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Magnetization reversal behavior of nanogranular CoCrPt alloy thin films studied with magnetic transmission X-ray microscopy

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Abstract

Magnetic transmission soft X-ray microscopy has been used to study element—specifically the magnetization reversal behavior of $(\text{Co}_{84}\text{Cr}_{16})_{87}\text{Pt}_{13}$ alloy thin films with a lateral resolution of 35 nm. Our results indicate that the magnetization switching is carried out by a random nucleation process that can be attributed to the reversal of individual grains. We found evidence of a large distribution of the switching fields at the nanogranular length scale, which has to be considered seriously for applications of CoCrPt systems as magnetic high-density storage materials.

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1. Introduction

CoCr-based alloy films have received significant attention as possible high-density magnetic recording media because of their strong magnetic anisotropy and a low media noise due to the decoupling of exchange interaction between the

magnetically isolated grains via the compositional segregation at grain boundaries [1,2]. In particular, CoCrPt alloy films have attracted considerable interest, since they provide desirable magnetic properties such as high coercivity and strong perpendicular magnetic anisotropy (PMA) for high-density recording [3,4].

In order to achieve high-density magnetic recording media, the magnetization reversal behavior on a submicron length scale is crucial since it is closely related to the size, irregularity, and

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stability of written domains [5,6]. So far, most of the studies on CoCrPt alloy films concentrated on the control of the grain size and the grain size distribution, which is essential to media processing and to suppress the media noise by reducing the intergranular exchange interaction between the neighboring grains [7–9]. Studies of magnetization reversal of CoCrPt alloy films published so far have been performed by macroscopic measurement techniques as well as by theoretical magnetization reversal models [10,11]. Therefore, no experimental evidences are available on magnetization reversal behavior in CoCrPt alloy films at the nanogranular size level, which is mainly due to the resolution limitation of the macroscopic measurement techniques employed.

Magnetic soft X-ray transmission microscopy (MTXM) combining X-ray magnetic circular dichroism as an element-specific magnetic contrast mechanism with soft X-ray microscopy offering a high lateral resolution provided by Fresnel zone plate optical elements has been established recently [12,13]. Here we report results of experimental studies on magnetization reversal behavior in CoCrPt alloy films on a length scale of the underlying nanogranular structure obtained with MTXM.

2. Experimental details

We have used the full-field magnetic transmission soft X-ray microscope (XM-1) at the Advanced Light Source in Berkeley, which has a lateral resolution down to 21 nm [14]. The experimental setup of this X-ray microscope is described elsewhere [15]. To record the images, first circularly polarized radiation emitted off-orbit from a bending magnet is monochromatized by a condenser (CZP) and a pinhole close to the sample due to the wavelength dependence of the focal length of the CZP. Second, the radiation passes through the ferromagnetic sample and is projected through the micro zone plate acting as the lens onto a 2048×2048 pixel array of a backside illuminated CCD camera. With a 1400-fold magnification and a physical pixel size of $13.5 \mu\text{m}$, one pixel corresponds to 9.6 nm . Since

the magnetic contrast is given by the projection of the magnetization onto the photon propagation direction, the CoCrPt sample with a pronounced PMA was mounted with its surface normal parallel to the photon beam direction. To study the magnetization reversal in the CoCrPt films the images have been recorded in varying external magnetic fields pointing perpendicular to the film plane. A solenoid is used to generate field strengths up to 5 kOe . To distinguish structural contrast (defects, inhomogeneities, etc.) from magnetic contrast, the images have been normalized to images taken in an external field sufficiently high to saturate the thin films. 50 nm thick $(\text{Co}_{83}\text{Cr}_{17})_{87}\text{Pt}_{13}$ alloy films were prepared on a 40 nm thick Ti buffer layer using dc magnetron cosputtering of a CoCr alloy target with Pt chips at a base pressure of better than $8 \times 10^{-7} \text{ Torr}$ and a sputtering Ar pressure of 3 mTorr . A 200 nm thick Si_3N_4 membrane was used as substrate in order to allow for sufficiently high transmission of soft X-rays. To achieve a better (002) HCP crystallographic alignment of the CoCrPt alloy film, the Ti buffer layer was first deposited onto the substrate. The sample was prepared at ambient temperature without heat treatment. The magnetic anisotropy and the macroscopic magnetic properties were characterized using a torque magnetometer and a vibrating sample magnetometer (VSM), respectively. The sample exhibits a PMA energy of $1.58 \times 10^6 \text{ erg/cm}^3$ and a saturation magnetization of $M_s = 362 \text{ emu/cm}^3$. The average grain size of the sample determined from analyzing TEM images using particle-analysis software was about 25.5 nm (Fig. 1).

3. Results and discussion

The MTXM images have been recorded at the Co L_3 edge (777 eV), therefore the magnetic structures seen in the data represent the local Co magnetization. Due to the high lateral resolution of MTXM, insight into the reversal mechanism can be obtained [16]. In Fig. 2, MTXM images taken at subsequent applied magnetic fields are shown together with magnetization data obtained by VSM for the identical sample. The arrows

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