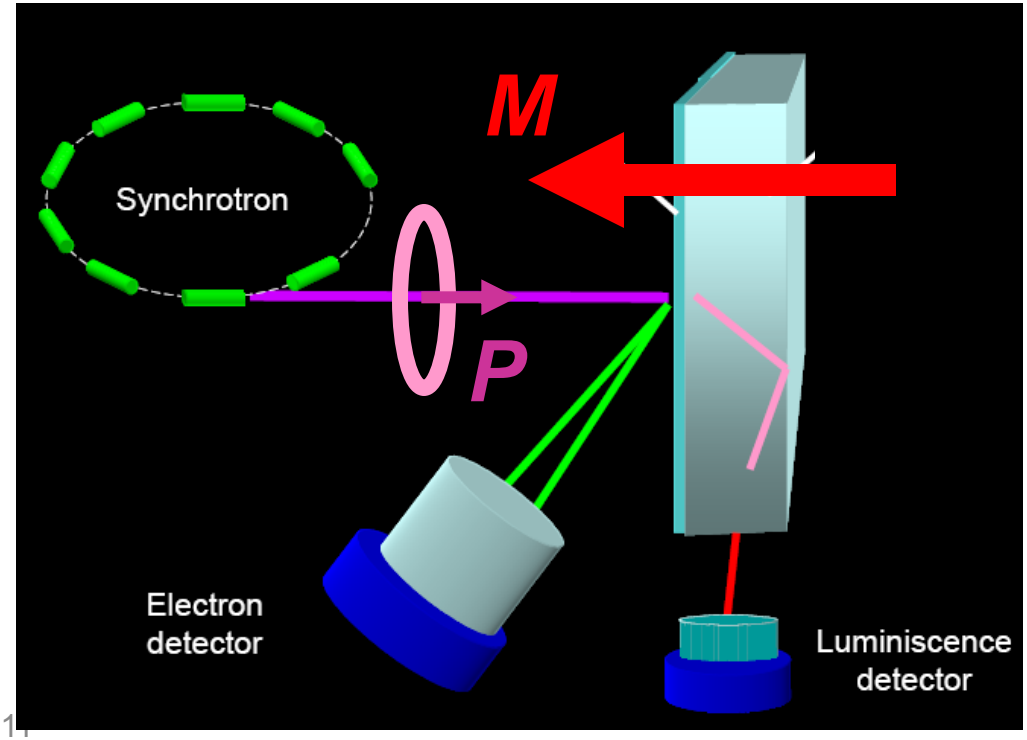
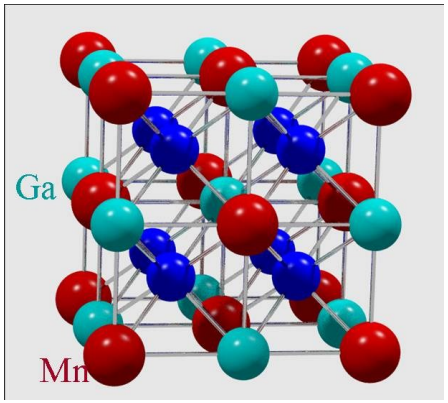
Circular dichroism elucidates spin-orbit interaction in magnets

Hans-Joachim Elmers

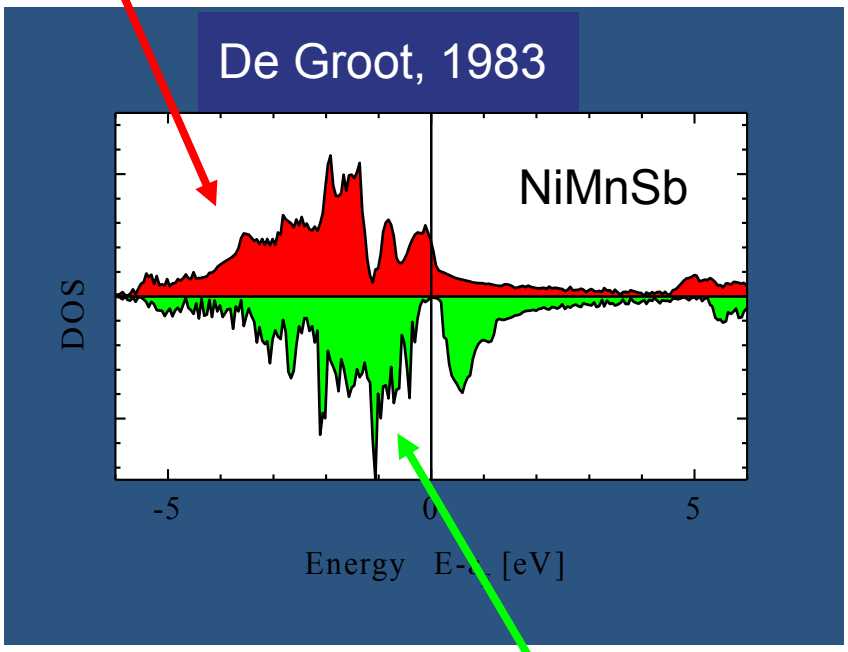
Institut für Physik, Universität Mainz, 55128 Mainz



Half-metallic ferromagnets

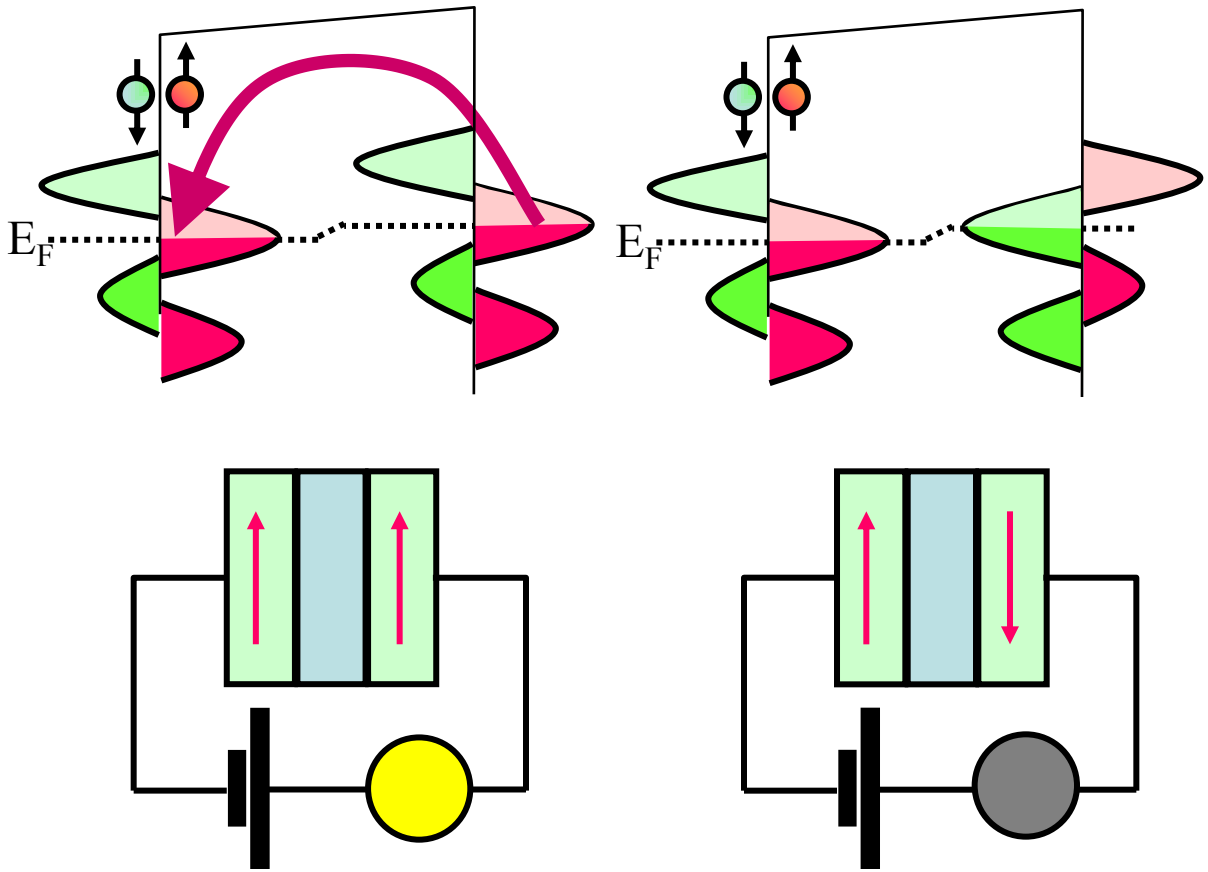


Metal



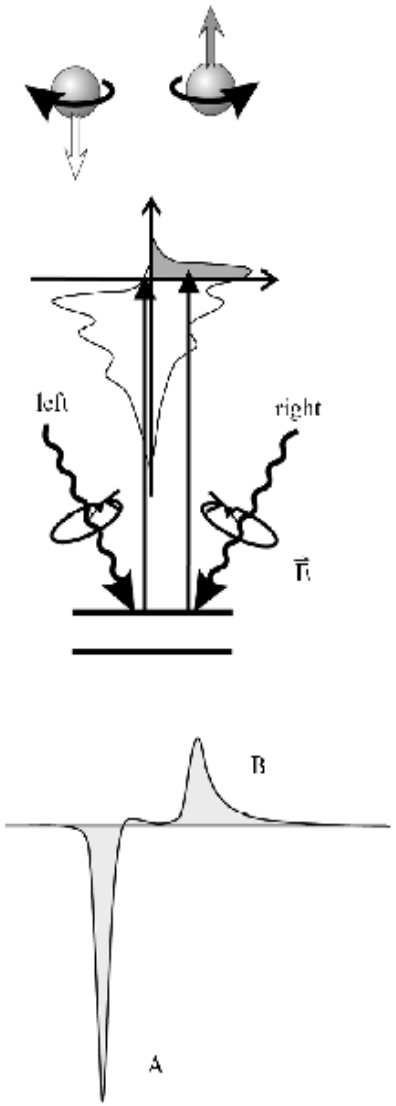
Semiconductor

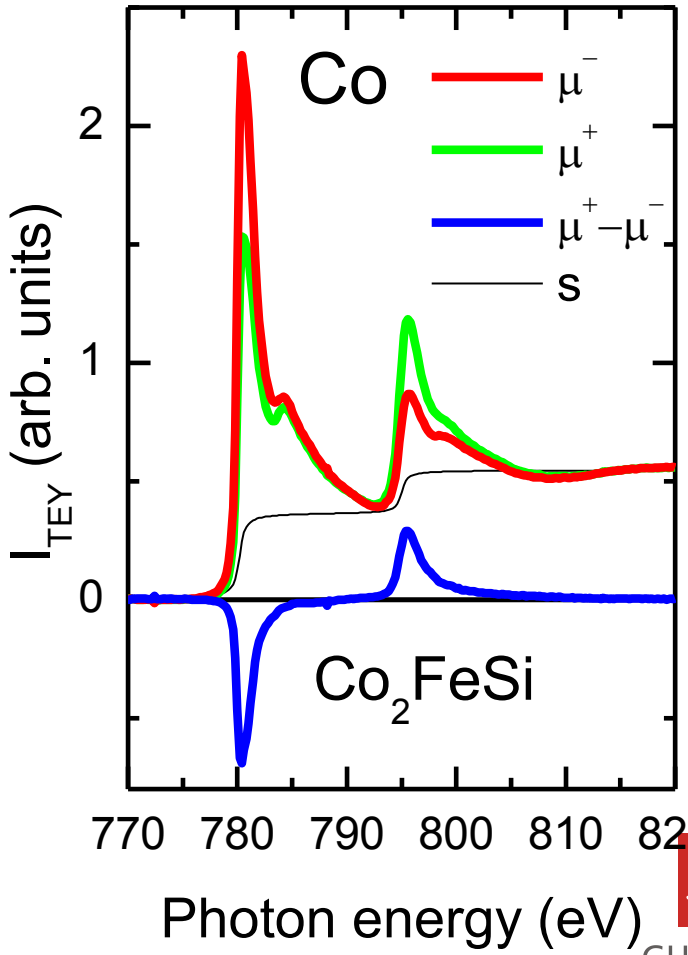
Tunneling magnetoresistance (TMR)



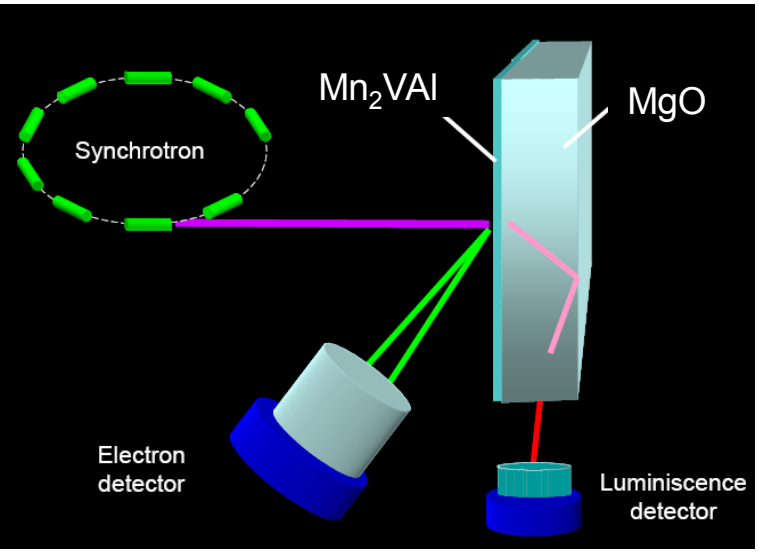
TMR with half-metallic ferromagnetic contacts works like a switch

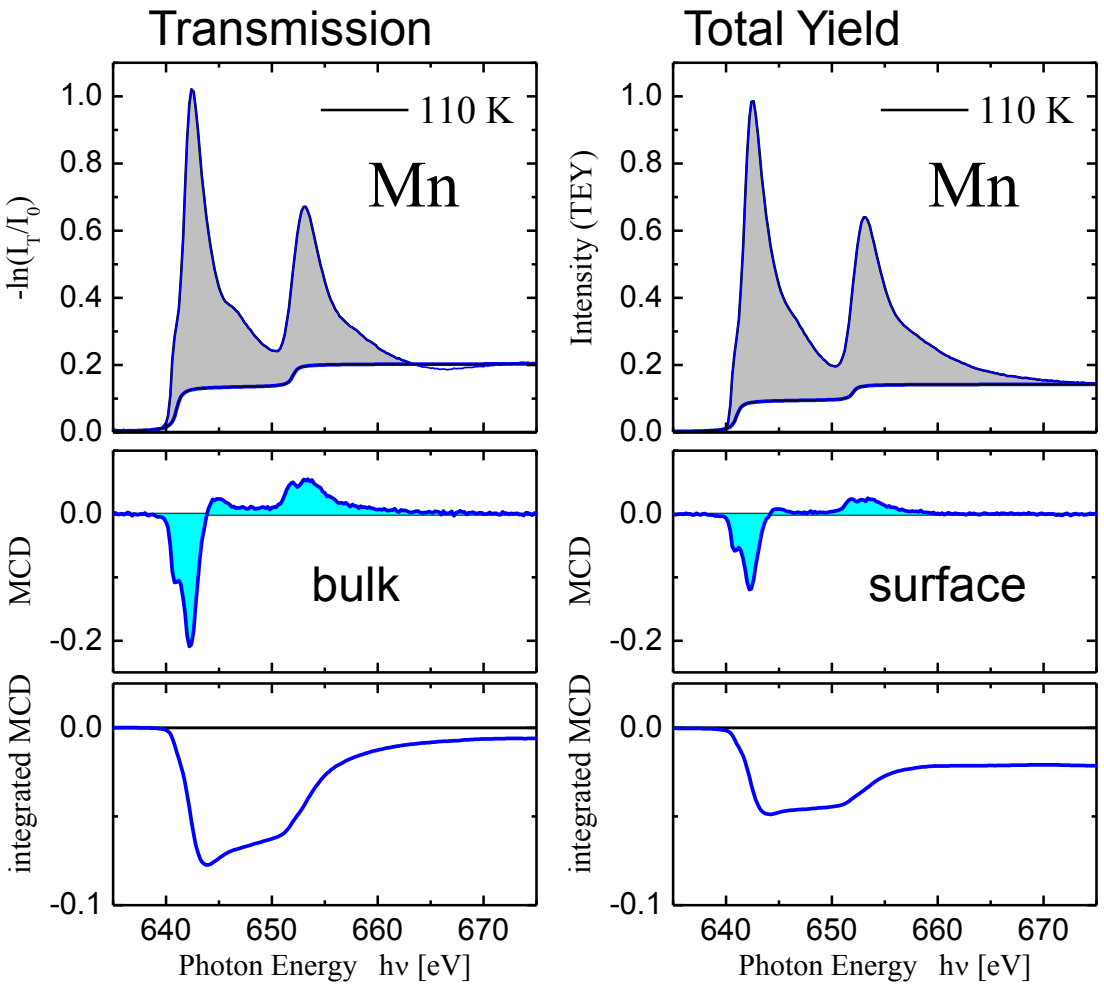
X-ray Magnetic Circular Dichroism (XMCD)





Element-specific Magnetometry



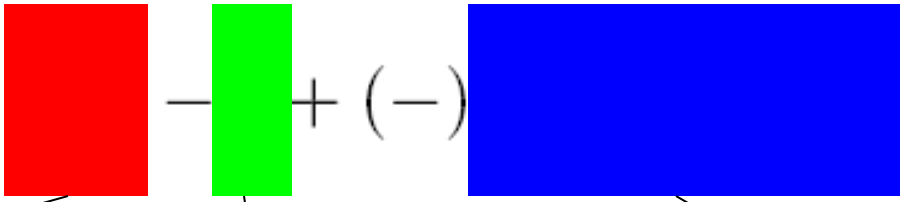


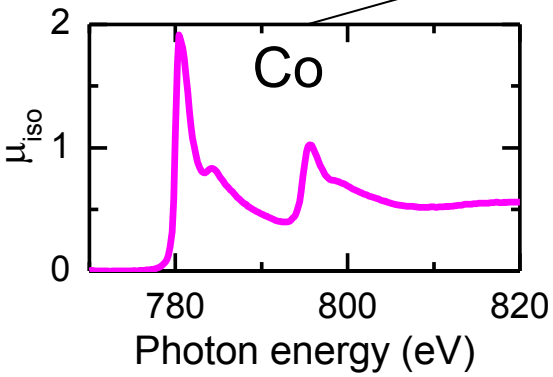
P. Klaer, Phys. Rev. B **82**, 024418 (2010)

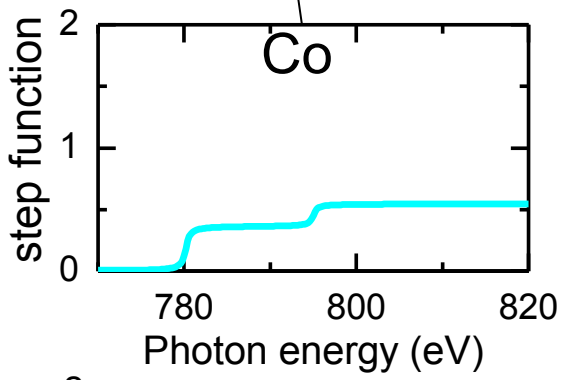
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

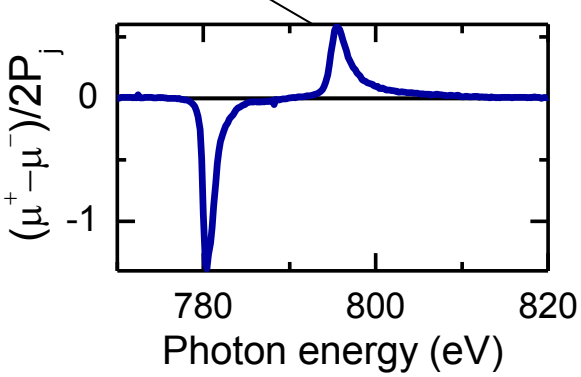
Recovering of spin-resolved partial density of states

$$D^{\uparrow(\downarrow)}(1 - f_F) \propto$$

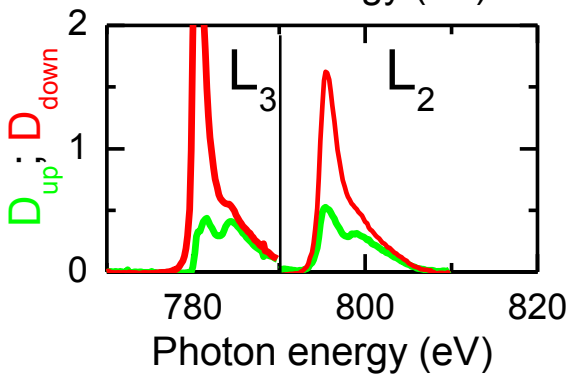








Result:



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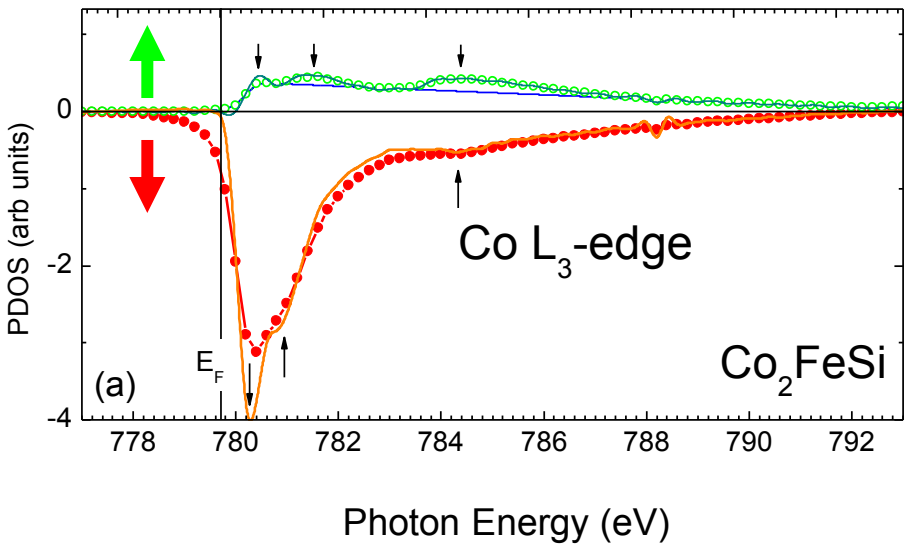
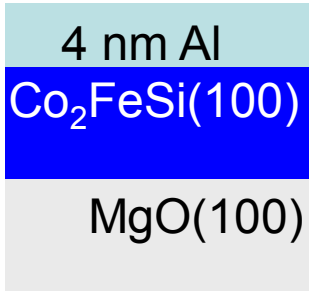
Recovering of spin-resolved partial density of states



Deconvolution
with
Lorentzian Function
FWHM = 0.4 eV



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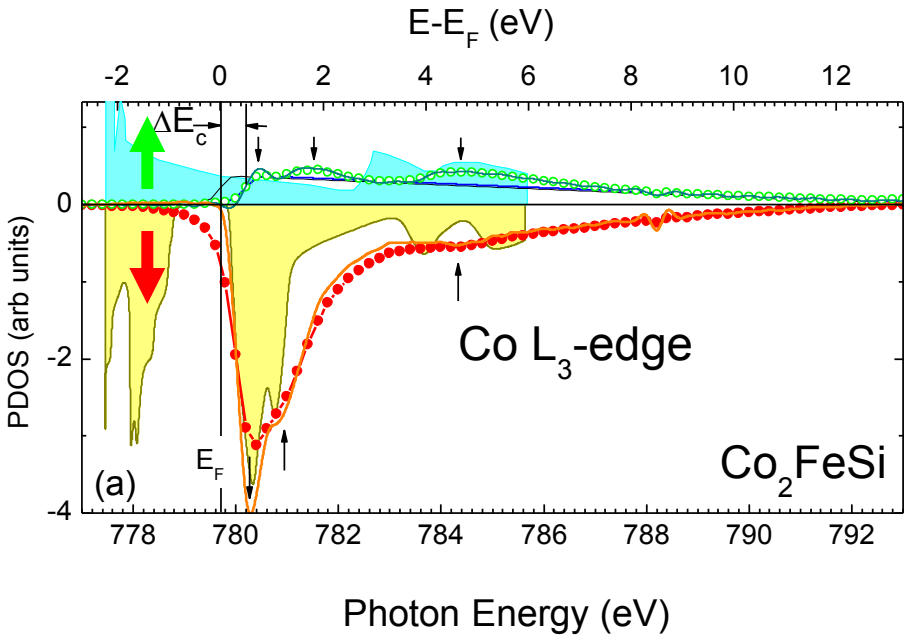
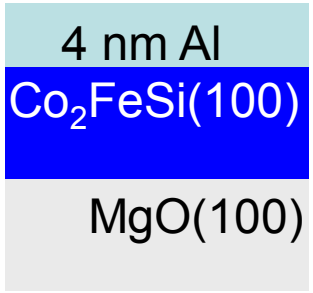
Recovering of spin-resolved partial density of states





Theory:
Kandpal et al. Phys. Rev. B 73, 094422 (2006)

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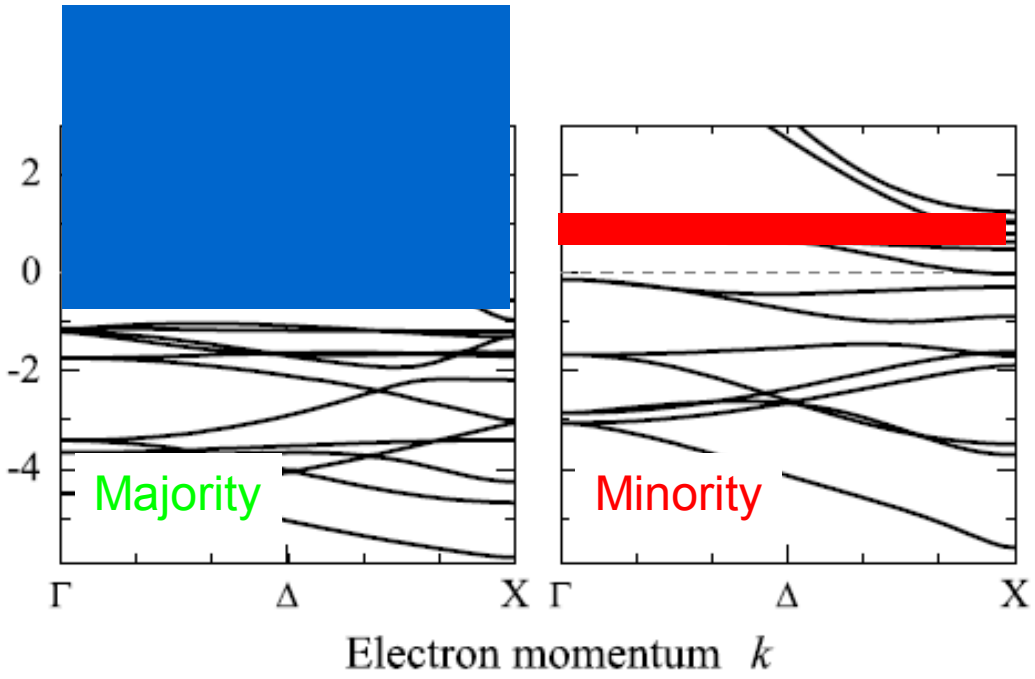
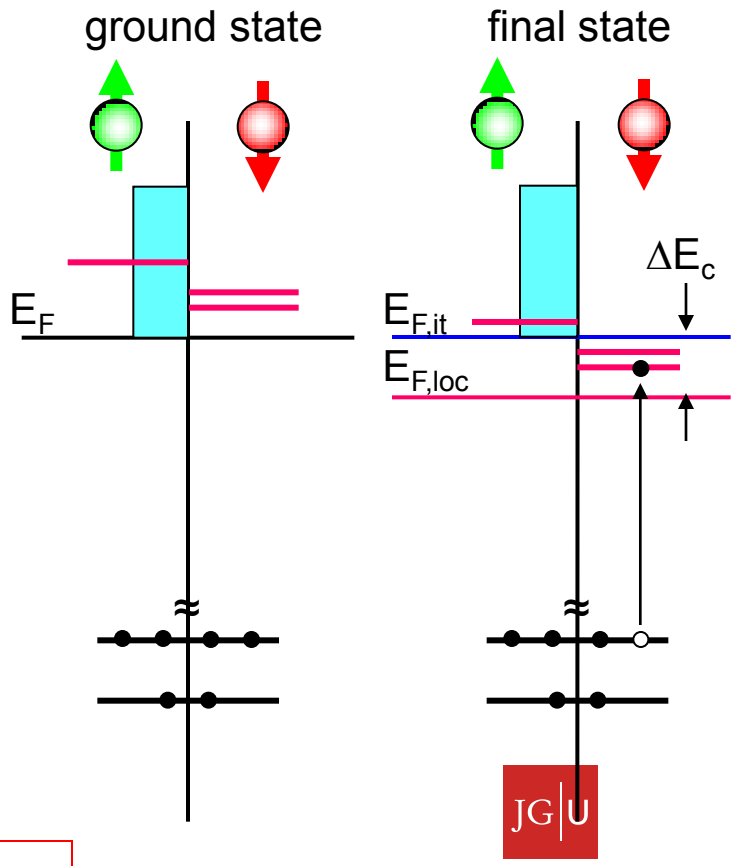
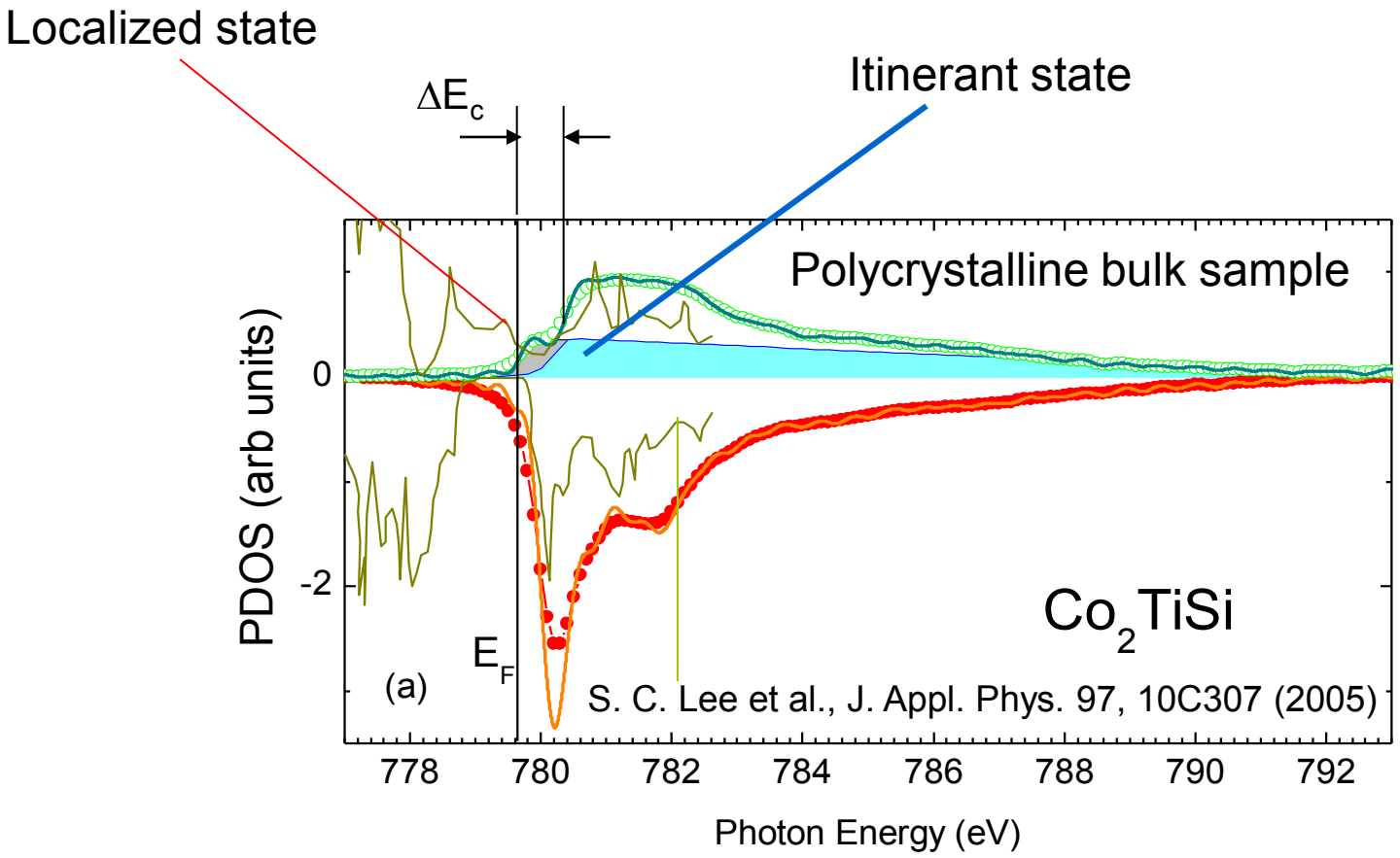
Correlation of core hole and excited electron





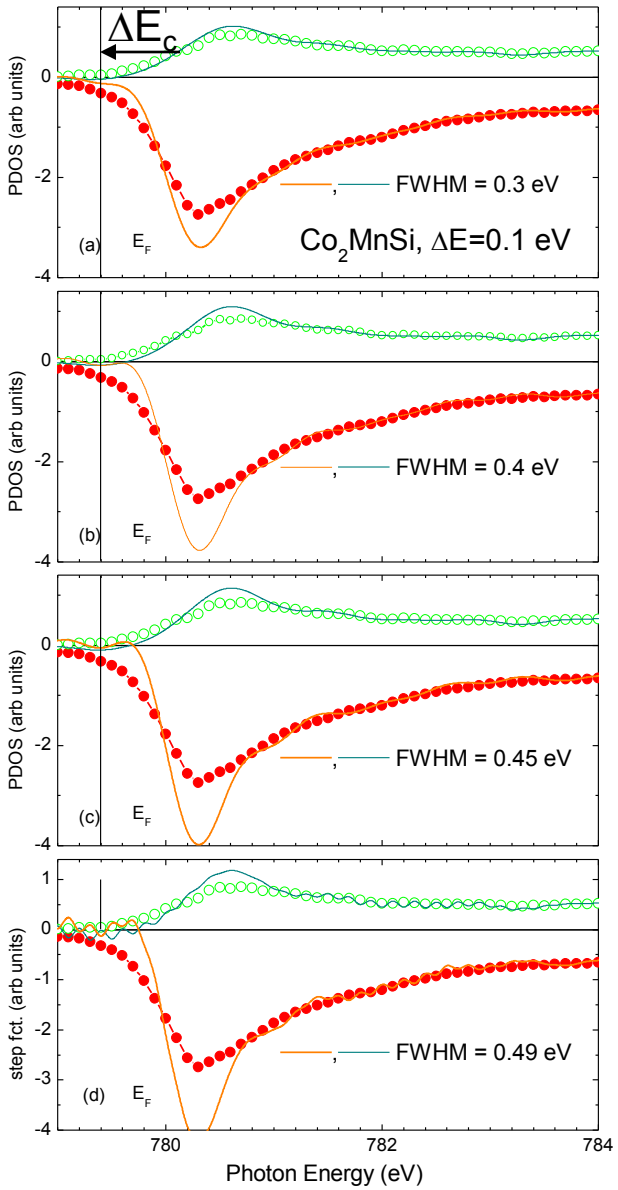
G.H. Fecher et al., J. Phys.: Condens. Matter **17** (2005) 7237–7252

$\Delta E_c = 0.5$ eV = const.



Two-step increase of majority states → Exp. Value of ΔE_c

Influence of
Lorentz - FWHM
on
deconvolution result



4 nm Al
Co_2MnSi(100)
MgO(100)

Robust half-metallic properties for Co_2MnSi

FWHM larger than life-time broadening →

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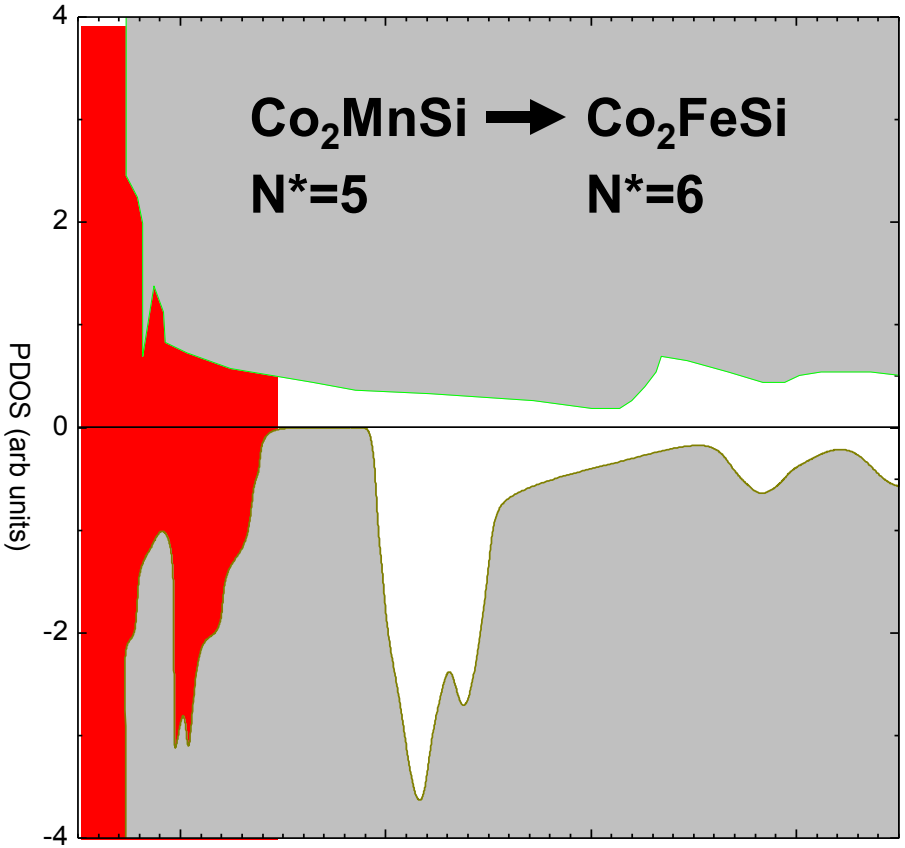
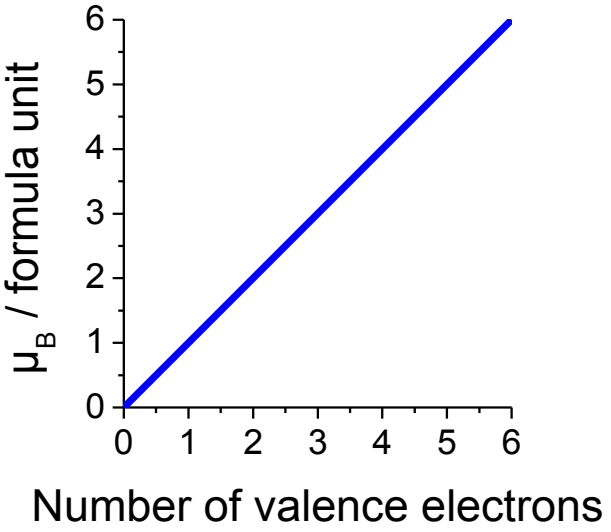
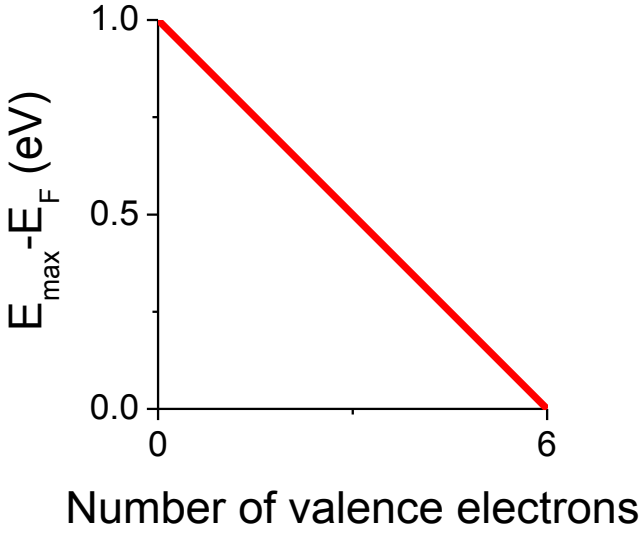
Rigid band model



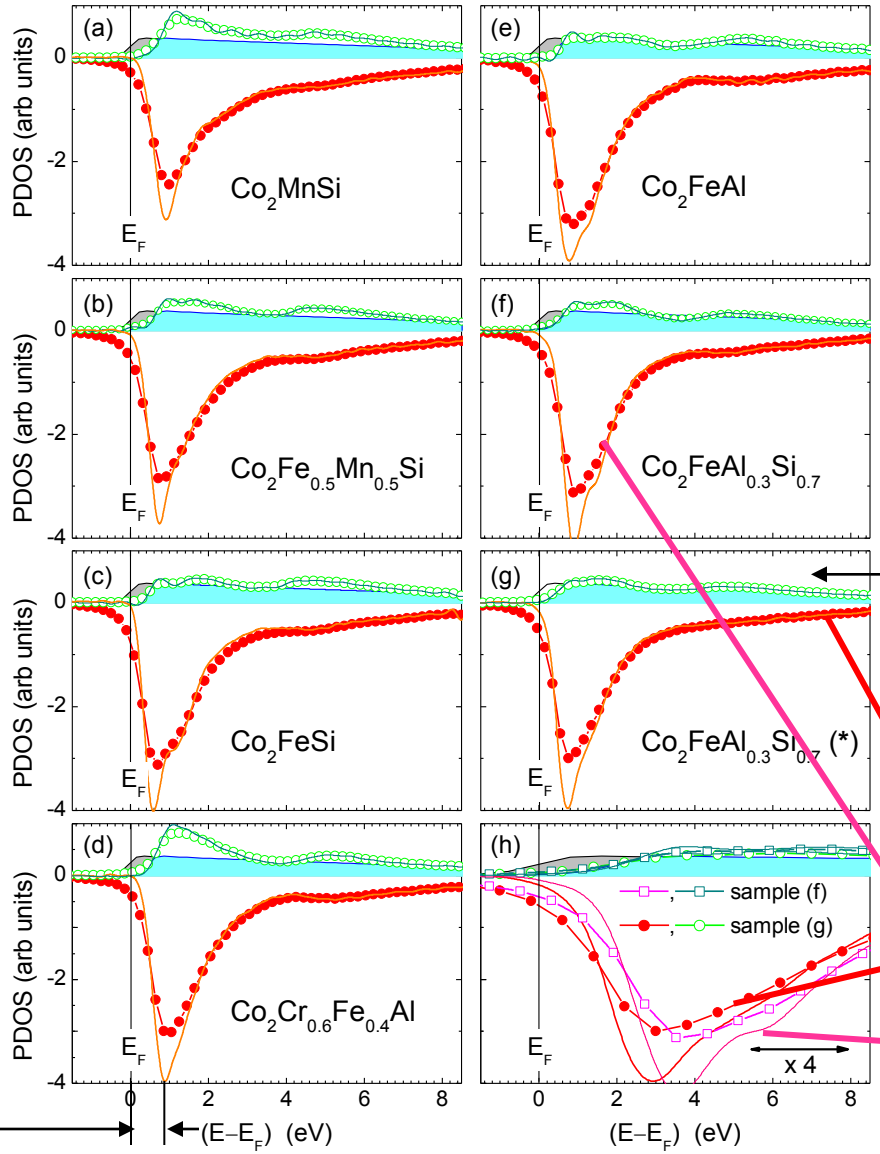




Tailoring of band structure in Co_2YZ

Doping on the Y-site

Doping on the Z-site



T_a=450 °C
$<T_{opt}$

B2

$L2_1$

4 nm Al

Co_2YZ(100)

MgO(100)

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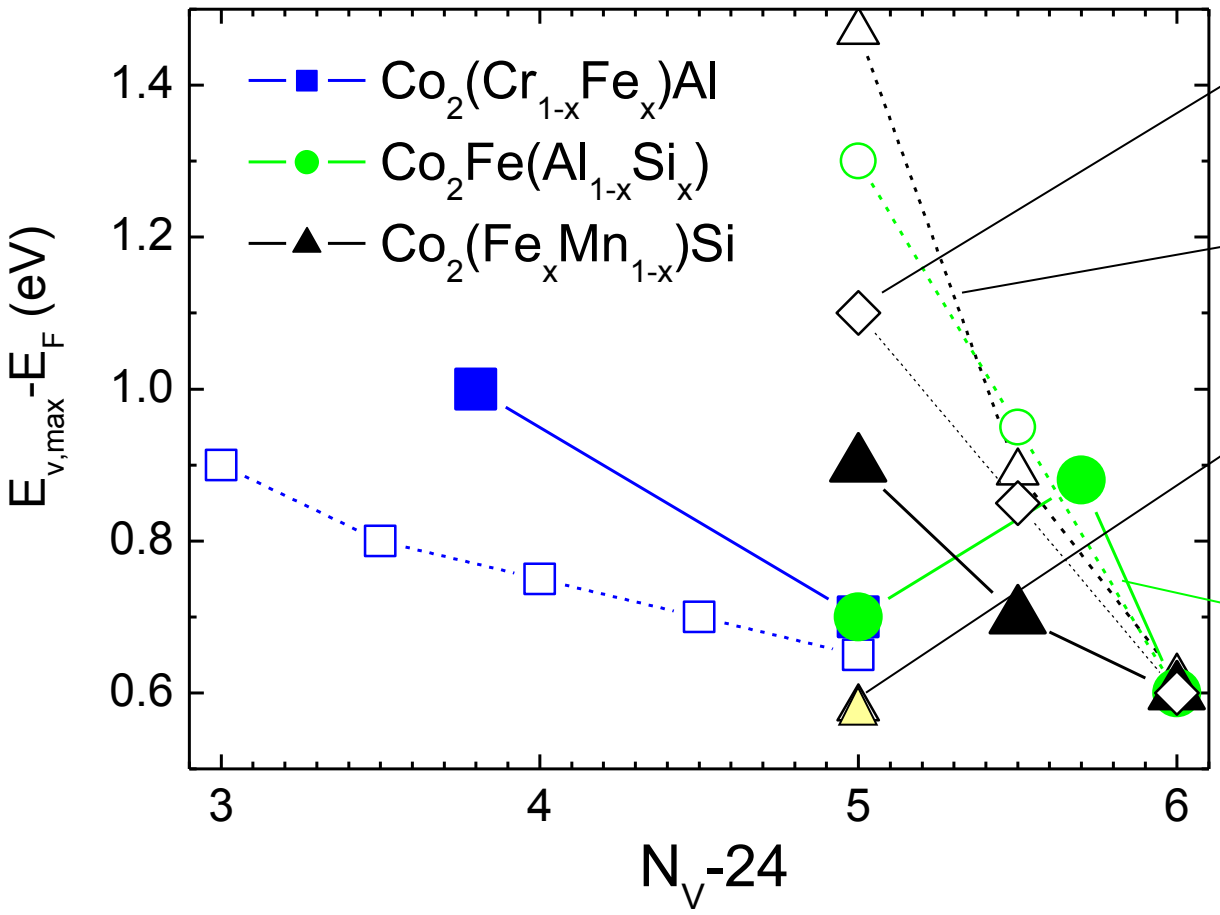
Comparison with theory



LDA+DMFT

S. Chadov et al., J. Phys. D: Appl. Phys. 42, 084002 (2009).

LDA+U

B. Balke et al., Phys. Rev. B 74, 104405 (2006)

LDA

K. Özdogan, et al., J. Appl. Phys. 101, 073910 (2007).

LDA+U

G.H. Fecher and C. Felser, J. Phys. D 40, 1582 (2007)

M. Kallmayer, et al. Phys. Rev. B **80**, 020406R (2009)

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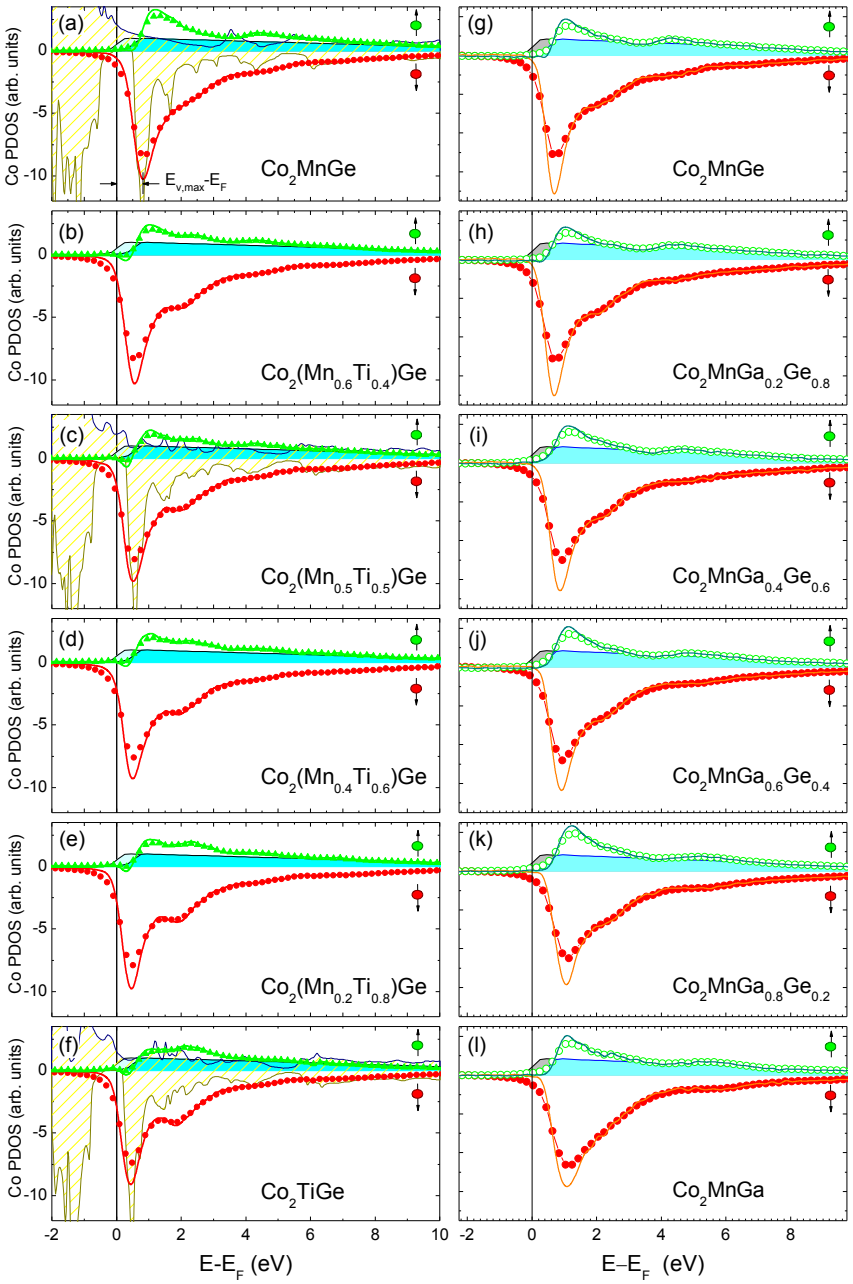
Co_2YZ Bulk

annomal
rigid band



normal
rigid band

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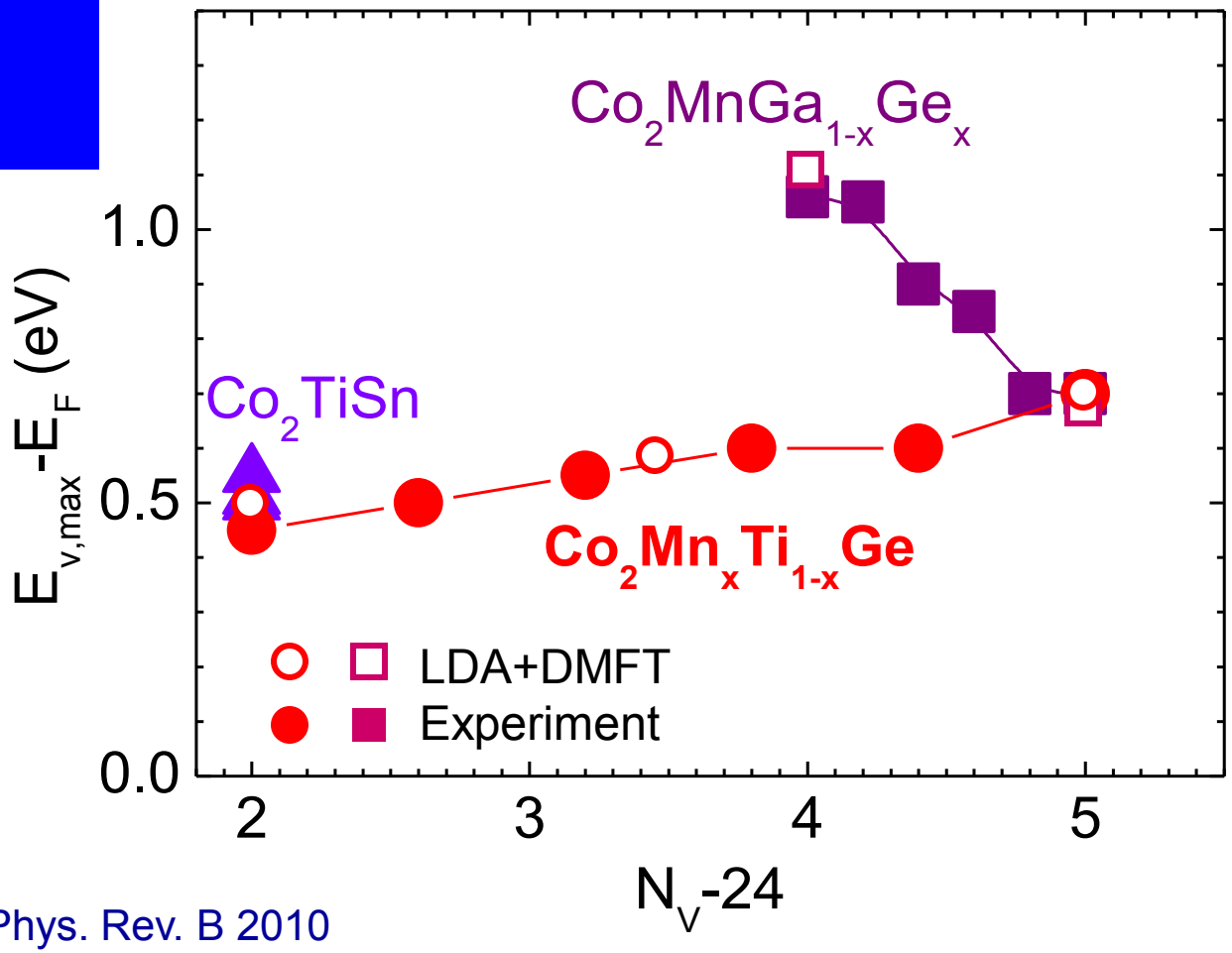
Comparison with theory

Co_2YZ
Bulk



Klaer et al. Phys. Rev. B 2010

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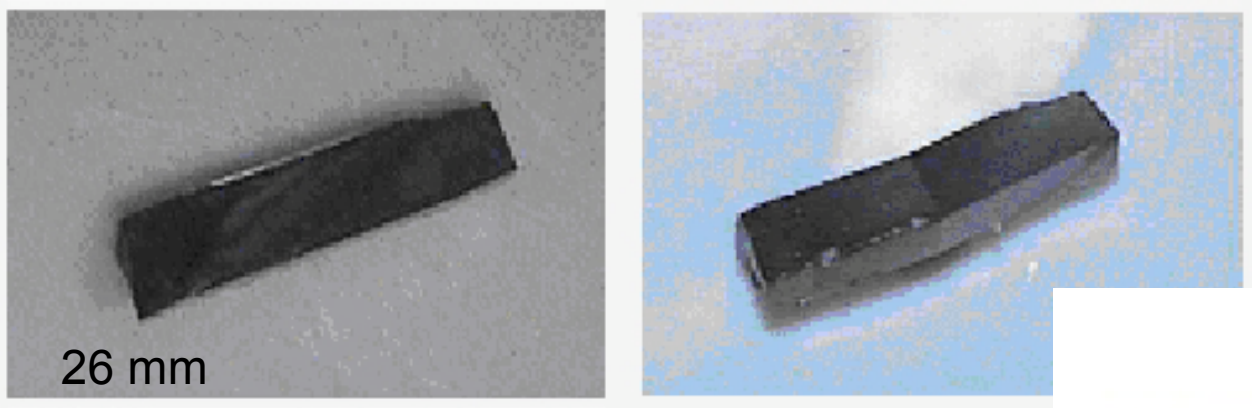
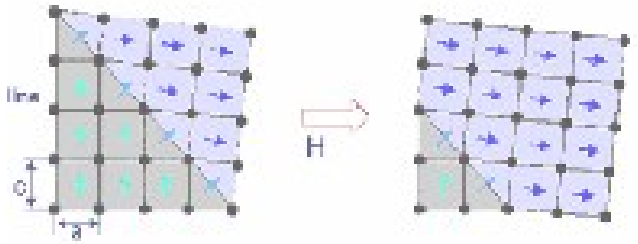
Ferromagnetic Shape Memory Alloys

Before .. after.. application of magnetic field



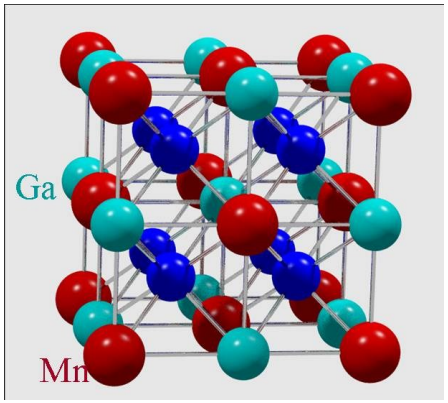
Single crystal Ni2MnGa

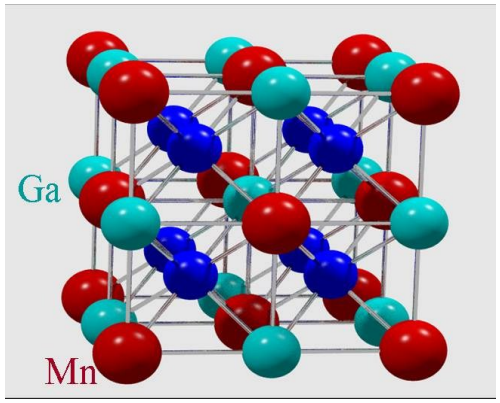


R. C. O'Handley

http://web.mit.edu/bobohand/www/fsma.html#Ferromagnetic Shape Memory Alloys

Ferromagnetic Shape Memory Alloys



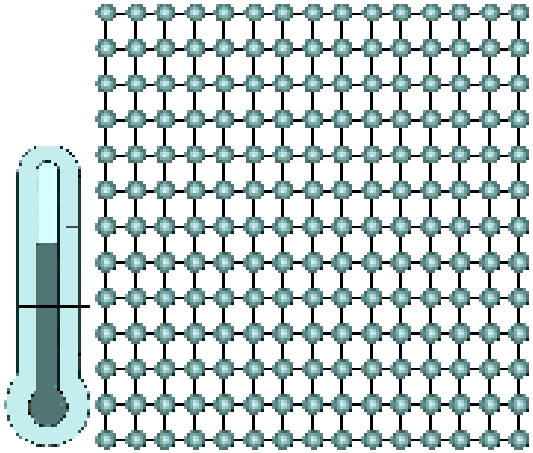


$T > T_m$

$c/a = 1$

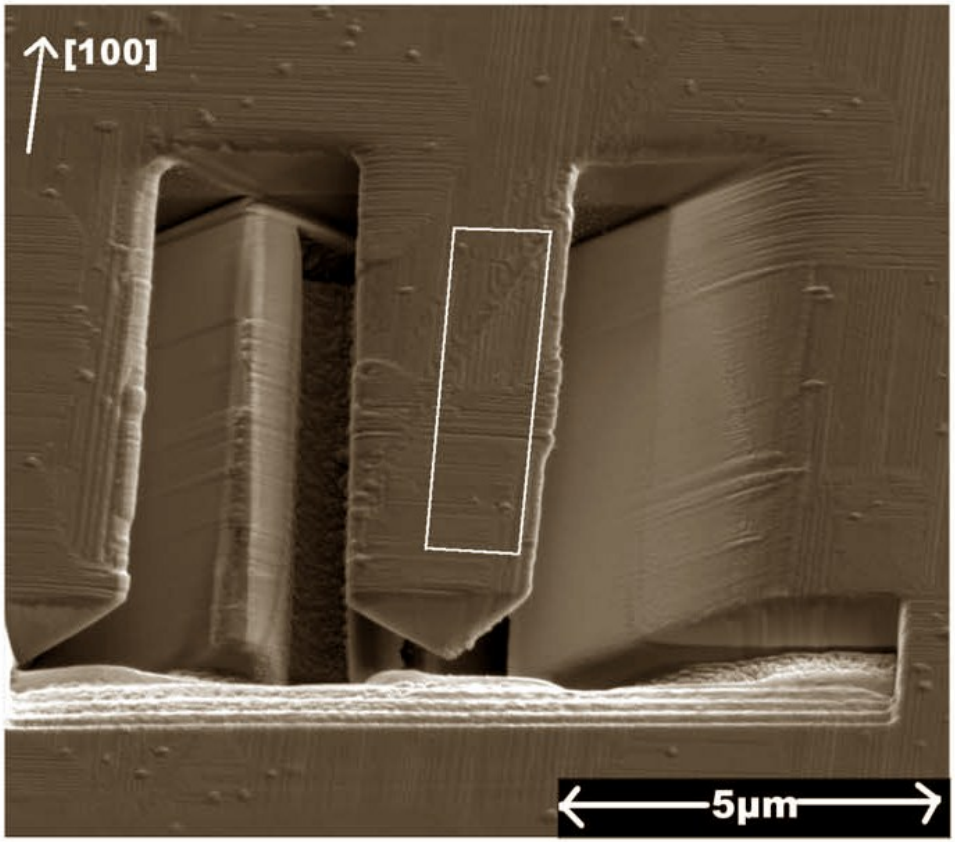
$T < T_m$

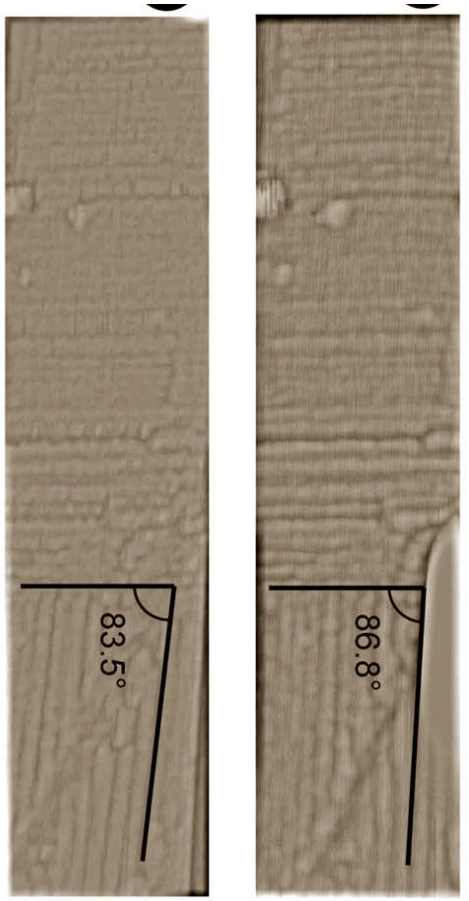
c/a 0.94



T. Hickel, MPI f. Eisenforschung, Düsseldorf

Ferromagnetic Shape Memory Alloys

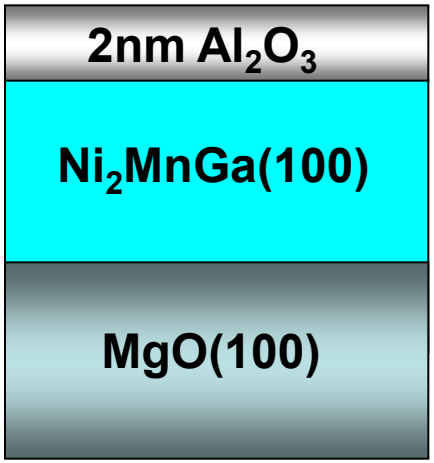




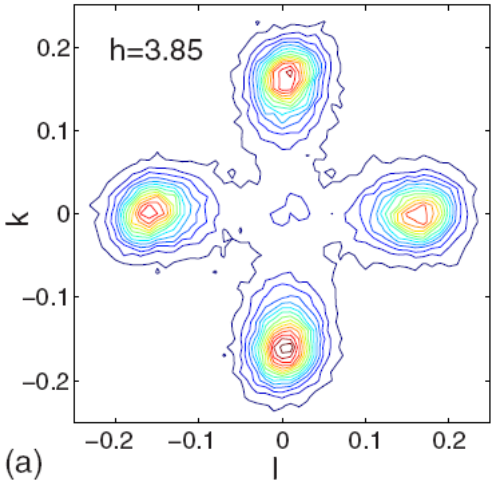
C. A. Jenkins, HJE, G. Jakob, et al. Appl. Phys. Lett. **93**, 234101 2008

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

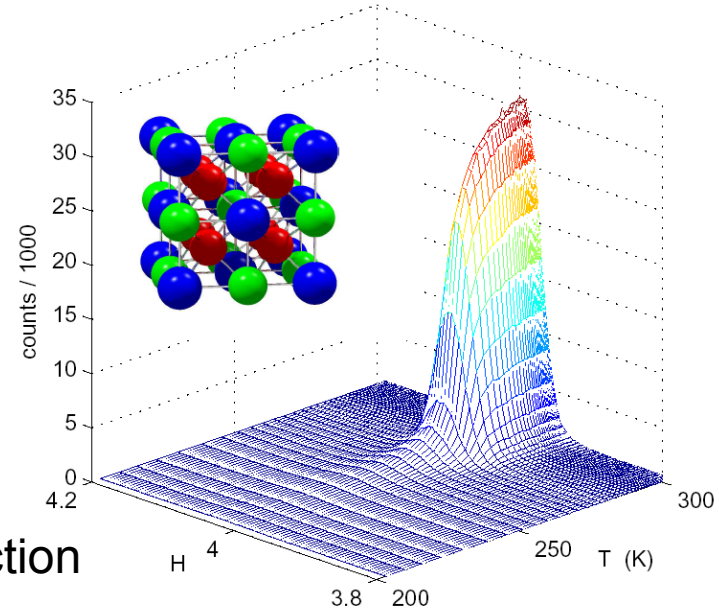
Growth of single crystalline films



DC magnetron sputtering
T = 500 °C
$P_0 = 10^{-8}$ mbar



Contour plot of *kl* scans near the 400 reflection of the AS phase.



400 reflection

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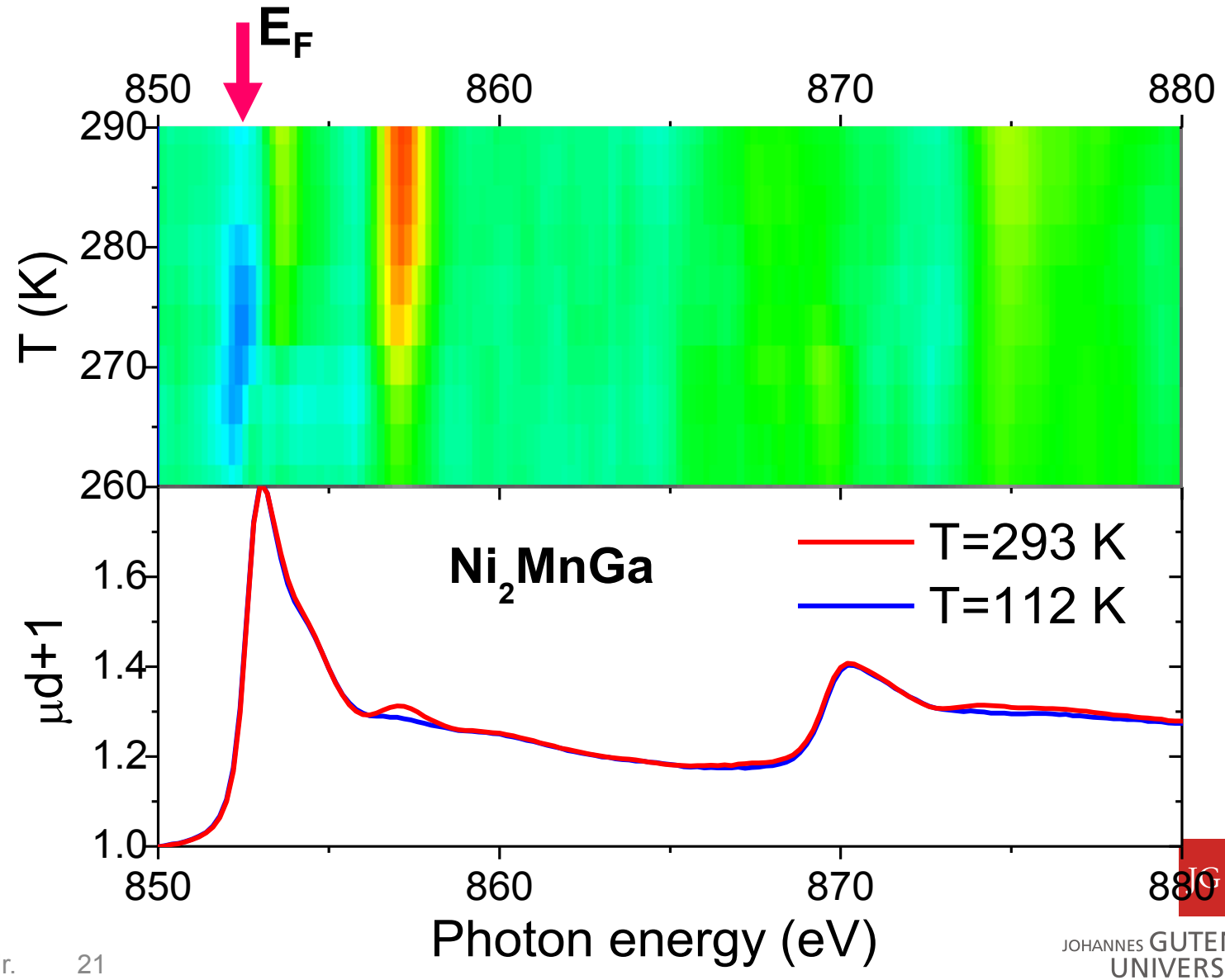
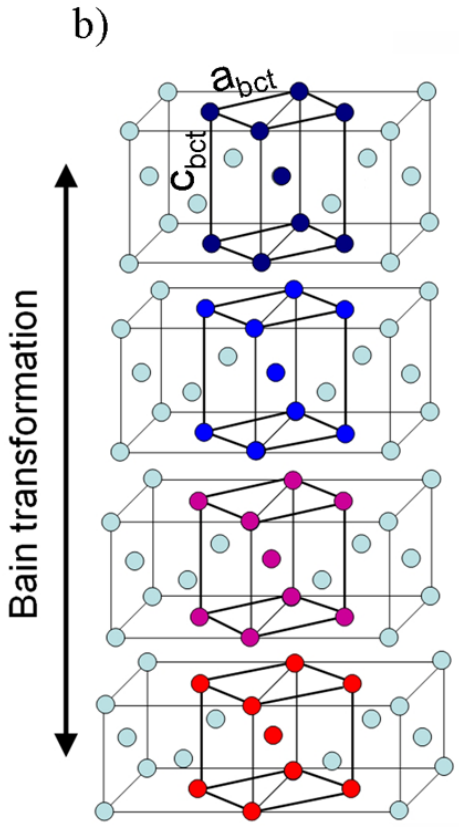
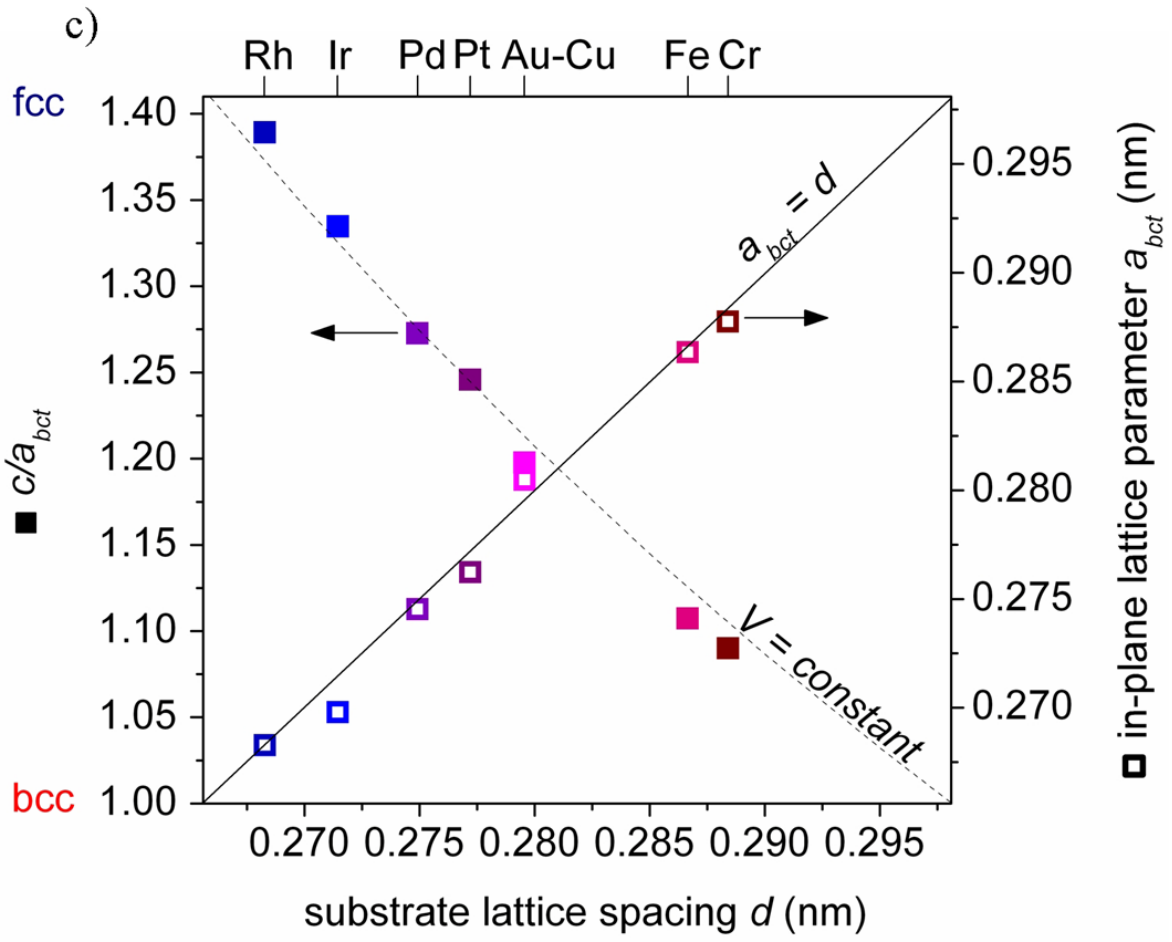
G. Jakob and HJE, J. Magn. Magn. Mater. 2007.

Correlation of structure and electronic properties



Tuning the Magnetic Anisotropy





J. Buschbeck et al. PRL **103**, 216101 (2009)

in collaboration with S. Fähler, IFW Dresden

JG|U
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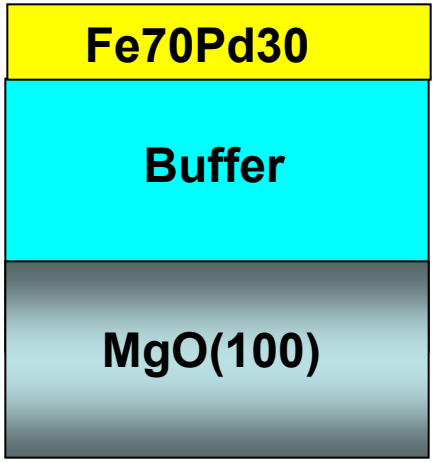
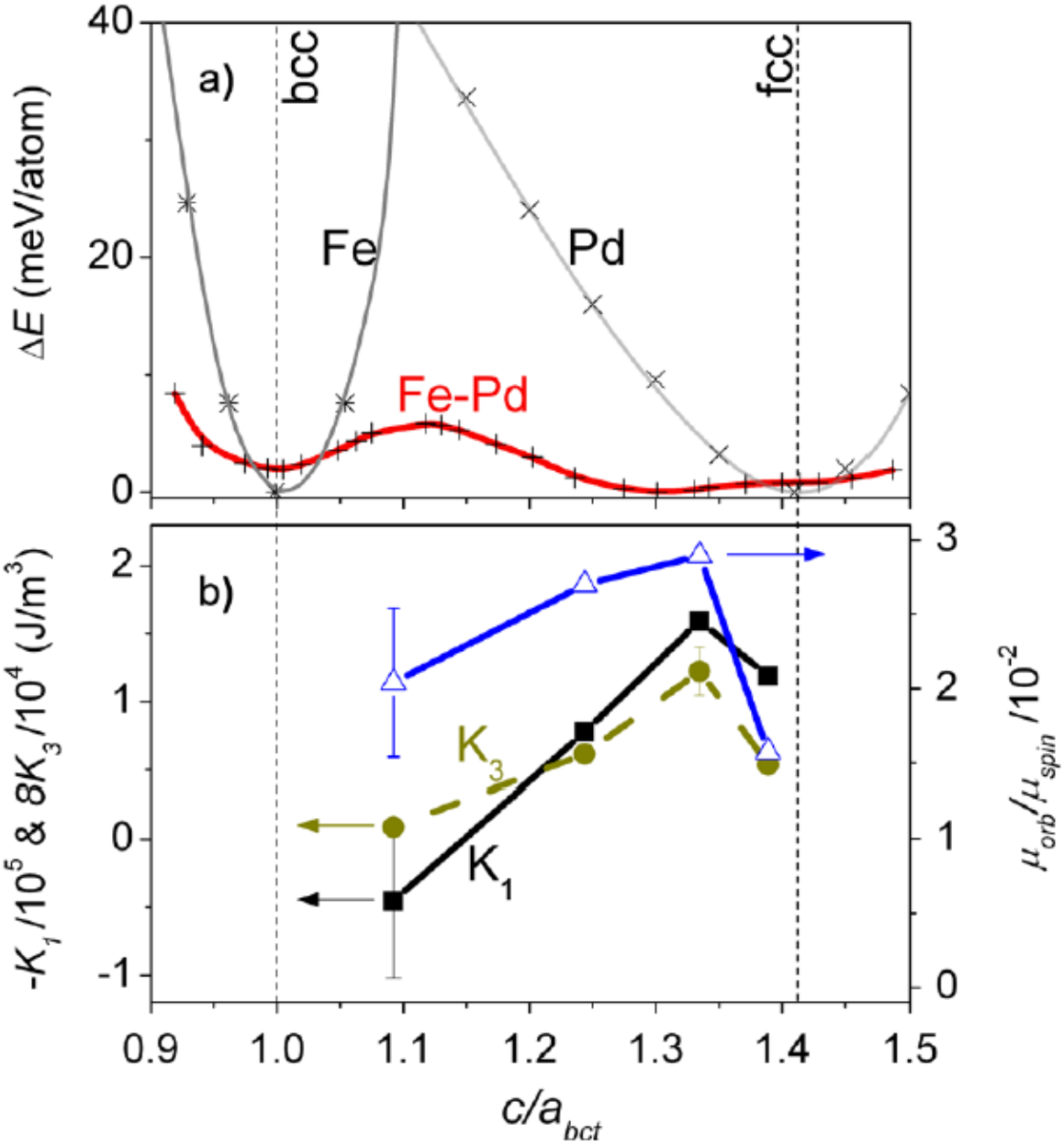
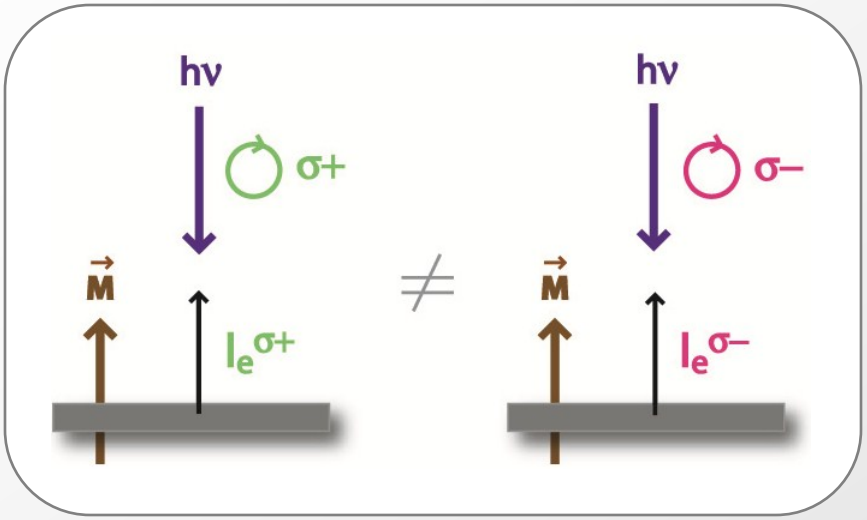
Tuning the Magnetic Anisotropy





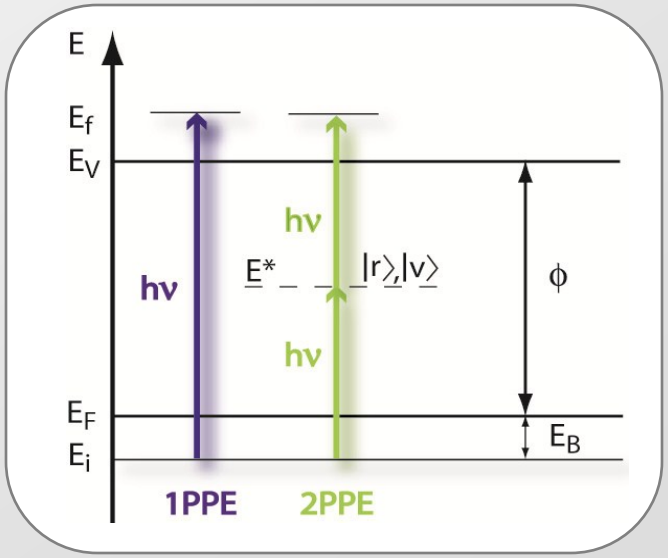
Magnetic Circular dichroism (MCD) Threshold photoemission

- Difference in the absorption probabilities for σ^+/σ^--polarized light in ferromagnets



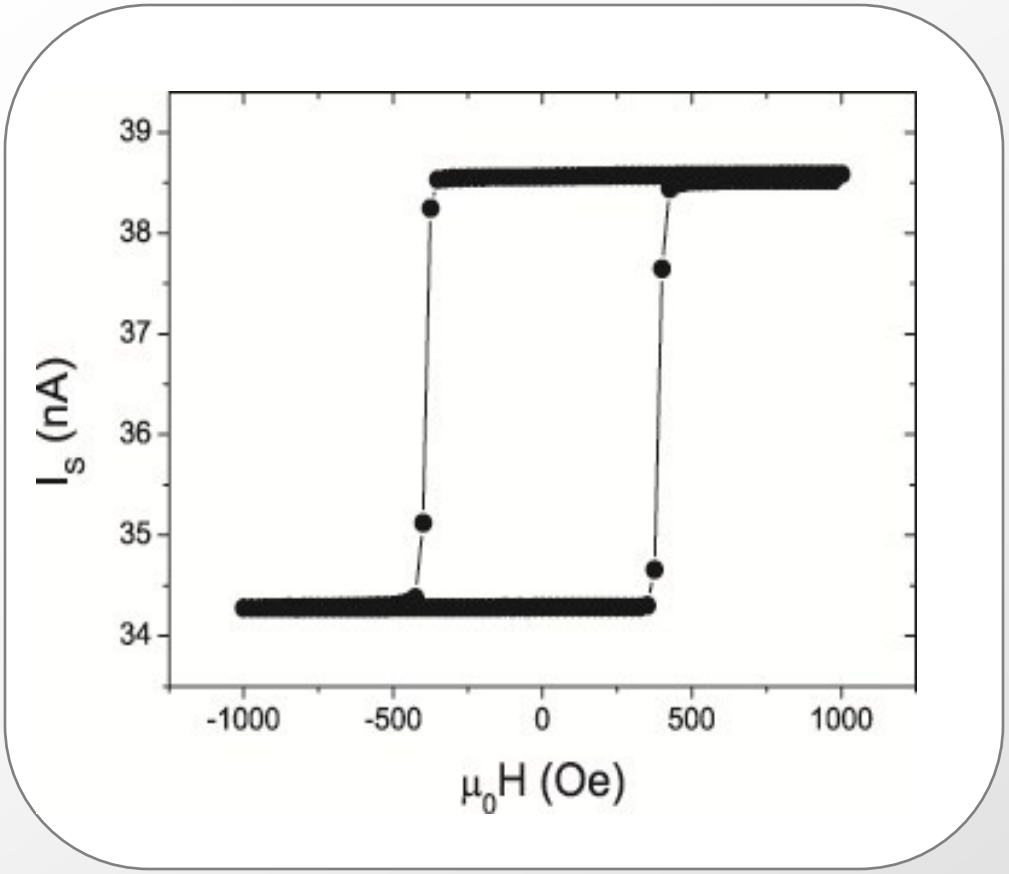
$$A_{MCD} = \frac{I_e^{\sigma^+} - I_e^{\sigma^-}}{I_e^{\sigma^+} + I_e^{\sigma^-}} = \frac{I_e^{M^+} - I_e^{M^-}}{I_e^{M^+} + I_e^{M^-}}$$

- if hν ≥ Φ : (1PPE)
- if 2hν ≥ Φ : (2PPE)

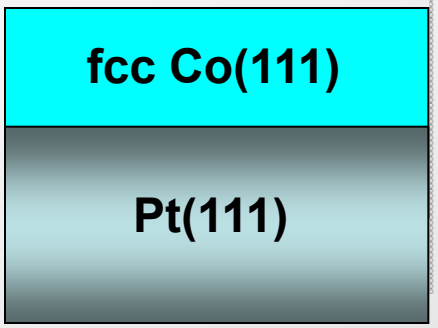


Magnetic Circular dichroism (MCD) Threshold photoemission

TPMCD measurement



Hysteresis



$$A_{TPMCD} = \frac{\bar{I}_S^{M^+} - \bar{I}_S^{M^-}}{\bar{I}_S^{M^+} + \bar{I}_S^{M^-}}$$

Kerstin Hild, et al. Phys. Rev, B **82**, 195430 (2010)
Kerstin Hild, et al. Phys. Rev. Lett. **102**, 057207 (2009)

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G. Jakob, M. Jourdan, G. Schönhense,
Institut für Physik, Universität Mainz, Germany

B. Balke, C. Blum, J. Barth, T. Graf,
G. H. Fecher, C. Felser,
Institut für Anorganische Chemie, Universität Mainz, Germany

T. Nakagawa, T. Yokoyama,
Institute for Molecular Science, University of Okazaki, Japan

K. Tarafder, P.M. Oppeneer,
Department of Physics, Uppsala University, Sweden

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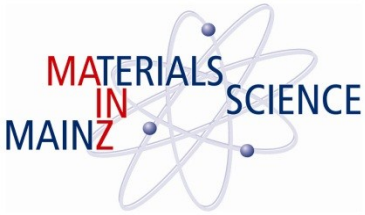
Funding

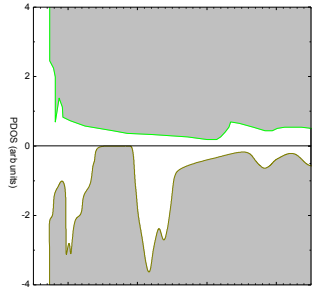

ZEISS


MATERIALS
IN
MAINZ
SCIENCE

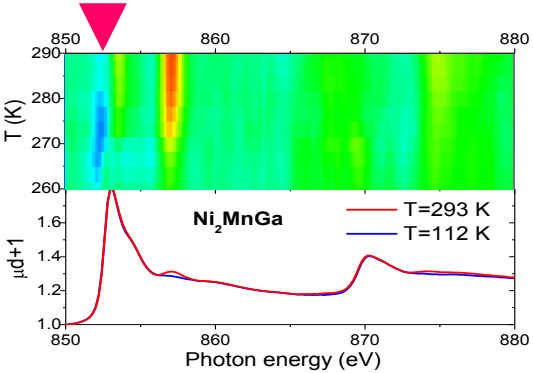

Deutsche
Forschungsgemeinschaft
DFG

Summary

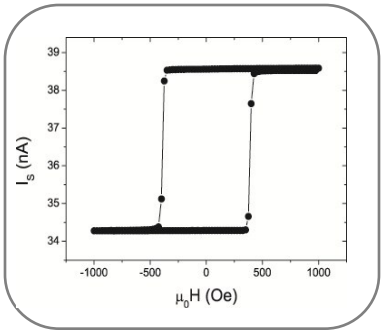
Tailoring of band-structure via doping in quarternary Heusler compounds



Origin of magnetic anisotropy in shape memory metal Ni2MnGa



Circular dichroism in the lab



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