

貴金属-遷移金属合金および交換結合二層膜の XMCDによる検討

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Background

光磁気記録媒体：

- 希土類遷移金属アモルファス合金 (TbFeCo)

垂直磁気異方性 $K_u \sim 10^6 \text{ erg/cc}$

Kerr回転角 $\theta_K \sim 0.3 \text{ deg at } 650 \text{ nm}$

媒体の均一性

適度なCurie点 $\sim 250 \text{ }^\circ\text{C}$

生産性, 経済性 等々

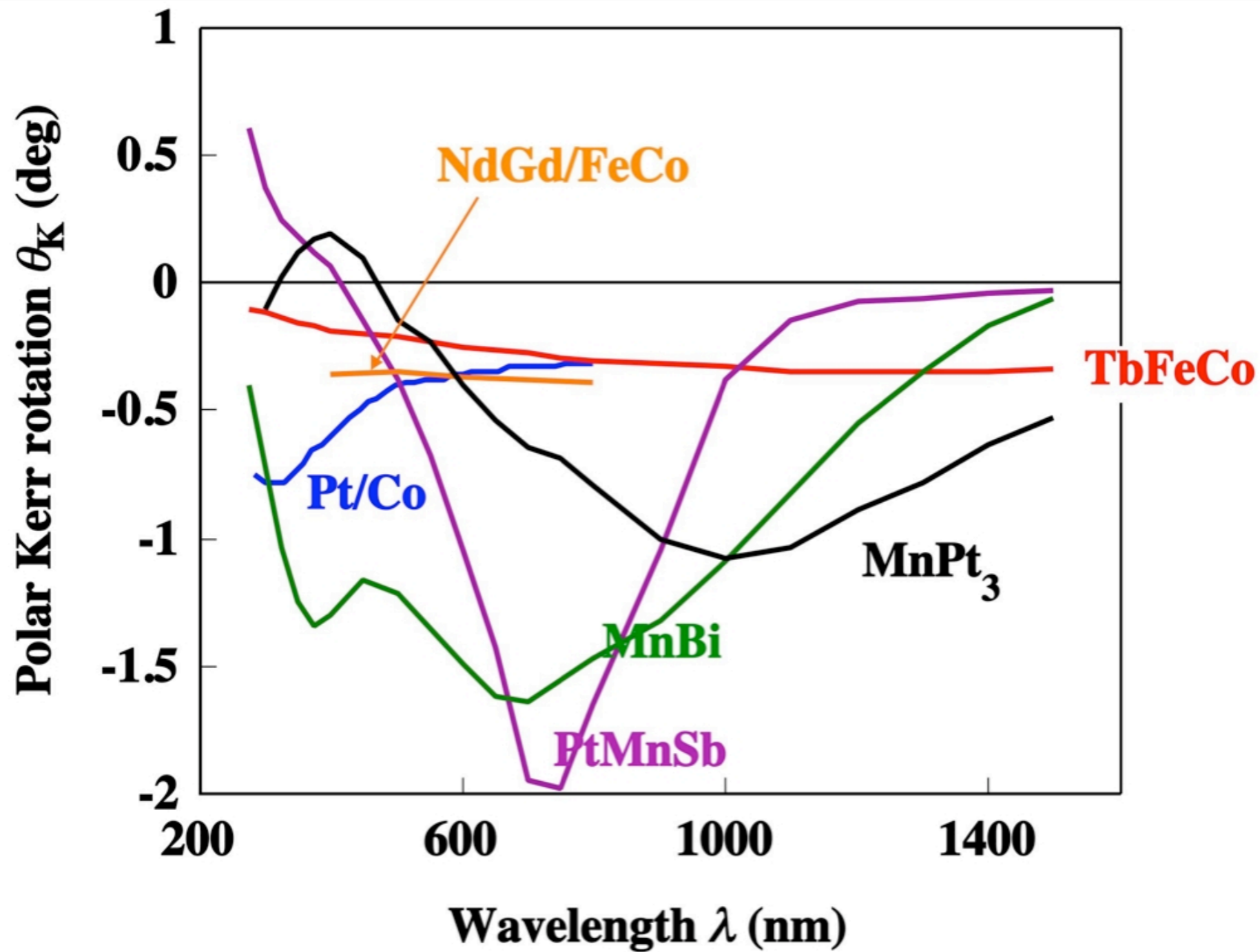
- 貴金属-遷移金属系材料 (Co/Pt多層膜)

垂直磁気異方性 $K_u \sim 10^7 \text{ erg/cc}$

Kerr回転角 $\theta_K \sim 0.6 \text{ deg at } 400 \text{ nm}$

多結晶膜, Curie温度などに問題

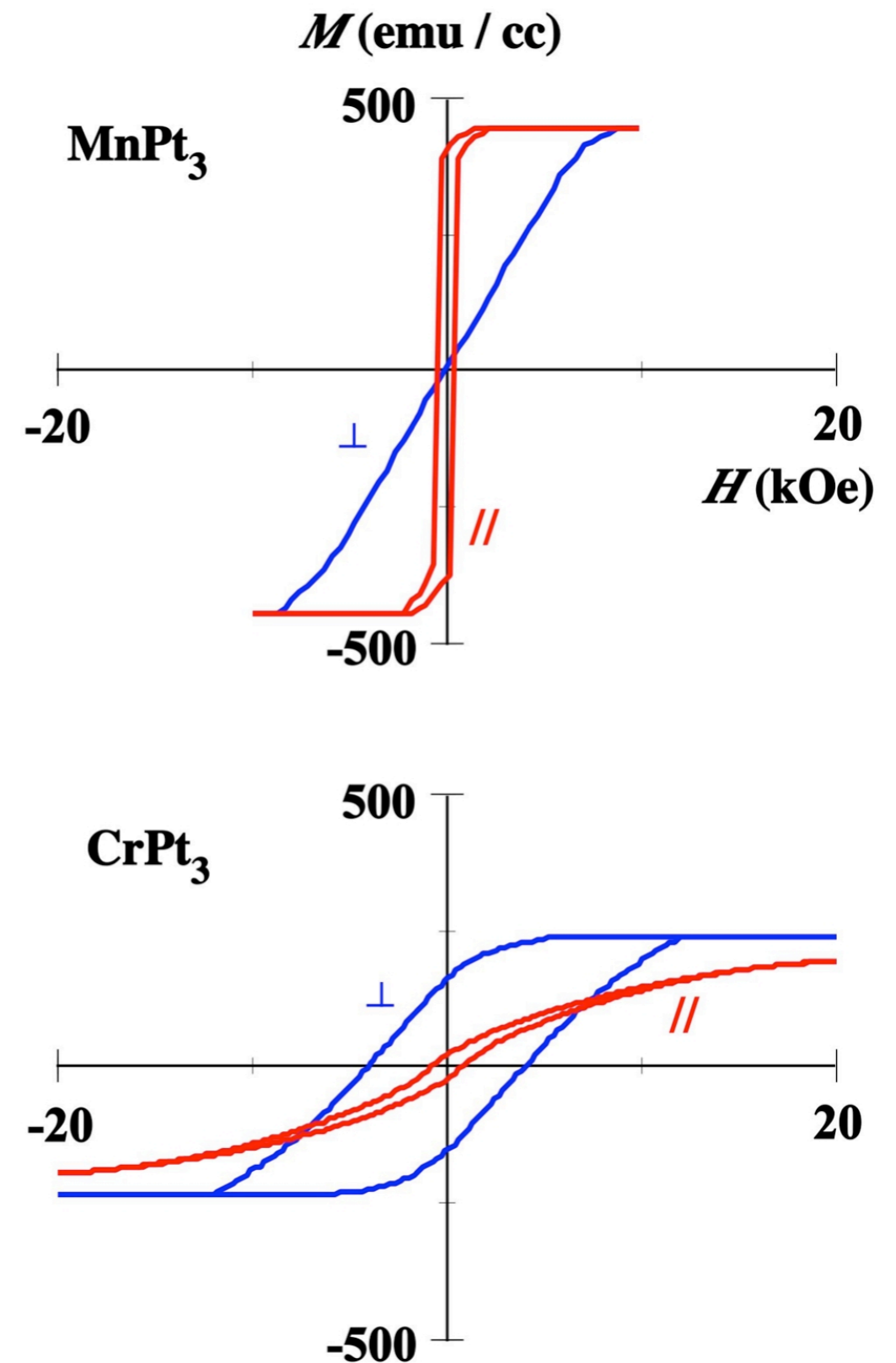
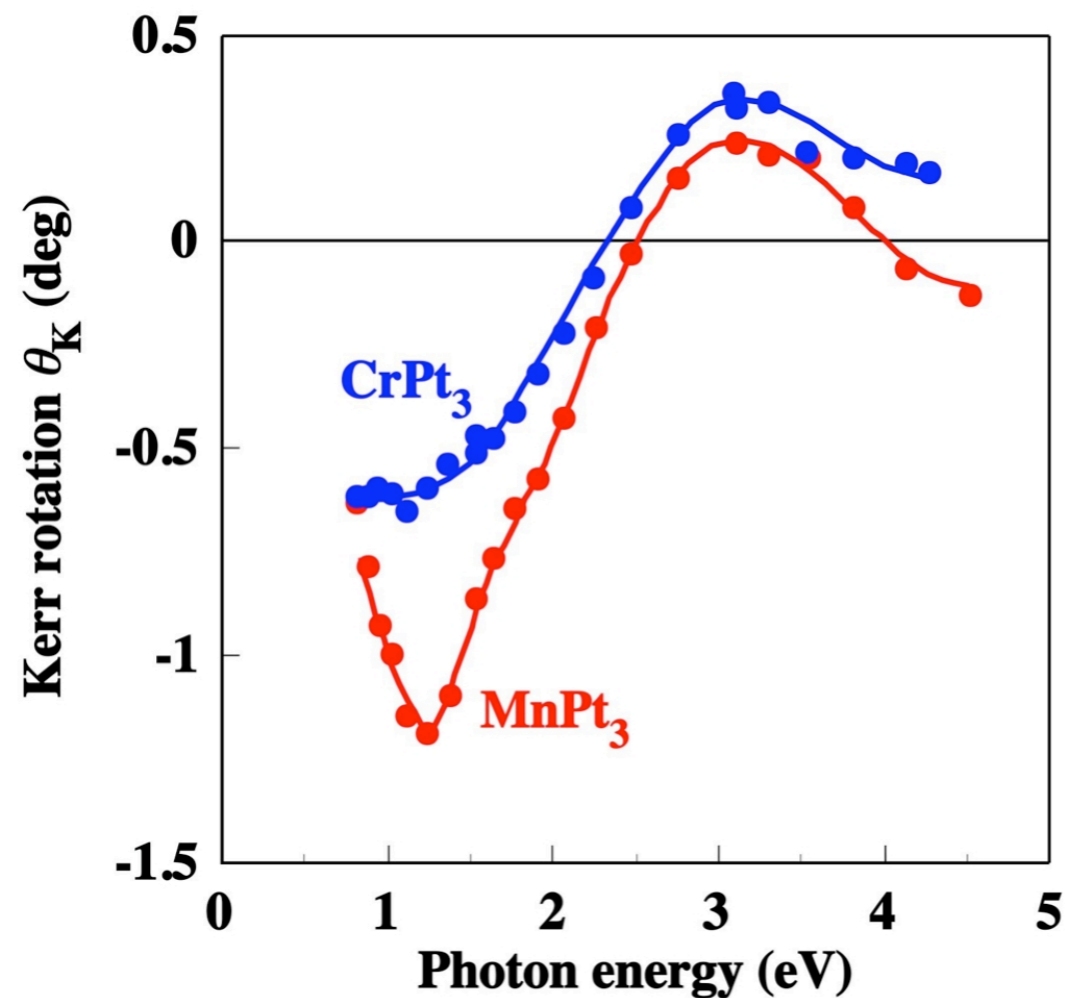
Kerr spectra of MO materials



MnPt₃, CrPt₃

MnPt₃, CrPt₃規則合金膜

- 1 eV付近で大きな θ_K
- 石英ガラス上のCrPt₃で大きな K_u



TM-Pt₃

TM-Pt₃規則合金膜の理解

研究例の少ないMnPt₃, CrPt₃, VPt₃の磁気異方性, 磁気光学特性, 磁気円二色性

バルクTM-Pt₃規則合金の構造と磁性

Material	Prototype	Magnetism	T_C / T_N (K)	μ at 0 K (μ_B)
VPt ₃	Cu ₃ Au	ferri	240	$\mu_V \approx 1, \mu_{Pt} \approx -0.3$
	TiAl ₃	ferri	210	$\mu_V \approx 1, \mu_{Pt} \approx -0.3$
CrPt ₃	Cu ₃ Au	ferri	690	$\mu_{Cr} = 2.3, \mu_{Pt} = -0.3$
MnPt ₃	Cu ₃ Au	ferro	370	$\mu_{Mn} = 3.6, \mu_{Pt} = 0.3$
FePt ₃	Cu ₃ Au	anti-ferro	170	$\mu_{Fe} \approx 3.3, \mu_{Pt} < 0.3$
CoPt ₃	Cu ₃ Au	ferro	290	—

近角ら (偏) : 磁性体ハンドブック

R. Jesser *et al.*: J. de Phys. 42 (1981) 1157.

Sample Preparation

RFマグネトロンスパッタ

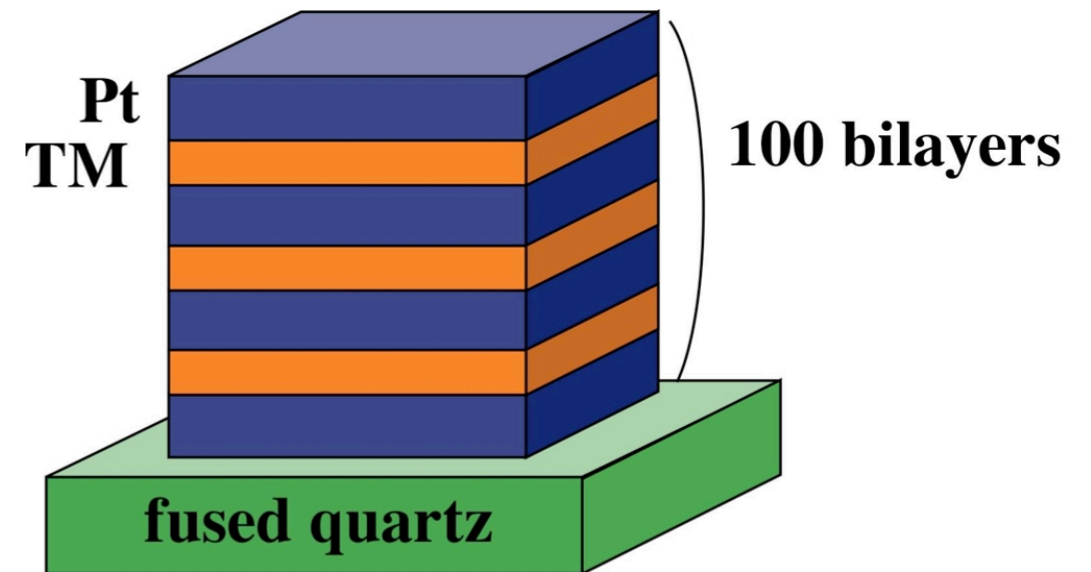
到達真空度 $< 3 \times 10^{-5}$ Pa

Ar圧 4 Pa

TM層 0.4 nm

(TM: $\text{Mn}_{1-x}\text{Cr}_x$, $\text{Cr}_{1-x}\text{V}_x$)

Pt層 0.9 - 1.4 nm



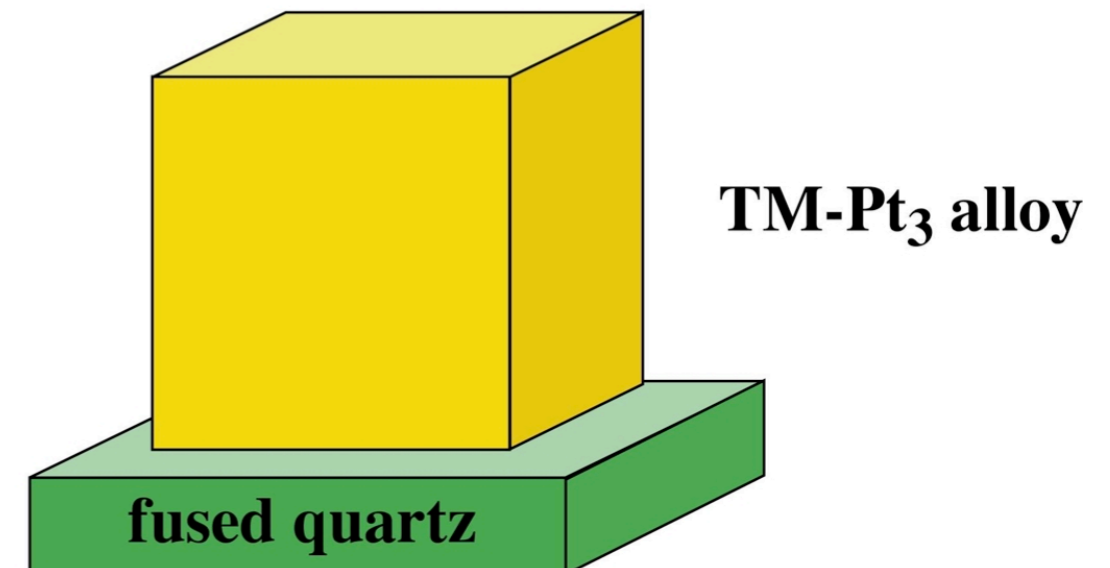
annealing in
vaccum chamber

真空中熱処理

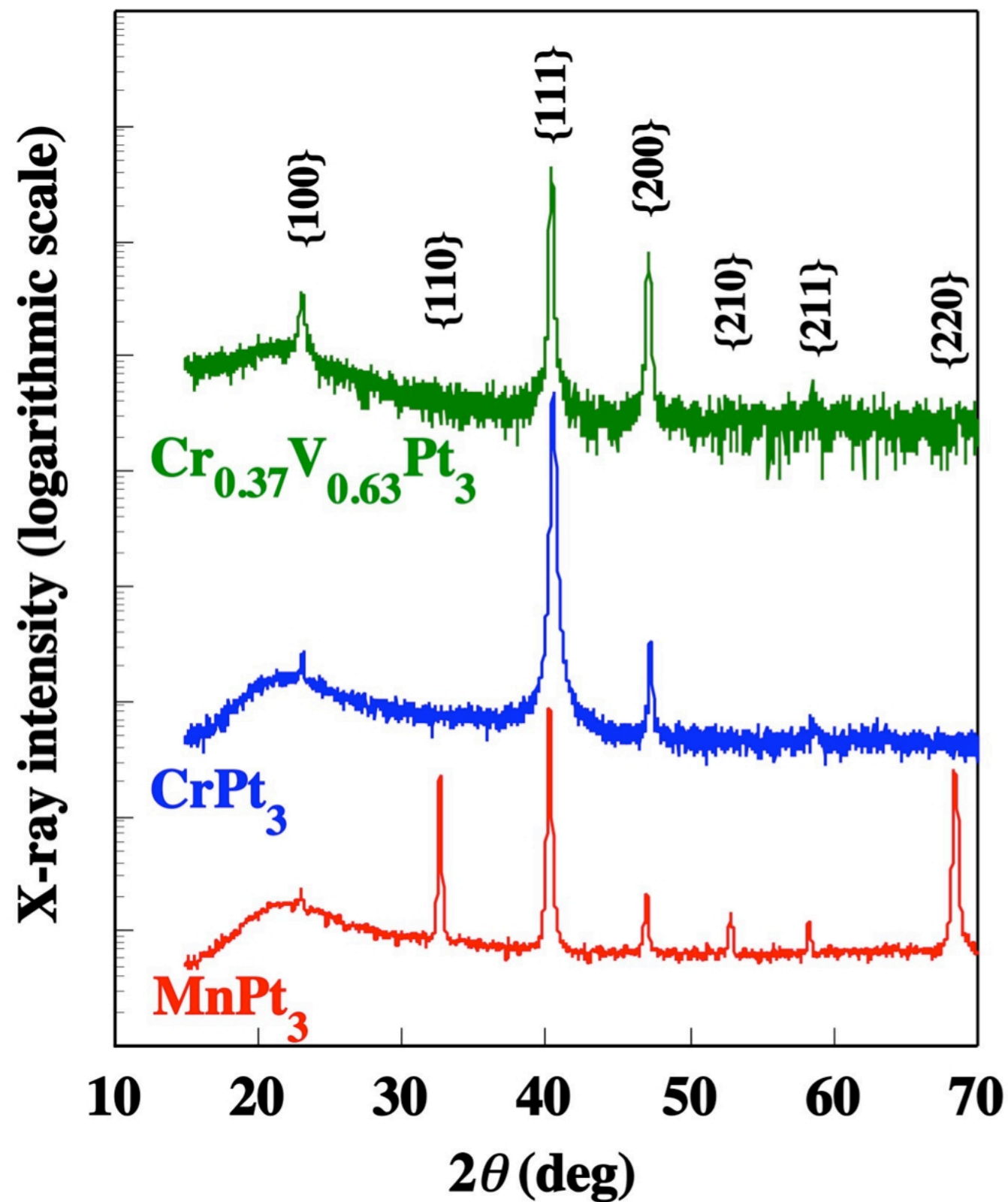
真空度 $< 3 \times 10^{-4}$ Pa

温度・時間 800 ~ 850 °C, 15 min

降温速度 10 °C/min

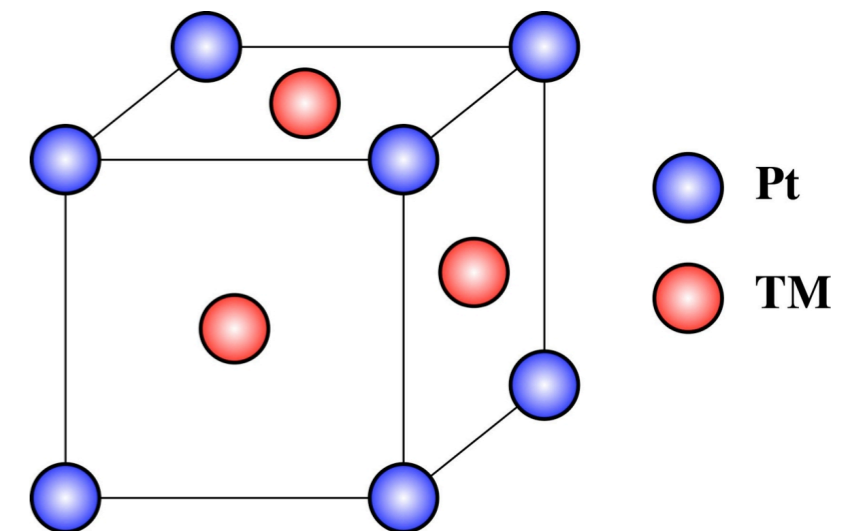


XRD patterns

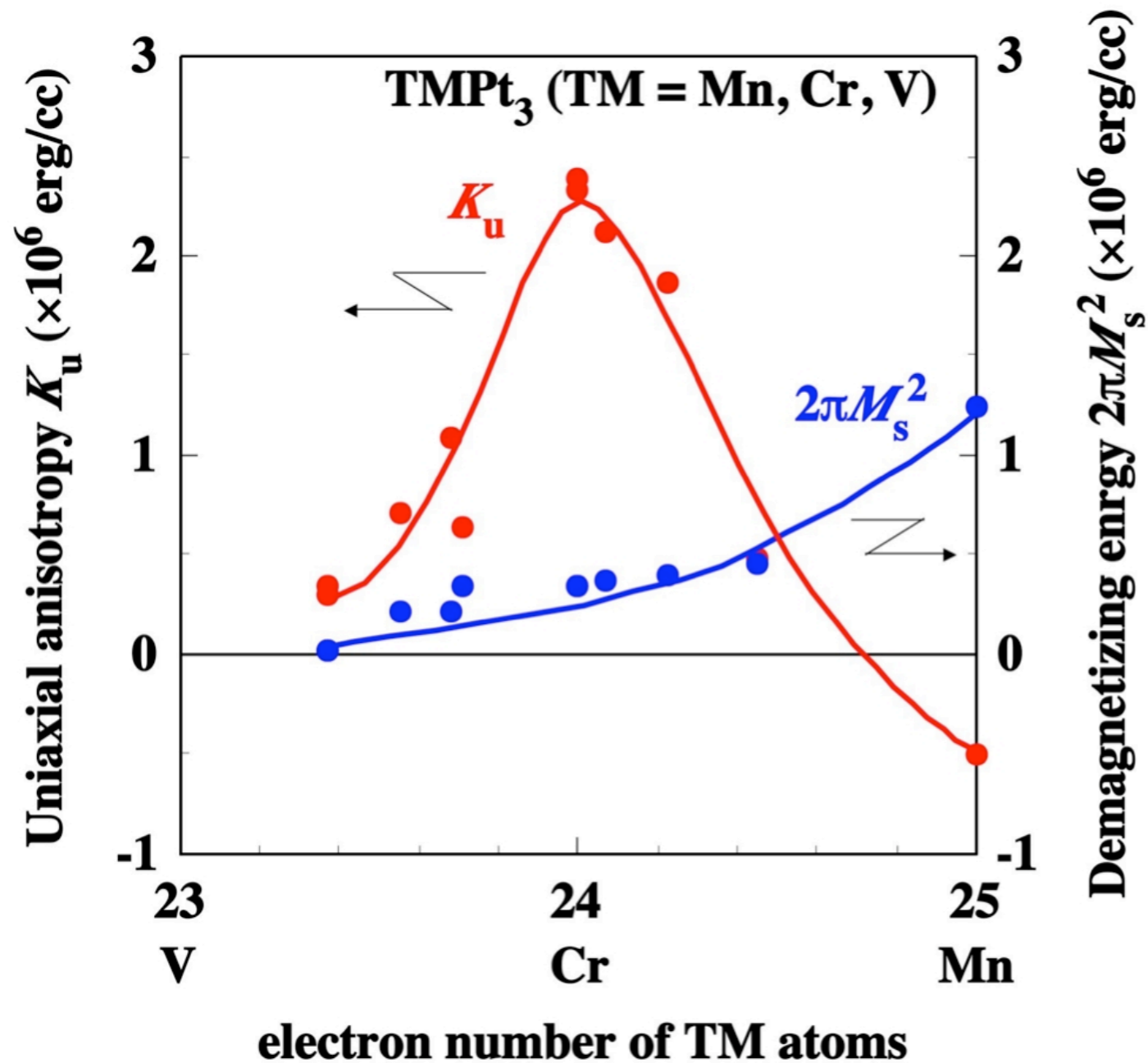
 $S = 1.0$

1.0

0.9

 Cu_3Au crystal structure

Uniaxial anisotropy



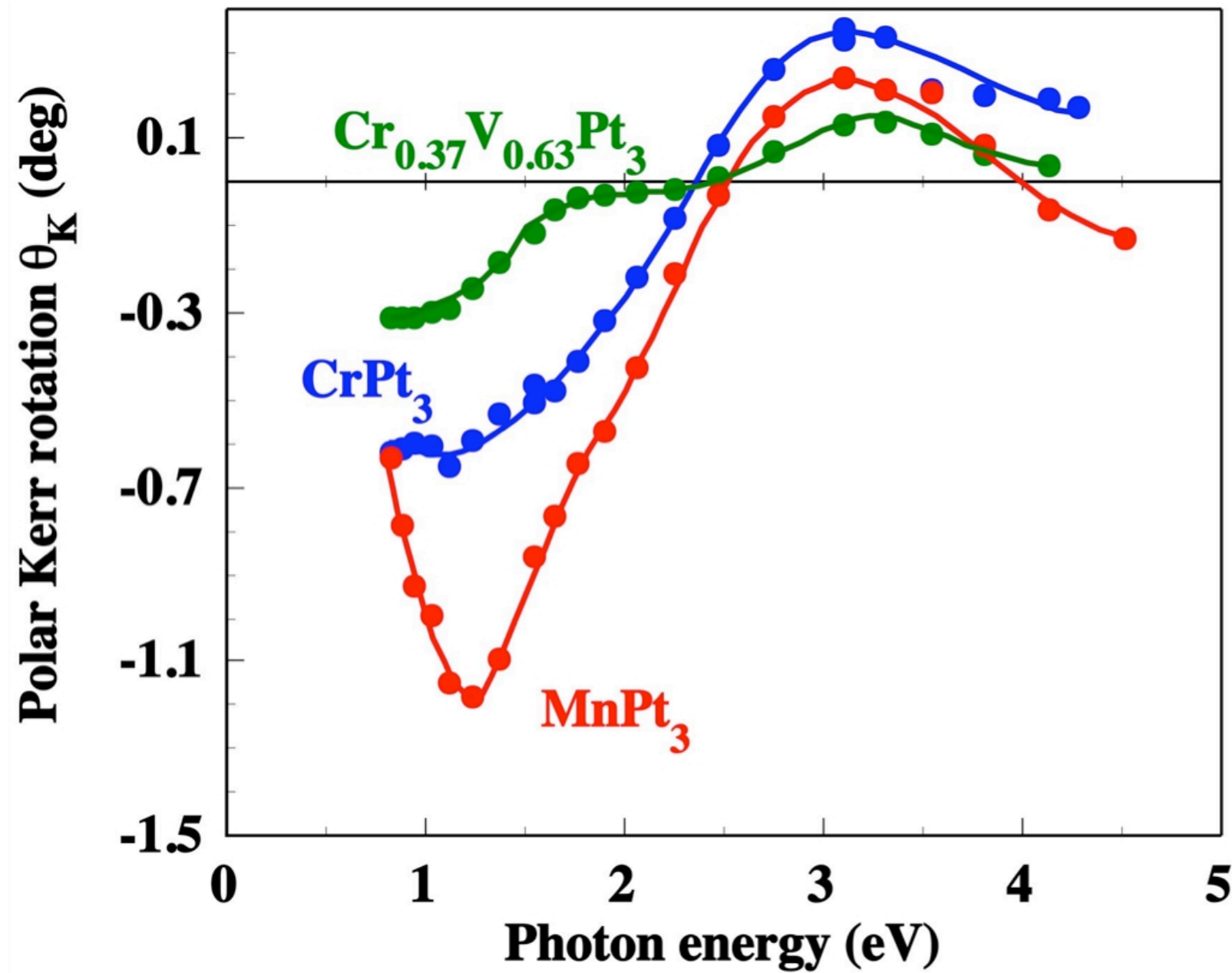
$$2\pi M_s^2 : \text{MnPt}_3 > \text{CrPt}_3 > \text{VPt}_3$$

$$K_u : \text{CrPt}_3 > \text{VPt}_3 > \text{MnPt}_3$$

$$\text{VPt}_3 : \text{正?}$$

Vモーメントは寄与している？

Kerr spectra



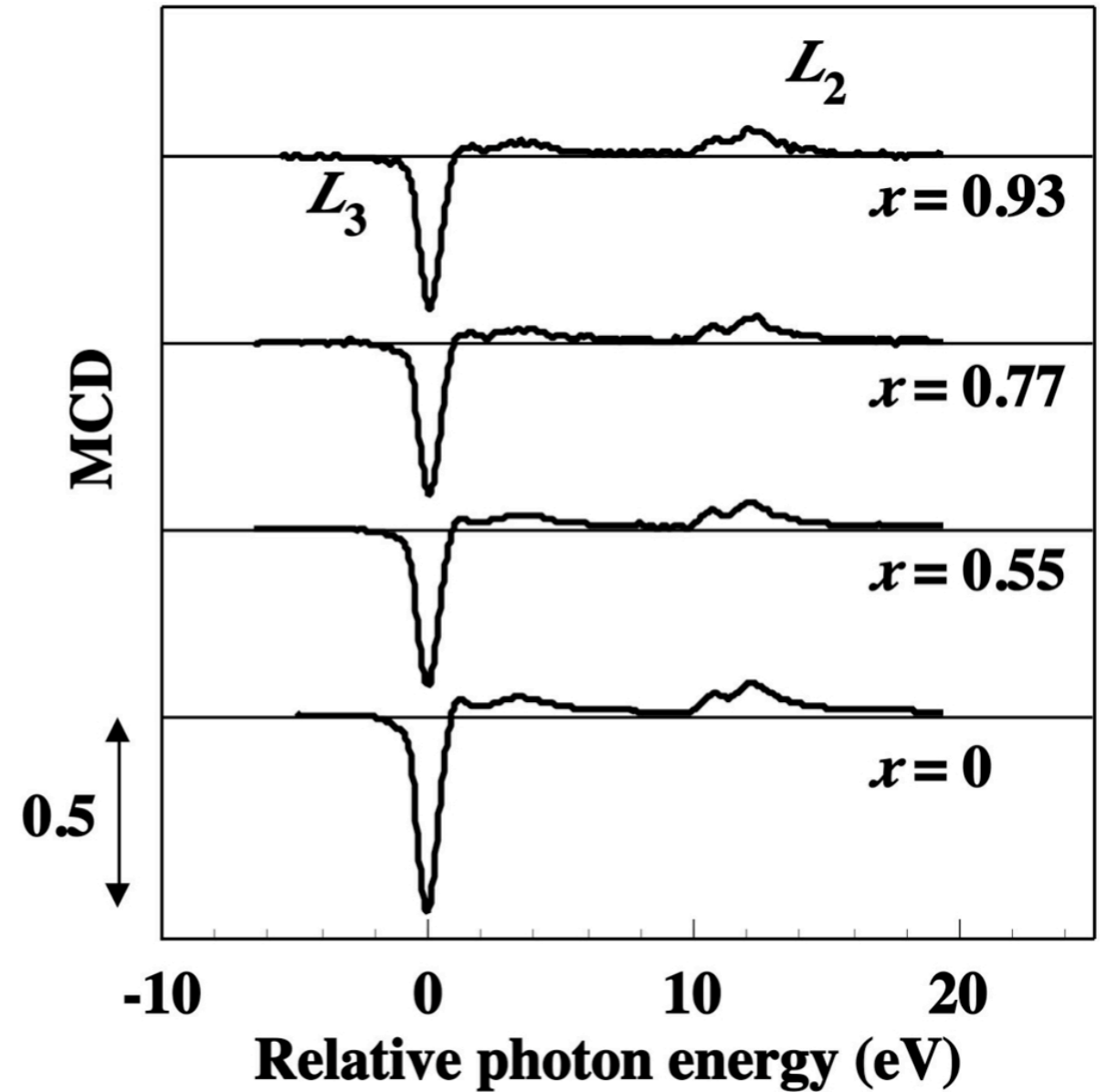
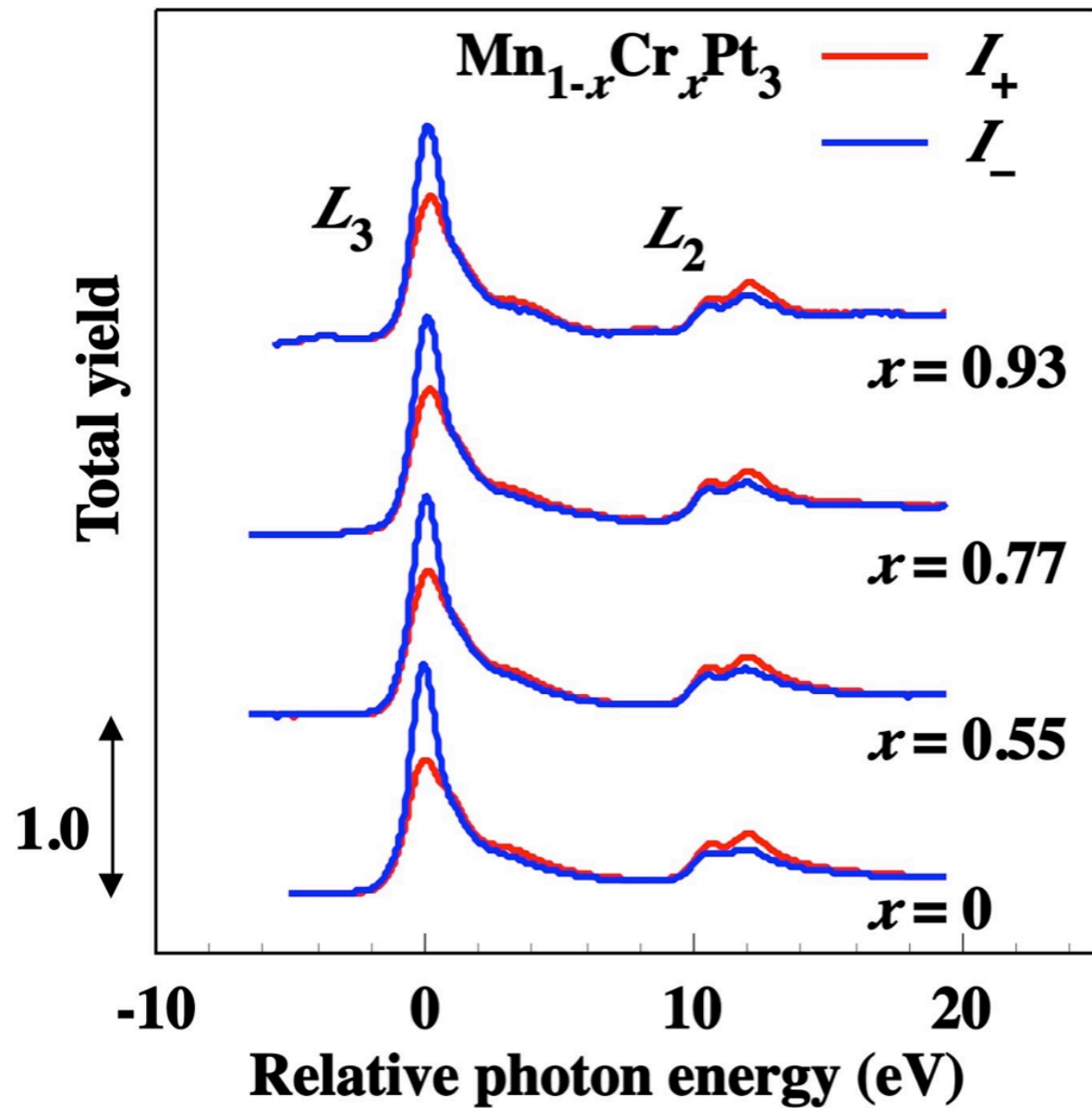
$\text{MnPt}_3 \Rightarrow \text{VPt}_3$

- 1 eVのピークが減少
- 1 eV, 3 eV付近のピークがより明瞭に分離

MCD spectra

$(\text{Mn}_{1-x}\text{Cr}_x)\text{Pt}_3$ 規則合金膜

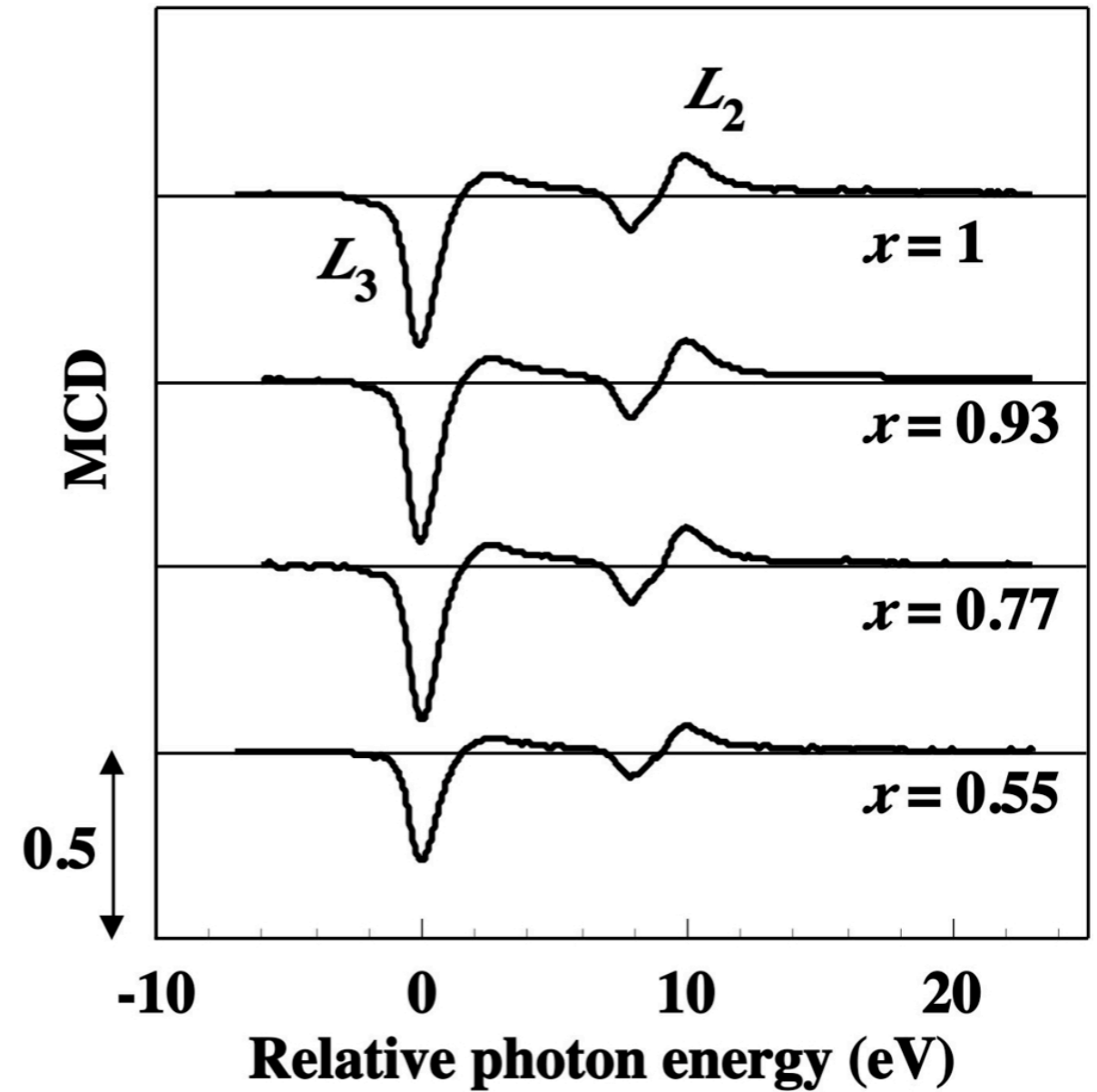
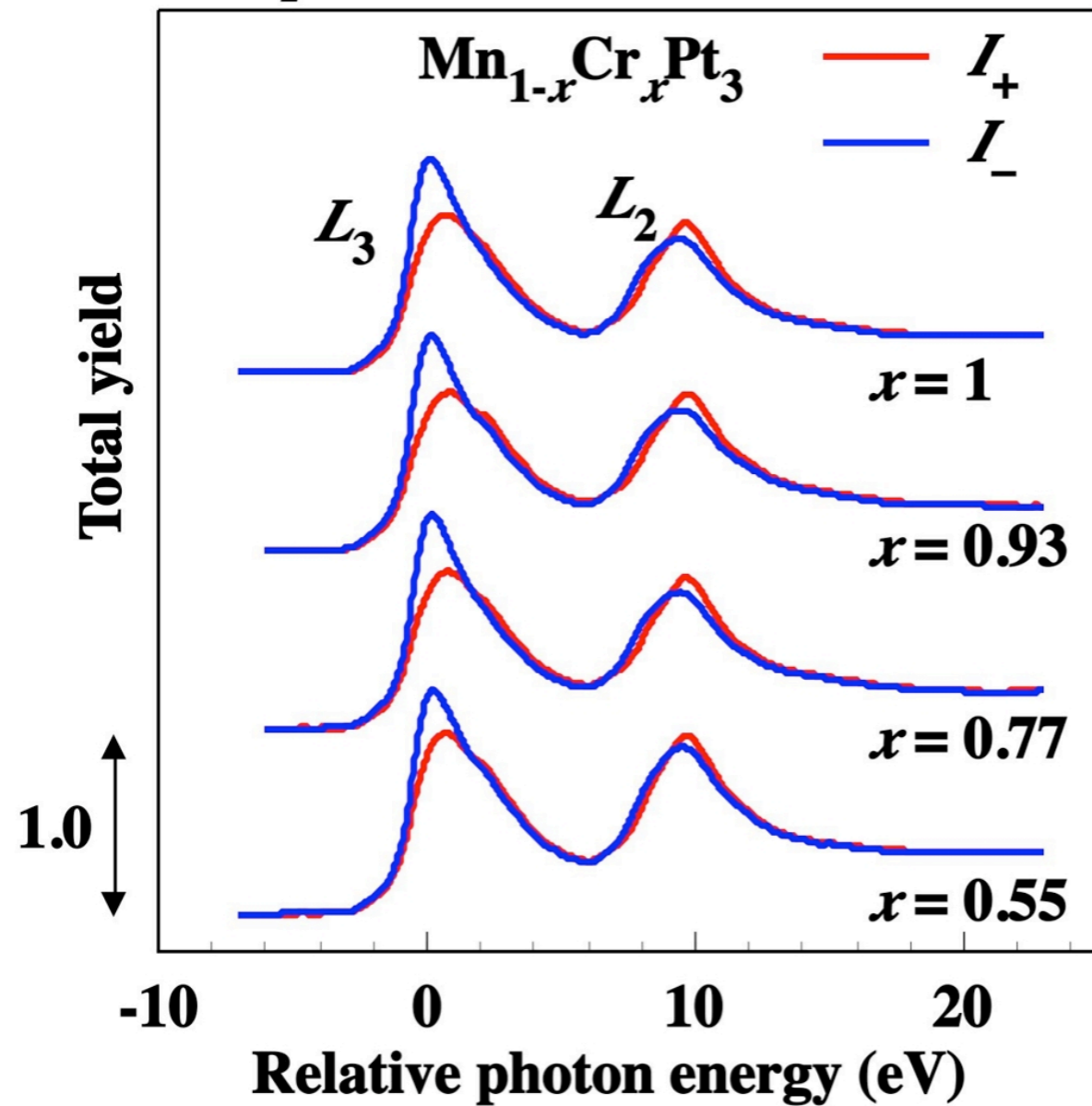
Mn $2p-3d$ excitation



MCD spectra

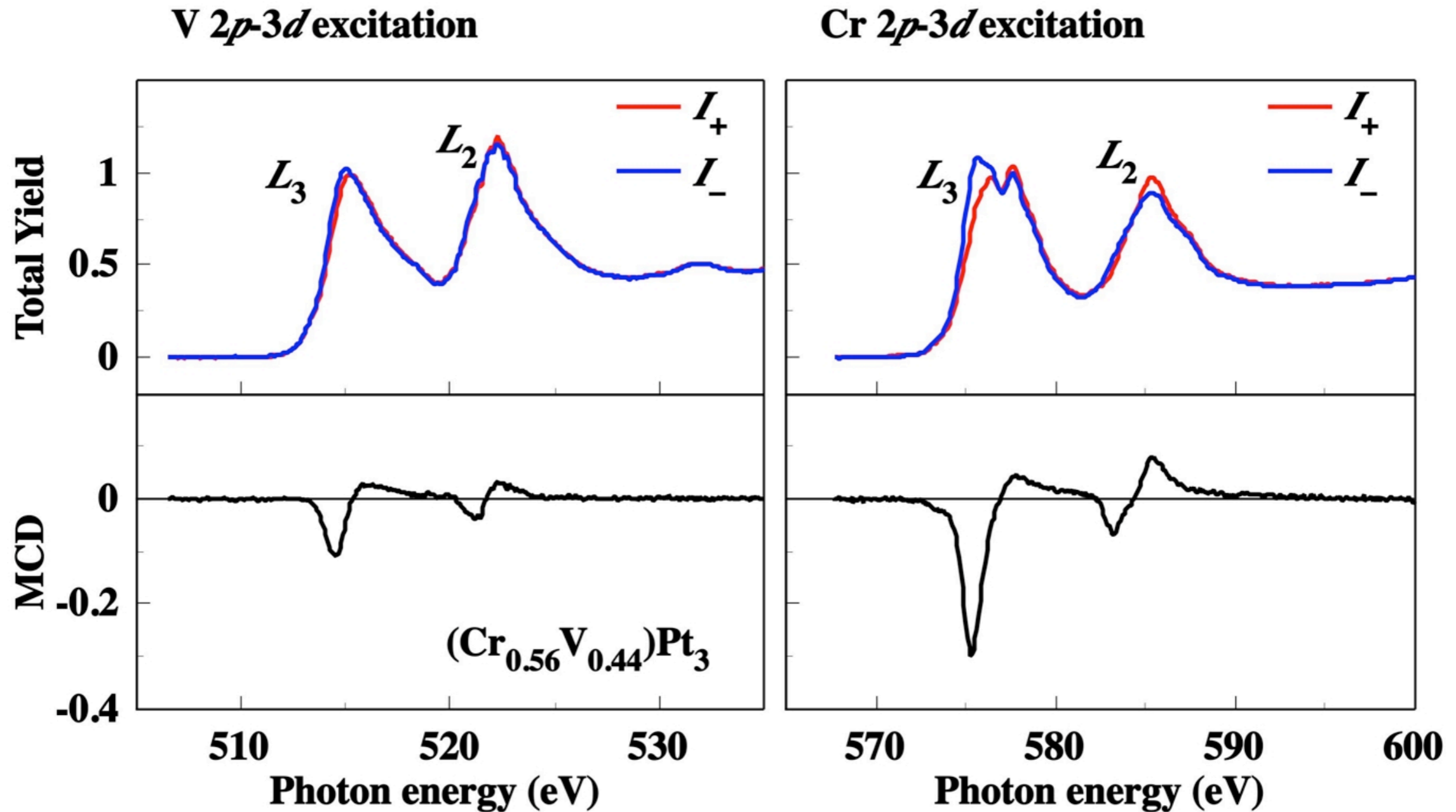
$(\text{Mn}_{1-x}\text{Cr}_x)\text{Pt}_3$ 規則合金膜

Cr 2*p* – 3*d* excitation



CrとMnモーメントの平行カップリング

MCD spectra



Vモーメントの強磁性的寄与

CrとVモーメントの平行カップリング

$$\langle L_z \rangle / 2 \langle S_z \rangle$$

Sample	Saturation magnetization M_s (T)	Uniaxial anisotropy constant K_u ($\times 10^5$ J / m ³)	MCD contrast at L_3			Corrected $\langle L_z \rangle / 2 \langle S_z \rangle$		
			Mn	Cr	V	Mn	Cr	V
MnPt ₃	0.56	-0.5	0.53	—	—	0.02	—	—
Mn _{0.45} Cr _{0.55} Pt ₃	0.34	0.5	0.40	0.29	—	0.05	0.18	—
Mn _{0.23} Cr _{0.77} Pt ₃	0.32	1.8	0.40	0.40	—	0.03	0.15	—
Mn _{0.07} Cr _{0.93} Pt ₃	0.31	2.1	0.40	0.42	—	0.03	0.15	—
CrPt ₃	0.30	2.4	—	0.40	—	—	0.15	—
Cr _{0.56} V _{0.44} Pt ₃	0.24	0.7	—	0.30	0.11	—	0.12	0.06

Correction factor

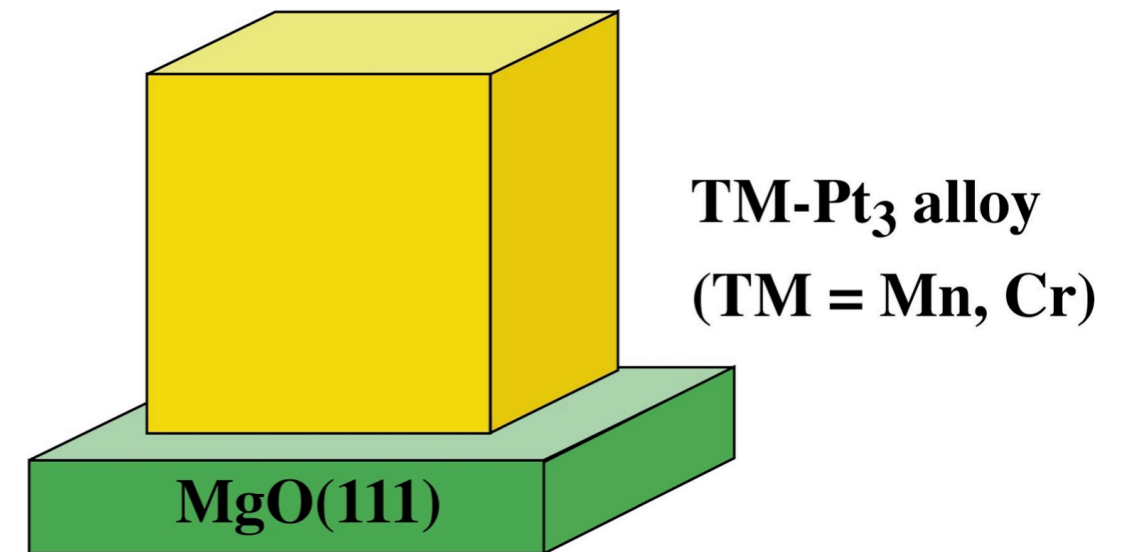
Mn: 0.78, Cr: 0.59, V: 0.40

Y. Teramura *et al.*: J. Phys. Soc. Jpn., **65** (1996) 1053.

MBE-grown TM-Pt₃

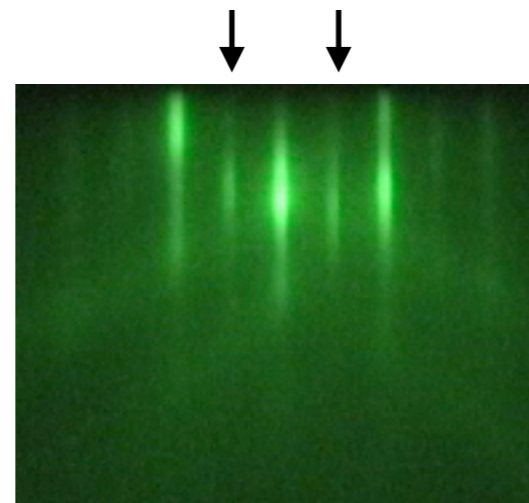
MBE法

成長中真空度	$< 2 \times 10^{-7}$ Pa
TM-Pt ₃ 層	600 nm
(TM: Mn, Cr)	(TMとPtの同時蒸着)
基板温度	600 °C
基板	石英ガラス, MgO, Al ₂ O ₃

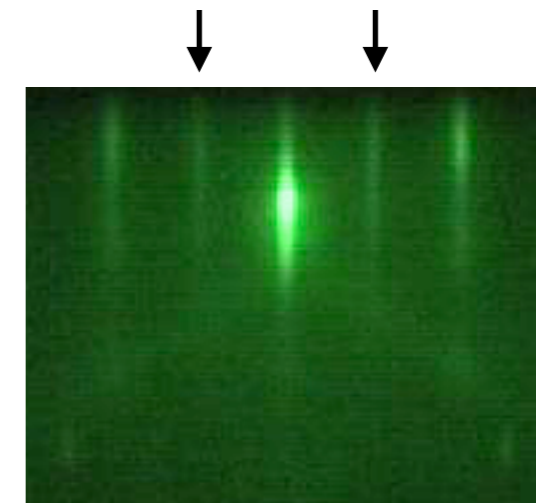


RHEED observation:

CrPt₃ / MgO(111)

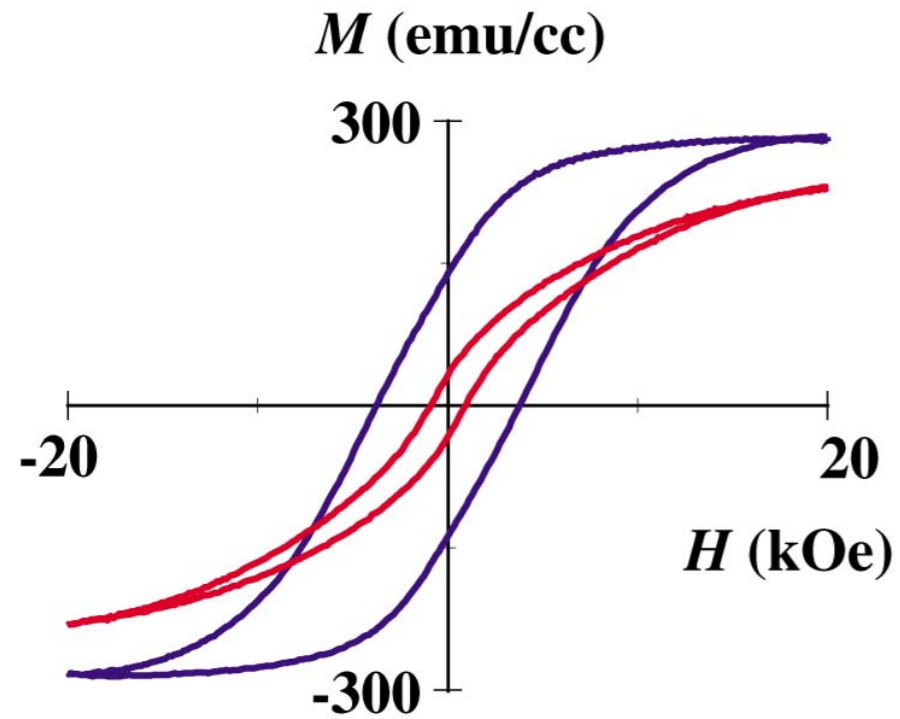


e^- beam // $\langle 10\bar{1} \rangle$

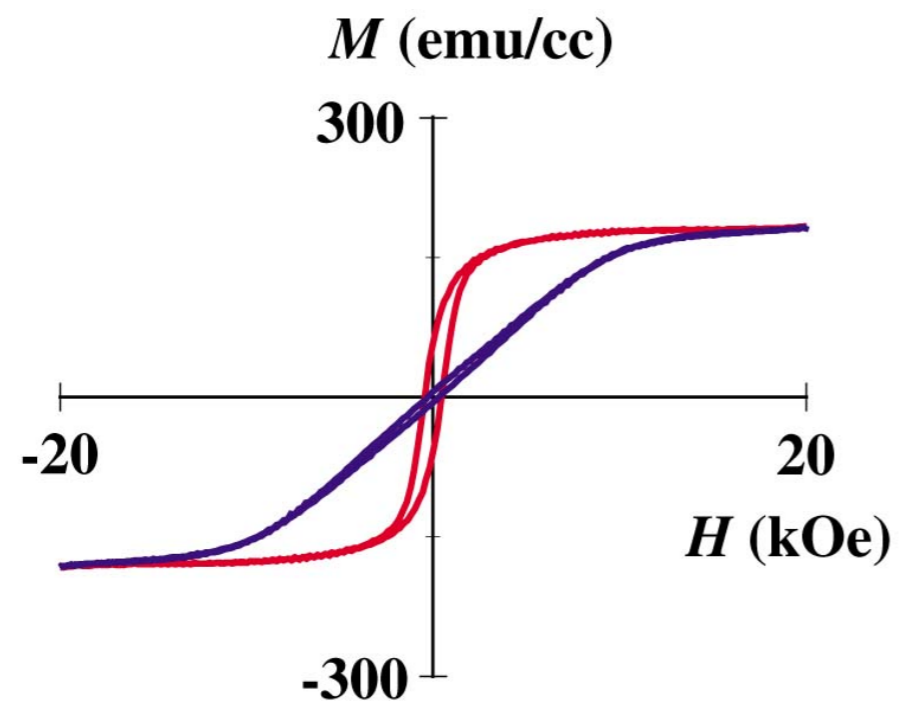


e^- beam // $\langle 11\bar{2} \rangle$

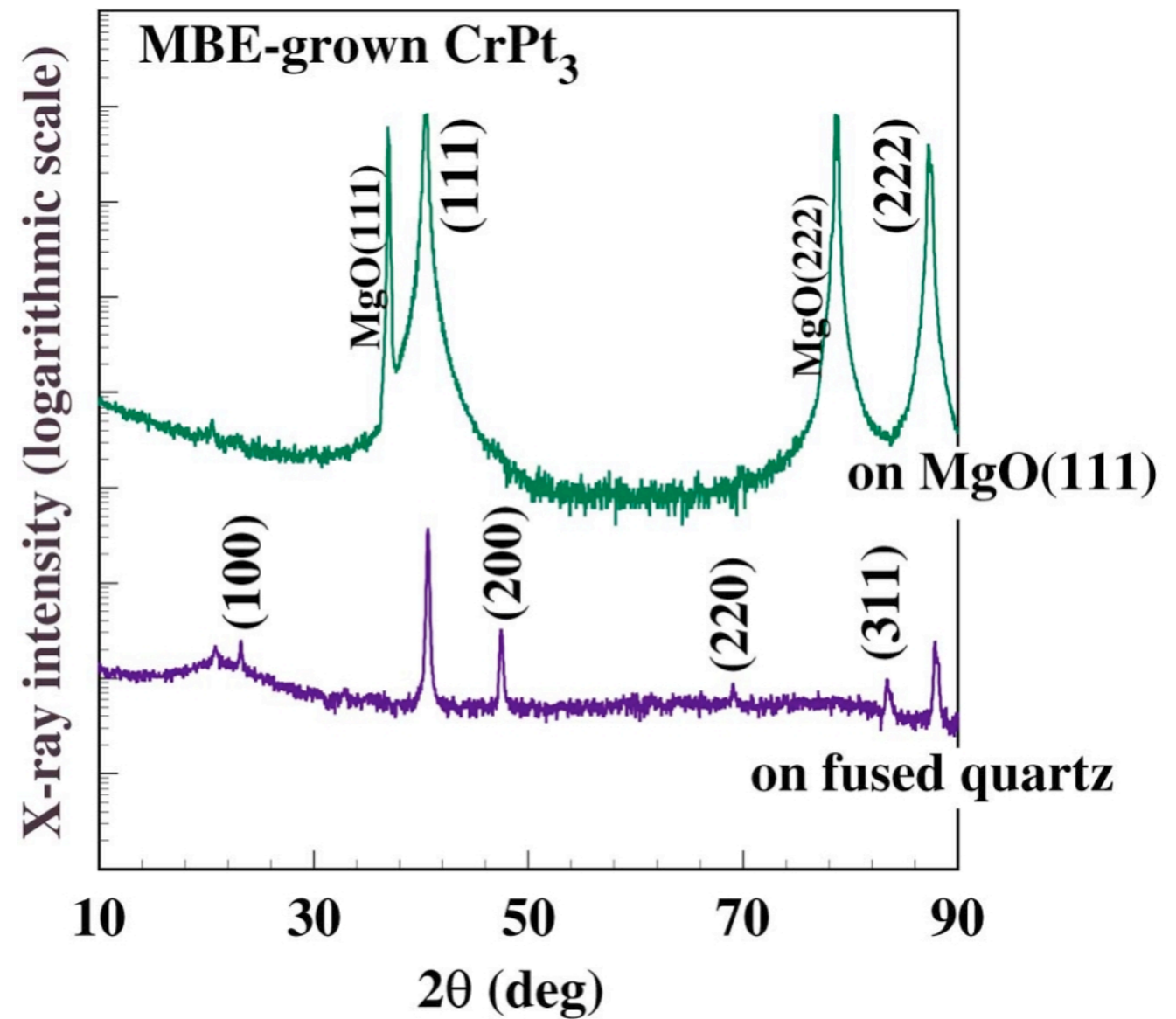
MBE grown CrPt_3



CrPt_3 / fused quartz

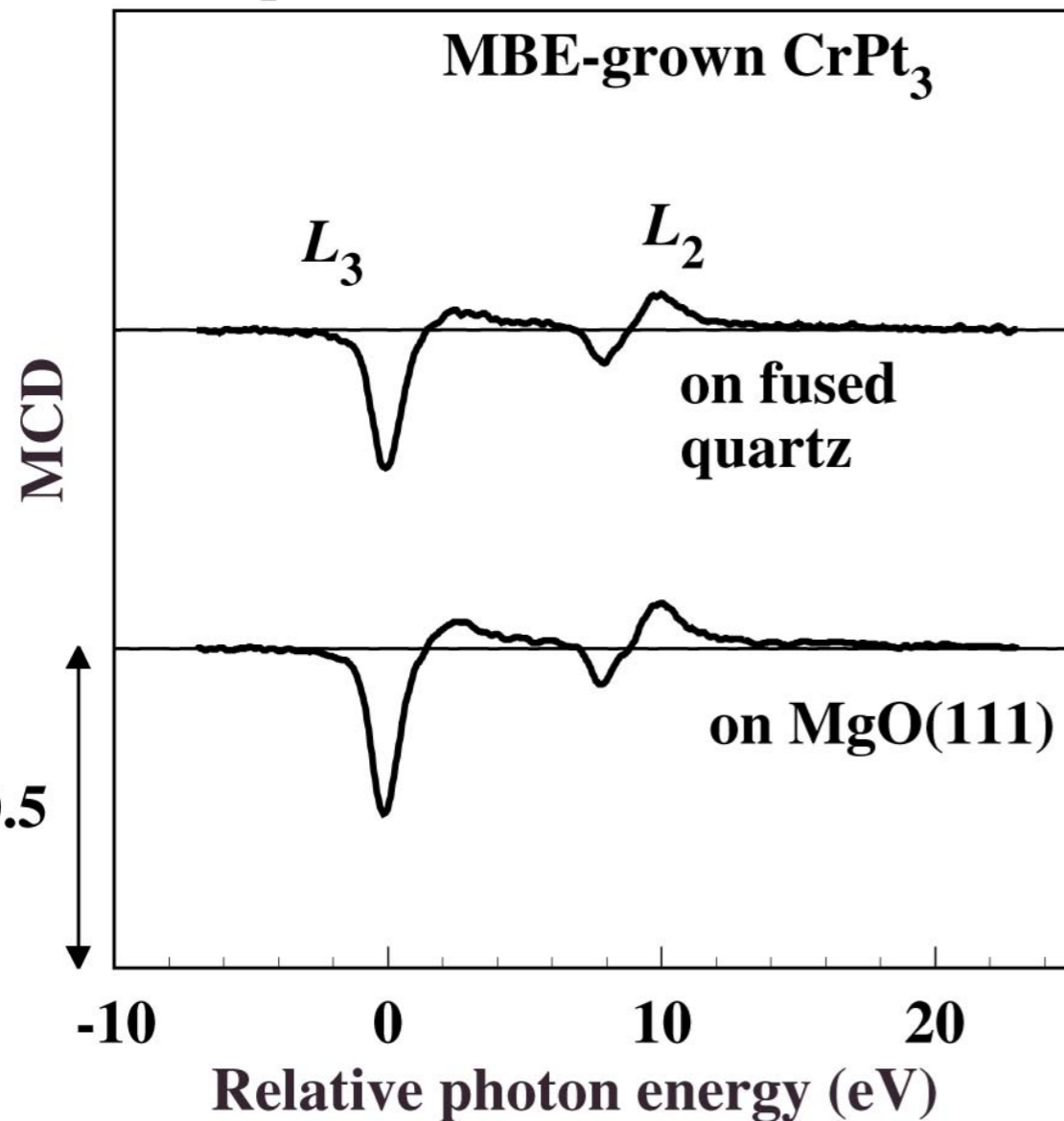


CrPt_3 / $\text{MgO}(111)$



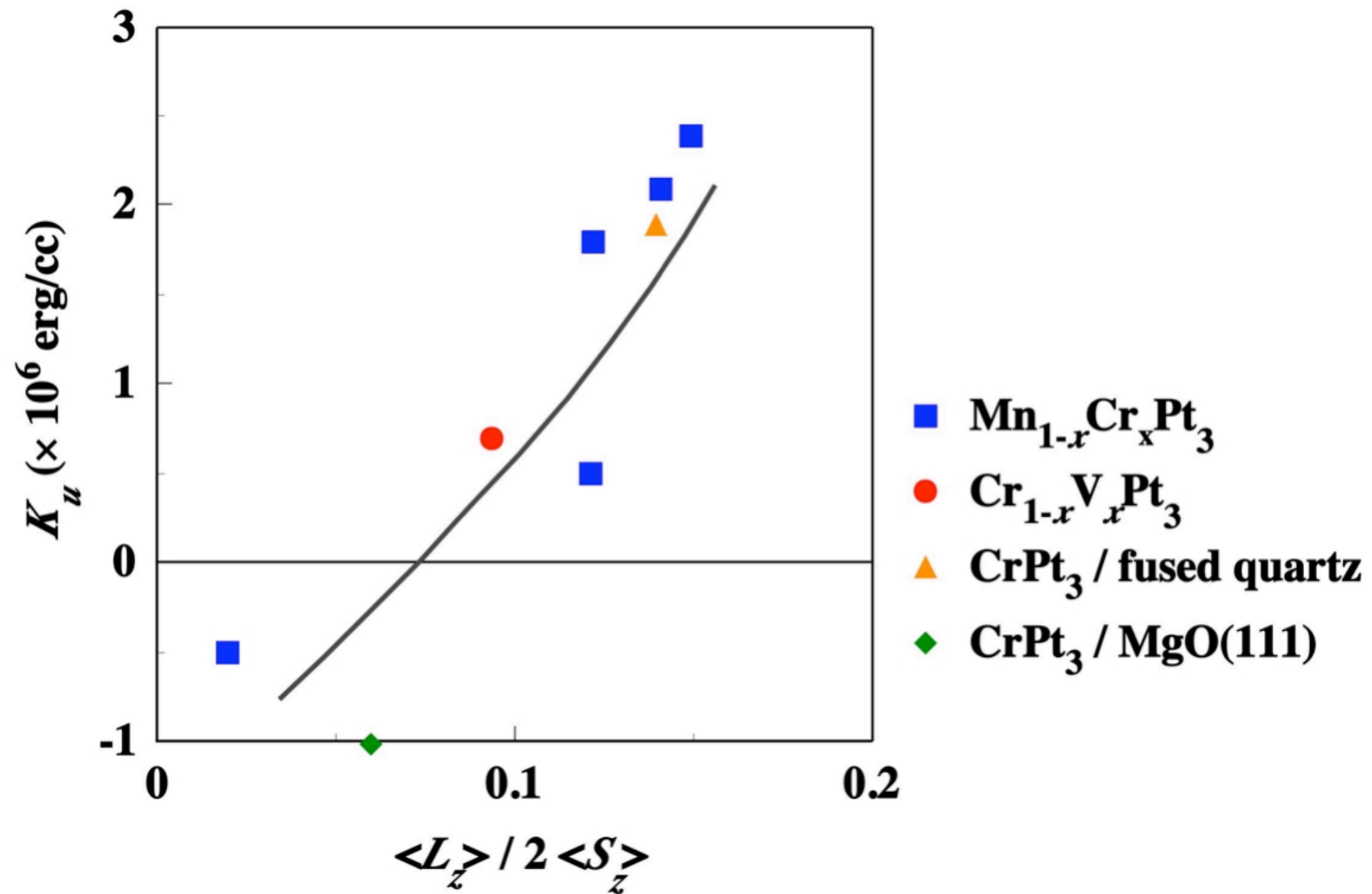
MCD of MBE grown CrPt₃

Cr 2p - 3d excitation

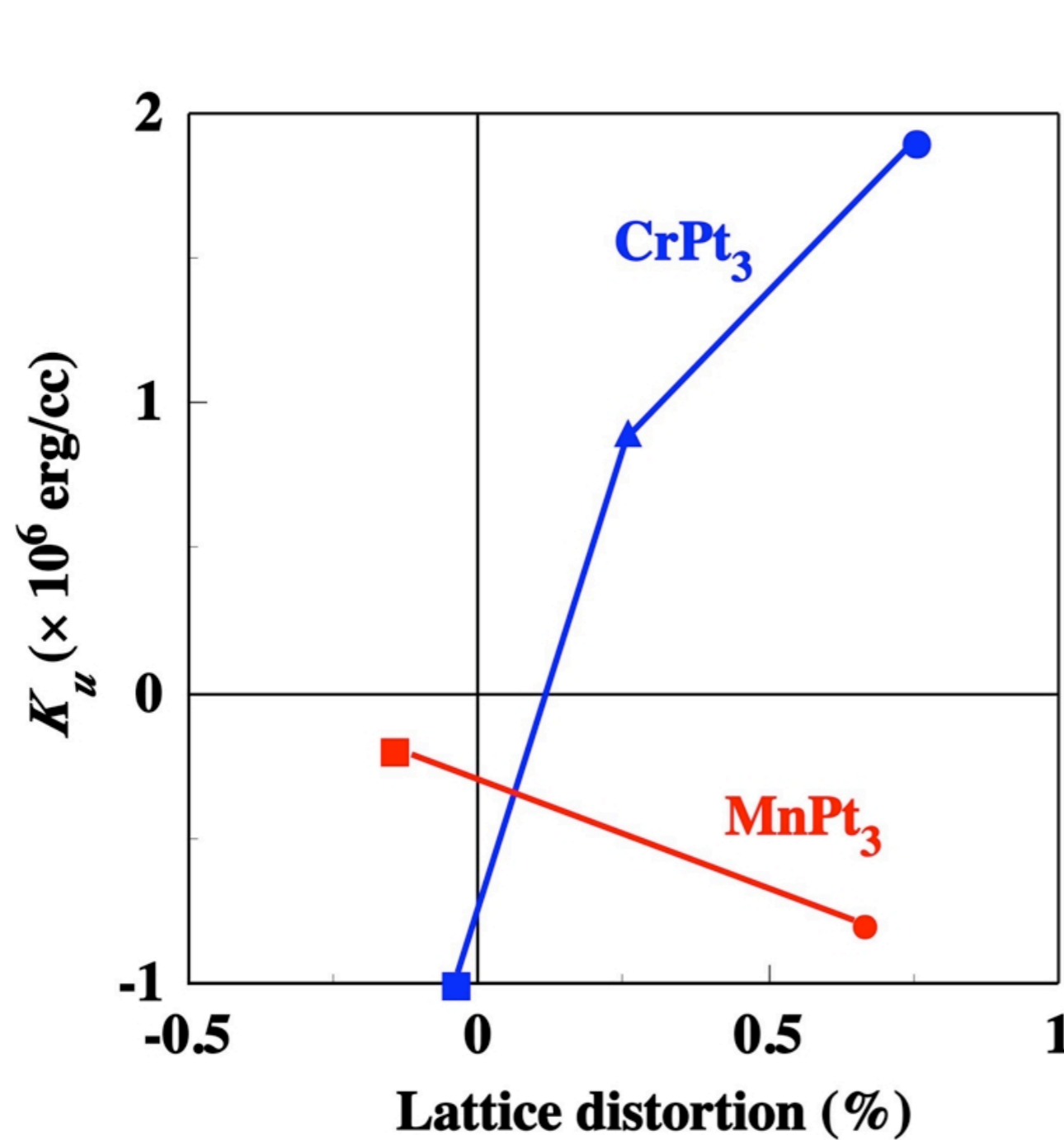


Substrate	Uniaxial anisotropy constant K_u ($\times 10^5$ J / m ³)	Corrected $\langle L_z \rangle / 2 \langle S_z \rangle$ Cr
Fused quartz	1.9	0.14
MgO(111)	-1.0	0.06

$$K_u \text{ \& } \langle L_z \rangle / 2 \langle S_z \rangle$$



K_u & lattice distortion



lattice distortion: $\frac{2(a_i - a_p)}{2a_i + a_p}$

- $\text{MgO}(111)$
- ▲ $\text{Al}_2\text{O}_3(001c)$
- fused quartz

Background

強磁性/反強磁性界面の交換結合

SVヘッド, MRAMにおいて重要な役割

交換結合のメカニズム

Random field model

A. P. Malozemoff: Phys. Rev. B 35 (1987) 3639.

Spin flop coupling

N. C. Koon: Phys. Rev. Lett., 78 (1997) 4865.

T. C. Schulthess *et al.*: Phys. Rev. Lett., 81 (1998) 4516.

メカニズムの理解は不十分

微細加工CoFeB/MnIr交換結合膜

XMCD-PEEM Co L_3 edge
 Fe L_3 edge
 Mn L_3 edge

CoFeB/MnIrの界面での磁気結合状態を評価

Sample Preparation

RFマグネトロンスパッタ

到達真空度 $< 2 \times 10^{-5}$ Pa

Ar圧 0.4 ~ 2 Pa

成膜中磁場 100 Oe

真空中熱処理

真空度 $< 1 \times 10^{-4}$ Pa

温度・時間 250 °C, 30 min

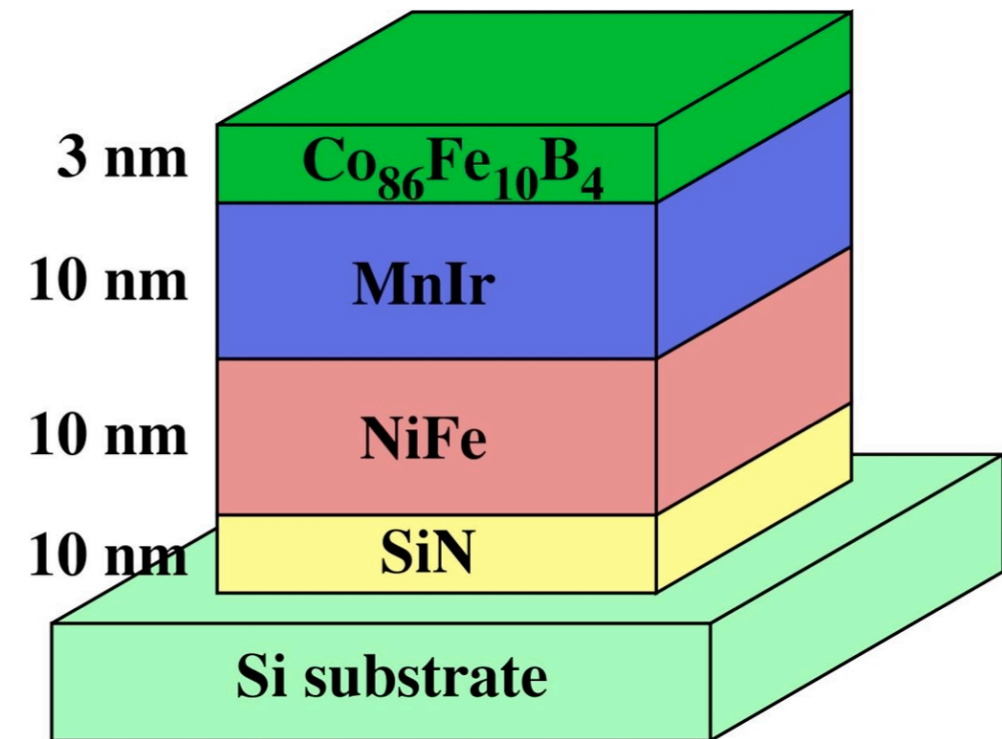
印可磁場 850 Oe

FIB加工

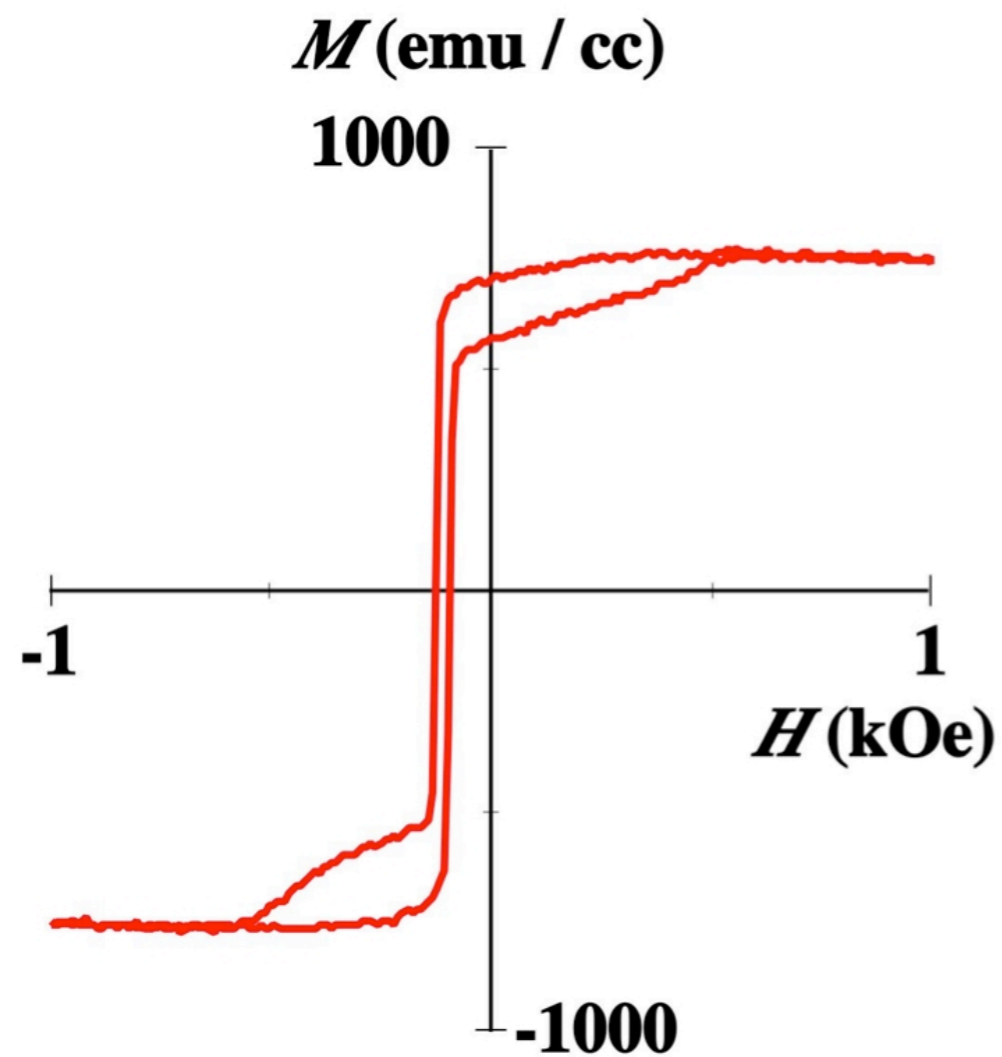
一次イオン 22 keV Ga⁺

ビーム電流 30 pA

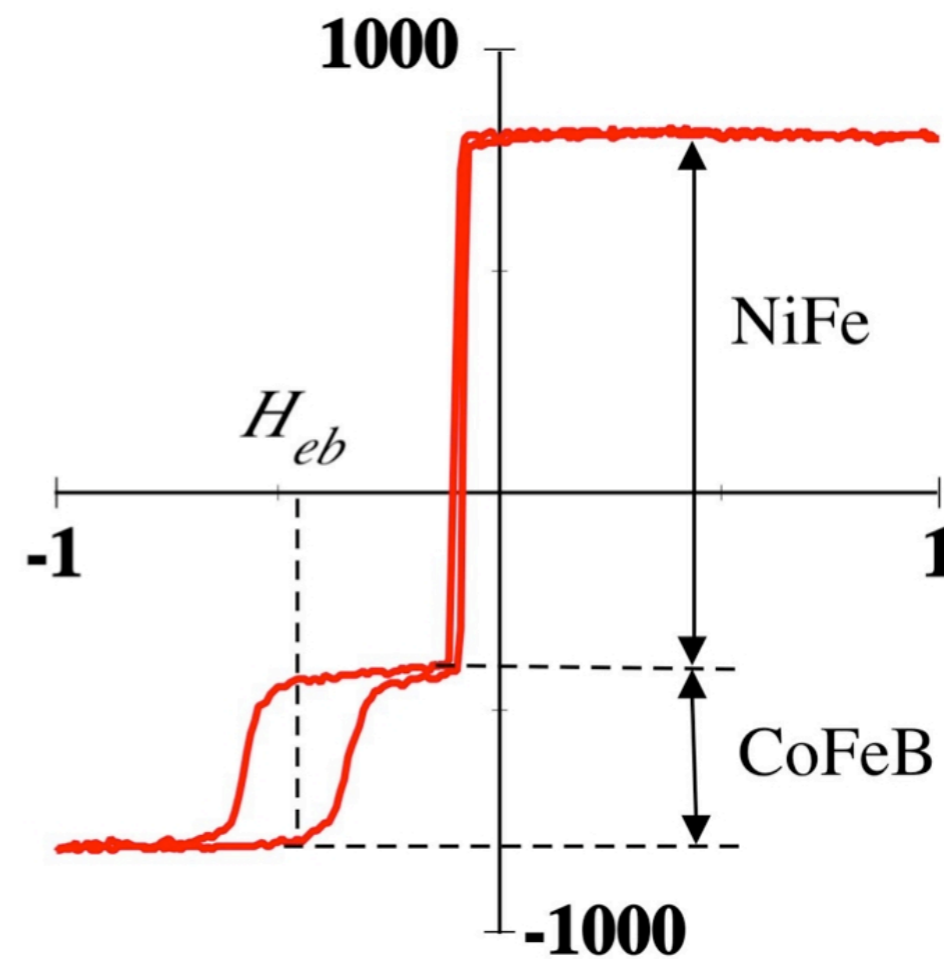
ビーム径 50 nm



MH of sheet films



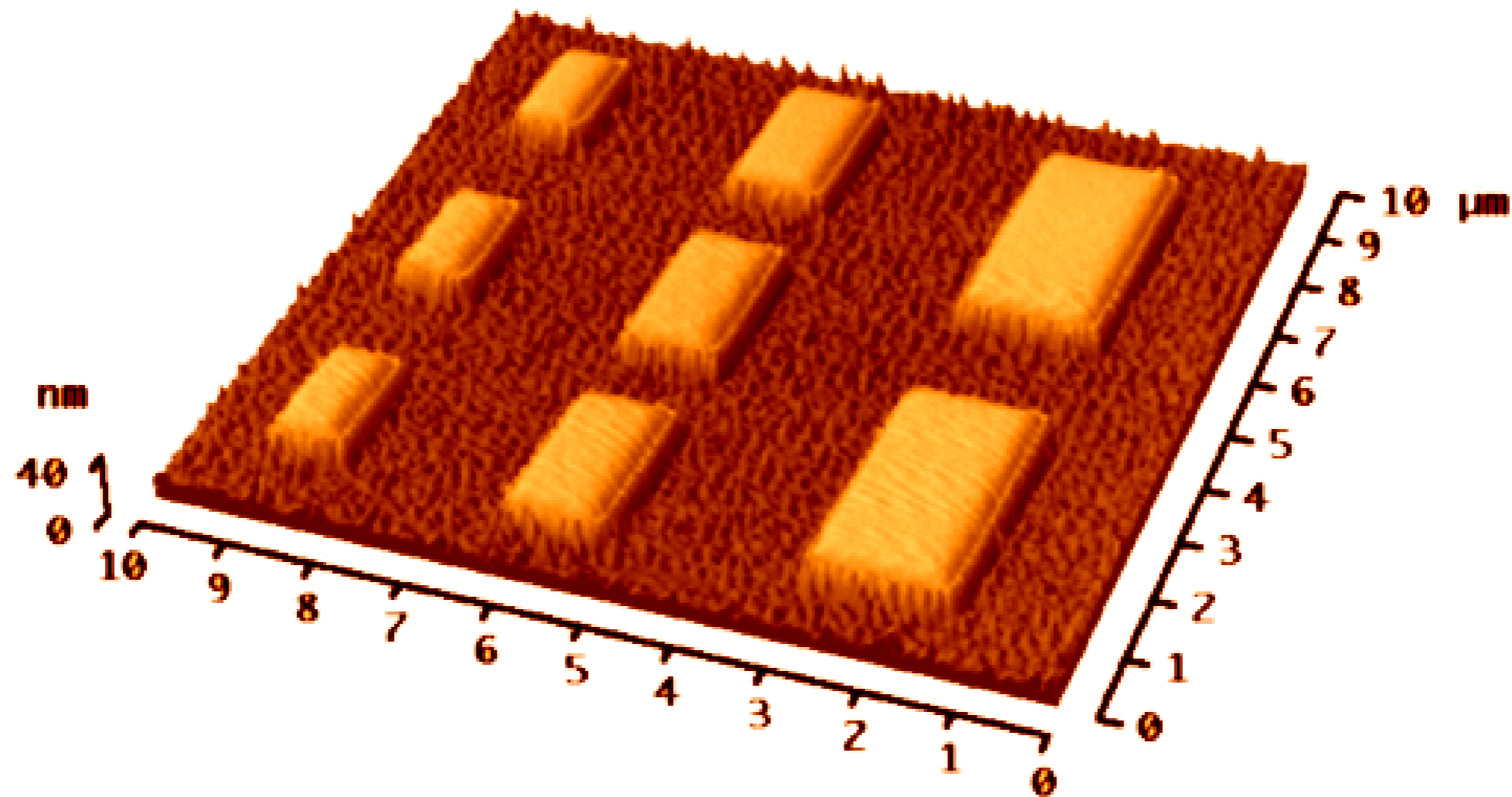
as-deposited



after heat treatment at 250 °C

FIB fabricated CoFeB/MnIr

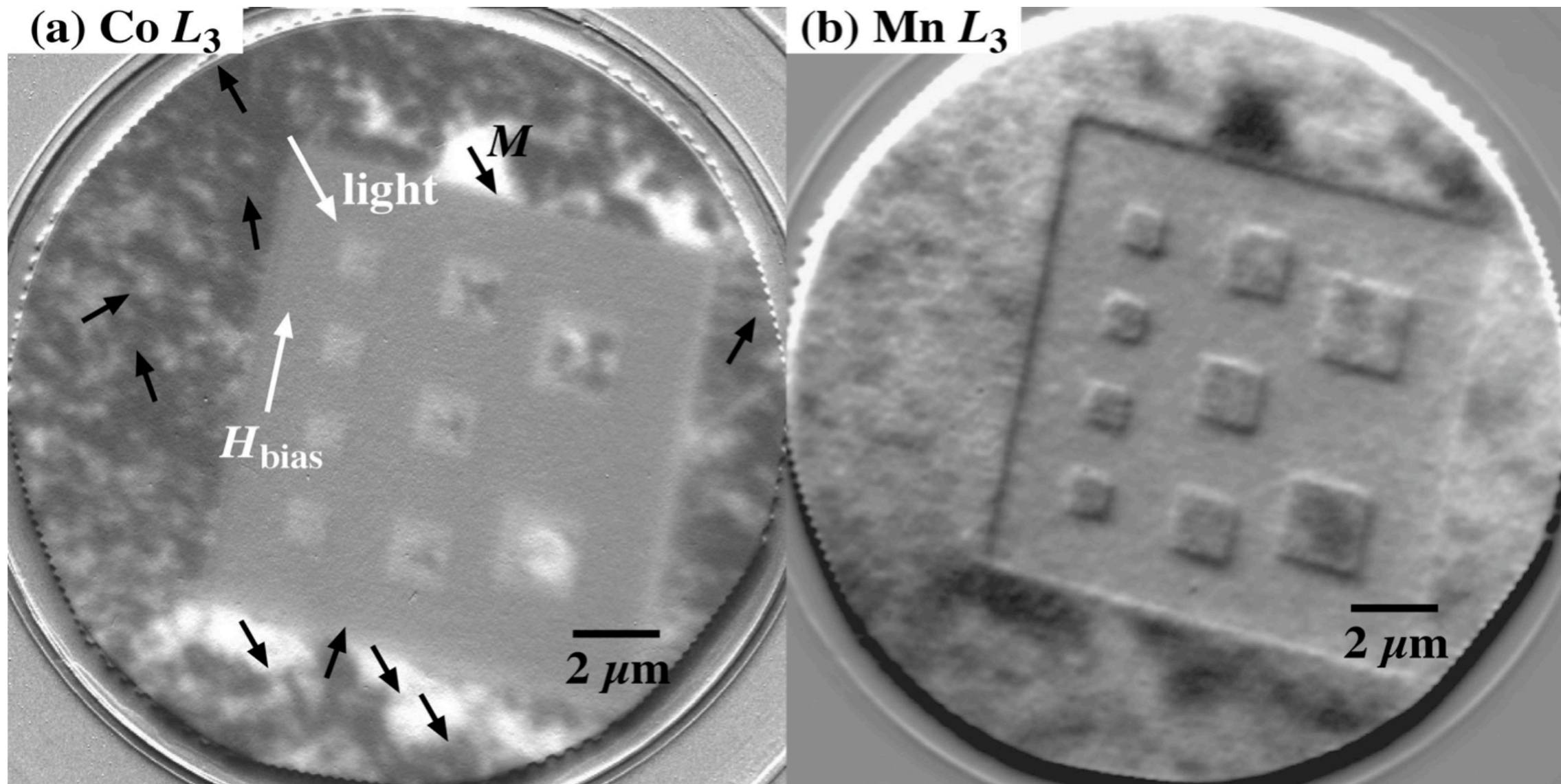
CoFeB (3 nm) / MnIr (10 nm) / NiFe (10 nm) / SiN (10 nm) / Si



etching depth ~ 18 nm

MCD-PEEM at Mn and Co edges

square shaped CoFeB (3 nm) / MnIr (10 nm)



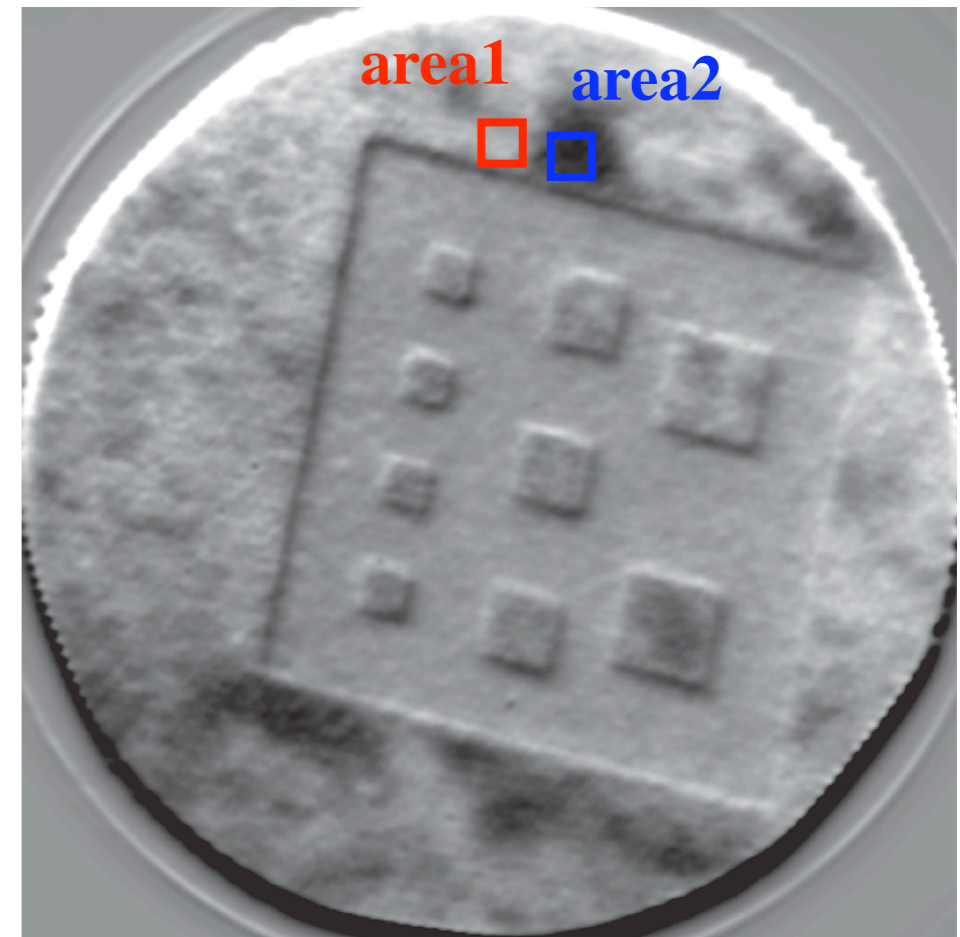
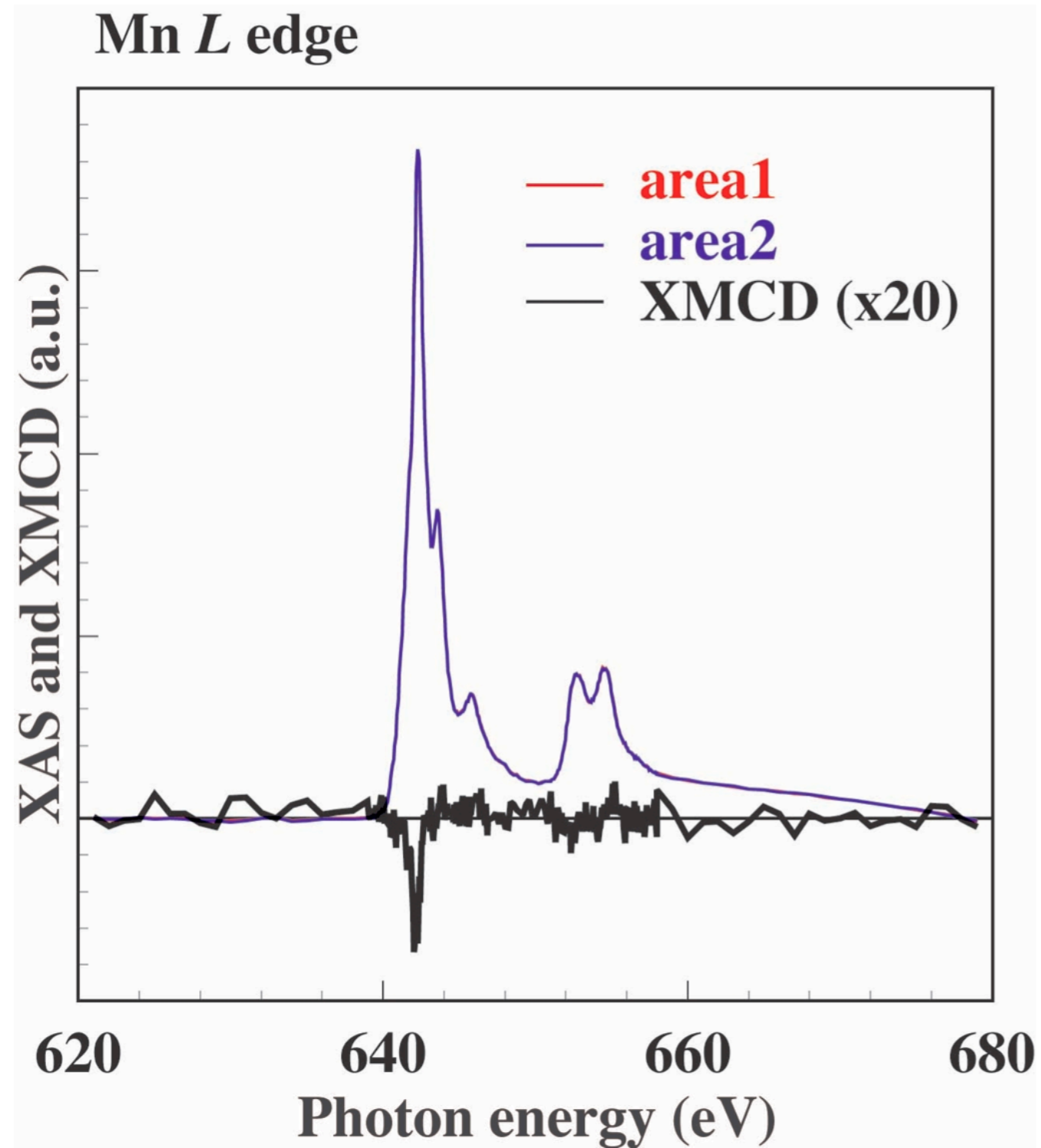
easy direction

300 nm程度の不規則な磁区

界面でMnの強磁性的配列

MnとCoの反平行結合

Mn MCD spectrum



easy direction

Summary

TM-Pt₃規則合金 (TM = Mn, Cr, V)

1. 垂直磁気異方性 : CrPt₃ > VPt₃ > MnPt₃
2. $\langle L_z \rangle / 2\langle S_z \rangle$: CrPt₃ > VPt₃ > MnPt₃
(Mn, Cr, Vのモーメントは全て平行に結合)
3. K_u は熱処理により誘導された格子ひずみと $\langle L_z \rangle / 2\langle S_z \rangle$ で良く説明される.

CoFeB/MnIr交換結合膜

1. 300 nm程度の不規則な磁区構造 (MnIrのランダムな結晶異方性?)
2. 界面での強磁性的Mnスピンの存在 (界面でのMnスピン再配列)
3. MnとCoの反平行カップリング