Pt thickness and buffer layer effects on the structure and magnetism of Co/Pt multilayers

J.C.A. Huang\textsuperscript{a,}\textasteriskcentered*, M.M. Chen\textsuperscript{a}, C.H. Lee\textsuperscript{b}, T.H. Wu\textsuperscript{c}, J.C. Wu\textsuperscript{d}, C.M. Fu\textsuperscript{e}

\textsuperscript{a}Department of Physics, National Cheng-Kung University, Ta-Hsueh Road, \#1, Tainan 701, Taiwan
\textsuperscript{b}Department of Engineering and System Science, National Tsing-Hua University, Hsinchu, Taiwan
\textsuperscript{c}Department of Humanities and Science, National Yunlin University of Science and Technology, Touliu, Taiwan
\textsuperscript{d}Department of Physics, National Changhua University of Education, Changhua, Taiwan
\textsuperscript{e}Department of Physics, National Kaohsiung Normal University, Kaohsiung, Taiwan

Abstract

[Co(3 Å)/Pt(\(t_{\text{Pt}}\))]\textsubscript{30} (1 1 1) multilayers were prepared by molecular beam epitaxy. X-ray diffractions show clear satellite peaks around the Co/Pt fundamental peak, indicative of a good modulated structure for all Co/Pt multilayers. The optimal perpendicular magnetic properties were obtained for 6 Å < \(t_{\text{Pt}}\) < 10 Å. The effect of Pt buffer (\(B_{\text{Pt}}\)) upon the magnetic property of [Co(3 Å)/Pt(10 Å)]\textsubscript{30}/Pt(\(B_{\text{Pt}}\)) is also studied. X-ray diffractions reveal that the superlattice peaks of [Co(3 Å)/Pt(10 Å)]\textsubscript{30}/Pt(\(B_{\text{Pt}}\)) increase with increasing \(B_{\text{Pt}}\). The Kerr rotations and polar coercivity \(H_{c}\) increase with increase in \(B_{\text{Pt}}\) but both saturate at about \(B_{\text{Pt}} = 200\) Å. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Multilayers; Molecular beam epitaxy; Perpendicular magnetic anisotropy; Kerr rotations

1. Introduction

Co/Pt multilayers with large perpendicular magnetic anisotropy (PMA) and enhanced Kerr rotations have received much attention in both basic research and application in high-density magnetic and magneto-optical (MO) recording \cite{1,2}. Compared with the RE–TM alloys currently used in commercial MO disks, the Co/Pt multilayers are attractive for their superior corrosion resistance and large Kerr rotations at short wavelength \cite{3}. Previously, we reported \cite{4} the influence of Co thickness and crystal orientation on the magneto-optical properties of [Co(\(t_{\text{Co}}\))/Pt(10 Å)]\textsubscript{30} multilayers \cite{4}. For these multilayers, the best PMA effect was obtained with \(t_{\text{Co}}\) of about 2.5–4 Å and (1 1 1) as the growth orientation. In an effort to optimize the PMA and MO properties of the Co/Pt multilayers, we investigate here, the influence of Pt thickness (\(t_{\text{Pt}} = 4, 6, 8, 10\) and 12 Å) in the multilayer and in the buffer layer (\(B_{\text{Pt}}\)) upon the PMA and Kerr rotations of the [Co(3 Å)/Pt(10 Å)]\textsubscript{30}/Pt(\(B_{\text{Pt}}\)) multilayers.

2. Sample preparations and characterizations

The [Co(3 Å)/Pt(\(t_{\text{Pt}}\))]\textsubscript{30} multilayers were prepared by a vacuum-product-made molecular beam epitaxy system. Details of the chamber in which crystal growth took place are provided elsewhere \cite{4,5}. These multilayers were grown on Pt seeding layer on epitaxial grade Al\textsubscript{2}O\textsubscript{3} (1 1 2 0) substrate. The Pt seeding layer and the subsequent Co/Pt multilayers were grown at optimal temperatures of 400°C and 100°C, respectively. The crystal structure and epitaxial relations of the Co/Pt multilayers were studied by reflection high-energy electron diffraction (RHEED) and X-ray diffraction (XRD). Magnetic property was investigated by polar magneto-optical Kerr effect (PMOKE) and a superconducting-quantum-interference-device (SQUID) magnetometer.

*Corresponding author. Tel.: +886-06-2757575; fax: +886-06-2747995.
E-mail address: jcahuang@mail.ncku.edu.tw (J.C.A. Huang).

0304-8853/02/$-see front matter © 2002 Elsevier Science B.V. All rights reserved.
PII: S0304-8853(01)00651-5
3. Results and discussion

On $\text{Al}_2\text{O}_3(11\overline{2}0)$ substrate, the Pt seeding layer and the subsequent Co/Pt MLs were grown as (111) single crystal films, as indicated by the RHEED and XRD observations. The 3D epitaxial relations of the Co/Pt multilayers, Pt seeding layer and sapphire substrate was determined as $\text{Co/Pt(111)}||\text{Pt(111)}||\text{Al}_2\text{O}_3(11\overline{2}0)$, $\text{Co/Pt(110)}||\text{Pt(110)}||\text{Al}_2\text{O}_3(000\overline{1})$, and $\text{Co/Pt(11\overline{2})}||\text{Pt(1\overline{1}2)}||\text{Al}_2\text{O}_3(\overline{1}10\overline{0})$. Fig. 1(a) shows the XRD spectra of the $[\text{Co}(3\text{A})/\text{Pt}(t_{\text{Pt}})]_{30}$ multilayers. As $t_{\text{Pt}}$ increases, the fundamental peak of the multilayer (indicated as $\text{Co/Pt(111)}$ in Fig. 1(a)) shifts towards the $\text{Pt(111)}$ peak, designating the increase of average lattice spacing for the Co/Pt multilayer. In addition, the XRD spectra show clear satellite peaks around the Co/Pt fundamental peak (indexed as $-S_1$ and $+S_1$), indicative of well-modulating structure. Lattice strain up to 2.8% of the Co/Pt multilayers had been measured [6] by careful XRD studies using a synchrotron radiation source [6].

![X-ray diffraction spectra](image)

Fig. 1. (a) X-ray diffraction spectra and (b) PMOKE hysteresis loops of $[\text{Co}(3\text{A})/\text{Pt}(t_{\text{Pt}})]_{30}$ multilayers grown on 200 Å Pt on $\text{Al}_2\text{O}_3(11\overline{2}0)$ substrate with $t_{\text{Pt}} = 4, 6, 8, 10$ and 12 Å. Note that the Laue oscillation peaks (30–37° in (a)) are due to the smoothness of both the sapphire substrate and the Pt seeding layer.

By PMOKE, we have also studied the dependence of PMA and Kerr rotations of $[\text{Co}(3\text{A})/\text{Pt}(t_{\text{Pt}})]_{30}$ multilayers upon the Pt thickness ($t_{\text{Pt}} = 4, 6, 8, 10$ and 12 Å) for a fixed Co thickness at 3 Å. The best polar coercivity $H_c$ (6.3 kOe) of the $[\text{Co}(3\text{A})/\text{Pt}(t_{\text{Pt}})]_{30}$ multilayers occurs at $t_{\text{Pt}} \sim 10$ Å, as shown in Fig. 1(b). The polar $H_c$ remains >3 kOe for $t_{\text{Pt}} > 6$ Å, and decreases very dramatically (<1 kOe) for $t_{\text{Pt}} < 4$ Å. In-plane magnetization of the $[\text{Co}(3\text{A})/\text{Pt}(t_{\text{Pt}})]_{30}$ multilayers was observed for $t_{\text{Pt}} = 2$ Å. On the other hand, the Kerr rotations ($\theta_K$) increase slightly with decrease in the Pt thickness in the multilayers ($\theta_K \sim 0.22–0.25^\circ$ for $t_{\text{Pt}} > 10$ Å, $\theta_K \sim 0.28–0.32^\circ$ for $t_{\text{Pt}} = 8$ and 6 Å, and $\theta_K \sim 0.38^\circ$ for $t_{\text{Pt}} = 4$ Å). For optimal Kerr and PMA effects, therefore, the best range of the Co and Pt layer thickness in the $\text{Co/Pt}(t_{\text{Pt}})$ multilayers was determined as 2.5 Å $< t_{\text{Co}} < 3.5$ Å and 6 Å $< t_{\text{Pt}} < 10$ Å, respectively.

We have also studied the influence of Pt buffer layer thickness ($B_{\text{Pt}}$) upon the magnetic property of $[\text{Co}(3\text{A})/\text{Pt(10A)}]_{30}/\text{Pt}(B_{\text{Pt}})$ multilayers. X-ray diffraction ($\theta$–2$\theta$) scans reveal that the fundamental and satellite peaks of $[\text{Co}(3\text{A})/\text{Pt(10A)}]_{30}/\text{Pt}(B_{\text{Pt}})$ improve with the increasing of $B_{\text{Pt}}$ (from 0 to 500 Å), as shown in Fig. 2(a). A similar

![X-ray diffraction spectra](image)

Fig. 2. (a) X-ray diffraction spectra and (b) PMOKE hysteresis loops of $[\text{Co}(3\text{A})/\text{Pt(3A)}]_{10}$ multilayers grown on Pt($B_{\text{Pt}}$) buffer layer with $B_{\text{Pt}}$ ranging from 0 to 500 Å.
trend was found in X-ray rocking curve scans and reflectivity measurements using synchrotron radiation source also [6]. For the magnetic property, the PMOKE studies indicate that Kerr rotations and polar coercivity \( H_c \) increase with the increase in \( B_{Pt} \) but both saturate at about \( B_{Pt} = 200 \) Å, as shown in Fig. 2(b). It is suggested that the 200 Å (Pt) buffer layer is sufficient for the Co/Pt multilayers.

Previously, we have studied the importance of using Pt and/or Mo seeding layers [7,8] on the structure and magnetism of the Co/Pt multilayer. We have also reported the effects of growth orientation and Co thickness on the PMA of Co/Pt multilayer [4]. From the present investigation, we further conclude that the optimal thickness parameters for the growth of \([\text{Co}(t_{Co})/\text{Pt}(t_{Pt})]_{30}/\text{Pt}(B_{Pt})\) multilayers are \(2.5 - 3.5 \) Å < \( t_{Co} \) < \( 6 \) Å < \( t_{Pt} \) < \( 10 \) Å, and \( B_{Pt} \) about 200 Å. Finally, we point out that the Co–Pt interfacial strain is crucial for the perpendicular magnetization of the Co/Pt multilayers. Details of structural studies using synchrotron radiation X-ray will be reported in a further publication.

Acknowledgements

We are grateful for the financial support by the ROC NSC under grant No. 89-2112-M-006-037.

References