unavoidable. Consequently, a distribution of energy barrier $f(\Delta E)$ appears, and the dynamics of the magnetization is modified. Taking account of such distribution, two approximated solutions of the magnetization dynamics equation have been derived. The first one gives the time dependence of the average magnetization in the presence of a steady magnetic field

$$M(t) = C - S\ln(t/t_0), \tag{2}$$

where $t_0 = 1$ s and S is the coefficient of magnetic viscosity (magnetization decay) [4]. This expected linear dependence of M on the logarithm of time, at least along some decades, is frequently observed.

The second solution obtains the dependence of the coercivity on the sweep rate of the applied field during the hysteresis cycle, dH/dt, from the variation of the magnetization with the field sweep rate [5,6]. Such expected dependence is

$$H_c = c + \frac{kT}{V^* M}\ln\left(\frac{dH}{dt}\right), \tag{3}$$

where V^* is an effective volume. Recently, it has been shown that the Eqs. (2) and (3) are essentially equivalent [7].

Table 1
Properties of the analysed thin-film media

Film	Thickness (nm)	$M_r t$ (memu/cm^3)	H_c (Oe)	V^* (cm^3)
CoCrTa	10	0.59	2650	1.3×10^{-18}
CoCrTa	20	0.90	2100	1.5×10^{-18}
CoCrTa	30	1.51	1900	1.6×10^{-18}
CoCrPtTa	10	0.54	2850	3.5×10^{-18}
CoCrPtTa	15	0.78	2500	2.5×10^{-18}

We experimentally analysed the thermal stability of the magnetic properties of the above-described media both measuring the magnetization decays (Eq. (2)) and measuring the coercivity variations (Eq. (3)).

Fig. 1 shows the magnetization decays, in the presence of a field close to coercivity, where the decays are the fastest, for analysed films. The decay results are slower and the magnetic viscosity S smaller in the quaternary CoCrPtTa film media than in the ternary CoCrTa ones, which indicates better stability of former media. Comparing films with different thickness, the behaviour of the two kinds of media is diversified. In ternary films, the decay becomes faster and S increases when the thickness decreases, indicating that in CoCrTa, as expected, the stability weakens when the thickness decreases. The CoCrPtTa films, surprisingly, do not follow this evolution, and the 10 nm film is more stable than the 15 nm film (slower decay and smaller viscosity S).

Fig. 2 shows the observed dependence of coercive field on the logarithm of the applied field sweep rate dH/dt for the analysed media. The quaternary films have a minor variability of H_c than the ternary films. The linear plots for CoCrPtTa have slopes ranging from ~20 to ~28 Oe, those of CoCrTa from ~43 to ~56 Oe. Comparing different composition films with the same thickness, we see that 10 nm-thick CoCrPtTa film has a slope of 19.5 Oe, against a slope of 55.7 Oe of 10-nm-thick CoCrTa film. The values of V^*, reported in Table 1, indicate that such volume is larger in quaternary than in ternary Co-alloy thin films. Such feature, consistently with the observed smaller variability of coercivity, reports for a better magnetic stability of CoCrPtTa film media. The slopes of the lines in Fig. 1 also show that in CoCrTa films, the stability weakens when the film thickness decreases. Accordingly, V^* is smaller (Table 1) in thinner films. In CoCrPtTa, the 10 nm film is more

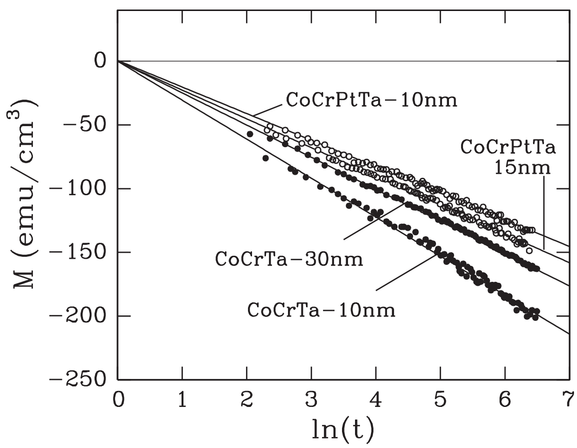

Fig. 1. Magnetization decays of the ternary and quaternary Co-based alloy thin films with different thickness.