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Perpendicular magnetic anisotropy and magnetooptical Kerr effect in Fe/Au(0 0 1) superlattices: comparison between monocrystalline and polycrystalline samples

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Abstract

Polycrystalline Fe/Au superlattices were prepared by monatomic layer control on quartz glass substrates with MgO underlayers having a (0 0 1) texture, and their structural and magnetic properties have been compared with those for monocrystalline samples grown on MgO(0 0 1) single-crystal substrates. X-ray analysis have shown that the interface roughness and/or the disorder of superlattice structure in polycrystalline samples are larger than those in monocrystalline samples. It has been found that the perpendicular magnetic anisotropy is very sensitive to the interface morphology, while the magnitude of the Fe moment and the magnetooptical Kerr spectra are not seriously influenced by the interface morphology.

Keywords: Superlattices—artificial; Anisotropy—perpendicular; Magneto-optical effects

Recent development of thin-film preparation techniques has realized monatomic layer growth of metal elements, and made it possible to investigate the structural and physical properties of superlattices designed on an atomic scale. In a previous paper [1], we succeeded in the artificial fabrication of an $L1_0$-ordered structure by alternate deposition of Fe(0 0 1) and Au(0 0 1) monatomic layers on a MgO(0 0 1) single-crystal substrate. This artificial ordered FeAu alloy film showed a large perpendicular magnetic anisotropy (PMA) and novel magneto-optical Kerr effect (MOKE). Furthermore, monocrystalline Fe/Au(0 0 1) superlattices modulated by a few atomic layers were also prepared and their magnetic properties were investigated [2,3]. In this paper, we prepared polycrystalline Fe/Au superlattices on glass substrates with MgO underlayers having a (0 0 1) texture. PMA and MOKE for polycrystalline samples are compared with those for monocrystalline samples grown on MgO single-crystal substrates to discuss the relationship between the structures and properties.

A MgO 1000 Å underlayer was deposited on quartz glass by ion beam sputtering using a sintered MgO target, and annealed at 800°C for 4 h. The X-ray diffraction (XRD) measurements indicated that the MgO underlayer had a (0 0 1) texture where the size of grains was approximately 100 Å. Fe 10 Å seed and Au 500 Å buffer layers were evaporated on the textured MgO underlayer in UHV, and subsequently, $[Fe(x\text{ML})/Au(x\text{ML})]_{100/x}$ superlattices ($x = 1, 2, 3, 4, 6, 8$) were grown by monatomic layer control. The surface structure during deposition was monitored by RHEED and the structural characterization was made by XRD. The magnetization was measured by a SQUID magnetometer. Magnetooptical Kerr spectra were measured between 1.2 and 5.0 eV by means of polarization modulation technique.

Fig. 1 shows the XRD patterns for $x = 1$ and 4. Sharp fundamental (0 0 2) peaks are observed, indicating the

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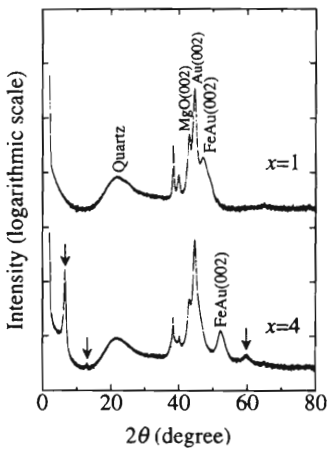

Fig. 1. XRD profiles for polycrystalline Fe(xML)/Au(xML) superlattices with $x = 1$ and 4. The arrows indicate the satellite peaks associated with the superlattice structure.

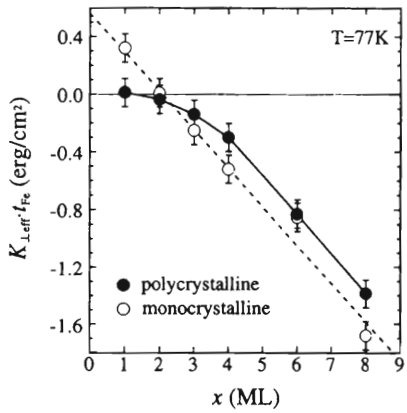

Fig. 2. The effective perpendicular magnetic anisotropy energy per unit area, $K_{\perp eff} t_{Fe}$ as a function of x for [Fe(xML)/Au(xML)] superlattices. Closed and open circles represent the data for polycrystalline and monocrystalline samples, respectively. The broken line is a least-squares fit to the data for monocrystalline samples, and the solid curve is a guide to the eye.

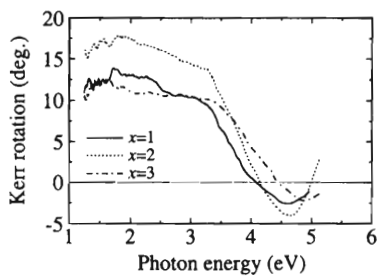

Fig. 3. Spectra of magnetooptical Kerr rotation for polycrystalline Fe(xML)/Au(xML) superlattices with $x = 1$, 2 and 3.

formation of a (0 0 1) texture, that is also confirmed by RHEED observation. The satellite peaks associated with the superlattice structure are clearly observed for $x \geqslant 2$. However, the intensities of satellite peaks are weaker than those for monocrystalline samples reported previously [2], suggesting that the interface roughness and/or the disorder of superlattice structure in polycrystalline samples are larger than those in monocrystalline samples. For $x = 1$, no clear satellite peak can be seen in contrast to the result of the monocrystalline sample with $L1_0$-ordered structure [1].

The magnetization measurements indicate that the average magnitude of Fe moment μ_{Fe} is larger than that of bulk BCC-Fe, and decreases gradually with increasing x, showing similar behavior as the result for monocrystalline samples. Fig. 2 shows the effective PMA energy per unit area, ($K_{\perp eff} t_{Fe}$) as a function of x. For monocrystalline samples (open circles), $K_{\perp eff} t_{Fe}$ vs. x shows a good linear relationship for x from 1 to 8. For polycrystalline samples (closed circles), on the other hand, PMA energy for $x \leqslant 3$ deviates from a linear relationship and decreases possibly due to the interface roughness. For $x \geqslant 3$, however, the PMA energies are somewhat larger than those for monocrystalline samples. Fig. 3 shows the spectra of magnetooptical Kerr rotation for $x = 1$, 2 and 3, which are very similar to those for monocrystalline samples [3]: the negative peaks are seen between approximately 4 and 5 eV. The magnetooptical Kerr ellipticity was also measured, and the dispersion-type structures have been found in the corresponding energy region.

In conclusion, it has been found that PMA is very sensitive to the interface morphology, while the magnitude of μ_{Fe} and MOKE spectra are not seriously influenced by the interface morphology.

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