Multi-state perpendicular remanence in Co/Pd multilayers

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Abstract

Co/Pd multilayers deposited on Si (1 1 1) by electron gun evaporation were investigated. The magnetization measurements indicated out-of-plane easy magnetization direction for the samples with small Co layer thickness. The normal-to-the-plane remanent magnetization curves of the sample with Co layer thickness of 4 Å show four well-defined levels depending on the field strength and direction. Each of these levels can be obtained by applying a broad range of fields making them easily accessible, and the high field remanence levels are lower in intensity than the low field ones. This seems to be an effect of competing magnetic anisotropies of different nature present in the samples. The coercive and switching fields, the remanence and all others technological requirements may eventually be tailored for a proper high-density recording media. © 2001 Elsevier Science B.V. All rights reserved.

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Perpendicular magnetic recording has been widely regarded as a method to achieve ultra-high-density recording. Co/Pd and Co/Pt multilayers containing thin Co layers have been extensively studied and considered to be promising candidates for perpendicular magnetic recording media [1–5] and magneto-optical recording media [6,7]. The density of bits in the present magnetic media, however, is bound to reach a limit either in materials where the recording is made longitudinally or in those where it is made perpendicularly.

One possibility to increase the storage capability is to make the media capable to withstand different levels of magnetic remanence in the same physical space (multistate bit), so that an alternative to the conventional binary recording scheme could be used.

The present work reports on the magnetization behavior of Co/Pd multilayers, where the Co layer thickness $t_{Co}$, is varied between 2 and 6 Å. [Co($t_{Co}$ Å)/Pd(15 Å)]$_{50}$ multilayers were deposited on Si (1 1 1) substrate by successive electron beam evaporation at 300 K. The pressure before deposition was 10$^{-9}$ mbar and the deposition rate was around 1 Å/s.

The structural characterization of the samples was made by CuK$_a$ X-ray diffraction in a 0–20 geometry in both low- and high-angle regions, and indicated highly (1 1 1)-textured Pd structure. Due to the low thickness of Co layers, the Co(200) or (1 1 1) peaks are small or invisible, and the stacking sequence (HCP or FCC) could not be uniquely determined.

Room temperature magnetization measurements were performed using an alternating gradient magnetometer. They indicated out-of-plane easy magnetization direction for the samples with small Co layer thickness, $t_{Co} < 6$ Å. None of the samples presented in-plane anisotropy. In Fig. 1, the perpendicular hysteresis loops for $t_{Co} = 2, 3, 4$ and 6 Å are plotted (the values are normalized to the saturation magnetization $M_s$). The loops show almost straight magnetization lines with a characteristic sharp knee for the samples with $t_{Co} < 6$ Å. The knee is normally attributed to domain-wall nucleation field; after nucleation, the domain walls move freely and the magnetization curve follows a straight line [8]. However, this explanation does not seem to hold for the samples under consideration because of their very small $t_{Co}$; it is difficult for one to imagine a domain wall formation in such samples.

The remanence and the coercivity decrease with increasing $t_{Co}$. 

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The normal-to-the-plane isothermal remanent magnetization curves $M_r(H)$ and the DC demagnetization remanence curves $M_d(H)$ for the samples with $t_{Co} = 2$, 3, 4 and 6 Å are shown in Fig. 2. The $M_d(H)$ curve is measured at first saturating the sample in a positive field and then measuring the remanence $M_d(H)$ after application and removal of negative fields. The $M_r(H)$ is instead obtained by applying and removing the field $-H$ to the demagnetized state; all curves are normalized to $M_r(\infty)$.

The most interesting feature of these remanence curves is the very unusual shape for the sample with $t_{Co} = 4$ Å. Each of the curves shows two well defined remanent magnetization levels depending on the field strength. Each of these levels can be obtained by applying a broad range of fields. The high field remanence levels are lower in intensity than the low field ones. The $M_d(H)$ and the $M_r(H)$ curves for $t_{Co} = 3$ Å also show (insignificant) minimum and maximum, respectively.

This phenomenon can be attributed to competing magnetic anisotropies of different nature present in the samples. Ultra-thin films provide conditions where uniaxial and cubic anisotropies may co-exist. Recent studies on such systems have revealed some interesting features, e.g. negative remanence in some cases, and a minimum in the $M_d(H)$ curve for a CoCu thin film [9,10]. Although more studies must be performed in order to understand the origin of this effect (investigations of the domain structure, the anisotropies involved, etc.), it can be interpreted by considering the sample with $t_{Co} = 4$ Å as a fine-particle system. The four remanent magnetization levels can be assigned to the saturation remanence contributions of some particles [10]. In the $M_d(H)$ curve, each of these particles has negative remanence for fields up to a certain value. For higher magnetic fields, the remanent magnetization is positive, resulting in an increase of the total remanent magnetization.

The four very distinct remanent magnetization levels in the same physical area of the sample with $t_{Co} = 4$ Å make it promising for use in the high-density recording. The coercive and switching fields, the remanence and all others technological requirements may eventually be tailored for a proper media.

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References