X-RAY REFLECTIVITY OF Gd THIN FILMS DEPOSITED ON Si WAFER

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Introduction

Gadolinium thin films exhibit extremely interesting magnetic properties, which strongly depends on surface and interface morphology.[1)] In the present study, morphology of Gd thin films was investigated using grazing incidence X-ray techniques, which are powerful for analyzing surfaces and interfaces of thin films.

Experimental

The films were prepared by evaporating Gd from a resistively heated tungsten boat on Si wafer substrates cooled by water to control surface migration. The experiment was carried out at BL-14A with 16 keV monochromatic X-rays. X-ray reflectivity was measured by a grazing incidence X-ray reflectometer[2)] developed in our laboratory. Incident beam was collimated by 0.4 mmϕ pinholes and a 0.05 mm width vertical slit. A YAP:Ce scintillation detector[3)] equipped with 0.05 mm vertical slit observes X-ray intensities scattered on a sample, which rotates on a goniometer. Aluminum plate (c.a. 3mm) was used as an attenuator when measuring the total-reflection region.

Results and Discussion

Figure 1 shows X-ray reflectivity of Gd thin films deposited on Si wafer. The reflectivity is very sensitive to the thickness of the films. Critical angle θ_c for total reflection increases from that for Si wafer (1.95 mrad) to that for Gd (3.22 mrad) as the films become thicker. Thickness of each film, the roughness of the surfaces and Gd/Si interfaces have been analyzed as summarized in Table 1.

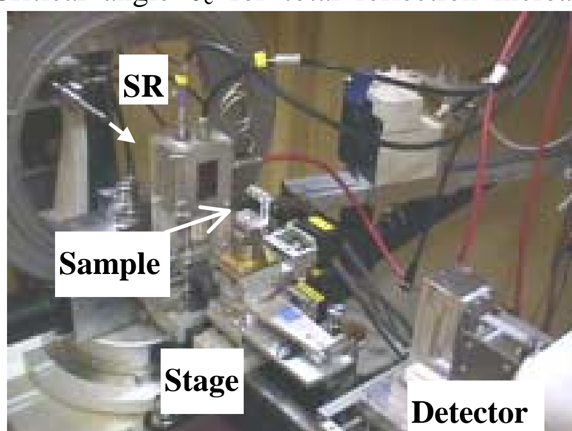

Photo Grazing incidence X-ray reflectometer assembled in the hatch.

Although Gd327B and Gd322A have very similar thickness, it was found that the surface roughness is quite different each other. This is because of the difference in deposition rates, i.e., evaporation temperature. When the temperature is high, Gd clusters evaporated from the source can have higher energy and could hit the surface of the Gd film harder during the growth. Further studies on rather thin films are now under way.

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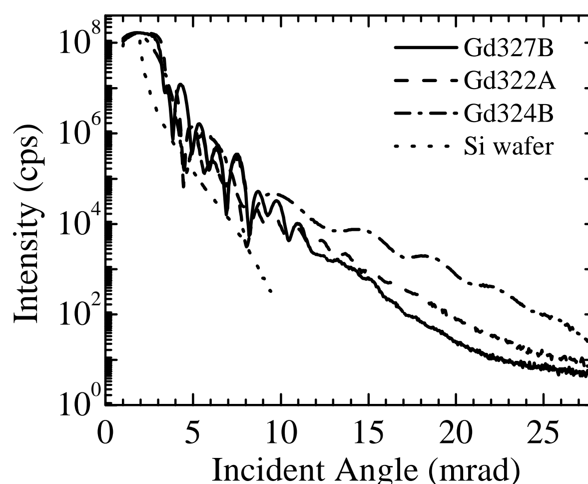

Figure 1 X-ray reflectivity of several Gd thin films.

Table 1 Analytical result of X-ray reflectivity data

Sample	Gd327B	Gd322A	Gd324B	Si wafer
Deposition rate (nm/min.)	0.54	0.10	0.22	–
Thickness (nm)	30.5	27.5	8.8	–
RMS roughness of Gd surface (nm)	1.1	0.3	0.8	–
RMS roughness of Gd/Si interface (nm)	0.4	1.0	0.1	1.0 (Si surface)

References

1) E. D. Tober et al., Phys. Rev. B **53** (9), 5444, 1996.
2) K. Sakurai et al., J. Synchrotron Rad. **5**, 554-556 ,1998.
3) M. Harada et al., PF Activity Report #16 B, 292, 1998.