GRAZING INCIDENCE X-RAY FLUORESCENCE OF MAGNETIC MULTILAYERS

In recent years, much activity has been devoted to the development of giant magnetoresistance (GMR) multilayers used in the MR head for high-density magnetic recording.

X-ray reflectometry has been applied to the analyzes of ultrathin multilayer (approximately 10-layer) structures such as film thickness, density, interfacial roughness, or the existence of mixing layer. However, since this method evaluates the layer profile by examining electron density as manifested by refractive index for each layer, the spin-valve components consisting of CoFeB, Cu and NiFe are difficult to distinguish since their atomic numbers, and densities, which directly relate to their refractive indices are nearly identical. In addition to that, the method cannot provide the direct information regarding isolated elements such as the diffusion of specific atoms at the layer boundary.

To solve this problem, we developed a grazing incidence X-ray fluorescence (GIXF) techniques using wavelength dispersive (WD) equipment [1]. Figure 1 is a schematic drawing of the measurement configuration. GIXF has been proposed to specify the composition profile for several years [2-5], but has not applied to the evaluation of real samples. This is due to the complexities in the data analysis in addition to the poor quality of the fluorescence data obtained by the energy-dispersive SSD detector, whose maximum count rate is lower than 10 kcps and possesses poor energy resolution. We overcame these difficulties using a WD detector with a high count rate and good energy resolution for measurement and incorporating the reflectivity data into the estimation of X-ray field intensity in the analysis.

The X-ray fluorescence equipment has been constructed at the undulator beamline **BL16XU** by a consortium of 13 industrial companies. This may represent the first device that can measure the fluorescent X-rays from the samples placed under the grazing or the total reflection conditions by a WD spectrometer with high detection sensitivity.

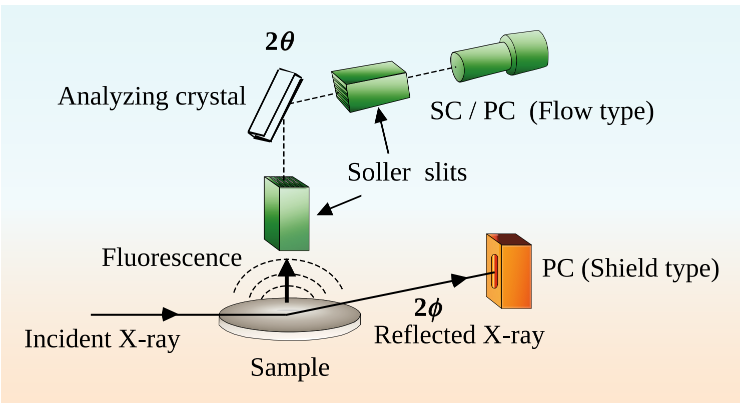


Fig. 1. Schematic drawing of the grazing incidence X-ray fluorescence configuration. Fluorescence emission from the sample were detected by the wavelength dispersive spectrometer using parallel optics.

In the experiment, a spin-valve sample with a stratified structure of Ta(6)/PdPtMn(25)/ CoFeB(2)/ Cu(3)/CoFeB(2)/NiFe(4)/Ta(5)/Si-sub was measured. The number in parenthesis indicate the thickness in nm. The X-rays from the undulator were monochromatized to 16 keV. A downstream Rh-coated focusing mirror suppresses the higher harmonics, reducing background fluorescence signals from the samples. In addition, the high-energy resolution of the WD spectrometer resolved many fluorescent peaks from the elements in the sample, as shown in Fig. 2. These features could not be attained by the energy dispersive measurements or by the conventional WD equipment using continuous X-rays in the laboratory.

In the angle resolved measurements, a non-overlapping peak of fluorescent X-rays for each element was chosen and the Bragg angle of the analyzing crystal was set at the peak. The results of a grazing angle scan for elements corresponding to each layer up to 0.7 degrees are shown in Fig. 3. The reflectivity was also recorded as shown in Fig. 4. The fluorescence intensity shows a clear oscillation that originates from the standing wave of X-rays generated by the interference inside the layers.

In the analysis, we extended the optimization program developed for the X-ray reflectivity, which based on the layered model of Vidal & Vincent [6], to calculate the energy flow of X-rays in the film from which the fluorescence yield can be calculated. The fluorescence profiles from each element and the reflectivity profile were simultaneously optimized to the layered model. In the analysis, layers with a similar density of different elements are resolved from the constraints on fluorescence yield for the elements. The

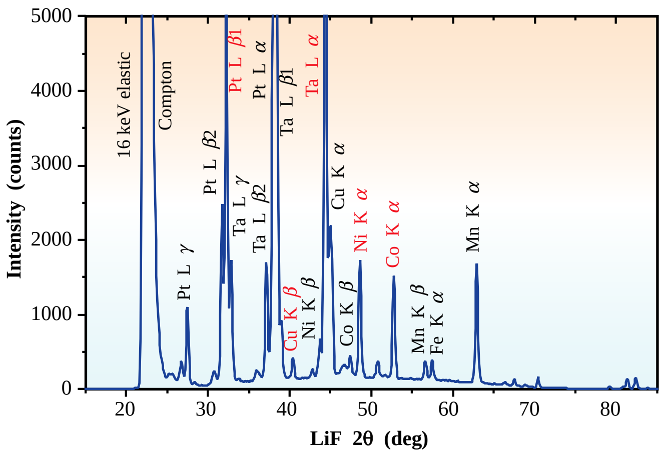


Fig. 2. Fluorescence peaks seen by the energy scan of the GMR multilayer with grazing angle of 1.5 deg.

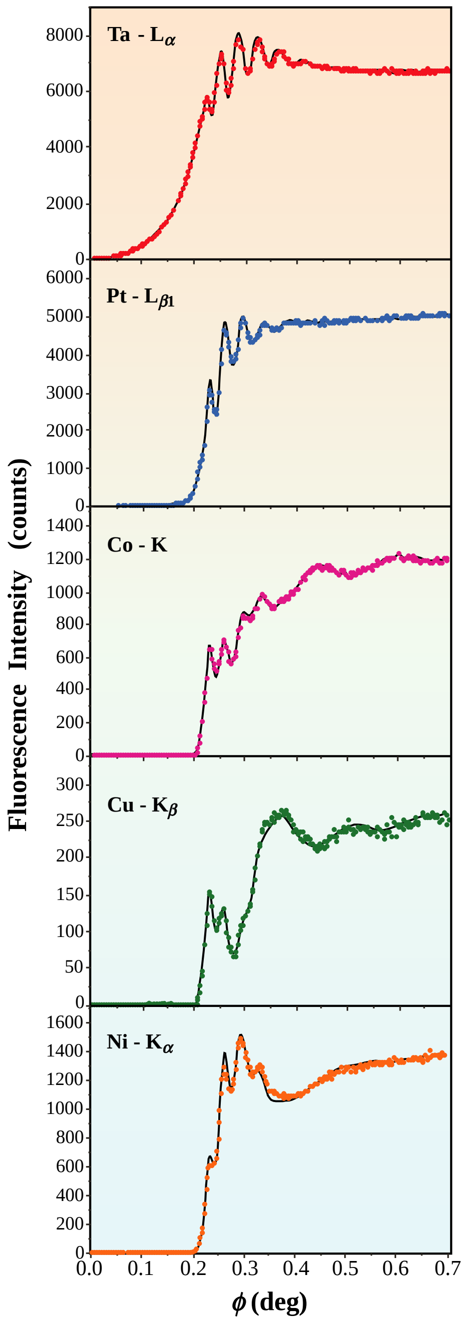


Fig. 3. Grazing angle dependence of fluorescence yields for the element corresponding to each layer. The solid line represents the calculation based on the layered model.

calculated profiles reproduce the complex fluorescence profile very well, as indicated by the solid line in Fig. 3 and Fig. 4. The reconstructed layer profile of the sample from GIXF analysis is shown in Fig. 5.

In summary, a new WD-GIXF method has been developed in which the atomic profiles of samples can be estimated and applied successfully in order to evaluate the complex GMR spin-valve samples. We succeeded in observing the change of a layered structure after thermal annealing by applying this method [7].

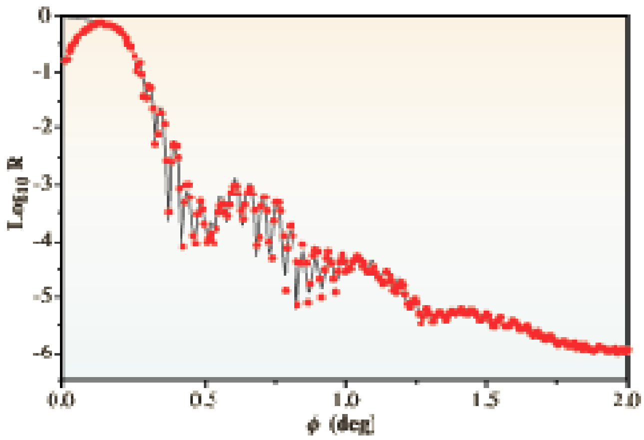
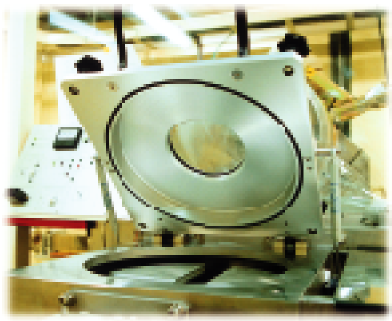


Fig. 4. Reflection profile of the GMR sample. The solid line shows the result of a calculation optimized with the fluorescence yield.



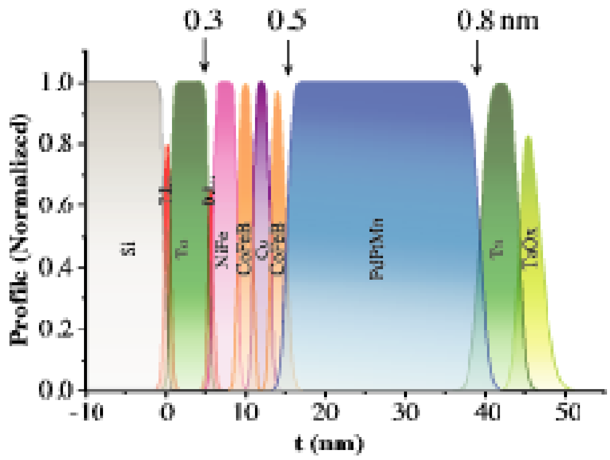


Fig. 5. Layer profile of the sample reconstructed from the results of GIXF analysis, where T.L. is the transition layer and D.L. is the dead layer introduced to reproduce the measured data. Numbers with arrow indicate the interfacial roughness.

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