Grazing Incidence X-Ray Diffraction of Longitudinal and Perpendicular Magnetic Recording Media for HDD

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Longitudinal magnetic recording media for HDD increased the recording density to 60Gbits/in^2 (80GB/disk), and perpendicular magnetic recording media achieved the recording density of 150Gbits/in^2. For further increase of the recording density of longitudinal magnetic media, antiferromagnetic coupling (AFC) with a thin Ru layer between top and bottom ferromagnetic thin films was proposed. The optimum thickness of the Ru layer is about 0.8nm. We measured grazing incidence X-ray diffraction (GIXD) profiles in circumferential and radial directions for each layer of AFC media. The X-ray energy was 10keV, and the grazing incidence angle was 0.2 degree. Figure 1 shows in-plane diffraction profiles in the circumferential direction for each layer of AFC media. As shown in the diffraction profile of the Ru layer 0.8nm thick, hcp-Ru(002), (100) and (102) diffraction peaks are observed for the first time from such a thin Ru film of AFC media with hcp-Co peaks from bottom magnetic layer.

For perpendicular magnetic media, we observed for the first time fcc phase with hcp phase in CoCrPt-SiO_2 granular magnetic media, in which 150Gbits/in^2 recording density was achieved, by using GIXD with χ-axis setting. By reducing fcc phase content in the magnetic layer, the recording density of perpendicular magnetic media would increase up to 400Gbits/in^2 in near future.

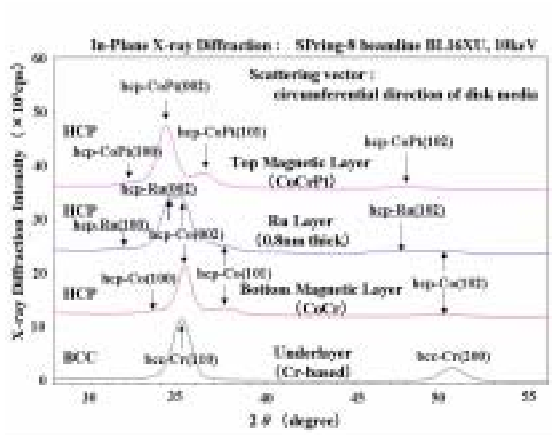

Fig. 1 In-plane diffraction profiles of each layer of longitudinal recording AFC magnetic media.

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My Talk is about

(1) in-plane diffraction of a thin Ru layer in antiferro-magnetically coupled (AFC) longitudinal recording media

(2) detection of FCC phase in perpendicular magnetic recording media

by grazing incidence X-ray diffraction (GIXD).

Introduction

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Recent Trend in Magnetic Recording Media for HDD

Longitudinal Media：60Gbits/in2 ⇒ 120Gbits/in2 （2003）
(80GB/disk）　(160GB/disk）

antiferromagnetic interlayer coupling (AFC) using a thin Ru layer has enhanced thermal magnetic stability.

Perpendicular Media :150Gbits/in2 ⇒ 400Gbits/in2 (future)

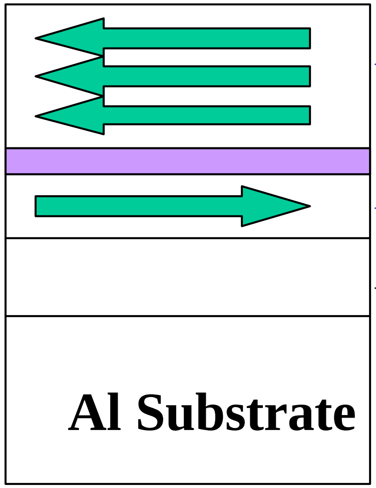
granular magnetic layer has been developed by Fuji Electric Co. and is expected to improve recording density.

I will show that GIXD at undulator beamline BL16XU in SPring-8 is very powerful for the crystallographic analysis of the polycrystalline thin films in these recently developed media.

(1) In-Plane X-Ray Diffraction of a thin Ru Layer of AFC Longitudinal Magnetic Recording Media

AFC (antifferomagnetic interlayer exchange coupling) Media

Ru layer （0.8nm）
（Spacer）

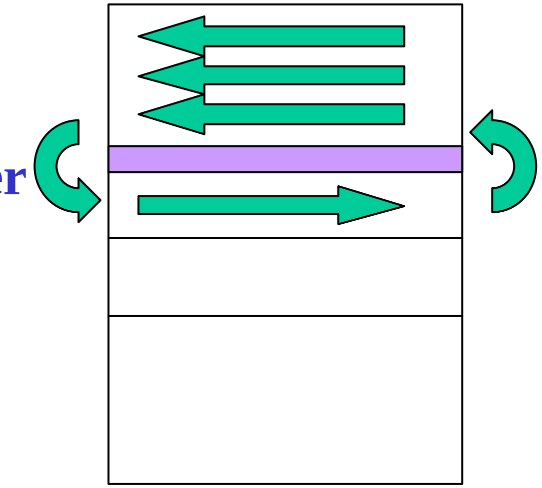


Top Magnetic Layer
(Recording Layer)

Bottom Magnetic Layer
（Stabilizer）

Underlayer
(Cr-alloy）

＜0.8nm＞
Ru: 4 atomic layers



Magnetic Stabilization

Roles of the Thin （0.8nm） Ru layer

(1) Spacer for AFC：thin and non-magnetic

(2) Crystallographic role for the layered structure?

⇓

We have tried in-plane diffraction measurements.

Measurements of In-Plane Diffraction

X-ray source and Optics

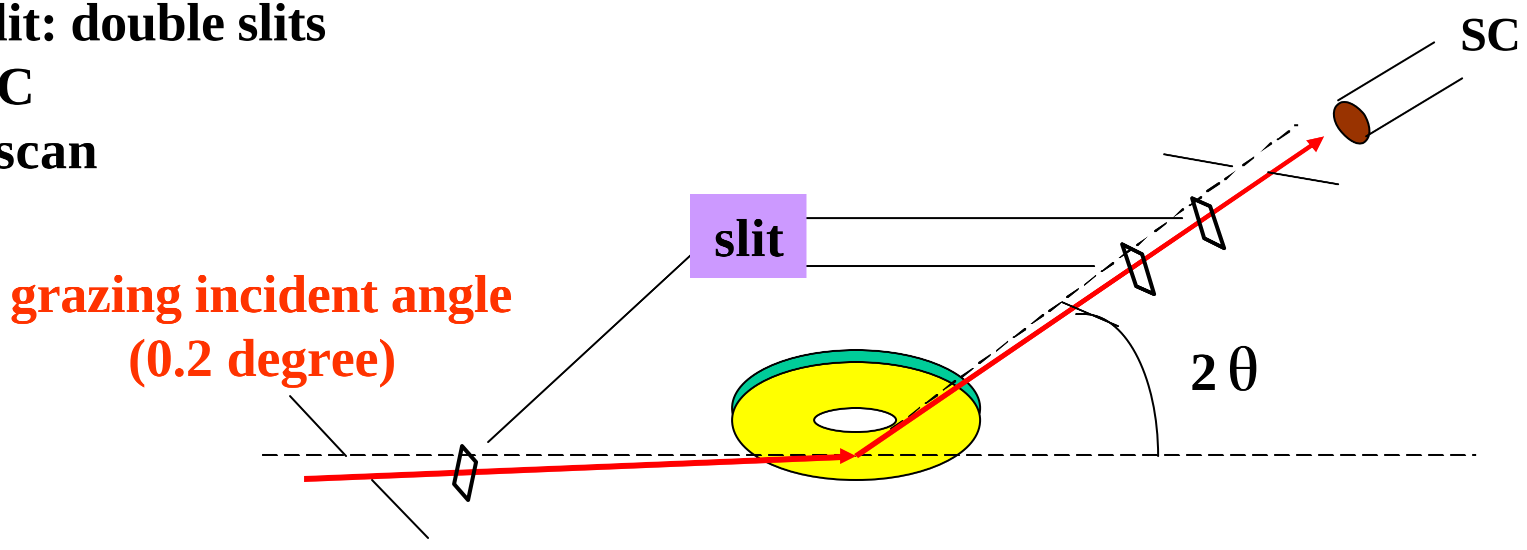
- in-vacuum type undulator at BL16XU in SPring-8
- Si(111) double monochromator
- a cylindrical mirror (incident angle: 4.5mrad)

Apparatus for X-ray diffraction

- 4-circle diffractometer

Measurement conditions for in-plane diffraction

- photon energy: 10keV (λ =1.24Å)
- grazing incident angle: 0.2 degree (Total Reflection, Reflectivity > 90%)
- incident slit: 0.1mm (horizontal) ×1mm (vertical)
- receiving slit: double slits
- detector: SC
- scan: 2θ scan



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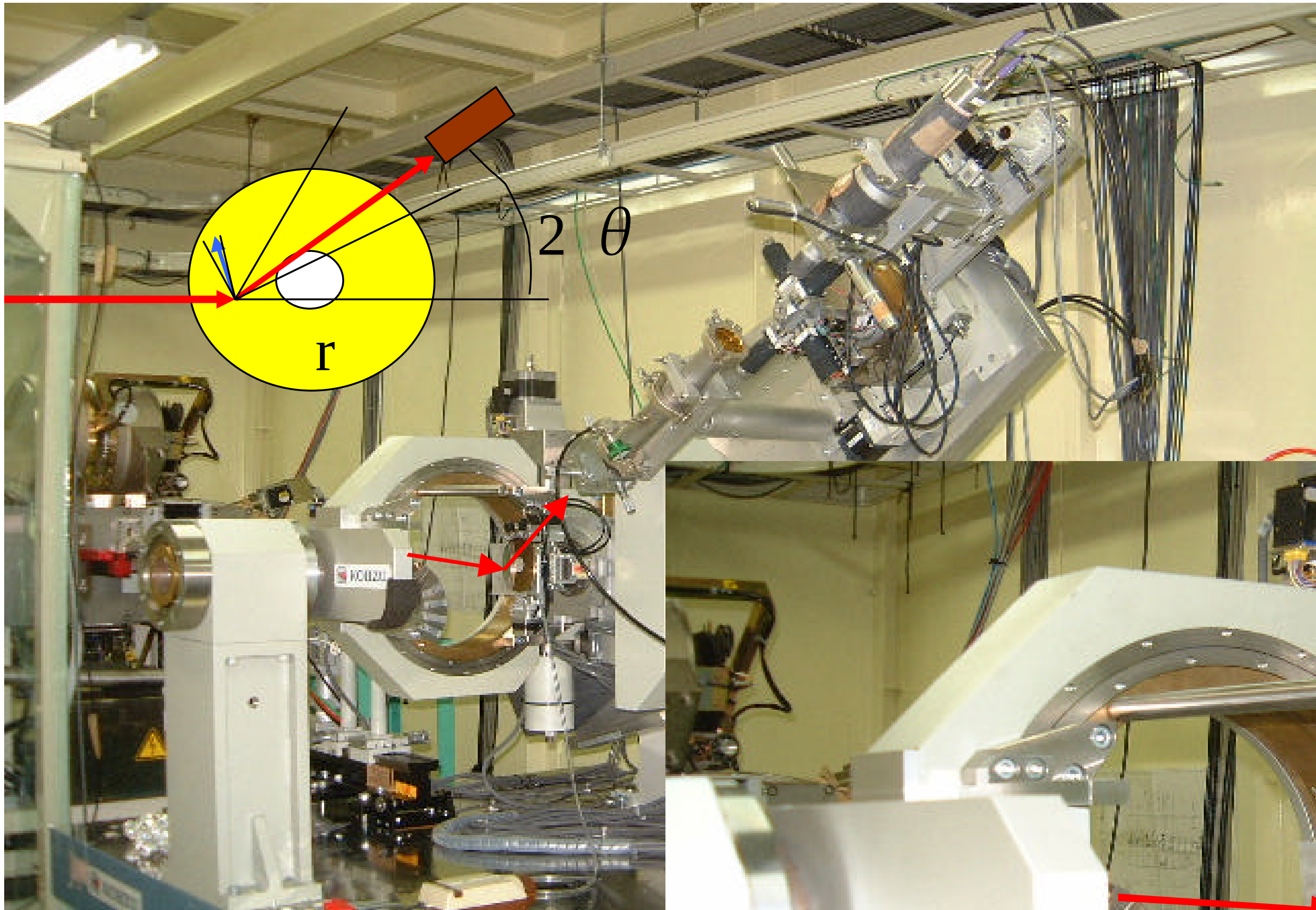
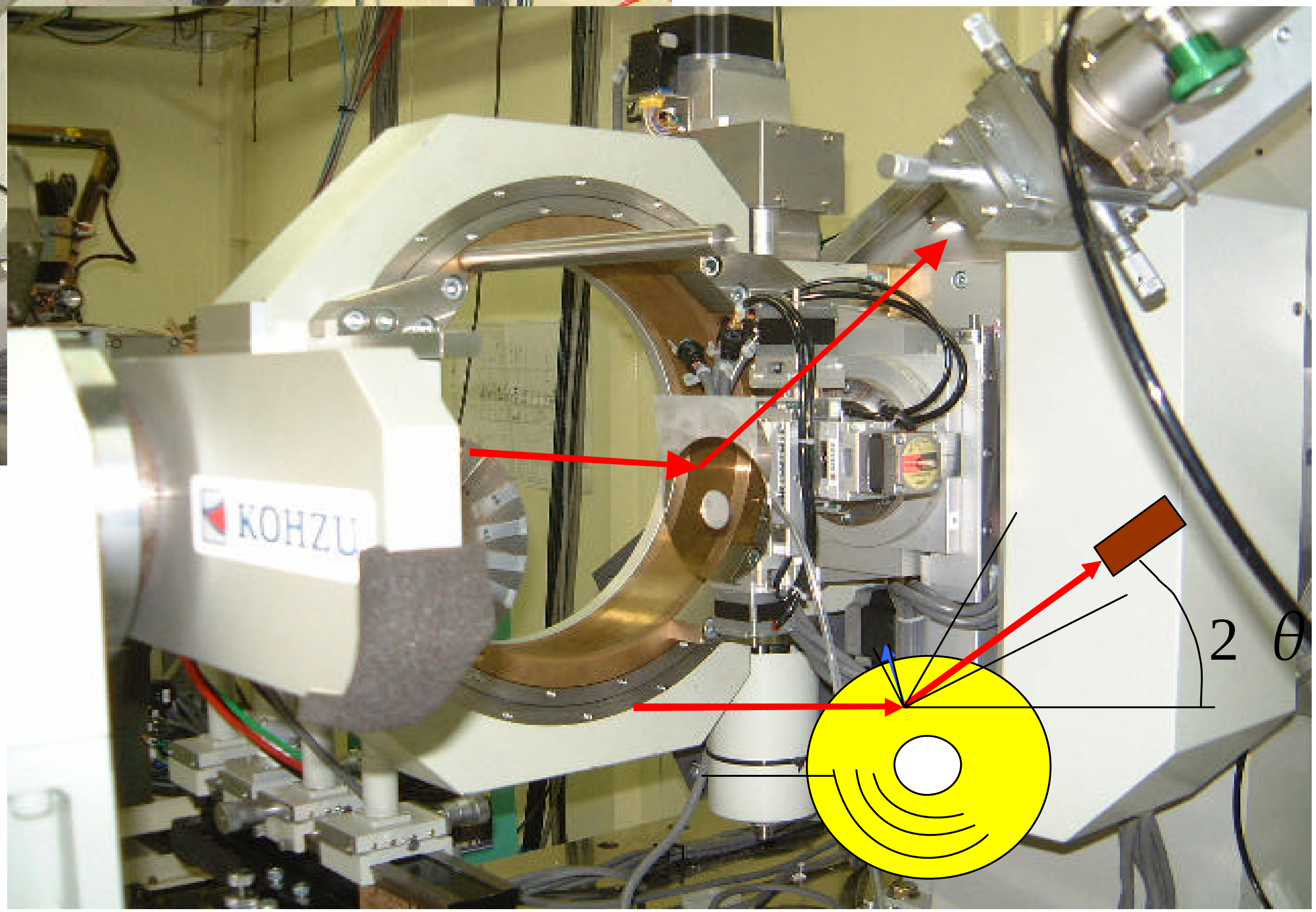


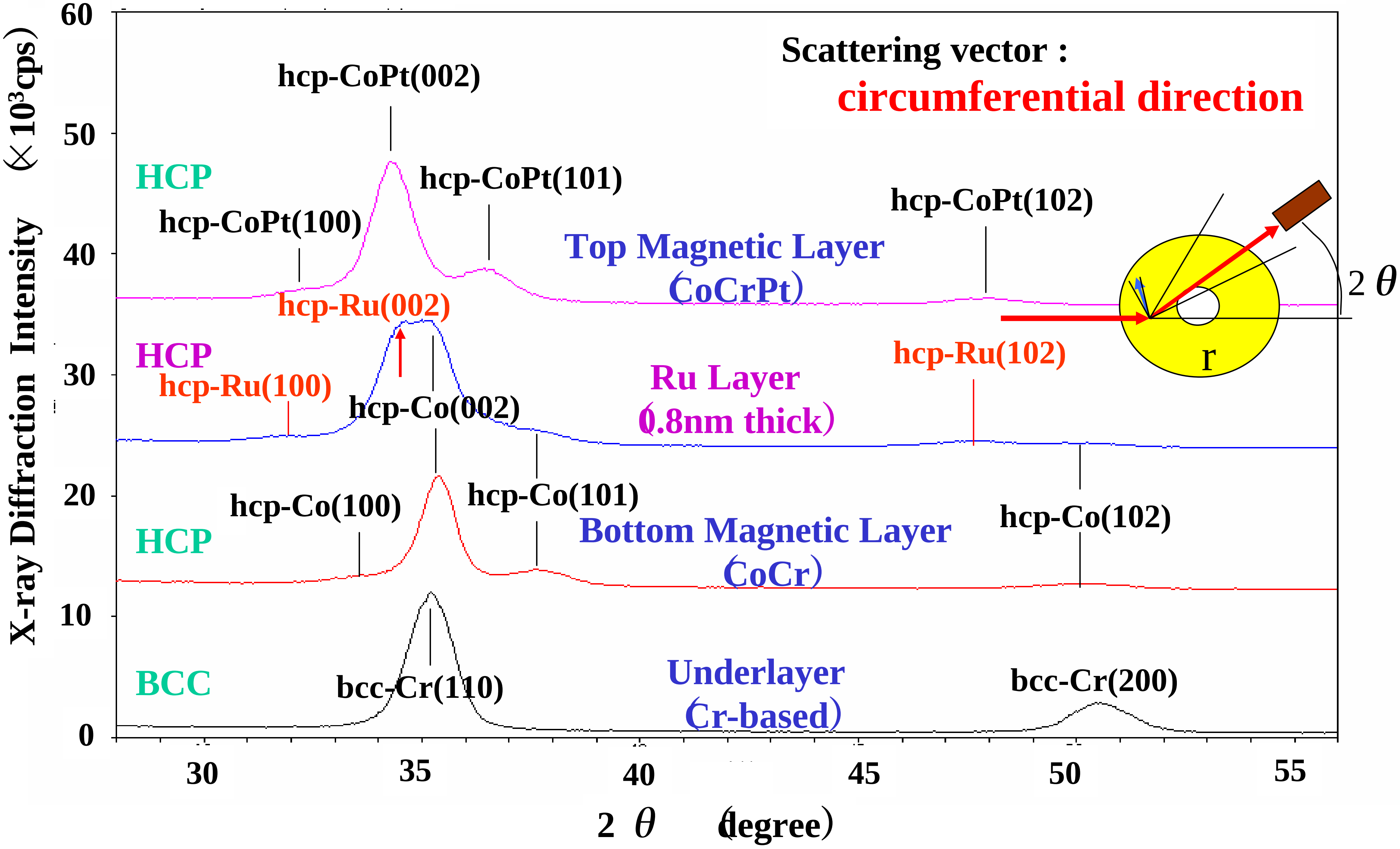
Scattering Vector:
Radial Direction



Scattering Vector:
Circumferential
Direction

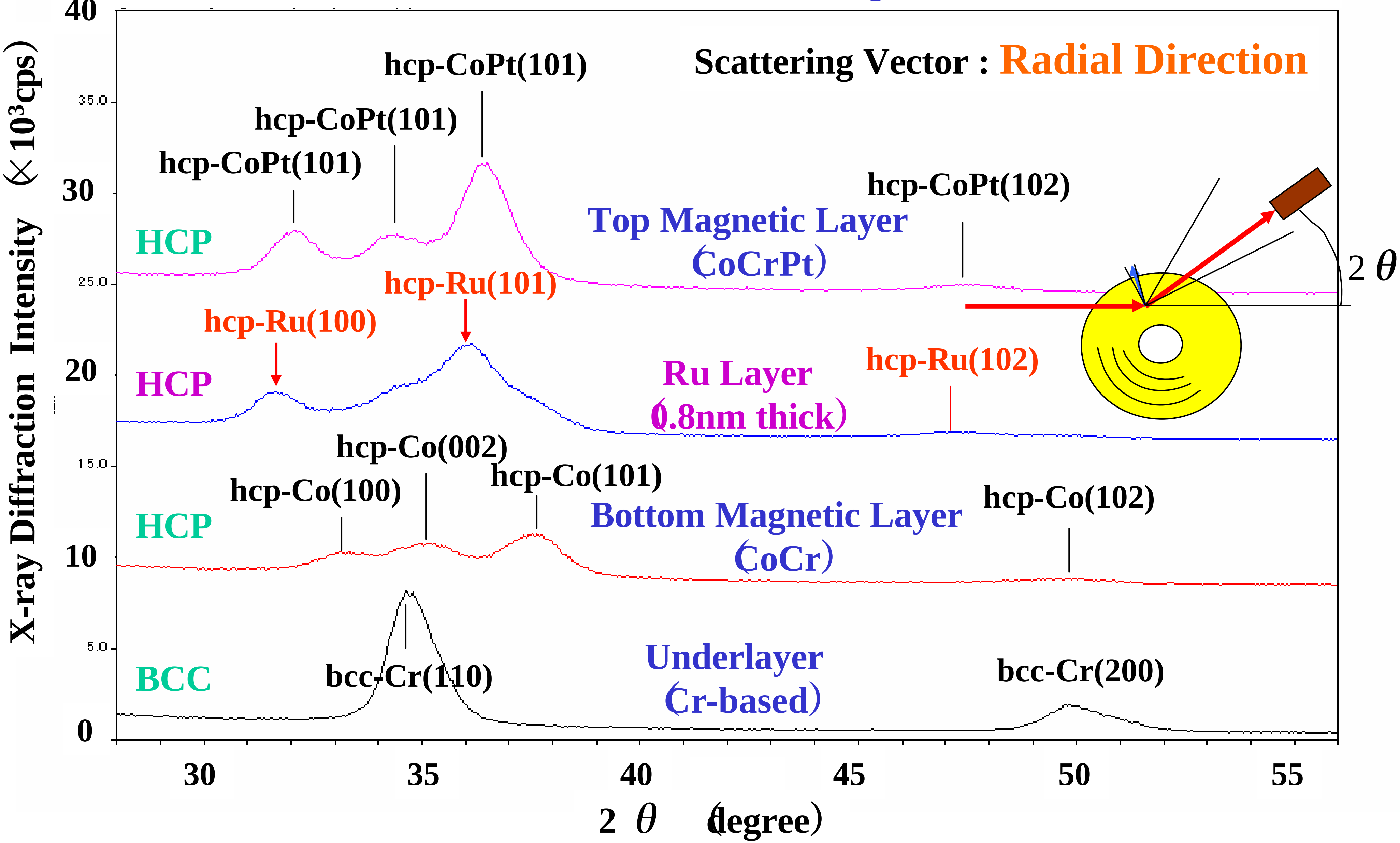
In-Plane X-ray Diffraction of Each Layer of AFC Media:

SPring-8 beamline BL16XU, 10keV



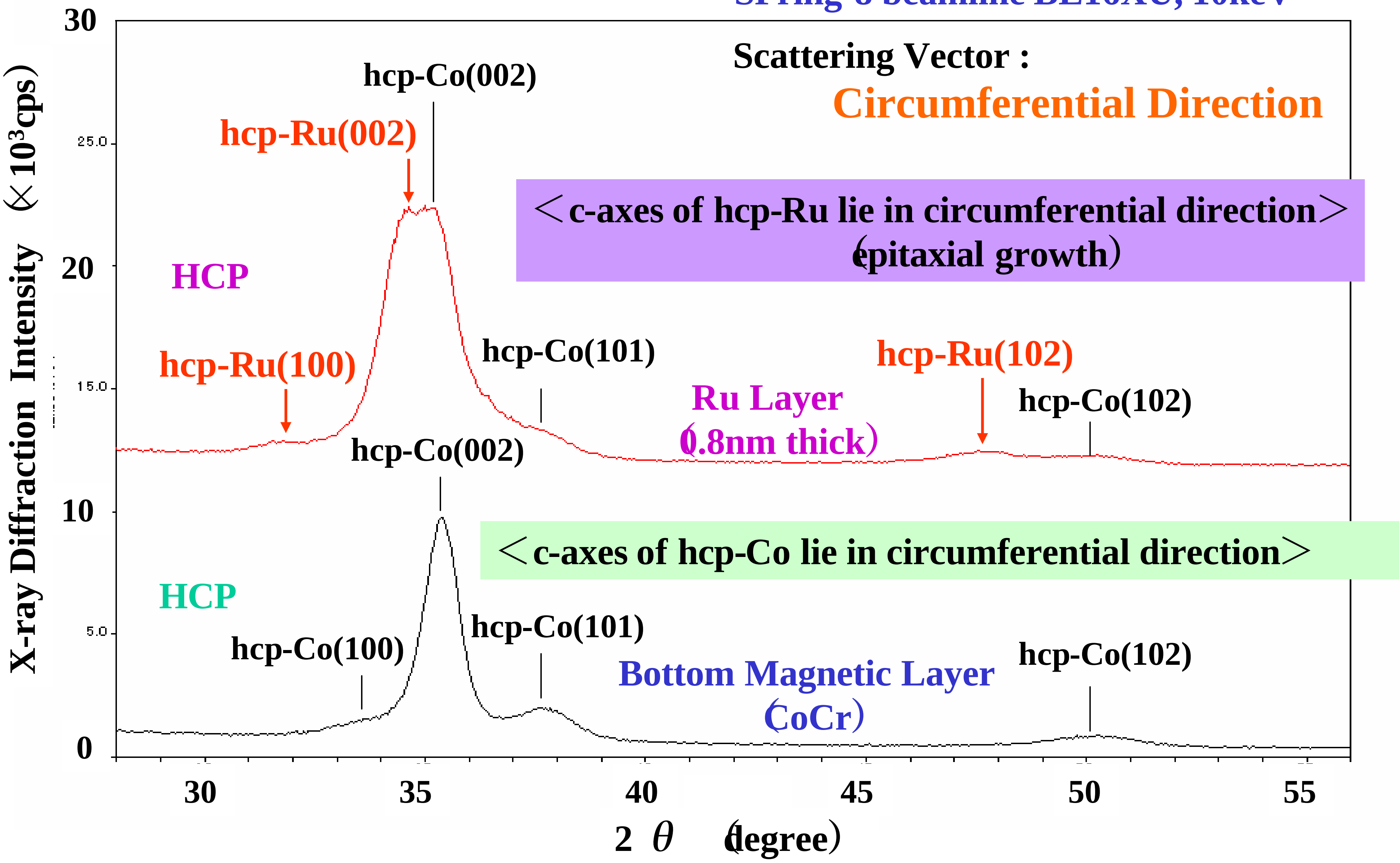
In-Plane X-Ray Diffraction of Each Layer of AFC Media:

SPring-8 beamline BL16XU, 10keV



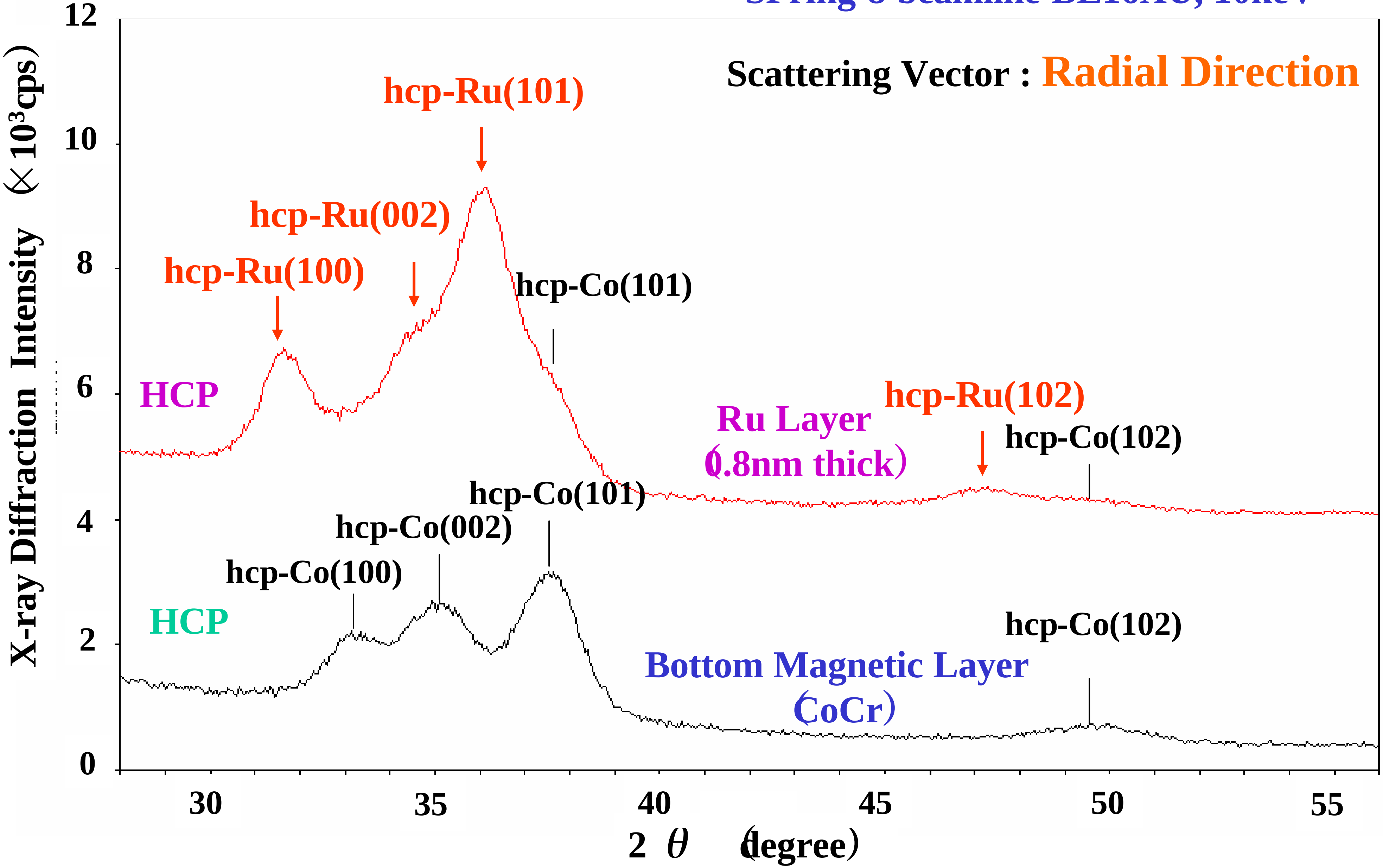
In-Plane X-Ray Diffraction of Ru Layer and Bottom Magnetic Layer:

SPring-8 beamline BL16XU, 10keV

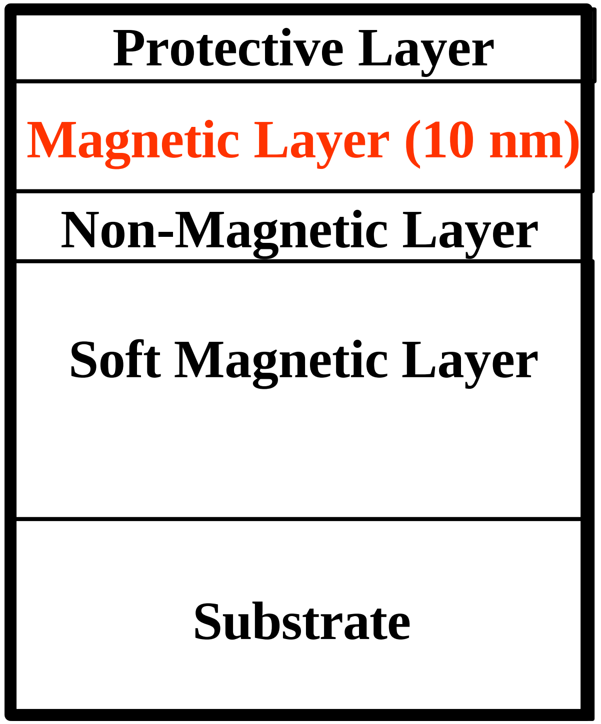


In-Plane X-Ray Diffraction of Ru Layer and Bottom Magnetic Layer:

SPring-8 beamline BL16XU, 10keV



2) Detection of FCC Phase in Perpendicular Magnetic Recording Media



Layered Structure of Perpendicular Magnetic Media

FCC Phase in Magnetic Layer (HCP-Co alloy)

- **Low Magnetic Anisotropy (low thermal stability)**
- **Origin of Noise**

Evaluation of FCC phase content in the magnetic layer is important, but difficult for the preferentially oriented HCP-Co alloy thin films.

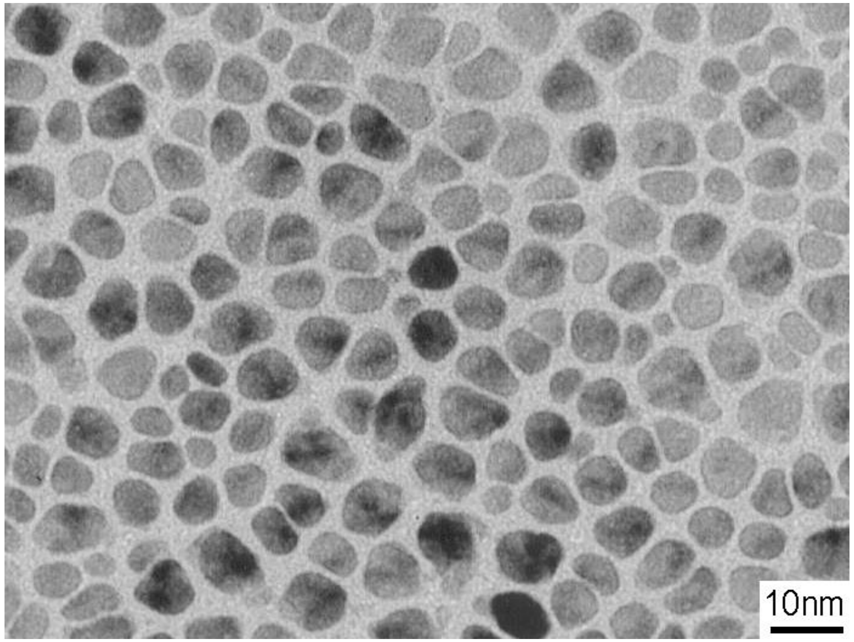
We tried GIXD measurements at BL16XU in SPring-8.

Granular Perpendicular Magnetic Layer

Perpendicular Magnetic Layer
Developed by Fuji Electric Co.

Granular Magnetic Layer
(CoPtCr-SiO2) Prepared by
Sputtering at RT

Recording Density: 150Gbits/in2

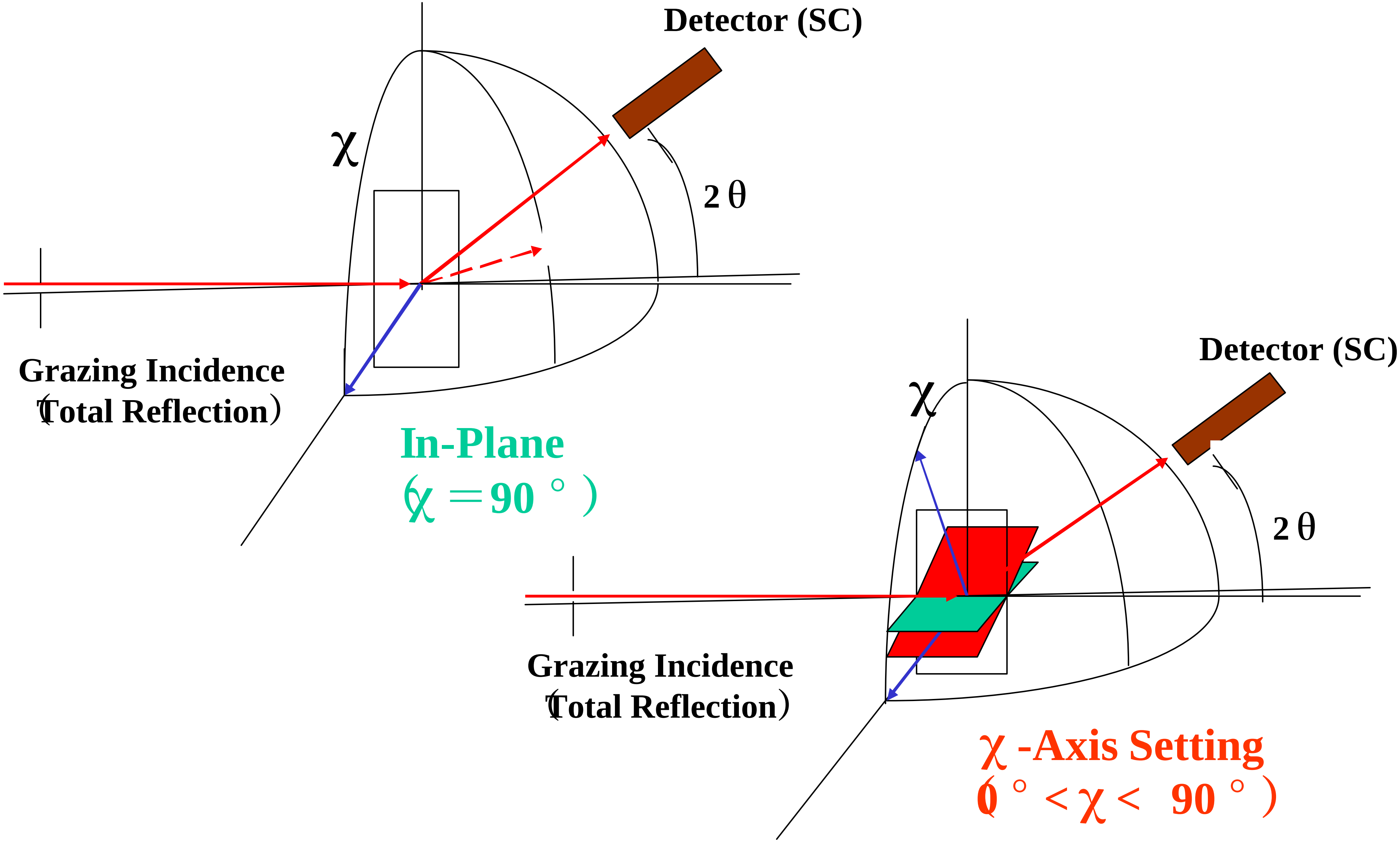


TEM Image (Plane-View)
(average grain size: 6.7nm)

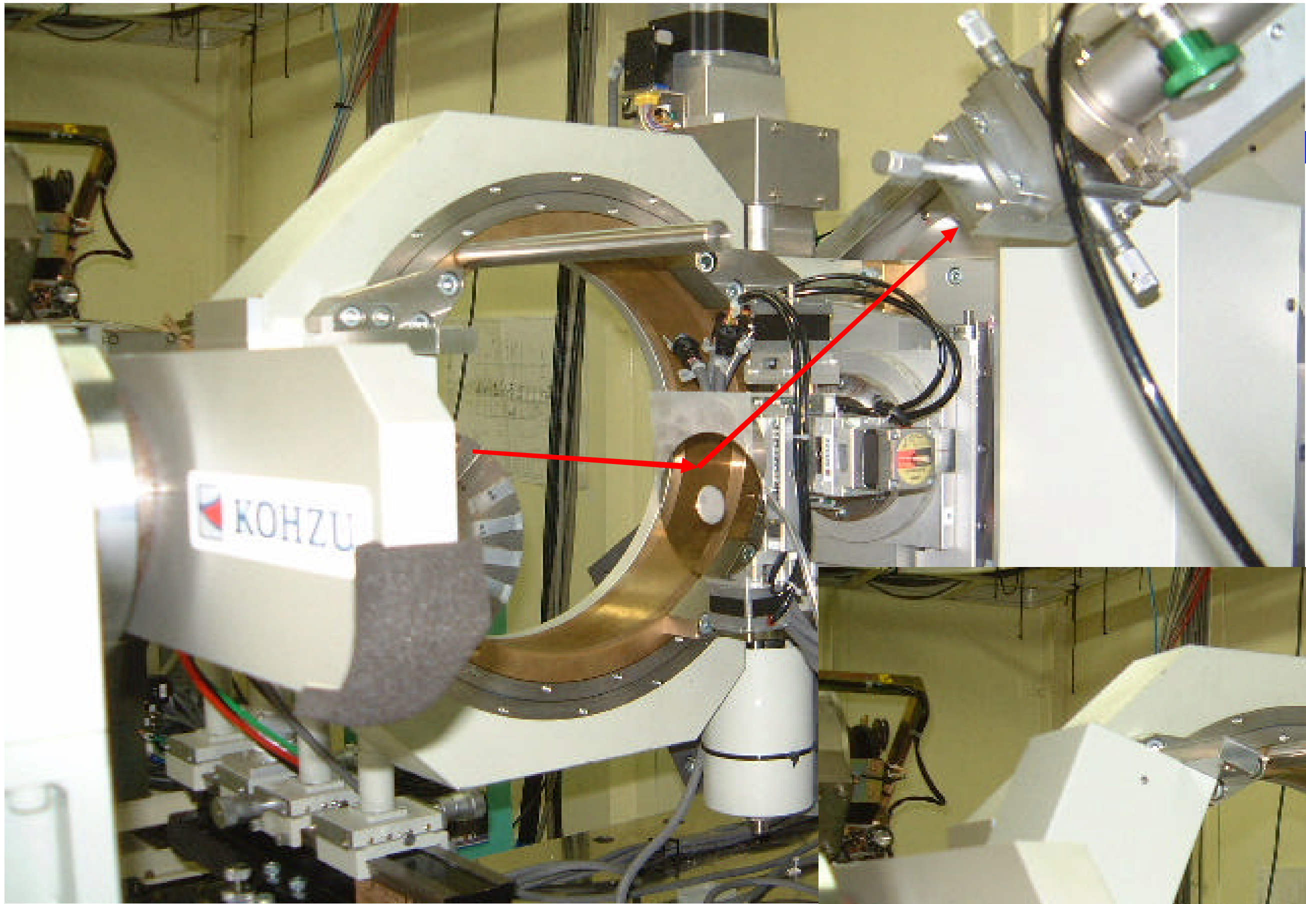
Experimental

- Samples : CoPtCr-SiO2 (20nm thick)
  - Sample A (Pt Content : low)
  - Sample B (Pt Content : high)
- GIXD
  - at BL16XU in SPring-8
  - grazing incident angle: 0.2 degree

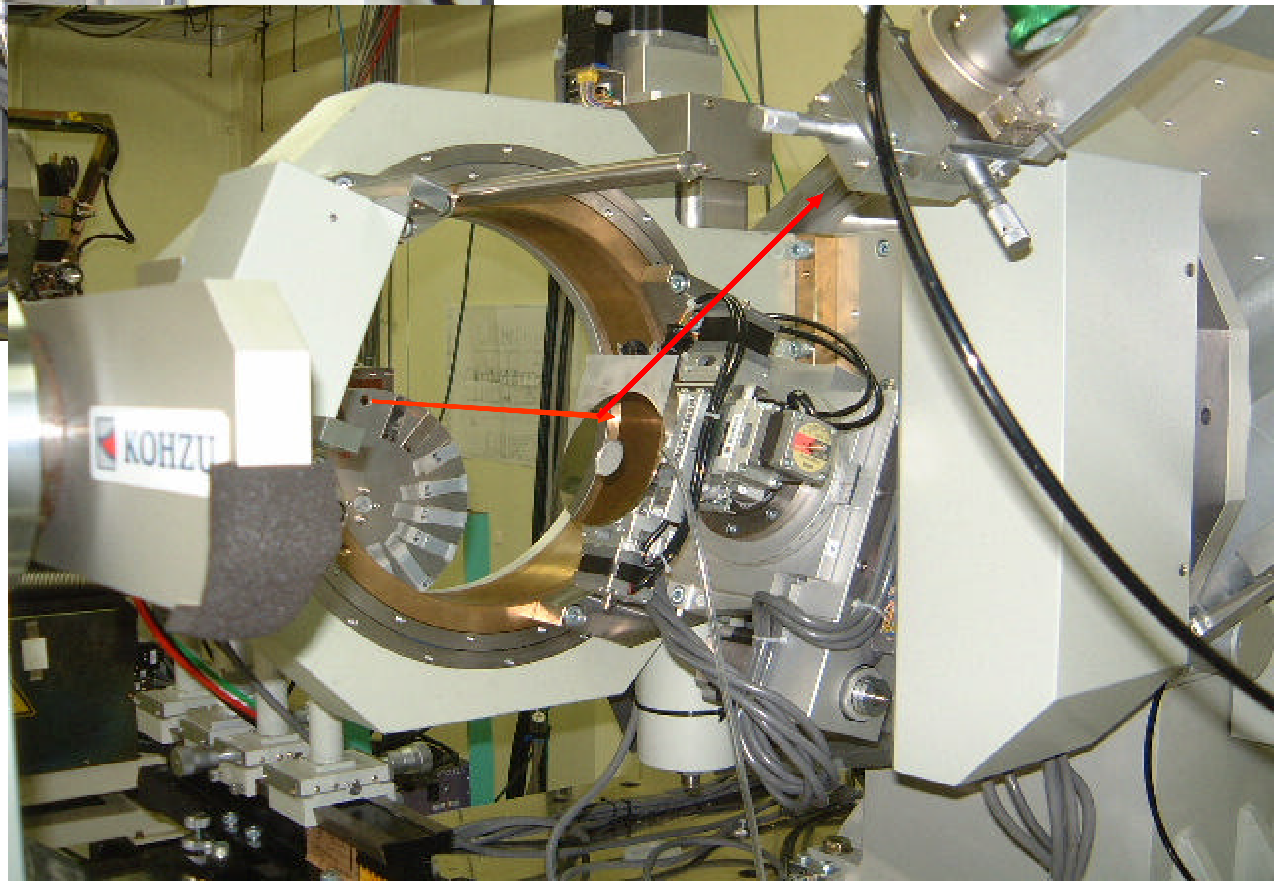
Method of FCC Phase Detection in Co-Alloy Thin Film



GIXD by 4-Circle Diffractometer



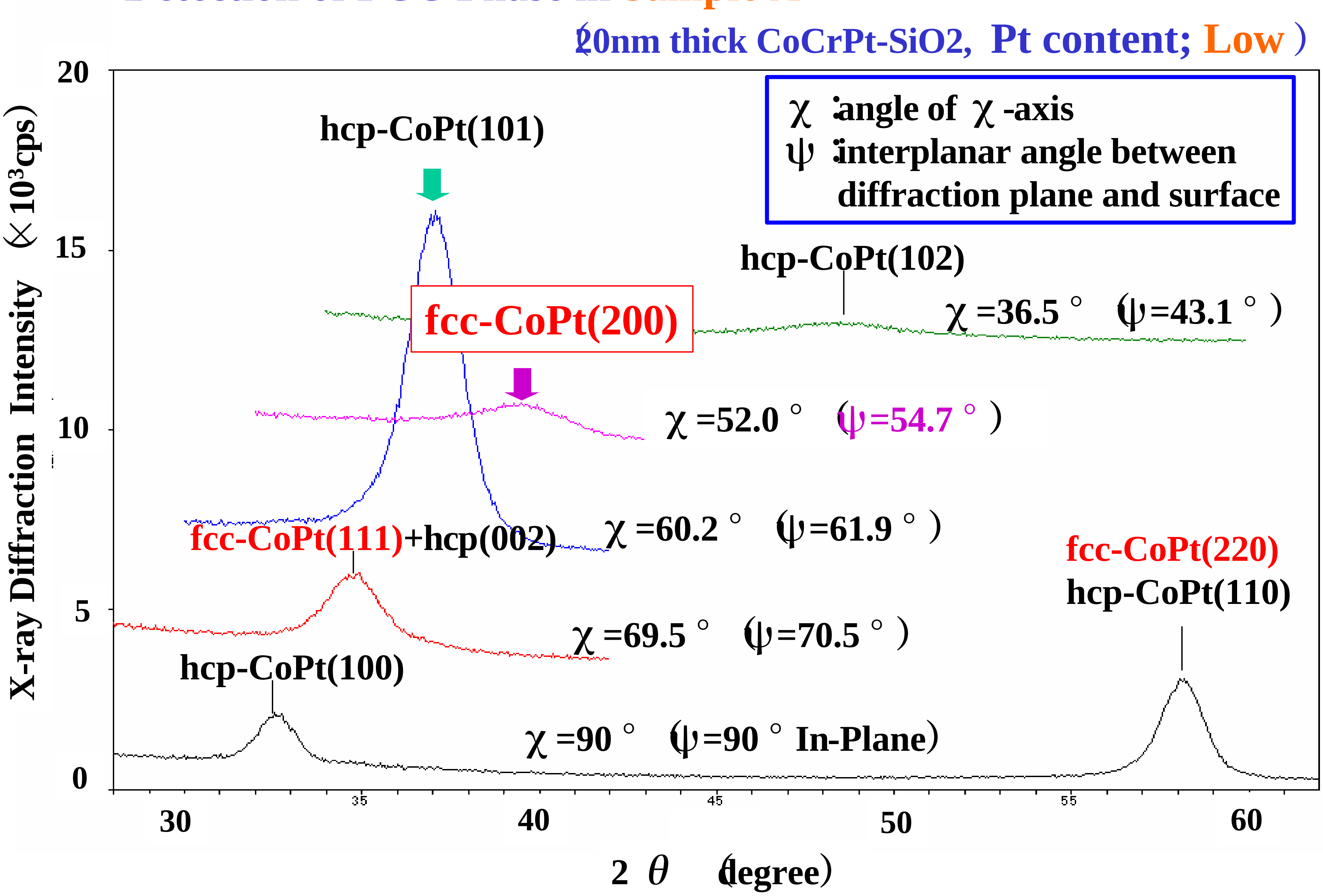
χ -Axis Setting
(0 ° < χ < 90 °)



In-Plane
(χ = 90 °)

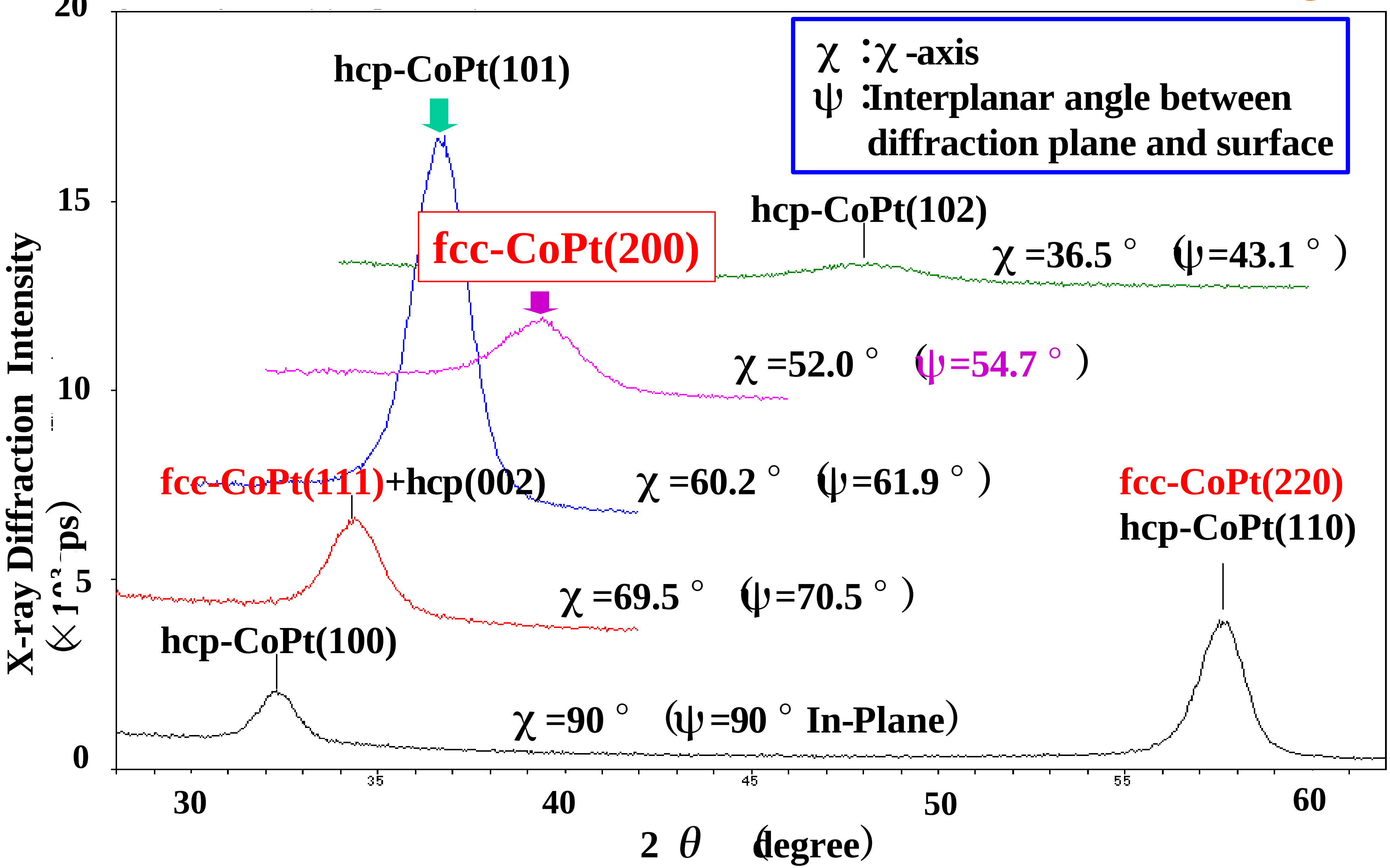
Detection of FCC Phase in Sample A

(20nm thick CoCrPt-SiO2, Pt content; Low)

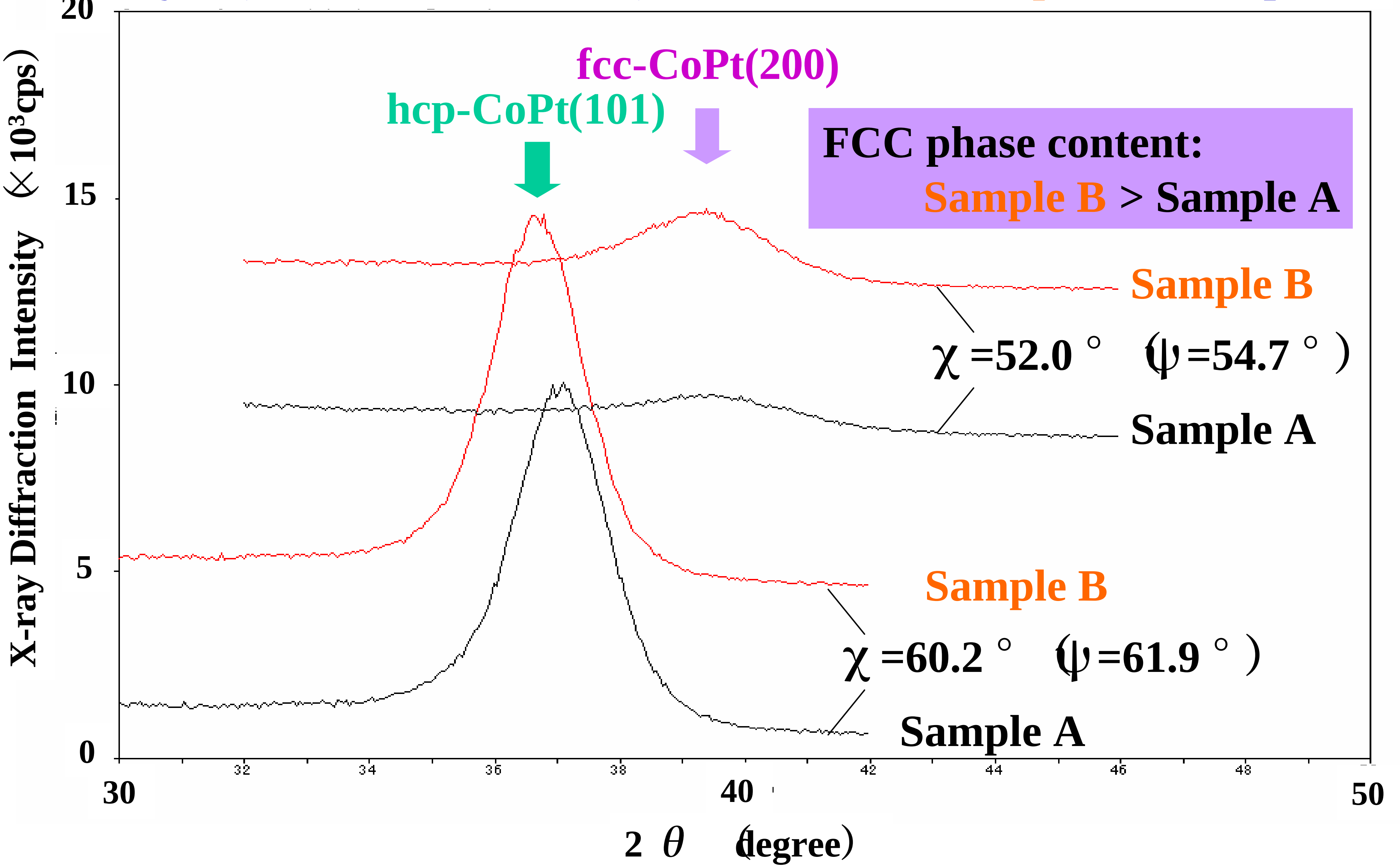


Detection of FCC phase in Sample B

（20nm thick CoCrPt-SiO2, Pt content; High）



FCC Phase Dependence on Pt Content in Perpendicular Magnetic Layer (CoCrPt-SiO2, 20nm)　Pt content：Sample B > Sample A



Summary

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About the longitudinal magnetic recording media,

we estimated for the first time the crystal structure, preferred orientation and lattice spacing of the 0.8nm thick Ru layer in the AFC media with the in-plane diffraction at BL16XU in SPring-8.

The 0.8nm thick Ru layer grows epitaxially, and have the same crystal orientation as the top and bottom magnetic layers.

About the perpendicular magnetic recording media,

we detected for the first time FCC phase in HCP phase granular magnetic layer with the GIXD χ -axis setting method.

The FCC phase content increases with the increasing Pt content in the magnetic layer.

Undulator beamline in SPring-8 is very powerful for the crystallographic analysis of thin films in recently developed magnetic media.