Journal of Magnetism and Magnetic Materials 177–181 (1998) 1199–1200

Journal of magnetism and magnetic materials

Magnetooptical Kerr effect in Fe/Au superlattices modulated by integer atomic layers

K. Takanashi[a,*], S. Mitani[a], H. Fujimori[a], K. Sato[b], Y. Suzuki[c]

[a] *Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-77, Japan*
[b] *Faculty of Engineering, Tokyo University of Agriculture and Technology, Koganei, Tokyo 184, Japan*
[c] *JRCAT-NAIR, Higashi, Tsukuba, Ibaraki 305, Japan*

Abstract

We have investigated the magnetooptical Kerr effect (MOKE) in Fe(n ML)/Au(n ML) superlattices where n is integer and ML represents monatomic layer thickness. The MOKE spectra show prominent structure between 3 and 5 eV. The n dependence of the prominent structure is discussed in comparison with the case of ultrathin Fe films which show the magnetooptical transitions associated with the quantum-well states. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Mangetooptical effects; Superlattices artificial; Quantum well; Thin films magnetic

Recent development of thin-film preparation techniques has made it possible to fabricate ordered alloys with layered structures artificially. In previous papers [1–3], we reported the artificial fabrication of a $L1_0$ ordered structure by alternate deposition of (0 0 1)Fe and (0 0 1)Au monatomic layers. The $L1_0$ ordered structure was successfully obtained although it does not exist in the equilibrium phase diagram. The ordered FeAu alloy film possesses large Fe moment exceeding 2.2 μ_B, large perpendicular magnetic anisotropy along the c-axis and novel magnetooptical Kerr spectra.

In this paper, we prepared Fe/Au superlattices modulated by integer atomic layers, i.e., Fe(n ML)/Au(n ML) superlattices where n is integer and ML represents monatomic layer thickness. The n dependence of the magnetooptical Kerr spectra is shown and discussed, particularly, compared to the results of ultrathin (0 0 1)Fe films sandwiched with Au [4, 5].

The samples were prepared on polished MgO(1 0 0) substrates by UHV deposition. Fe n ML and Au n ML were alternately deposited on a thick Au buffer. n was varied in the range from 1 to 12. The repetition number, N, was $100/n$, or the integer closest to $100/n$ when $100/n$ is non-integer. The spectra of the Kerr rotation θ_K and ellipticity η_K were measured between 1.2 and 6.0 eV by means of polarization modulation technique.

The θ_K and η_K spectra for $n = 1, 2, 3, 4, 6, 8$ and 12 are shown in Fig. 1a and Fig. 1b, respectively. For $n \geqslant 6$, a sharp peak of θ_K and a dispersion-type structure of η_K are observed around 2.4 eV, which are caused by the enhancement of magnetooptical signals by plasma resonance of conduction electrons in Au layers [6]. On the other hand, the enhancement is not clearly observed for $n \leqslant 4$, suggesting a considerable change in the electronic structure of Au layers.

Another remarkable feature is a definite dispersion-type structure between approximately 3 and 5 eV in the θ_K spectra for $1 \leqslant n \leqslant 8$. Correspondingly, the η_K spectra show the peak around the dispersion center of θ_K. These prominent structures shift to higher energies as n increases from 1 to 6. Fig. 2 shows the spectra of the absolute values of $\omega\sigma_{xy}$, the off-diagonal element of the complex conductivity tensor multiplied by angular frequency. The $w\sigma_{xy}$ spectra were obtained from the experimental data of θ_K, η_K and the diagonal dielectric constant, ε_{xx}, evaluated by the Kramers–Kronig analysis of the reflectivity spectra. The arrows in Fig. 2 indicate the peaks corresponding to the prominent structures observed in the θ_K and η_K spectra. The Fe-layer thickness d_{Fe} and/or n dependence of the position of the peak in the

* Corresponding author. Tel.: + 81 22 215 2098; fax: + 81 22 215 2096; e-mail: koki@imr.tohoku.ac.jp.

0304-8853/98/$19.00
PII S0304-8853(97)00439-3

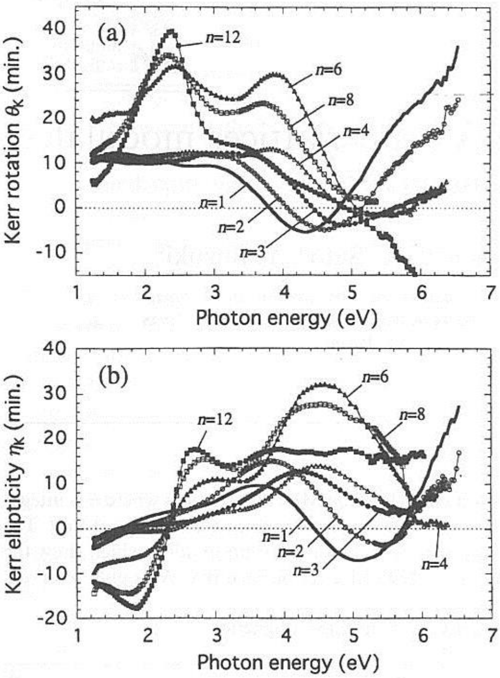

Fig. 1. (a) Magnetooptical Kerr rotation θ_K and (b) ellipticity η_K spectra for Fe(n ML)/Au(n ML) superlattices.

$\omega\sigma_{xy}$ spectra is shown in Fig. 3 (○). The position of the peak shifts from approximately 3.2 to 4.4 eV as n increases from 1 to 4. For $n \geqslant 4$, however, it shows no considerable change. This result is compared to the case of ultrathin Fe films. Suzuki et al. [4] reported the appearance of new structures in the magnetooptical Kerr spectra of ultrathin (0 0 1)Fe films sandwiched with Au, and they associated the new structures to transitions from the Δ_5 band to quantum well states in the Δ_1 band of Fe films [5]. The transition energy obtained from the $\omega\sigma_{xy}$ spectra of the ultrathin Fe films are also shown in Fig. 3 (●). The d_{Fe} dependence of the $\omega\sigma_{xy}$ peak in Fe/Au superlattices has similar tendency to that of the transition energy associated with the quantum-well states in ultrathin Fe films. This suggests the formation of quantum-well states within Fe layers even for Fe/Au superlattices, which causes the peak of $\omega\sigma_{xy}$. Quantitatively, however, the transition energies in Fe/Au superlattices are somewhat higher than those in ultrathin Fe films. Particularly, considerable discrepancy is seen for $n < 3$. We consider that for $n < 3$ the electrons cannot be confined completely within Fe layers because Au layers are also very thin, and the quantum-well states are spread into minibands, leading to the discrepancy between the transition energies in ultrathin Fe films and in Fe/Au superlattices.

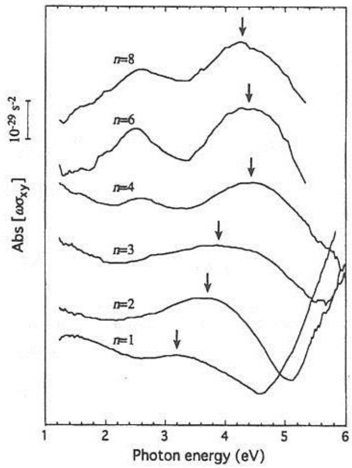

Fig. 2. Absolute values of $\omega\sigma_{xy}$, the off-diagonal element of the complex conductivity tensor multiplied by angular frequency, for Fe(n ML)/Au(n ML) superlattices as a function of photon energy. The arrows indicate the peaks corresponding to the prominent structures observed in the θ_K and η_K spectra (Fig. 1).

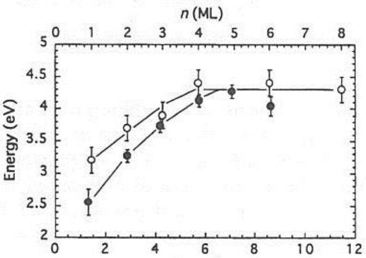

Fig. 3. Fe layer thickness d_{Fe} and/or n dependence of the position of the peak in the $\omega\sigma_{xy}$ spectra for Fe(n ML)/Au(n ML) superlattices (○). For comparison, the magneto-optical transition energies associated with quantum-well states in ultrathin (0 0 1)Fe films sandwiched with Au[6] are shown (●).

References

[1] K. Takanashi, S. Mitani, M. Sano, H. Fujimori, A. Osawa, H. Nakajima, Appl. Phys. Lett. 67 (1995) 1016.

[2] S. Mitani, K. Takanashi, H. Nakajima, K. Sato, R. Schreiber, P. Grünberg, H. Fujimori, J. Magn. Magn. Mater. 156 (1996) 7.

[3] K. Sato, J. Abe, H. Ikekame, K. Takanashi, S. Mitani, H. Fujimori, J. Magn. Soc. Japan 20 (Suppl. S1) (1996) 35.

[4] Y. Suzuki, T. Katayama, S. Yoshida, K. Tanaka, K. Sato, Phys. Rev. Lett. 68 (1992) 3355.

[5] W. Geerts, Y. Suzuki, T. Katayama, K. Tanaka, K. Ando, S. Yoshida, Phys. Rev. B 50 (1994) 12581.

[6] K. Sato, H. Kida, T. Katayama, Japan. J. Appl. Phys. 27 (1988) L237.