Hard X-ray Photoemission Spectroscopy Combined with Magnetic Circular Dichroism (MCD-HXPS)

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Introduction

- **HX-PES Combined with MCD (MCD-HXPES)**

  How to obtain magnetic information from PES spectra?

  *Spin-resolved PES*  Direct way, but efficiency is very low.

  *Non spin-flip mean free path of high kinetic energy electron is unknown.*

  *PES combined with MCD*  Complementary experiment such as spin-resolved PES

  *MCD is determined by photo-excitation probability.*

We expect that MCD-HXPES is conventional technique to obtain electronic structures and magnetic information of various materials without UHV condition, surface cleaning, and magnetization reversal in UHV.

MCD-PES using hard X-rays is very simple way in comparison with that using soft X-rays and ultra violet light.
**Experiment**

Experimental configuration at BL39XU. A diamond phase retarder was used to obtain circularly polarized X-rays. $h\nu = 7.94$ keV, $P_C \sim 0.95$.

Experimental configuration at BL15XU. A helical undulator was used to obtain circularly polarized X-rays. $h\nu = 5.95$ keV, $P_C \sim 0.6$.

For typical HXPES set-up, see e.g., Y. Takata et al., Nucl. Inst. Methods A 547 (2005) 50.
Fe$_{3-x}$M$_x$O$_4$ (M=Mn, Zn)

- We used a Fe$_3$O$_4$ thin film as a sample for MCD-HXPES experiments.

Fe$_{3-x}$M$_x$O$_4$ (M = Mn, Zn) : $T_C > RT$ and carrier control by M substitution ratio.

(a) Carrier concentration and mobility of Fe$_{3-x}$M$_x$O$_4$ (M = Mn, Zn) thin films on MgO(001).

(b) Schematic local structure of Fe$_{3-x}$M$_x$O$_4$ (M = Mn, Zn).

Highlight data

Fe 2p MCD-HXPES of Fe₃O₄ thin film

10 nm thick film

- Helicity was changed by a diamond phase retarder.
- without surface cleaning.
- Magnetized in the air.

Measured at BL39XU

P_C ~ 0.95
M_R/M_S ~ 0.39
~ 40% asymmetry

[Fe³⁺(↓:5 μ_B)ₐ][Fe³⁺(↑:5 μ_B)Fe²⁺(↑:4 μ_B)]ₐO₄


We have succeeded in measuring MCD-HX-PES without surface cleaning.
Fe 2p MCD-HXPES of Fe$_{2.5}$Mn$_{0.5}$O$_4$ thin film

$\nu = 5.95$ keV
Fe$_{2.5}$Mn$_{0.5}$O$_4$
Fe 2p

100 nm thick film

Measured at BL15XU
Helical undulator was used.
P$_c$ $\sim$ 0.6
without surface cleaning.
Magnetized in the air.
M$_R$/M$_S$ $\sim$ 0.45
Mn 2p MCD-HXPES of Fe$_{2.5}$Mn$_{0.5}$O$_4$ thin film

Measured at BL15XU

Helical undulator was used.

$P_C \sim 0.6$

without surface cleaning.

Magnetized in the air.

$M_R/M_S \sim 0.45$

Magnetic moments of Fe and Mn are parallel.
Summary and future plan

- We have succeeded in measuring MCD-HXPES in the simple practical way. (No UHV, no surface cleaning)
- MCD-HXPES can be an effective tool for measuring both electronic and magnetic states.

For spin-resolved HXPES,

Forward scattering geometry can be one of the methods to conduct the spin detection.

A planned spin-resolved HXPES does not require a spin detector.

What I would like to say is ....
A planned spin-resolved HXPES

Mott scattering in the capping layer helps to detect the spin polarization.

Simple way!

Problem: effective Sherman function? non spin-flip mean free path?

or insulator (BGO)

Insulating layer acts as a widow for valence bands near $E_F$.


Combination with photoelectron diffraction will enhance the efficiency.

Thank you for your attention!