Peak Separation of In-Plane Diffraction Patterns from Cu / NiFe Thin Film Using Anomalous Dispersion Effect.

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The induced magnetoelastic energy in a thin magnetic film may arise from residual stress combined with magnetostriction, which is sensitive to the crystal structure. Thus, it is important to optimize the magnetostriction in giant magnetoresistive (GMR) sensor films that consist of Co, Cu and NiFe layers. The structure analysis, however, is difficult because their lattice constants are very close for each layer. Therefore, a peak separation method from Cu / NiFe multilayer diffraction patterns was examined using anomalous dispersion effect.

The layer of the sample, Ta (2 nm) / Cu (2.2 nm) / Co (0.5 nm) / NiFe (3 nm) / Co (0.5 nm) were deposited on underlayers in turn. The in-plane XRD of the sample were measured at four wavelengths. The x-ray wavelengths were 0.13812nm (Cu-K edge), 0.14542nm (Cu post edge), 0.14887nm (Ni-K edge) and 0.15499nm (Ni post edge).

In-plane XRD patterns of the film were slightly different each other. Fig. 1 shows the differential Cu pattern obtained by simple substraction of the Cu K-edge pattern from Cu post edge one. The differential NiFe pattern is also shown in Fig. 1. The peak positions are clearly different for the Cu and NiFe differential patterns. This result indicates that it is possible to analyze the crystal structure in each layer for Co, Cu and NiFe multilayer film using anomalous dispersion effect.

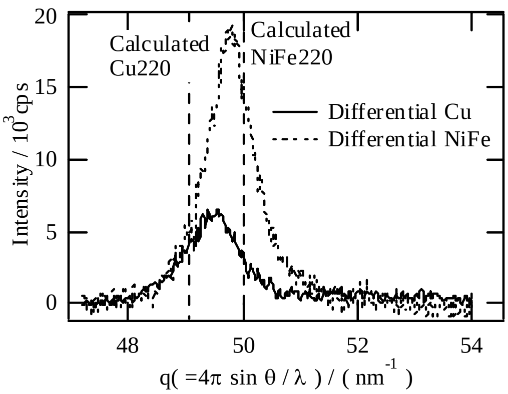

Fig.1 Differential Cu and NiFe diffraction patterns (post edge – K-edge pattern). Two dashed lines show the peak positions based on JCPD.

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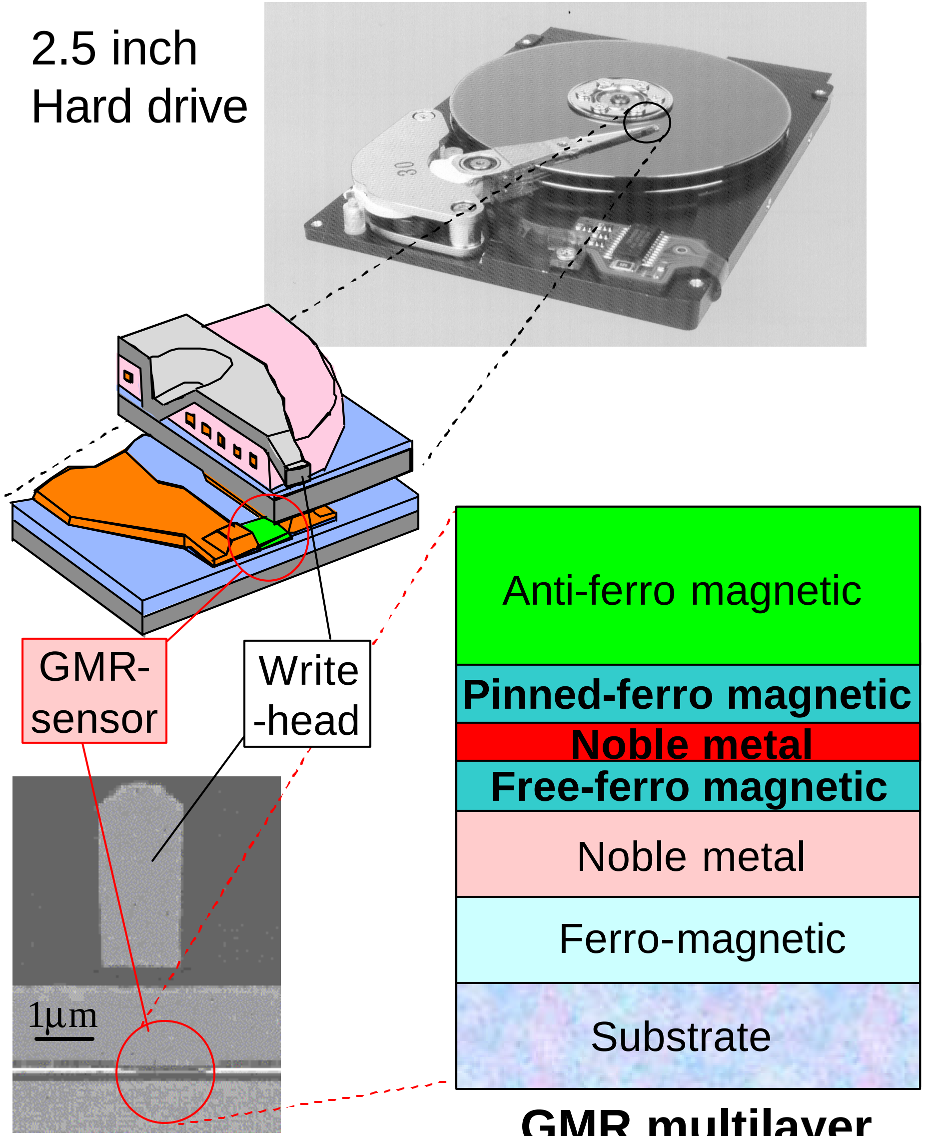
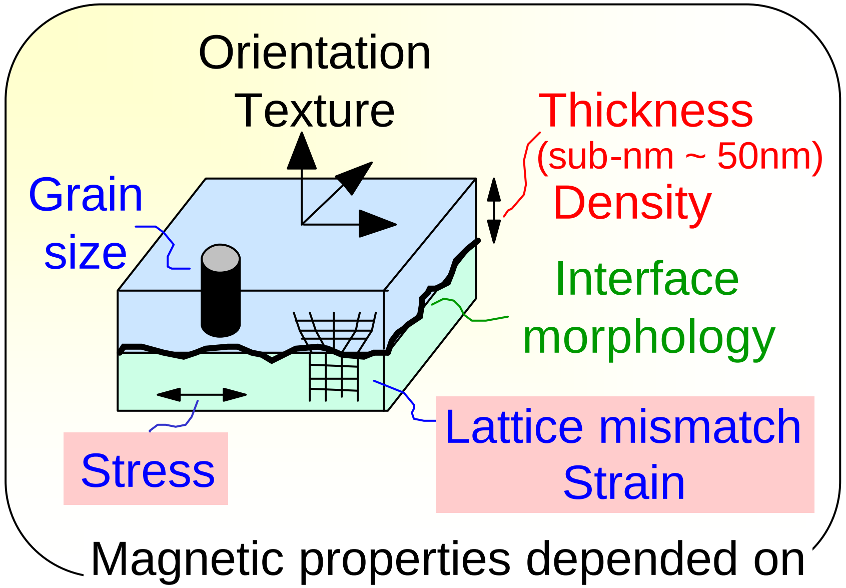
Background

2.5 inch
Hard drive



GMR multilayer

Sensor
layers

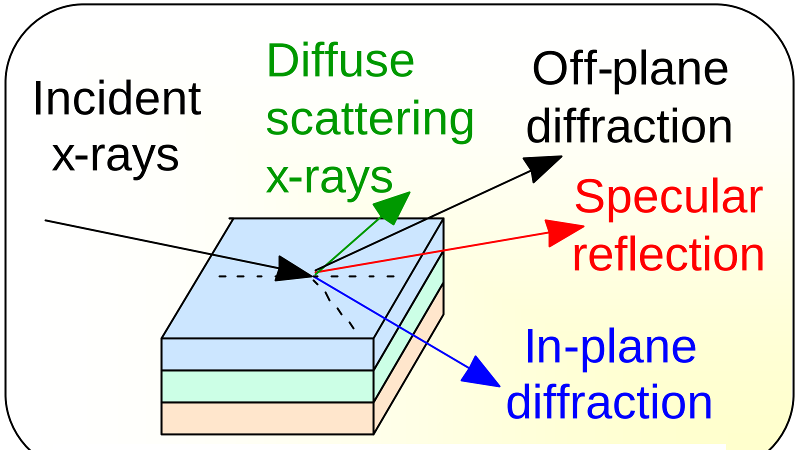


Magnetic properties depended on structure of the magnetic layers

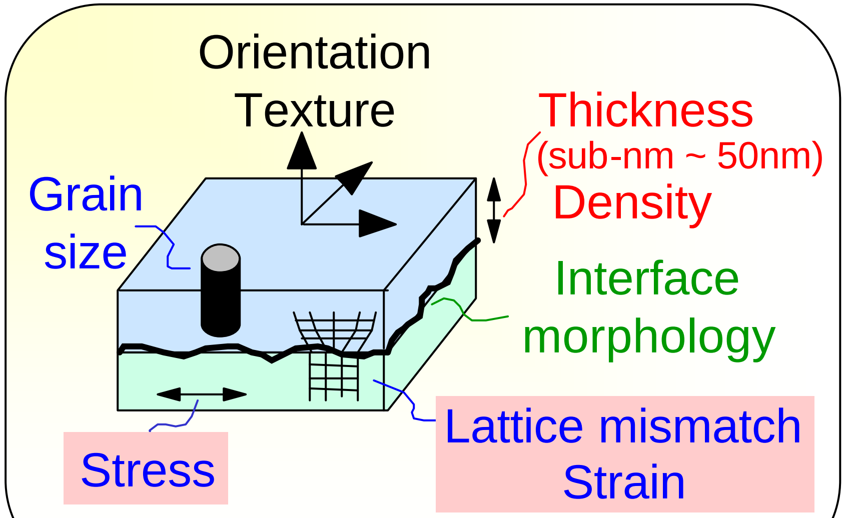
It is important to analyze the stress in the sensor, because the magnetostriction is sensitive to the crystal structure.

GMR:Giant MagnetoResistivity

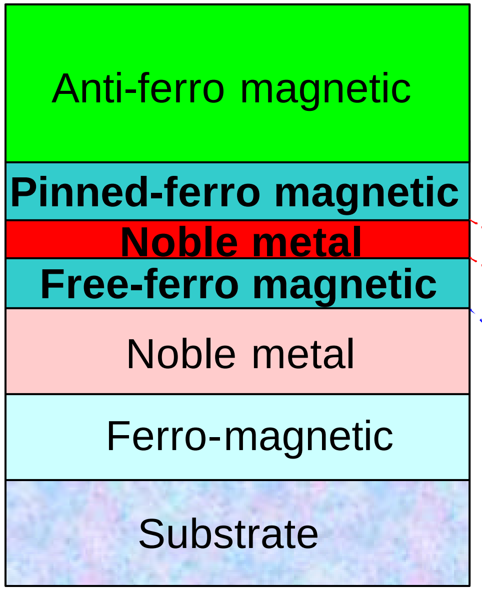
Subject



Measurement using SR x-rays



Magnetic properties depended on structure of the magnetic layers



GMR multilayer

Table 1 Sensor's layer structure

Element	Crystal structure	Lattice constant	Thickness	Grain size
Cu	fcc	0.3615nm	~2 nm	~20nm
Co	fcc	0.3545nm		
$Ni_{0.8}Fe_{0.2}$	fcc	0.354nm		

It was difficult to separate diffraction patterns from Cu / NiFe / Co thin films multilayer.

Objective

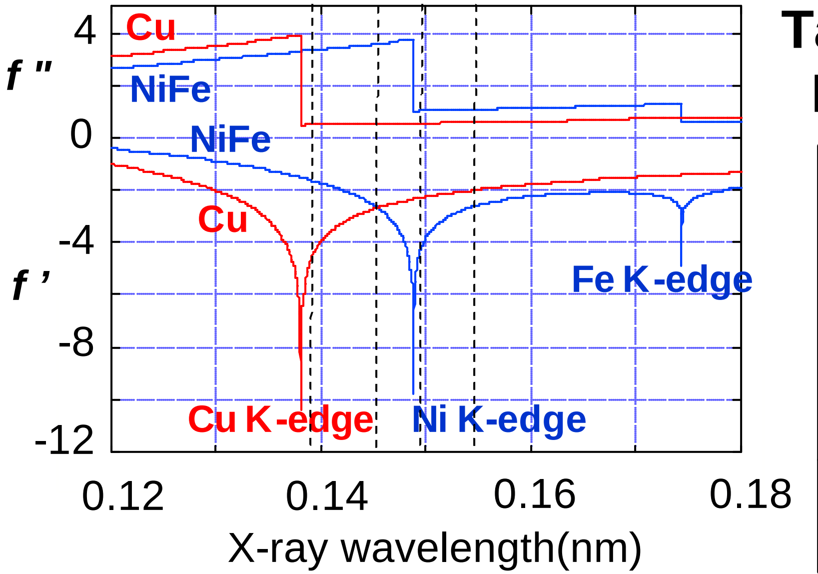


Fig.1 Dependence of Anomalous dispersion effect on wavelength

f 'and *f* "depend on X-ray wavelength strongly.

Table2 Calculated Structure factors and Diffraction intensities on wavelengths

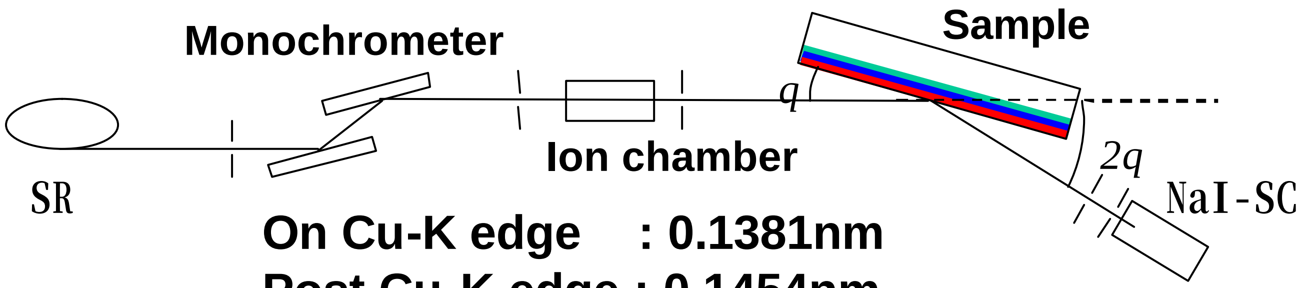
wave length (nm)	Cu		NiFe	
	on edge	post edge	on edge	post edge
	0.13812	0.14542	0.14887	0.15499
$\|F_{Cu}\|^2$	936	2611	2900	2904
$\|F_{NiFe}\|^2$	2819	2394	1143	2252
$\frac{I_{on\ edge}}{I_{post\ edge}}$	81%		77%	

Anomalous dispersion effects were changed diffraction intensity from specific elements.

Objective

We studied that a peak separation method from Cu / NiFe multilayer diffraction patterns examined using anomalous dispersion effect.

Experimental procedure (1)



On Cu-K edge : 0.1381nm
Post Cu-K edge : 0.1454nm
On Ni-K edge : 0.1488nm
Post Ni-K edge : 0.1549nm

Fig.2 Schematic of x-ray optics for a symmetry diffraction

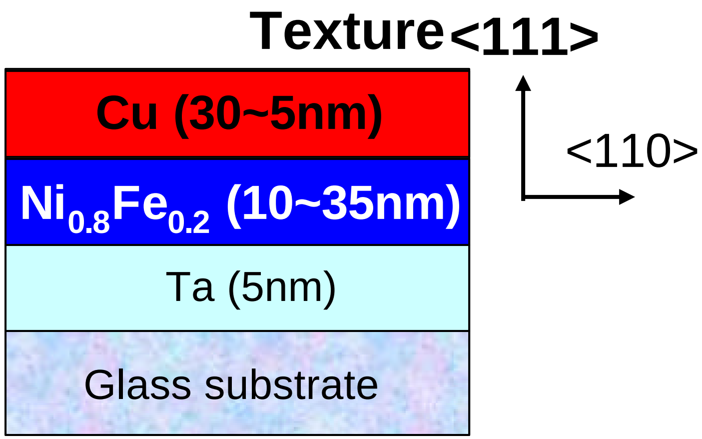


Fig.3 Schematic drawing of samples

Table3 Design thickness of samples

Sample	Thickness (nm)	
	Cu	NiFe
(a)	30	10
(b)	20	20
(c)	10	30
(d)	5	35

Diffraction patterns from samples

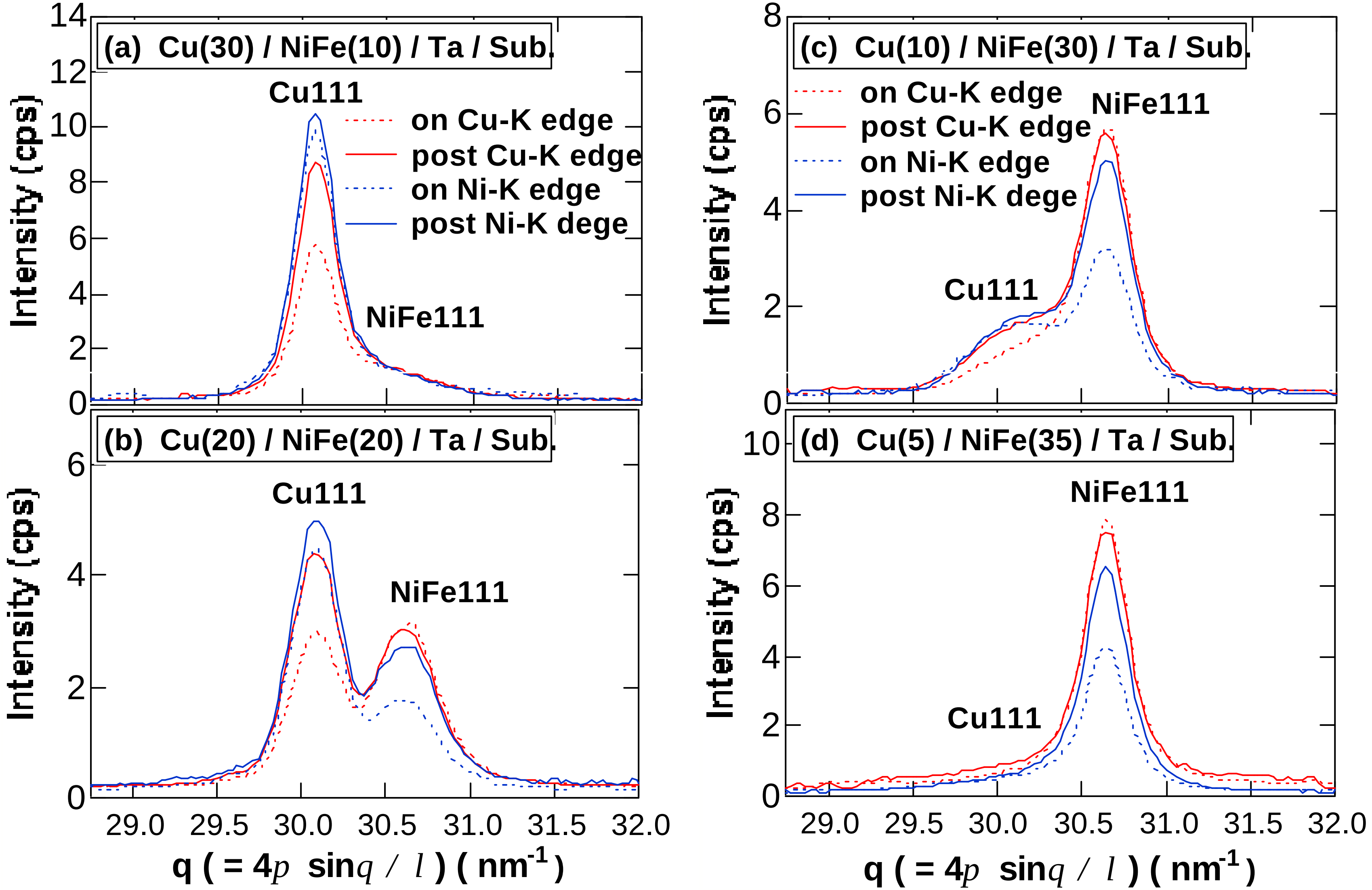
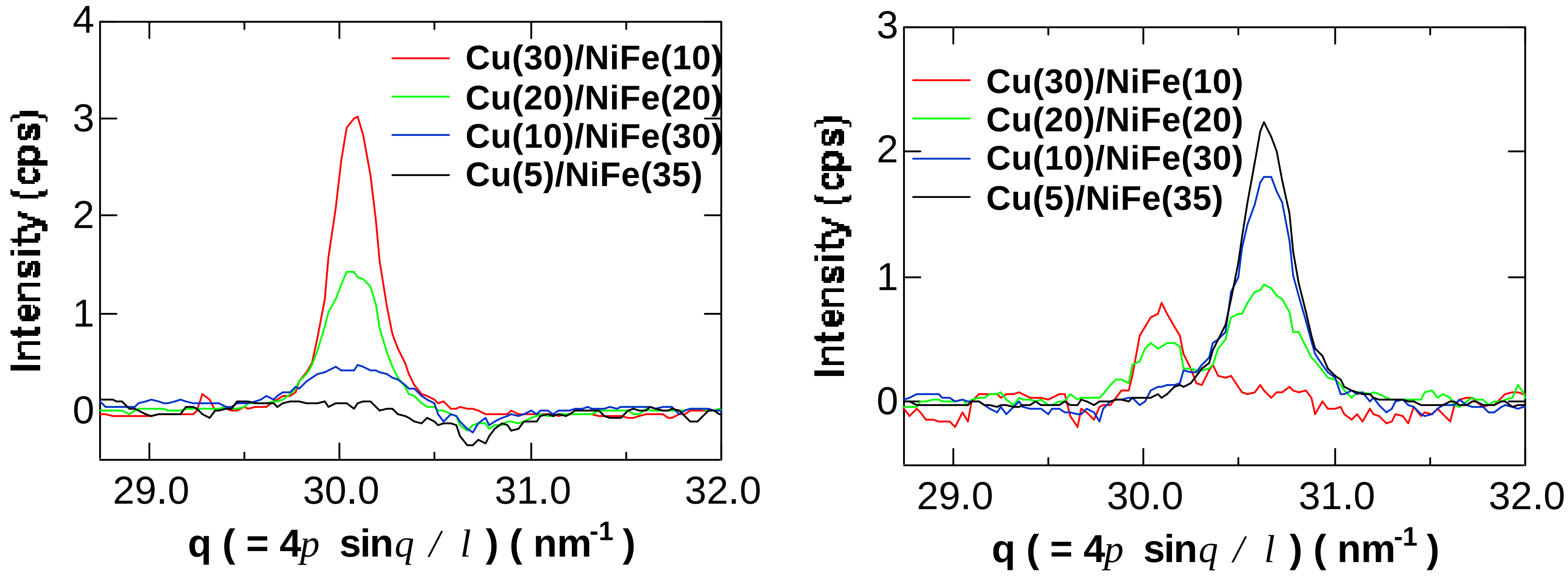


Fig.4 111 Diffraction patterns for the samples to stack Cu and NiFe measured at four wavelengths.

7 Differential patterns of the diffractions



(a) Differential Cu diffraction patterns at near Cu-K edge.

(b) Differential NiFe diffraction patterns at near Ni-K edge.

Fig.5 Differential Cu and NiFe diffraction patterns.
(Differential pattern = post Cu-K edge pattern - Cu-K edge pattern)

Experimental results

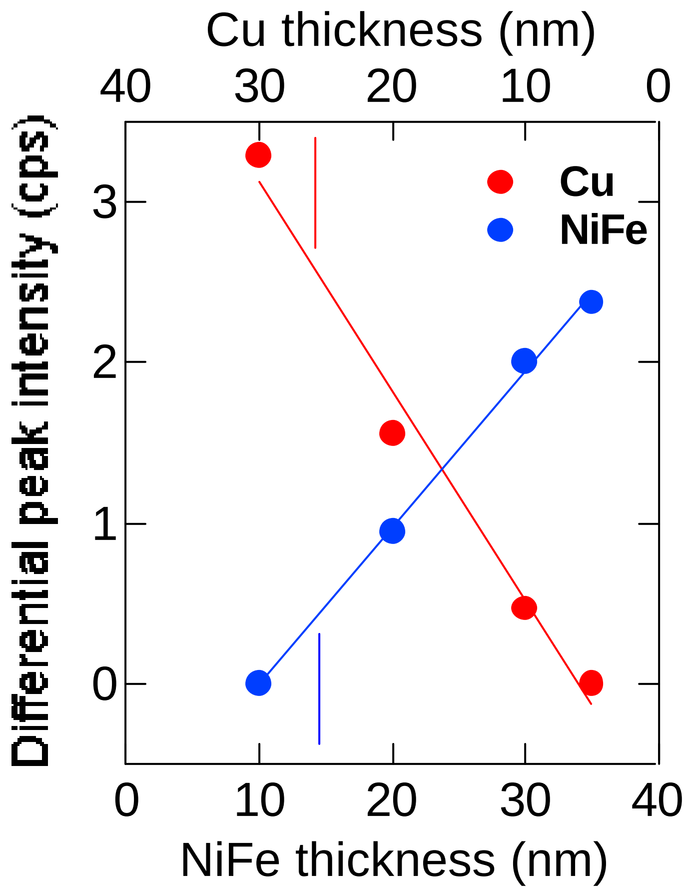


Fig.6 Differential peak intensity versus Cu and NiFe thickness.

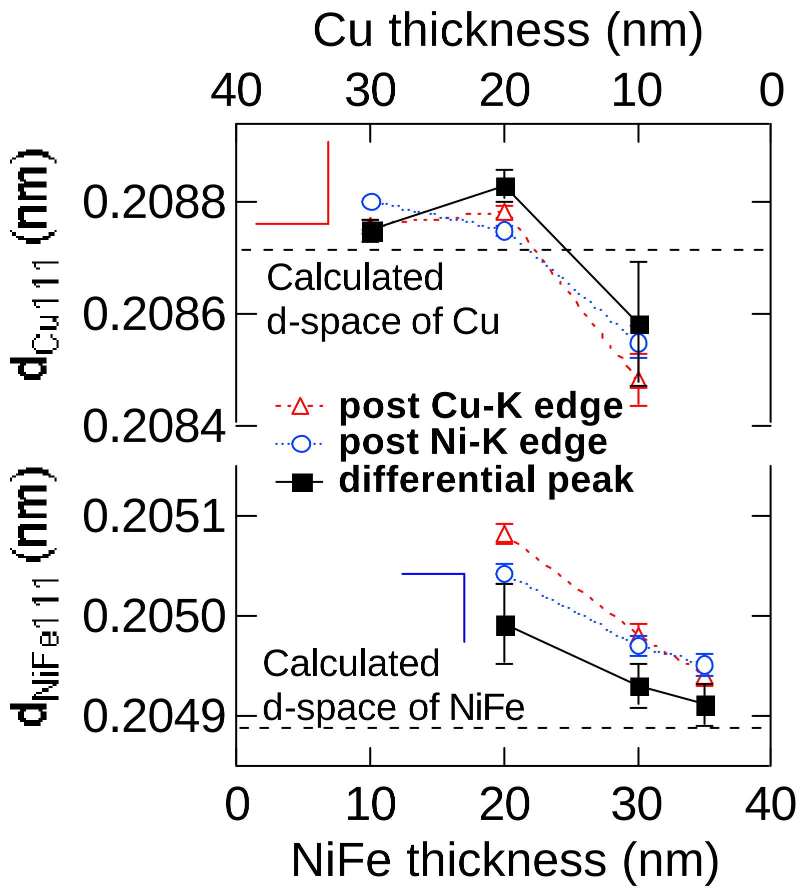


Fig.7 A d-space versus the thicknesses

The crystal structure analysis is possible in each layer for Cu and NiFe stacked sample using anomalous dispersion effect.

Experimental procedure (2)

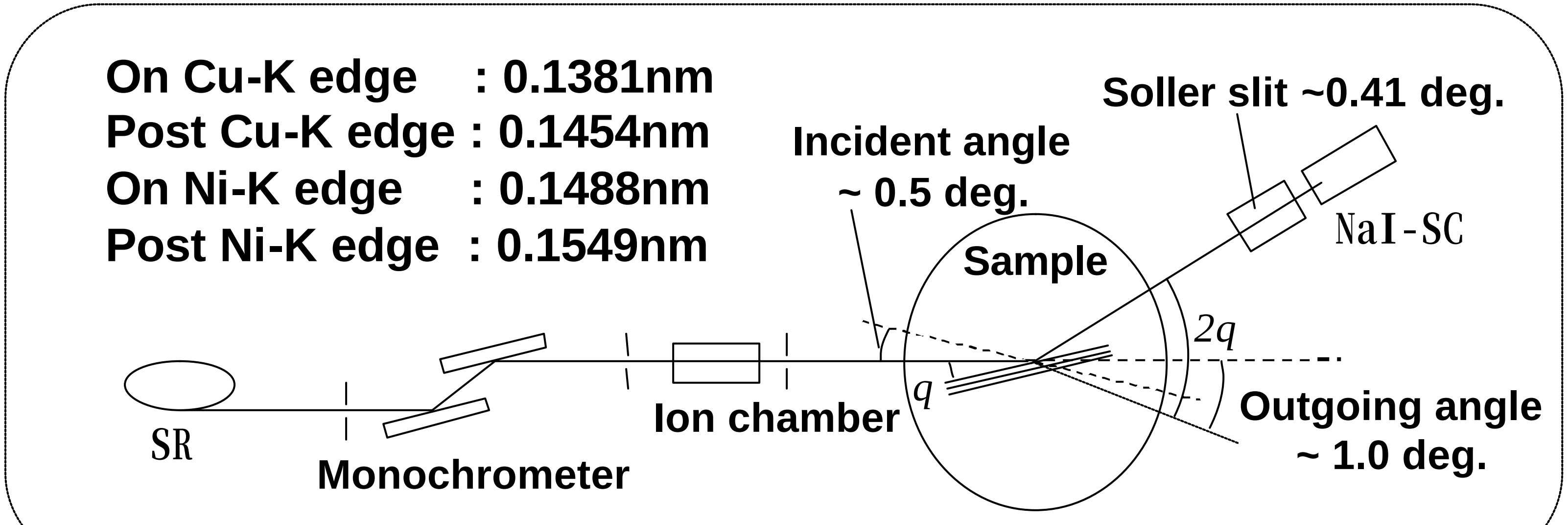


Fig.8 Schematic of x-ray optics for a in-plane diffraction

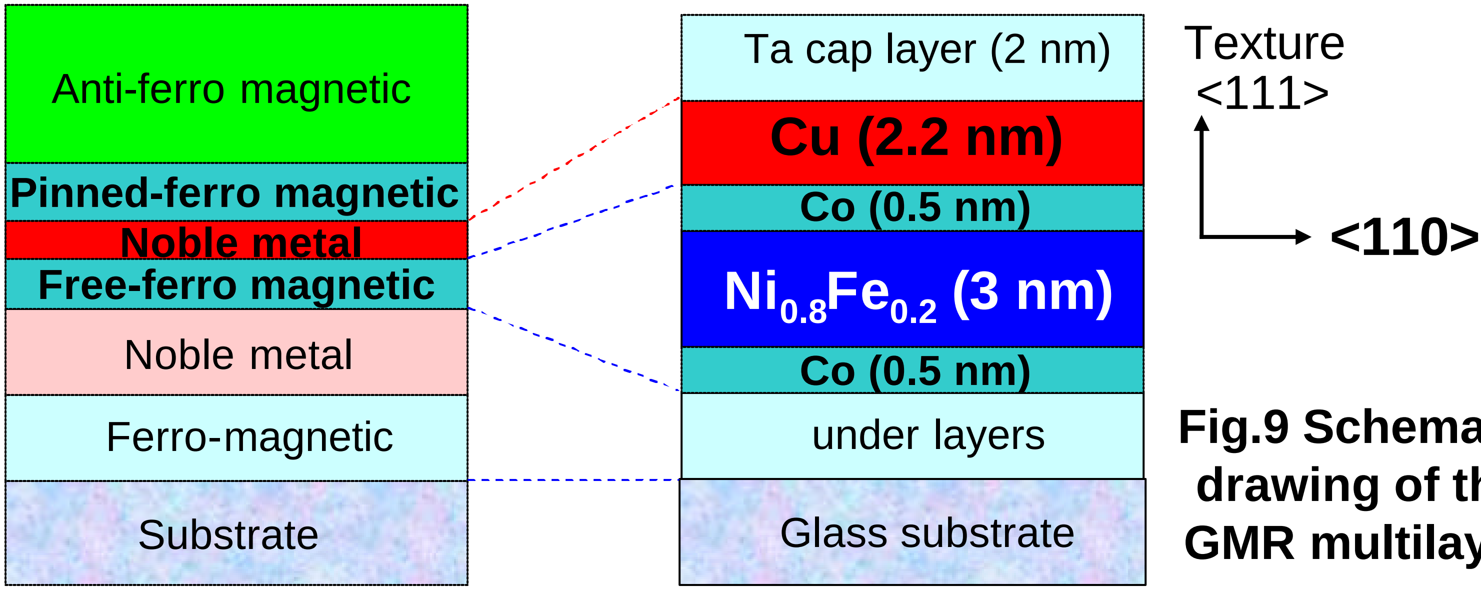
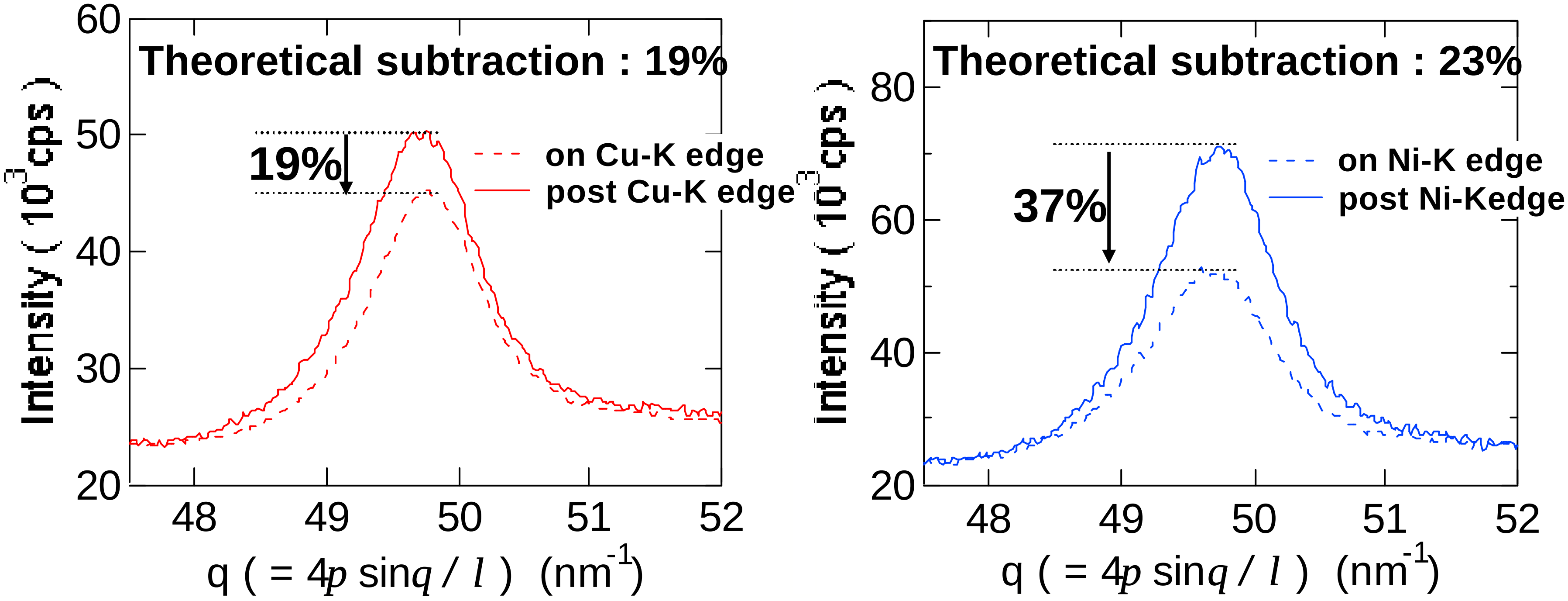


Fig.9 Schematic drawing of the GMR multilayer

In-plane 220 diffraction patterns



(a) Differential Cu diffraction patterns at near Cu-K edge.

(b) Differential NiFe diffraction patterns at near Ni-K edge.

Fig.8 In-plane 220 diffraction patterns of Cu and NiFe multilayer film was measured at four wavelengths.

Differential patterns from sensor

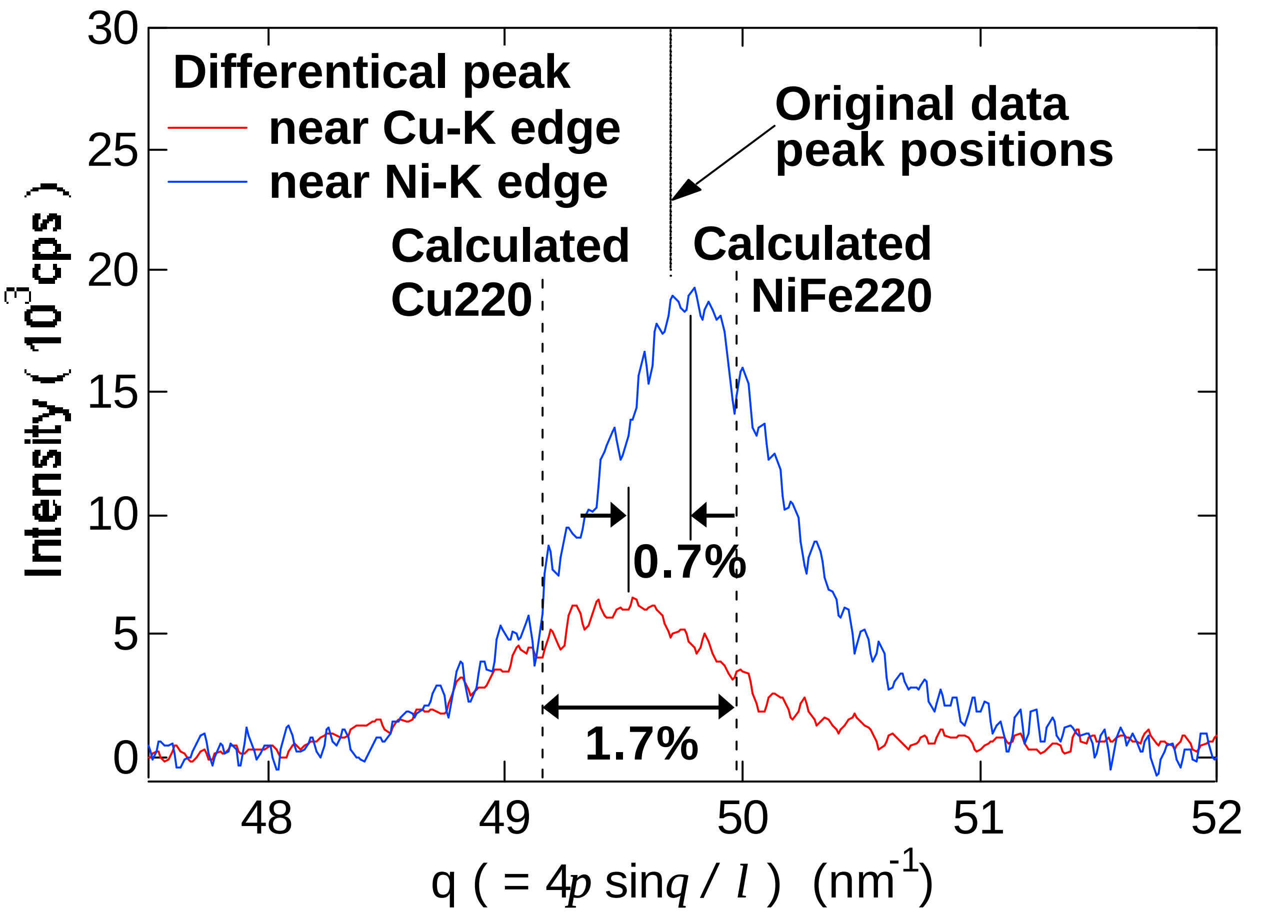


Fig.9 Differential Cu and NiFe diffraction patterns.
Two dashed lines shows the calculated peak positions based on JCPDS.

Conclusions

Peak separation method from Cu and NiFe multilayer diffraction patterns was examined using anomalous dispersion effect. The results were as follows.

(1) The differential diffraction pattern was obtained by simple subtraction of the just K-edge pattern from post K-edge one. The differential Cu and Ni diffraction patterns were separated each other.
(2) The differential peaks intensity of Cu and Ni edge was in proportion to the thickness of the Cu and NiFe layers.
(3) The Cu layers was compressed by NiFe layer and NiFe layer was strained by Cu layer. The lattice misfit between Cu and NiFe was smaller from 1.7% to 0.7%.