

Perpendicular magnetic anisotropy and magneto-optical Kerr rotation in FePt(001) monoatomic multilayers

S. Mitani ^{a,*}, K. Takanashi ^a, M. Sano ^a, H. Fujimori ^a, A. Osawa ^b, H. Nakajima ^b

^a Institute for Materials Research, Tohoku University, Katahira 2, Aoba-ku, Sendai 980-77, Japan

^b Department of Materials Science and Technology, Iwate University, Morioka, Iwate 920, Japan

Abstract

[Fe(1 ML)/Pt(1 ML)] (001) monoatomic multilayers, equivalent to the L1₀ ordered phase, have been prepared by depositing alternate monoatomic layers of Fe and Pt. The surface flatness and the degree of layer ordering improve with increasing substrate temperature. The perpendicular magnetic anisotropy and Kerr rotation ($\lambda = 633$ nm) at room temperature increase with increasing degree of layer ordering. The highly ordered Fe/Pt monoatomic multilayers grown at 500°C show a very large perpendicular anisotropy, which is close to the magnetocrystalline anisotropy of FePt (L1₀) ordered alloy, and a high saturation Kerr rotation of 0.69°.

It is expected that novel properties can arise from structurally controlled thin films or multilayers using new fabrication techniques. As an example of such a fabrication technique, vacuum evaporation, combined with in-situ reflection high-energy electron diffraction (RHEED), has been used to fabricate monoatomic multilayers of Fe/Pt(001) equivalent to the L1₀ ordered phase. FePt alloy films show significant magneto-optical Kerr rotation spectra and they are attracting much interest as magneto-optical recording media for the future. Magneto-optical and transport properties have been reported in FePt/Pt multilayers [1], and enhanced magneto-optical Kerr rotation and large perpendicular magnetic anisotropy have also been reported in epitaxial ordered FePt(001) thin films [2]. It has been shown that the site ordering and preferential orientation are essentially important. Here, we have studied [Fe(1 ML)/Pt(1 ML)] multilayers in order to clarify the detailed behaviour of FePt {001} ordered alloy.

[Fe(1 ML)/Pt(1 ML)]_n(001) multilayer films were prepared using an UHV deposition system, with two independent e-guns. An epitaxial Pt(001) seed layer of 250 Å was grown on MgO(001) at 500°C, upon which monoatomic layers of Fe (1.4 Å) and Pt (2.0 Å) were deposited alternately at various temperatures. The typical deposition rate was 0.1 Å/s. RHEED patterns were monitored during deposition. X-ray diffraction was performed for a structural characterization of the layer ordering and

the preferential orientation. The magnetic anisotropy was measured by a SQUID magnetometer at room temperature. The magneto-optical Kerr rotation at 633 nm was also measured at room temperature.

The epitaxial growth of the Fe and Pt layers was confirmed by RHEED. Fig. 1 shows the RHEED pattern of the uppermost Pt layer of a [Fe(1 ML)/Pt(1 ML)]₁₀₀ multilayer film grown at 500°C. The streak pattern implies that the surface of this FePt film is considerably flat on an atomic scale. It is considered that the Fe and Pt monoatomic layers grow layer-by-layer due to surface diffusion at 500°C. Fig. 2 shows the X-ray diffraction pattern of this FePt film, in which the FePt(001) and FePt(003) ordered lines are clearly observed. On the other hand, the RHEED pattern of a [Fe(1 ML)/Pt(1 ML)]_n film grown at room

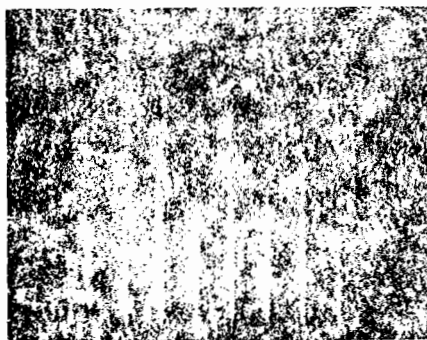


Fig. 1. RHEED pattern of the uppermost Pt layer of the [Fe(1 ML)/Pt(1 ML)]₁₀₀(001) multilayer film grown at 500°C, [110] azimuth.

* Corresponding author. Fax: +81-22-215-2096, e-mail: mitani@magmate.imr.tohoku.ac.jp.

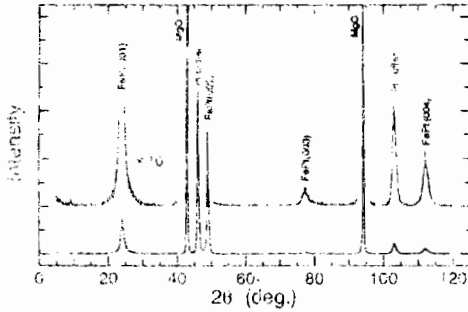


Fig. 2. X-ray diffraction pattern of the [Fe(1 ML)/Pt(1 ML)]₁₀₀(001) multilayer film grown at 500°C.

temperature is spotty and indicates that island growth occurs. According to the RHEED pattern, the FePt(001) ordered line can not be observed for the Fe/Pt multilayer film grown at room temperature.

Fig. 3(a) shows the magnetization curves parallel ($H_{||}$) and perpendicular (H_{\perp}) to the film plane for the [Fe(1 ML)/Pt(1 ML)]₁₀₀ film grown at 500°C. The in-plane magnetization curve, which does not saturate even at 55 kOe, indicates the large perpendicular anisotropy of this ordered FePt film. The saturation Kerr rotation of this ordered FePt film is 0.69° at 633 nm, as shown in Fig. 3(b). This value is larger than either of the values reported for ordered FePt alloy (0.33°) [4] and for ordered FePt(001) alloy film (0.38°) [5]. (However, a much larger value of 0.8° has recently been reported [5].) The observed Kerr loops are significant from a practical application point of

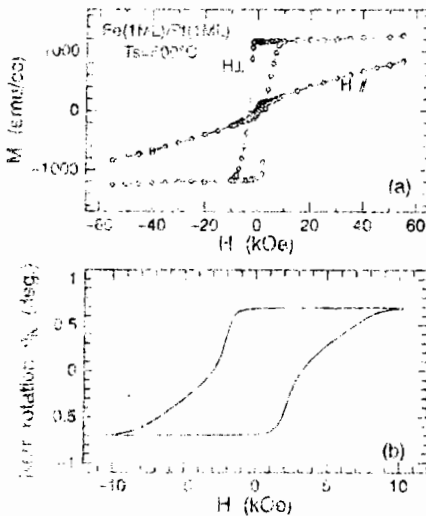


Fig. 3. (a) Magnetization curves parallel and perpendicular to the film plane, and (b) magneto-optical Kerr rotation at room temperature for the [Fe(1 ML)/Pt(1 ML)]₁₀₀(001) multilayer film grown at 500°C.

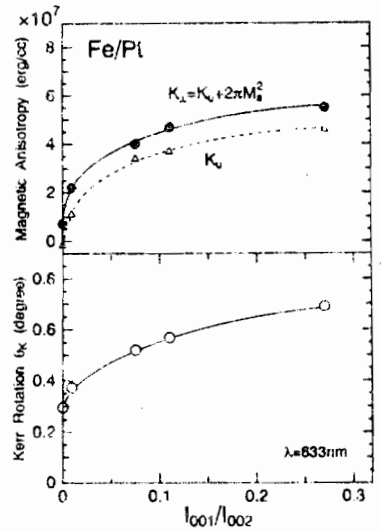


Fig. 4. Perpendicular magnetic anisotropy (K_{\perp}) and magneto-optical Kerr rotation (polar) at room temperature versus the degree of layer ordering represented by the X-ray intensity ratio I_{001}/I_{002} . The perpendicular magnetic anisotropy (K_{\perp}) is obtained from the uniaxial anisotropy K_u plus the shape anisotropy $2\pi M_s^2$.

view because of the residual rotation angle equal to the saturation one and the large coercivity.

The perpendicular anisotropy and the Kerr rotation at 633 nm of the [Fe(1 ML)/Pt(1 ML)]₁₀₀ multilayer films grown at lower temperatures are much smaller than those grown at 500°C. As shown in Fig. 4, the perpendicular anisotropy and the Kerr rotation increase with increasing degree of layer ordering, which is represented by the X-ray intensity ratio of the FePt(001) ordered line to FePt(002) ($= I_{001}/I_{002}$), for [Fe(1 ML)/Pt(1 ML)]₁₀₀(001) multilayer films. Therefore, the FePt(001) ordered film without any stacking faults and/or defects may show larger perpendicular anisotropy and Kerr rotation.

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Magnetic anisotropy and interlayer exchange coupling in Fe(110)/Au(111) ultrathin films

C. Chappert*, P. Bruno, B. Bartenlian, P. Beauvillain, A. Bounouh, R. Megy, P. Veillet

Institut d'Electronique Fondamentale, CNRS URA 22, Bât. 220, Université Paris-Sud, F-91405 Orsay Cedex, France

Abstract

In using in situ polar Kerr effect measurements on stepped wedge samples, we have investigated experimentally the magnetic anisotropy at room temperature of a bcc Fe(110) ultrathin film on Au(111), during the first stages of the deposition of an Au overlayer. We observe a maximum in the perpendicular anisotropy around 1 AL of Au coverage, in surprising similarity with previous observations on Co ultrathin films. We have then measured the interlayer exchange coupling through Au(111) on Au/Fe/Au/Co/Au(111) trilayers. We find evidence for oscillating coupling, with about the same period as in Co/Au(111)/Co structures, but a very different phase

In situ polar magneto-optical Kerr effect (PMOKE) measurements have been successfully used recently on Co ultrathin films to investigate the building of interface perpendicular magnetic anisotropy during the growth of a metallic overlayer [1,2]. Good-quality ultrathin bcc Fe films can also be grown on Au(111) substrates [3], and the Au/Fe/Au(111) structures show interesting properties [4], with for instance a perpendicular easy magnetization axis below 3 AL of Fe at 10 K. We have applied our techniques to study the magnetic anisotropy during the growth of an Au overlayer on Fe.

Our preparation and characterization techniques have been published elsewhere [2,5]. By annealing an Au film deposited on a float glass platelet we obtained a perfect (111) texture with an atomically flat surface. Co then grows smoothly with an hcp structure, and the Au/Co/Au sandwiches then display perpendicular anisotropy up to more than 10 AL of Co. Fe grows under its stable bcc structure, with its [110] direction perpendicular to the film. The surface roughness increases slowly during growth, but with a clear smoothing effect at 1 AL of the Au overlayer [3], as for the Co films [2]. To study the anisotropy, we first grew a Fe stepped wedge on the Au(111) substrate, with terrace thicknesses ranging from 1 to 8 AL, followed by successive depositions of 0.5 AL thick Au layers up to a total Au thickness of 8 AL. At each step, PMOKE loops were taken on all terraces of the sample. The deposition and measurements were performed at room temperature.

Ferromagnetic loops are observed on uncovered Fe films from $t_{Fe} = 1.5$ AL. Moreover, as can be seen in Fig. 1, there is a clear tendency to perpendicular anisotropy when t_{Fe} decreases, with a maximum initial slope of the loop for 2.5 AL. The decrease in the slope below this thickness could be related to a rapidly decreasing Curie temperature. As displayed in Fig. 2, the deposition of only 0.5 AL of an Au overlayer drastically increases the perpendicular anisotropy with a maximum of the initial slope for $t_{Au} \sim 1$ AL: this behavior is similar to that observed for Au/Co/Au structures [1,2]. Note that the coercive force

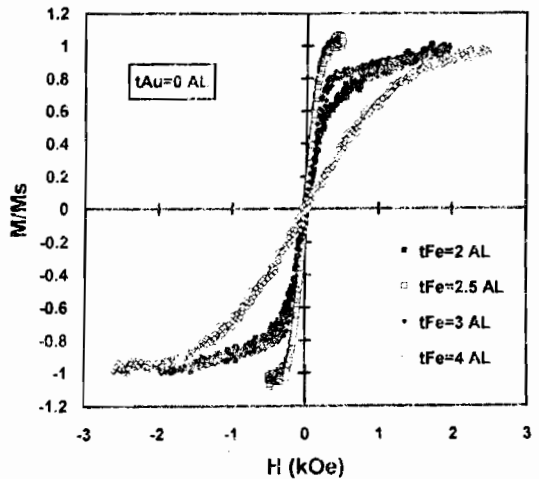


Fig. 1. Polar Kerr effect hysteresis loops measured at room temperature on an uncovered Fe layer on a Au(111) substrate, for different Fe thicknesses.

* Corresponding author. Fax: + 33-1-60192593; e-mail: chapert@ief-paris-sud.fr