UNIVERSITÀ DEGLI STUDI DI MILANO

Istituto Officina dei Materiali

Probing magnetism in multiferroic heterostructures with synchrotron light

10 october 2017 - First year workshop - XXXII cycle

Magnetic Sensors

Pro:

- Non-volatile
- High endurance
- Low power

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Magnetic Sensors

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- Non-volatile
- High endurance
- Low power

How to read&write?

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Magnetic Sensors

Pro:

- Non-volatile
- High endurance
- Low power

How to read&write?

- read/write “heads”

- moving parts
- slow access time

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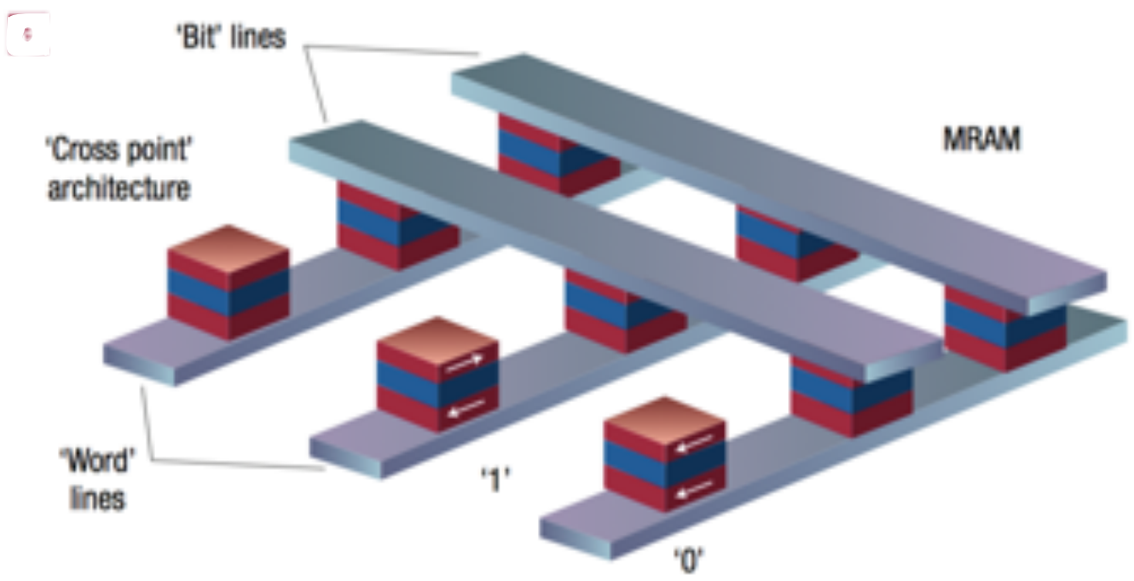
Magnetic Sensors

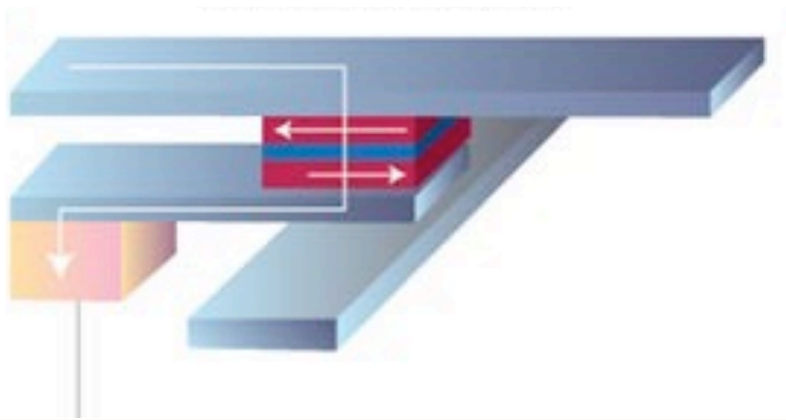
Pro:

- Non-volatile
- High endurance
- Low power

How to read&write?

- read/write “heads”
- Spin-Transfer Torque
- currents dissipate power!





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Magnetic Sensors

Pro:

- Non-volatile
- High endurance
- Low power

MULTIFERROIC!

How to read&write?

- read/write "heads"
- Spin-Transfer Torque
- electric fields

- no heat, no dissipation
- easier to control
- new functionalities

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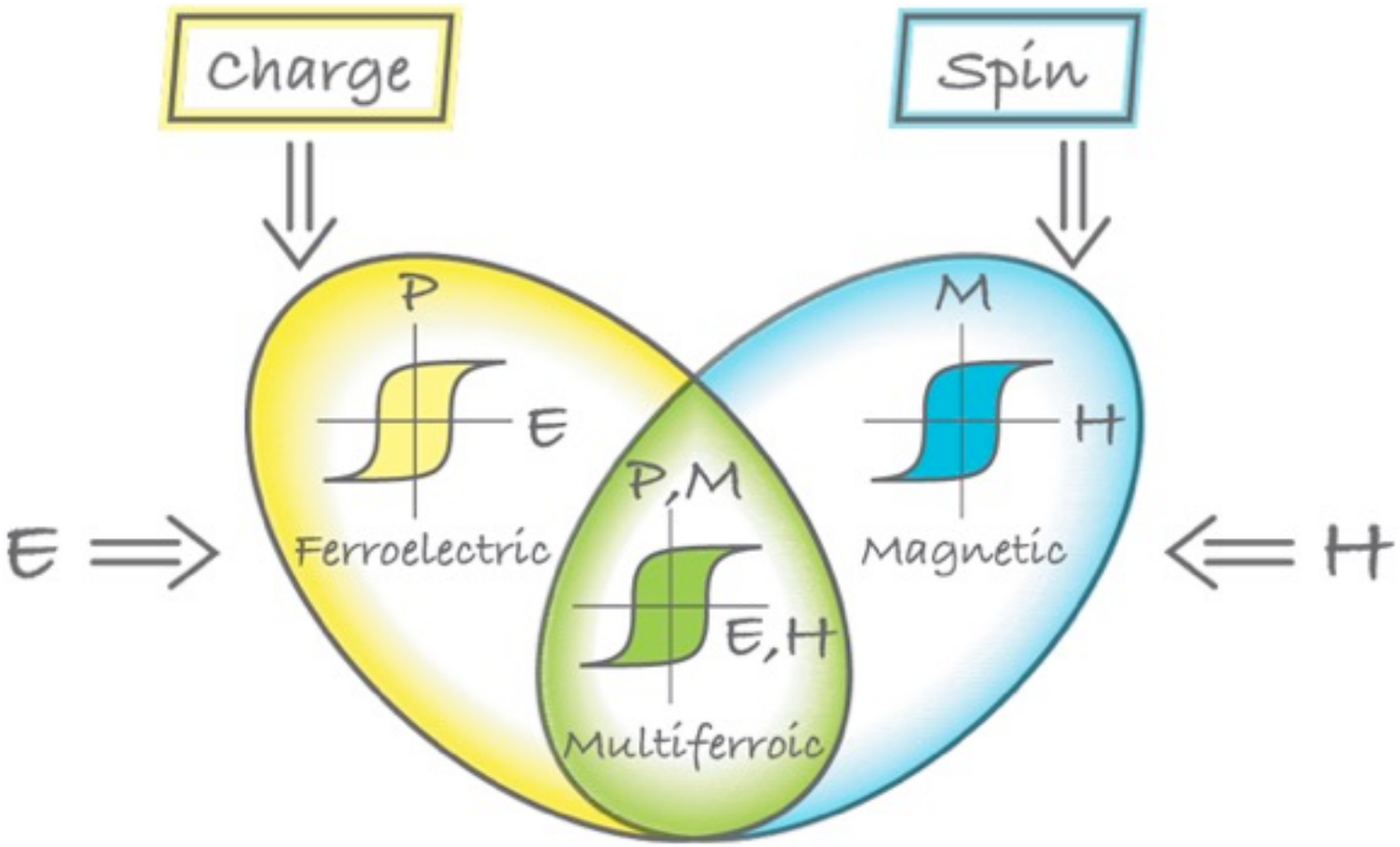
Multiferroic Materials



Magnetism &
Ferroelectricity

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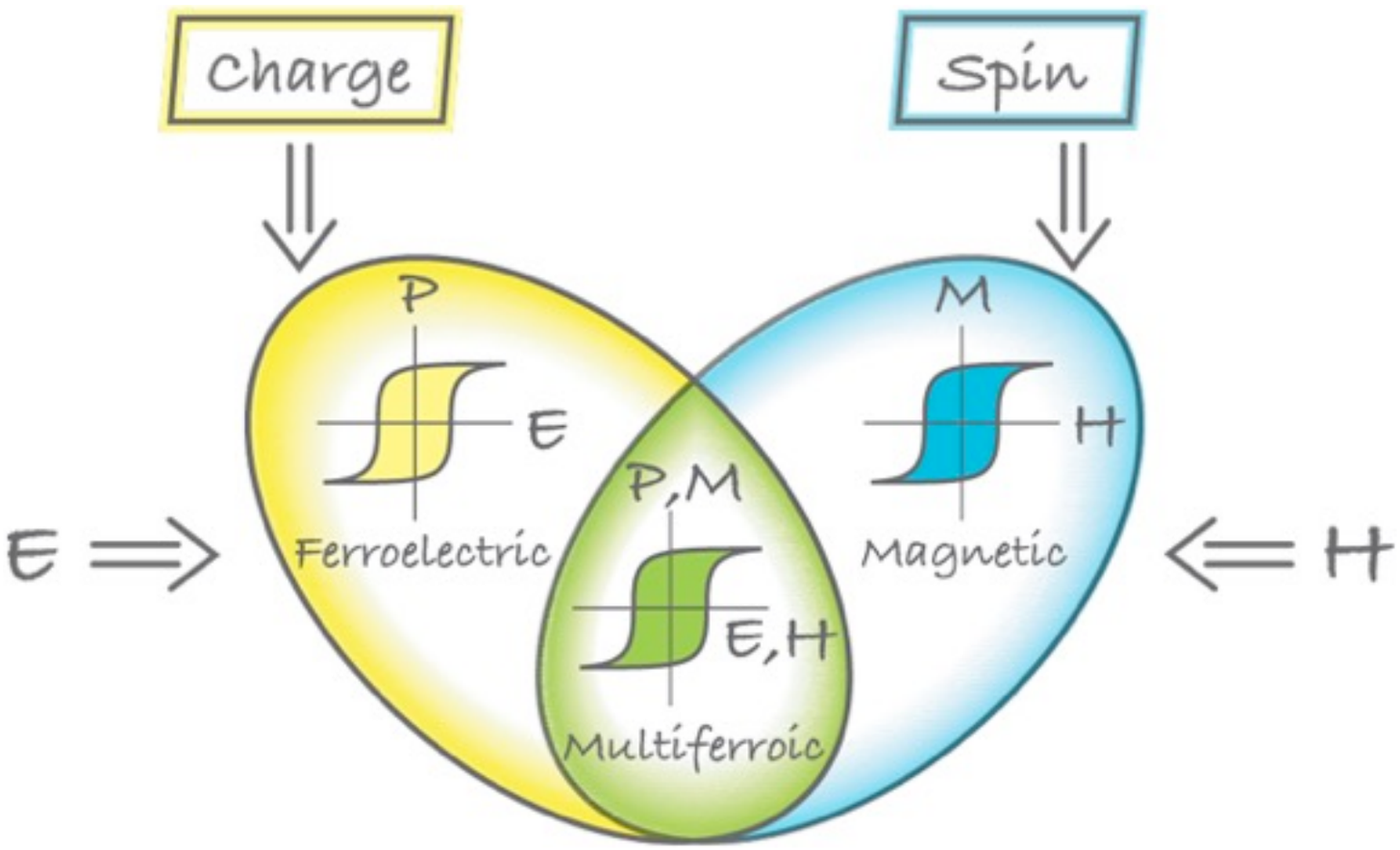
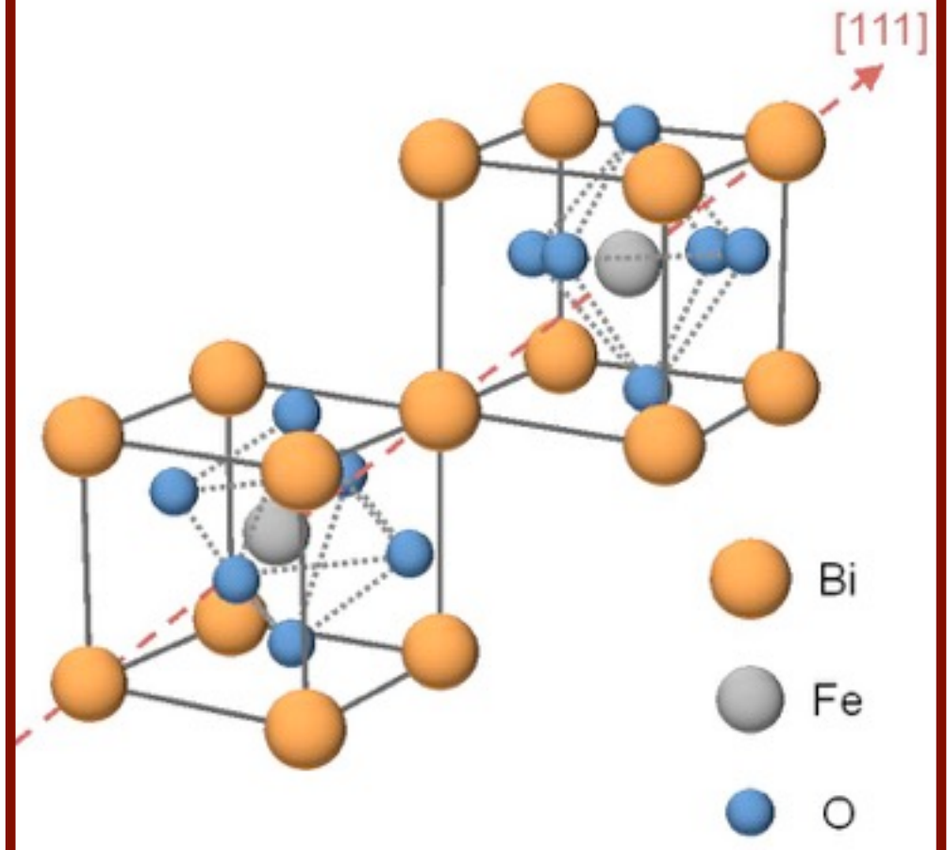
Multiferroic Materials



Magnetism &
Ferroelectricity

They are so few, and mostly
ANTI-ferromagnetic.

Example: $BiFeO_3$



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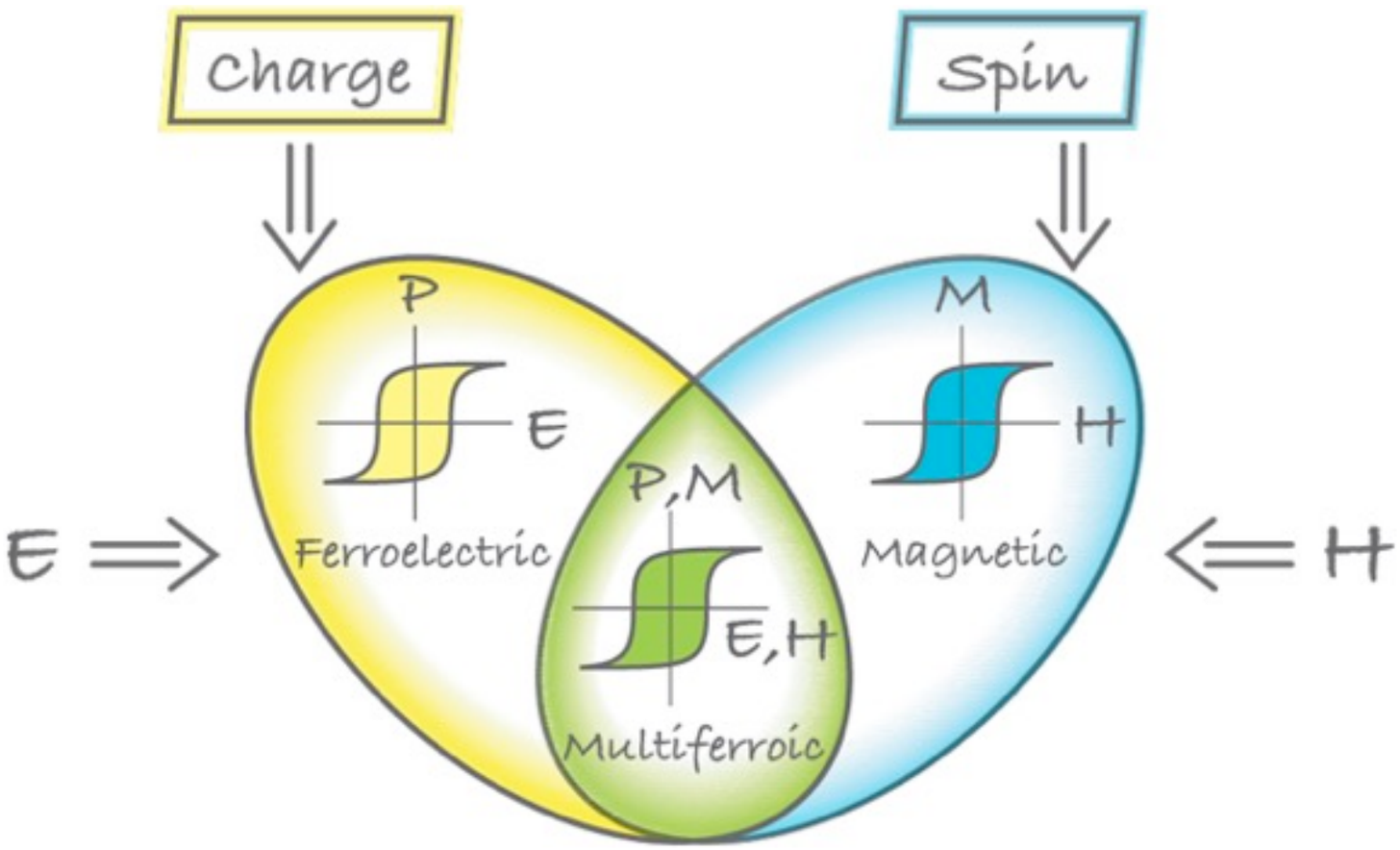
Multiferroic Materials

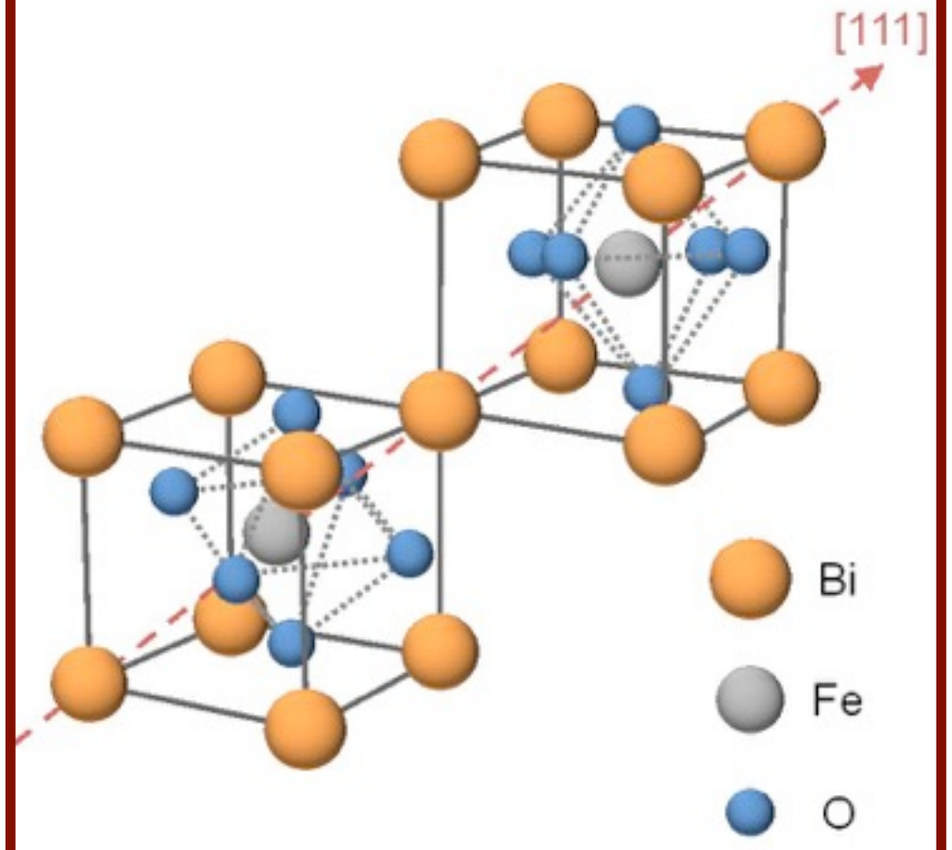


Magnetism &
Ferroelectricity

They are so few, and mostly ANTI-ferromagnetic.

What's next?

Example: $BiFeO_3$



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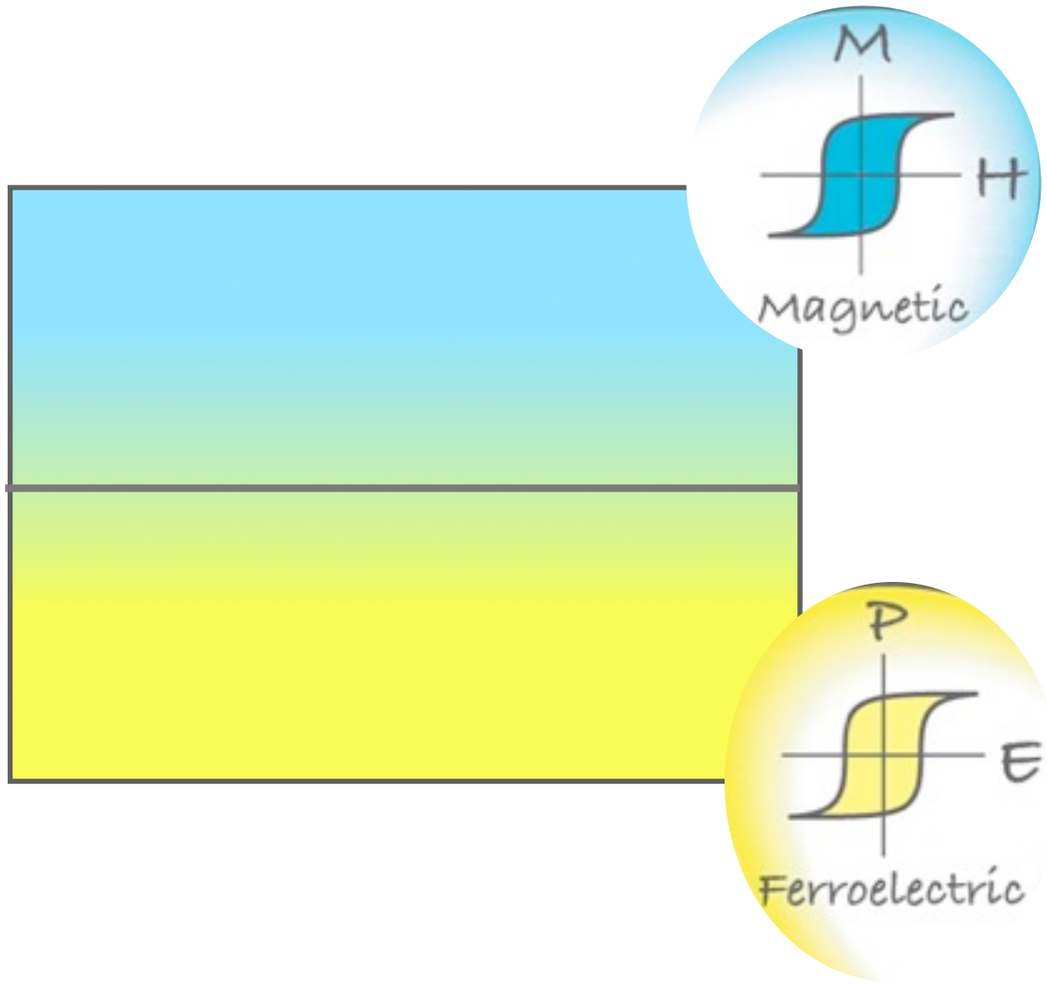
Multiferroic Heterostructures



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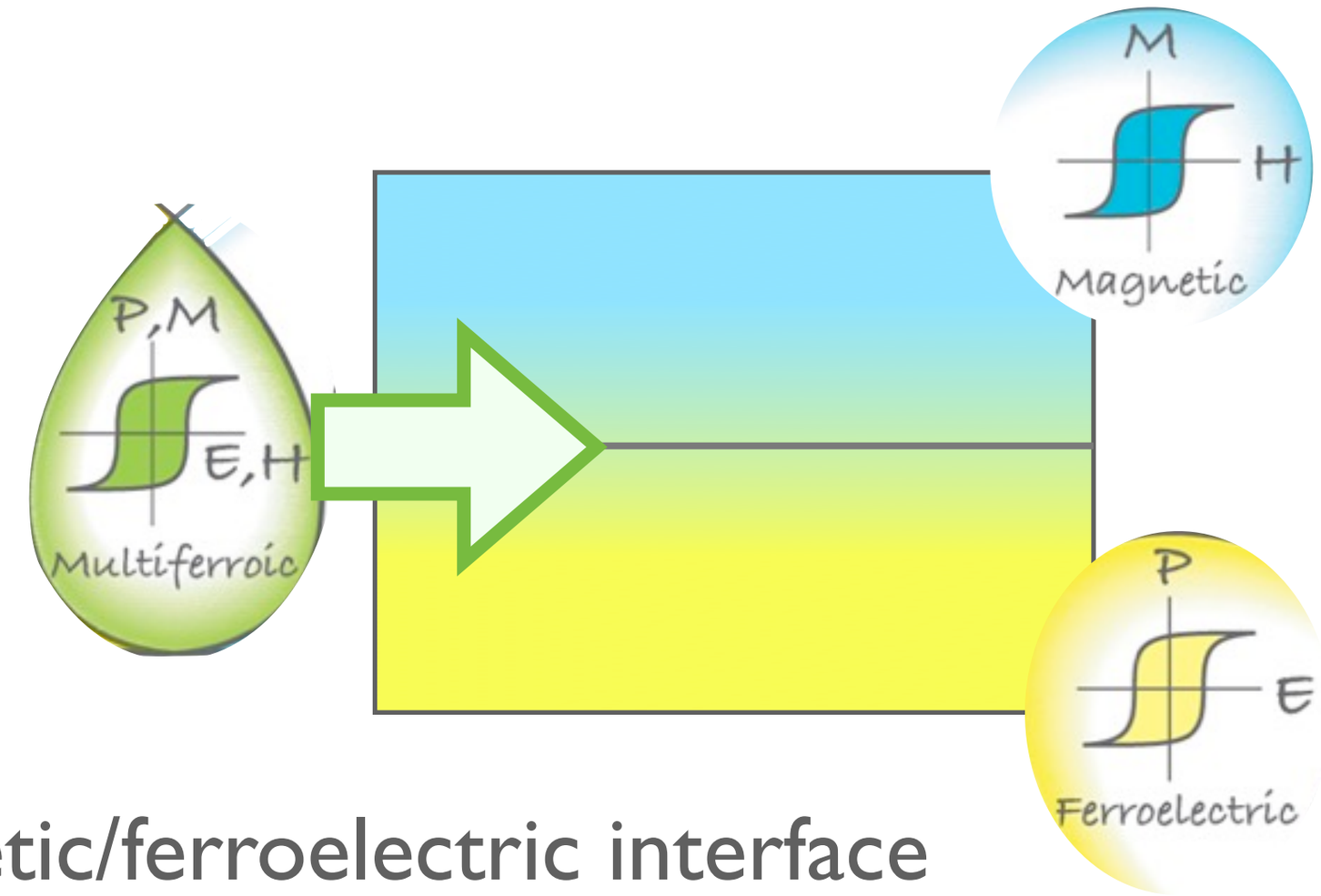
Multiferroic Heterostructures

Coupling of:

- charge
- spin
- strain

across the ferromagnetic/ferroelectric interface



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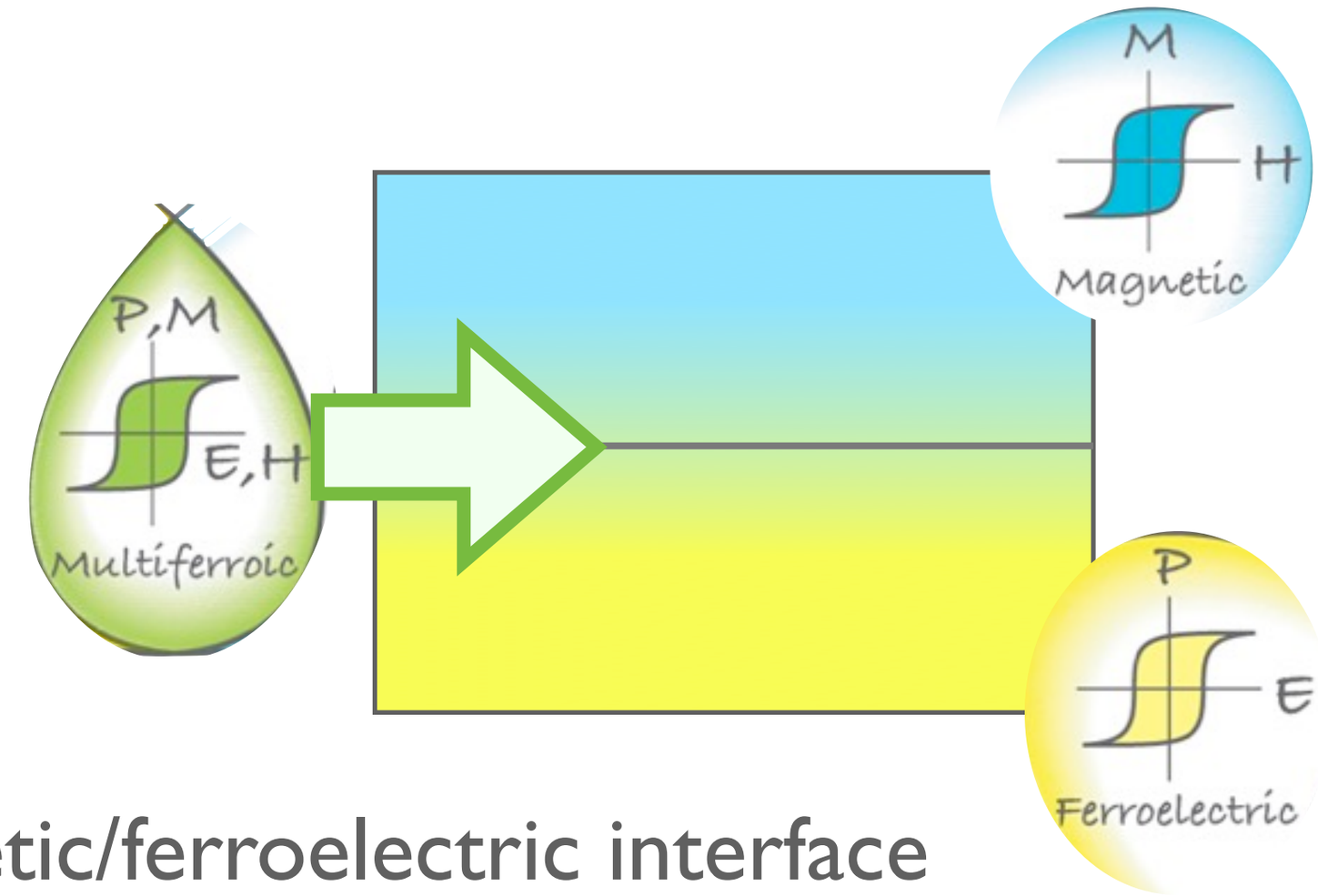

Key goal:

Understanding the interplay of different degrees of freedom

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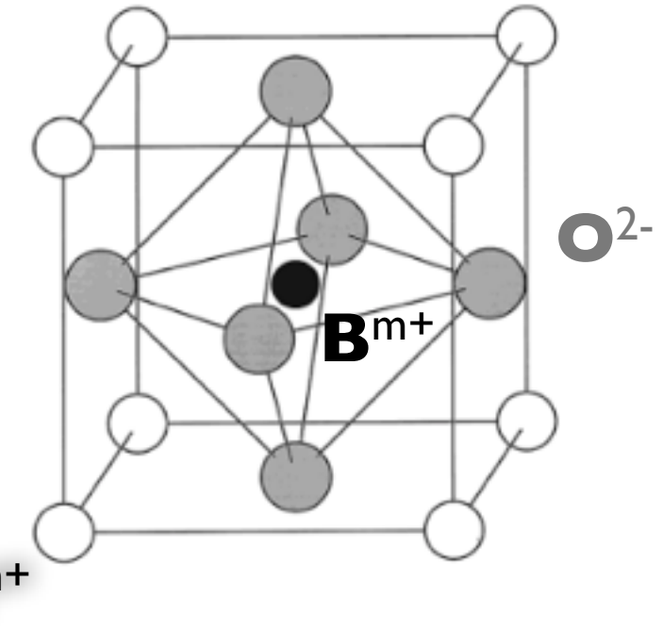
Which materials?

- Strong electronic correlations
- Coupling of charge, spin, lattice
- Broken symmetry at the interface

Perovskites: ABO_3



ferromagnets:	ferroelectrics:	multiferroics:
$La_{1-x}Sr_xMnO_3$	$BaTiO_3$	$BiFeO_3$
$Pr_{1-x}Ca_xMnO_3$	$PbTiO_3$	$YMnO_3$
$SrRuO_3$	$Pb_{1-x}Zr_xTiO_3$	$BiMnO_3$
...	...	...

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Which materials?

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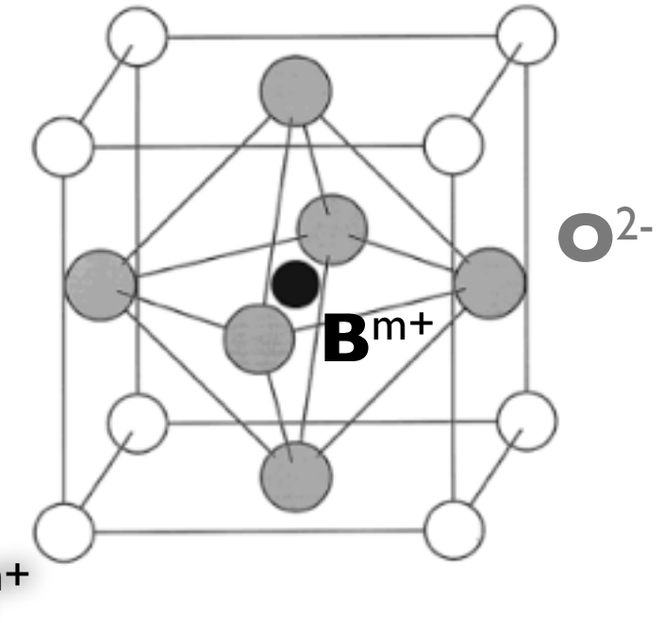
Perovskites: ABO_3



Multiferroic effects

ferromagnets:	ferroelectrics:	multiferroics:
$La_{1-x}Sr_xMnO_3$	$BaTiO_3$	$BiFeO_3$
$Pr_{1-x}Ca_xMnO_3$	$PbTiO_3$	$YMnO_3$
$SrRuO_3$	$Pb_{1-x}Zr_xTiO_3$	$BiMnO_3$
...	...	...

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Which materials?

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Which materials?

Ferromagnetic:

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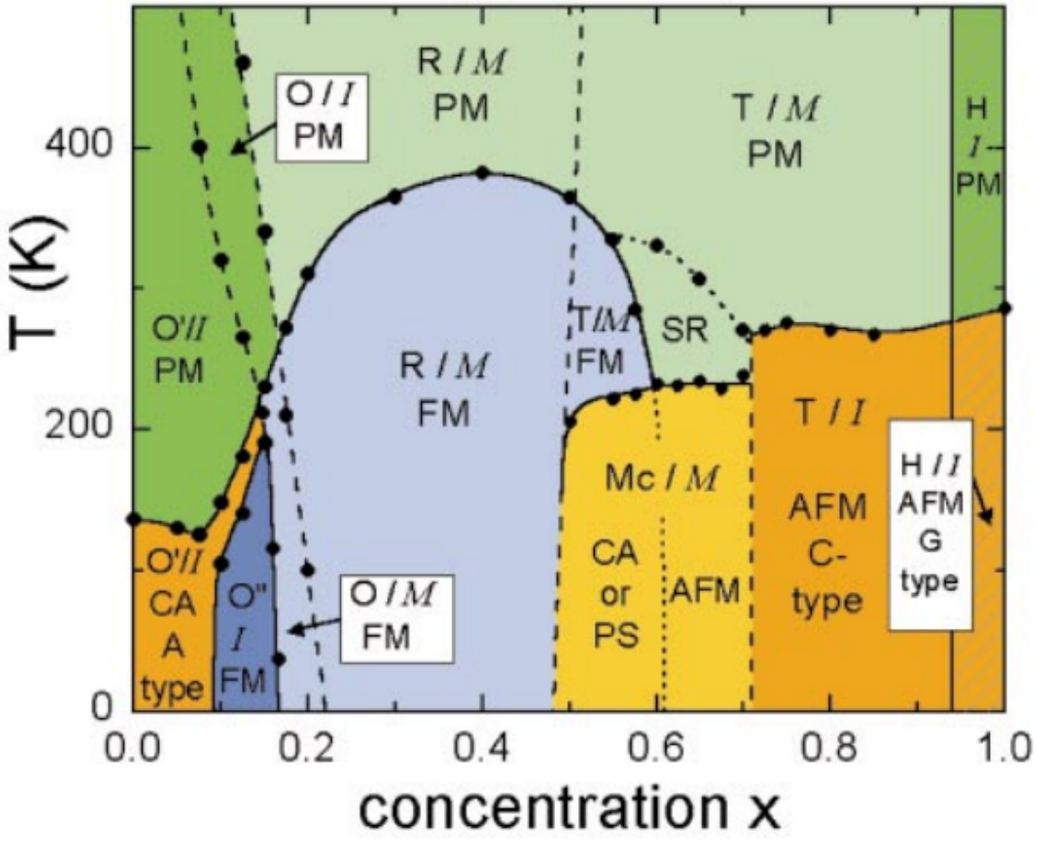
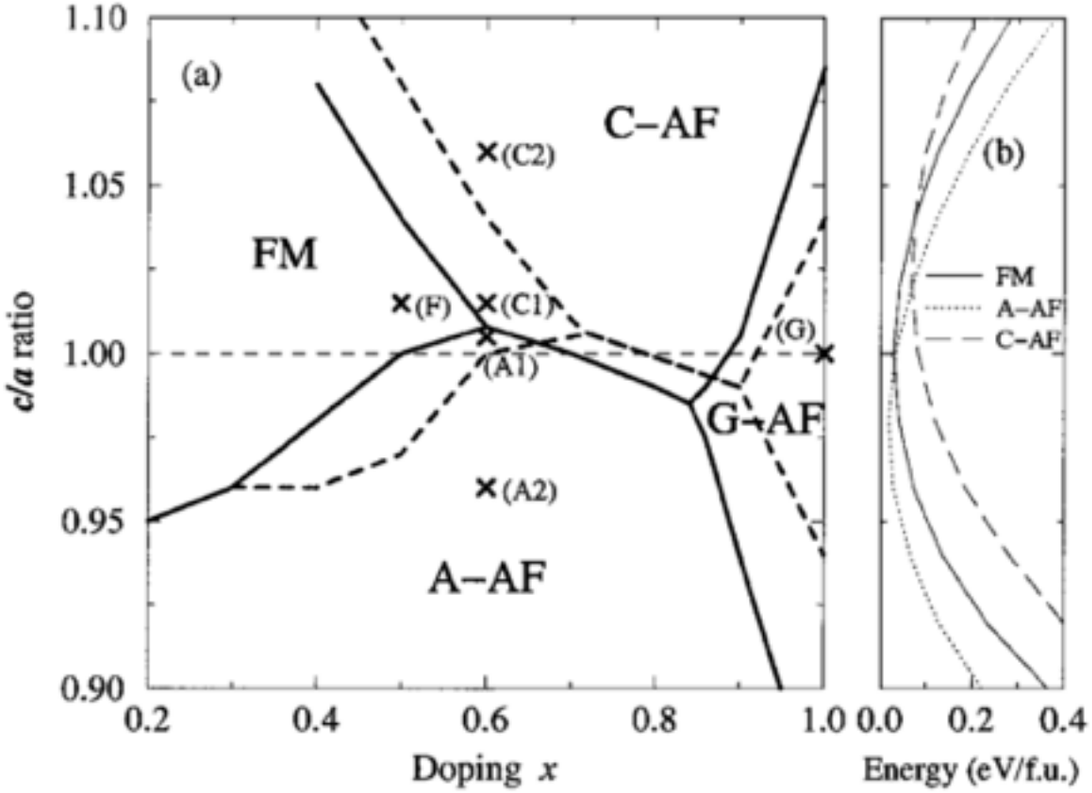
Which materials?

Ferromagnetic:

- $La_{1-x}Sr_xMnO_3$ (LSMO)

J. Hemberger *et al.*, PRB **66**, 094410 (2002)





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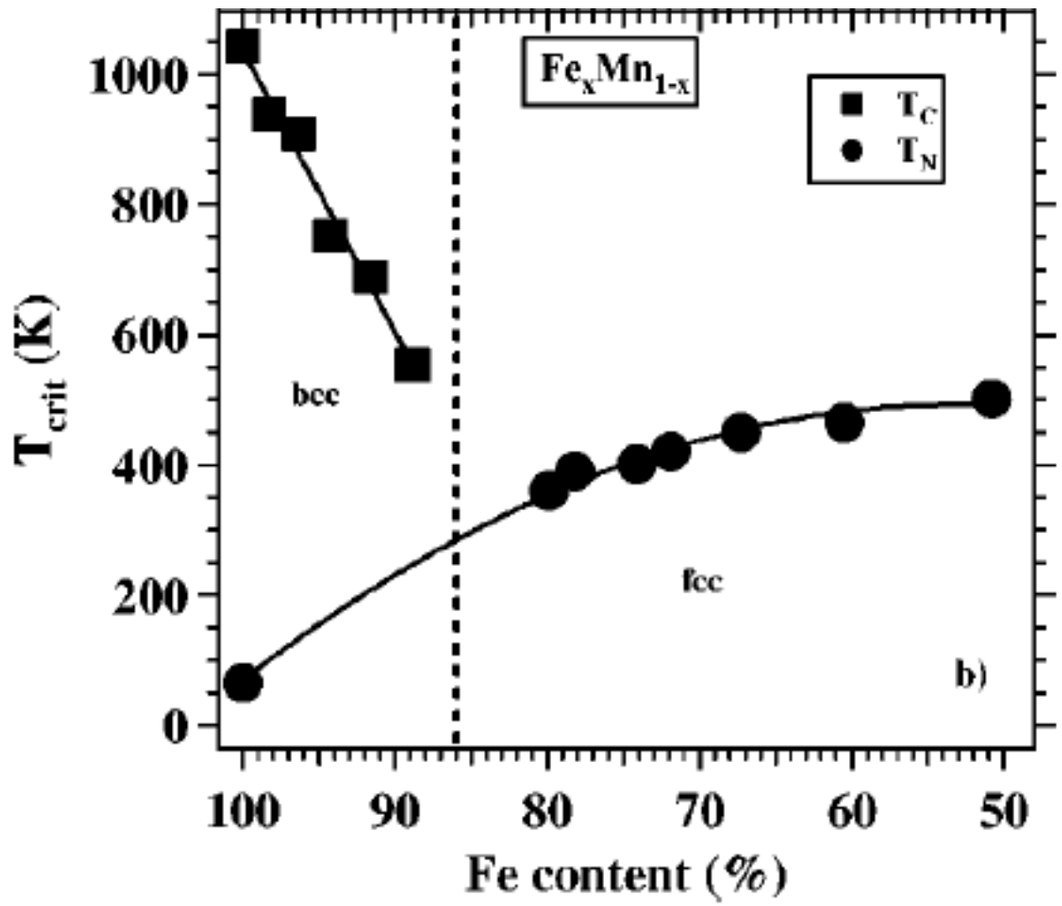
Which materials?

Ferromagnetic:

- $La_{1-x}Sr_xMnO_3$ (LSMO)
- Fe_xMn_{1-x}



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Which materials?

Ferromagnetic:

- $La_{1-x}Sr_xMnO_3$ (LSMO)
- Fe_xMn_{1-x}

Ferroelectric:

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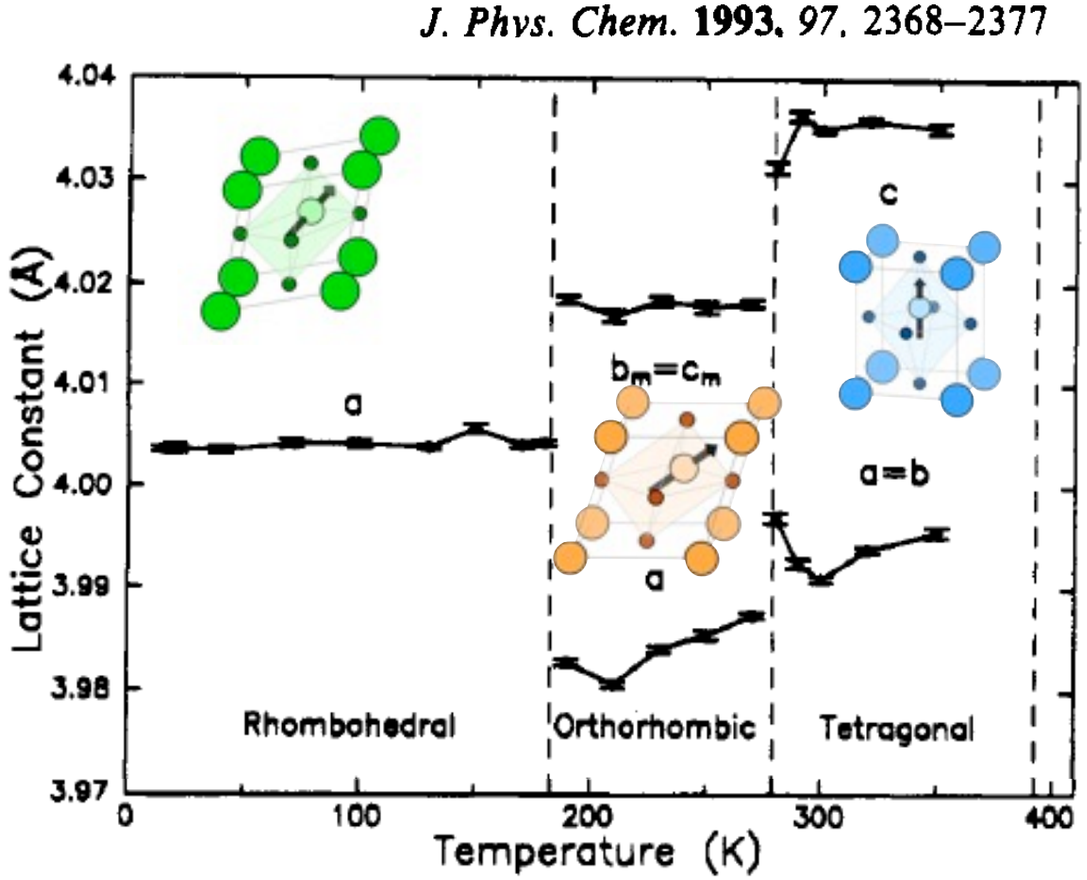
Which materials?

Ferromagnetic:

- $La_{1-x}Sr_xMnO_3$ (LSMO)
- Fe_xMn_{1-x}

Ferroelectric:

- $BaTiO_3$ (BTO)



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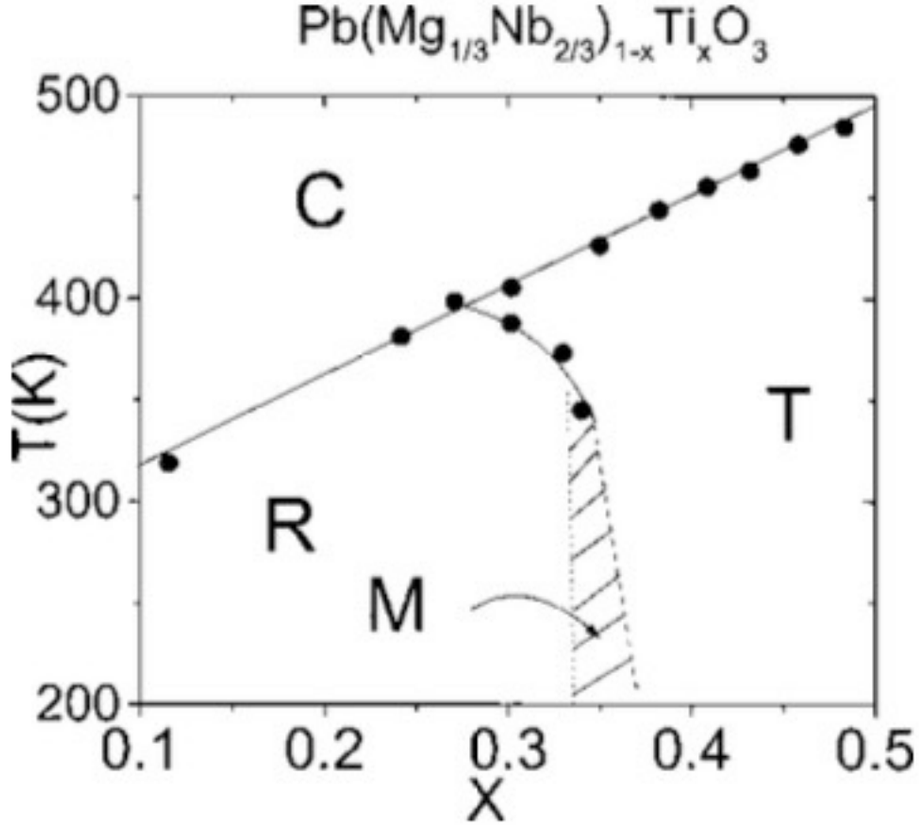
Which materials?

Ferromagnetic:

- $La_{1-x}Sr_xMnO_3$ (LSMO)
- Fe_xMn_{1-x}

Ferroelectric:

- $BaTiO_3$ (BTO)
- PMN-PT



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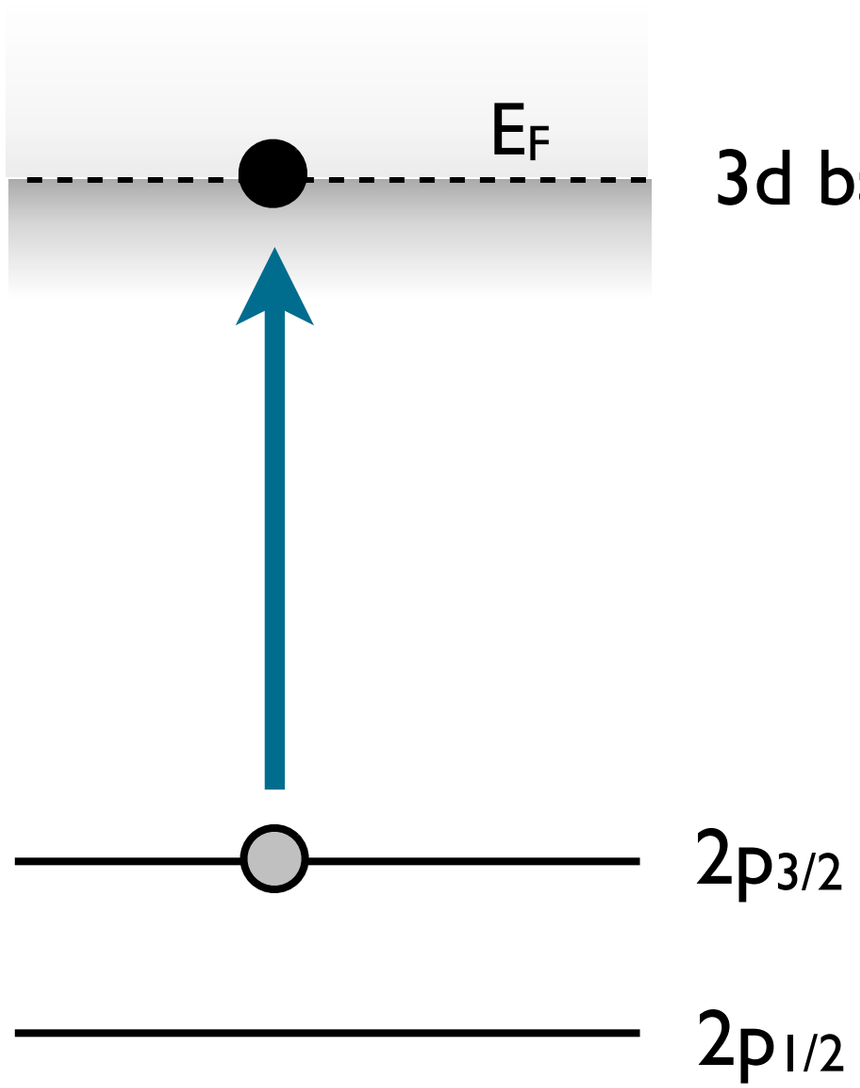
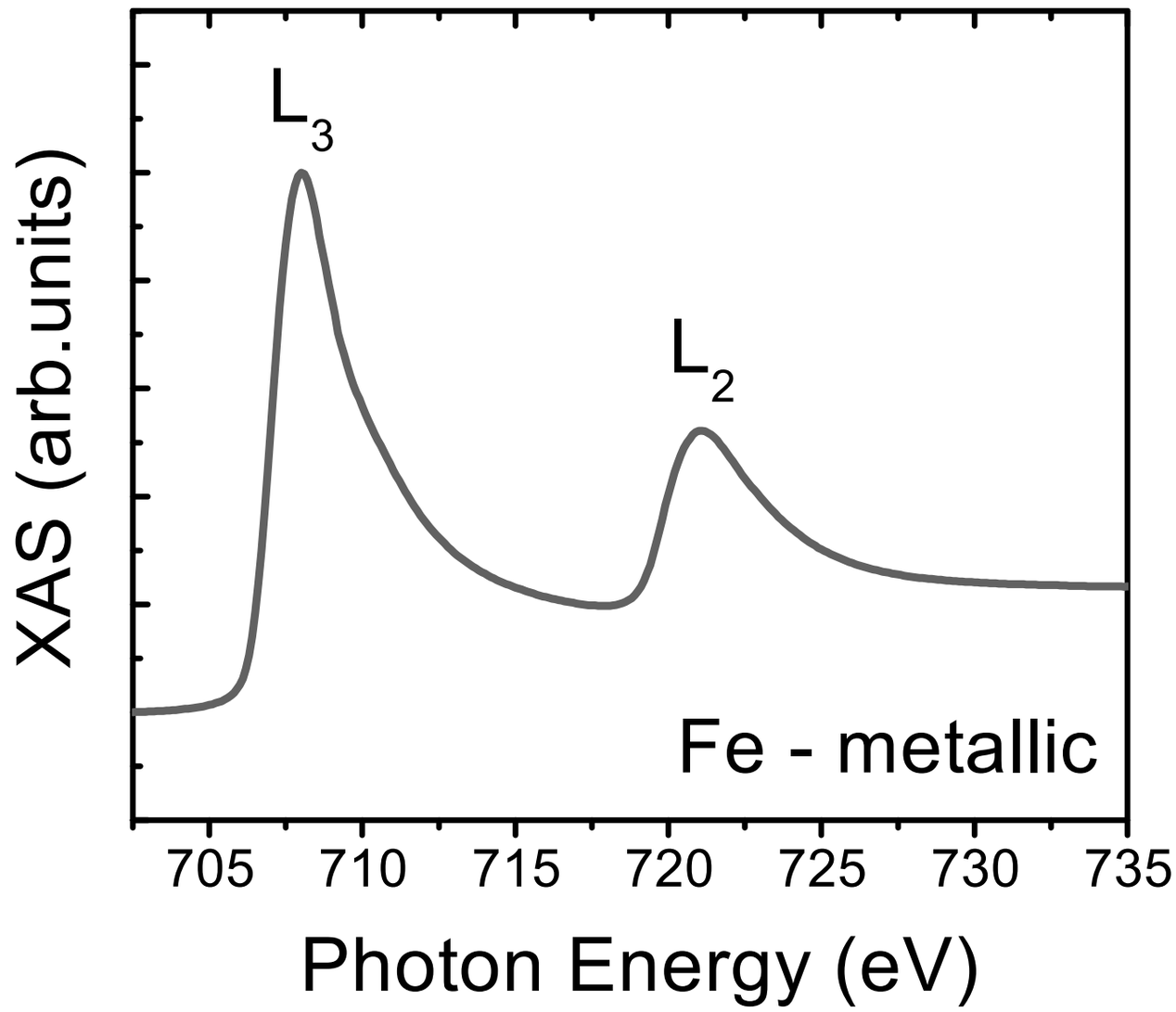
X-ray Absorption Spectroscopy





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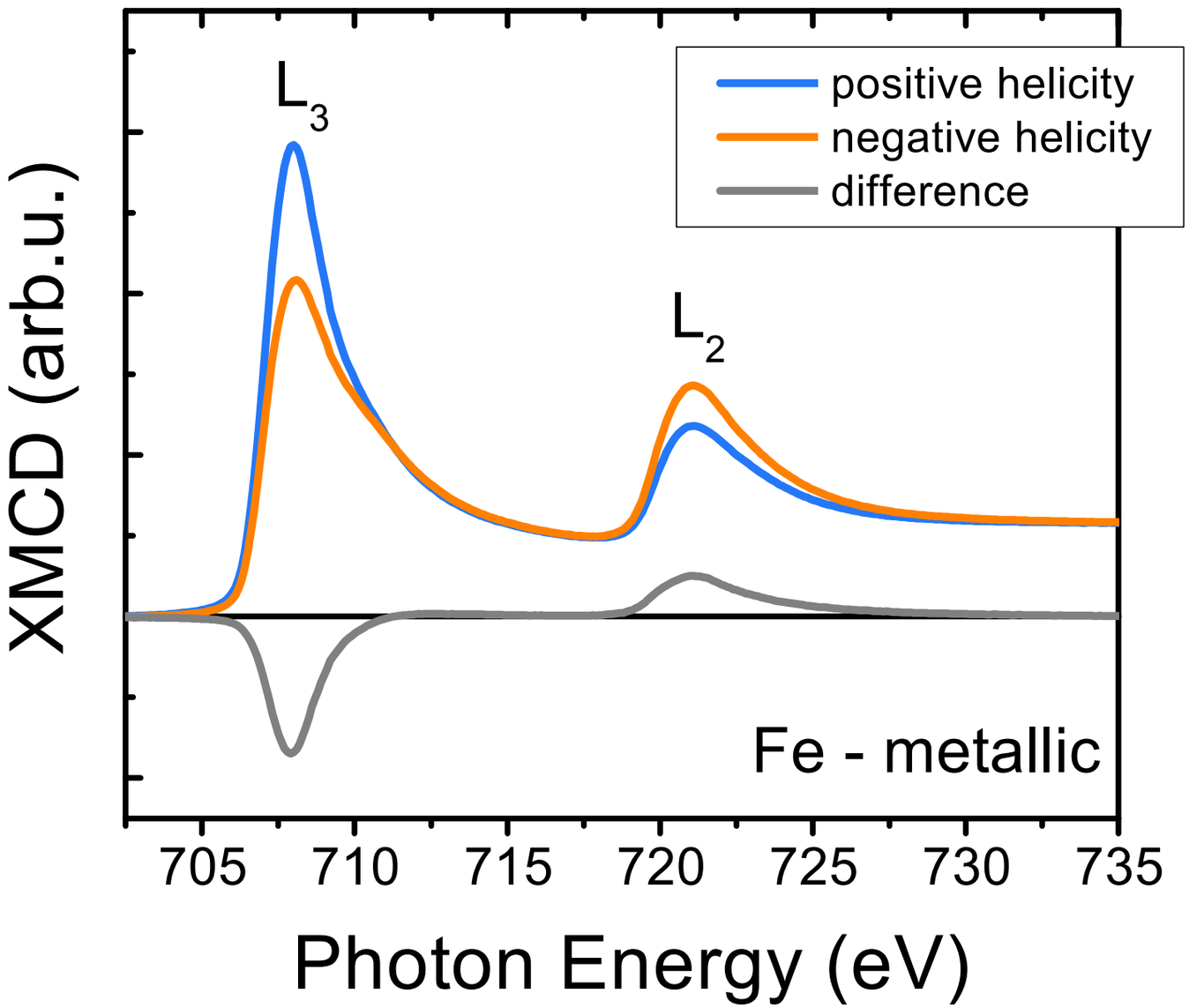
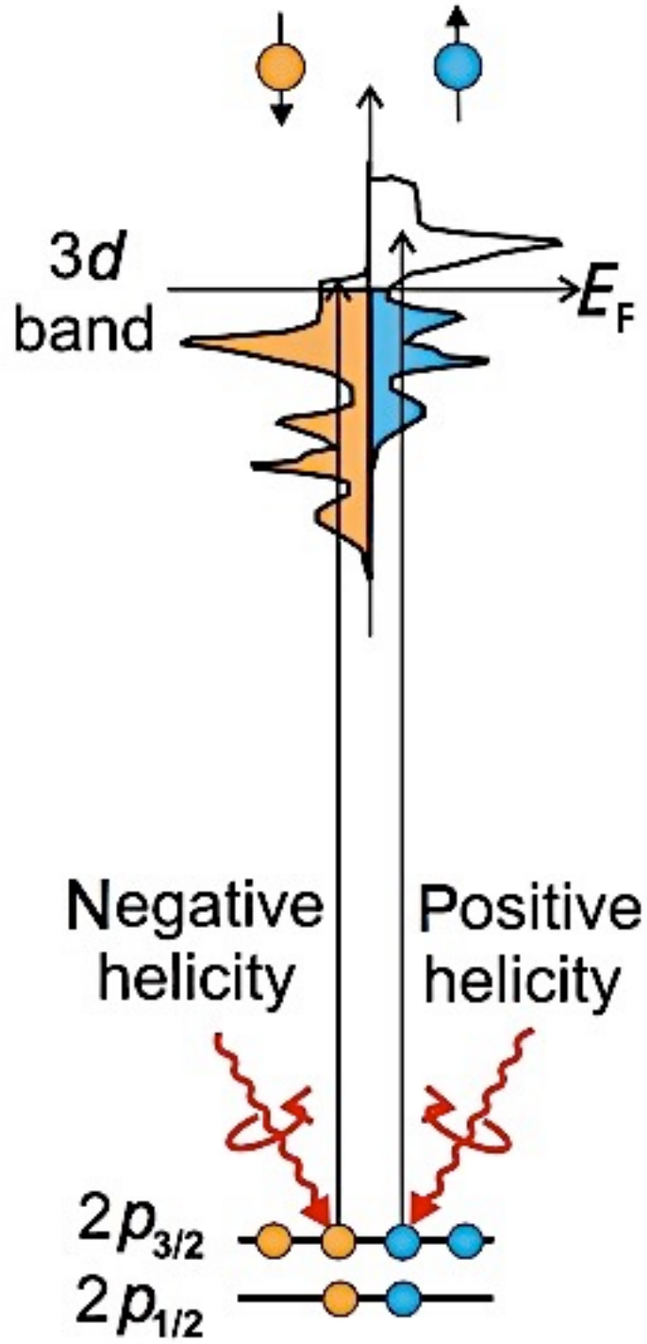
X-ray Magnetic Circular Dichroism





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X-ray Magnetic Circular Dichroism

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X-ray Magnetic Circular Dichroism

Advantages:

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X-ray Magnetic Circular Dichroism

Advantages:

- Elemental sensitivity

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X-ray Magnetic Circular Dichroism

Advantages:

- Elemental sensitivity
- Chemical information

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X-ray Magnetic Circular Dichroism

Advantages:

- Elemental sensitivity
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- Suited for thin-films

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X-ray Magnetic Circular Dichroism

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- Elemental sensitivity
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Requirements:

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Requirements:

- High-intensity X-rays

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X-ray Magnetic Circular Dichroism

Advantages:

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Requirements:

- High-intensity X-rays
- Energy tuning

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X-ray Magnetic Circular Dichroism

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Requirements:

- High-intensity X-rays
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- Control on polarization

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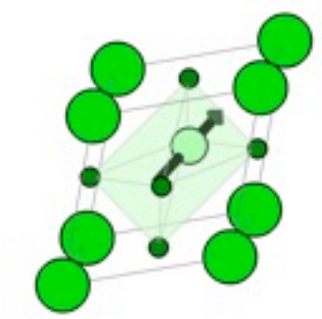
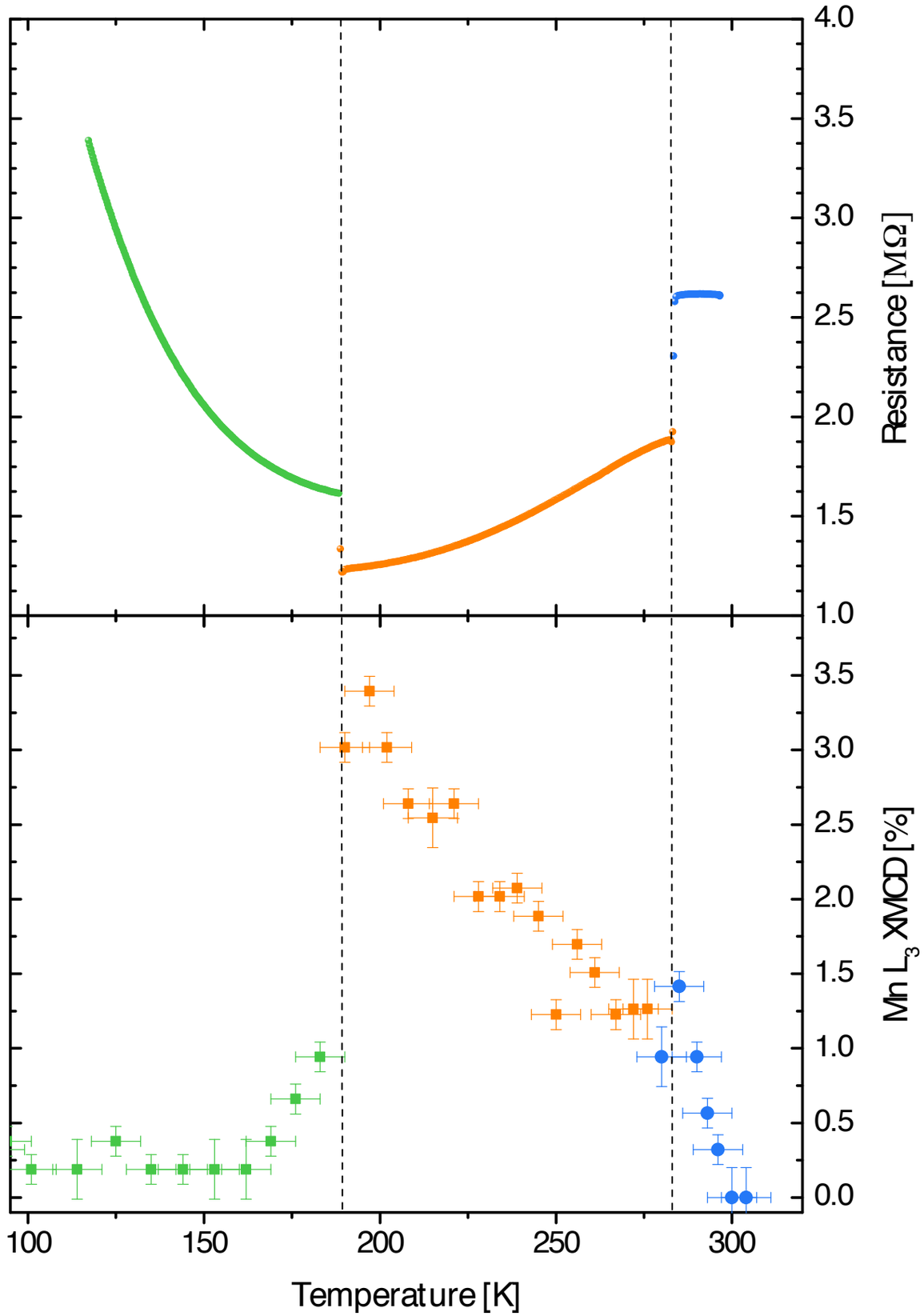
LSMO / BTO





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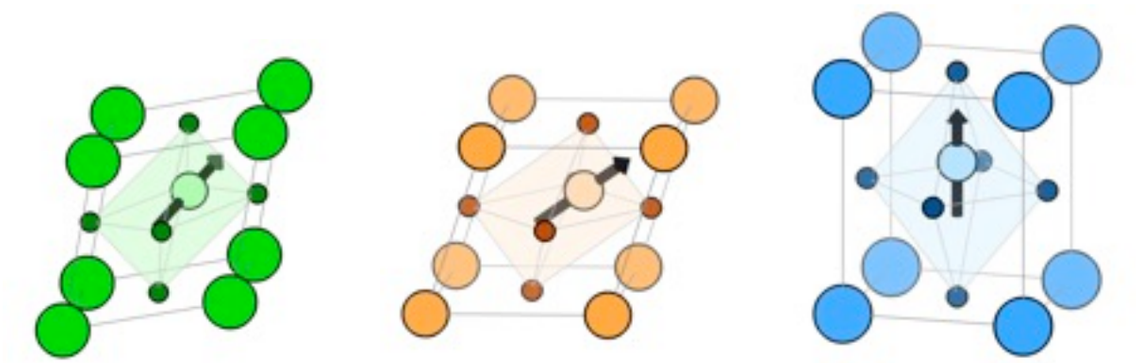
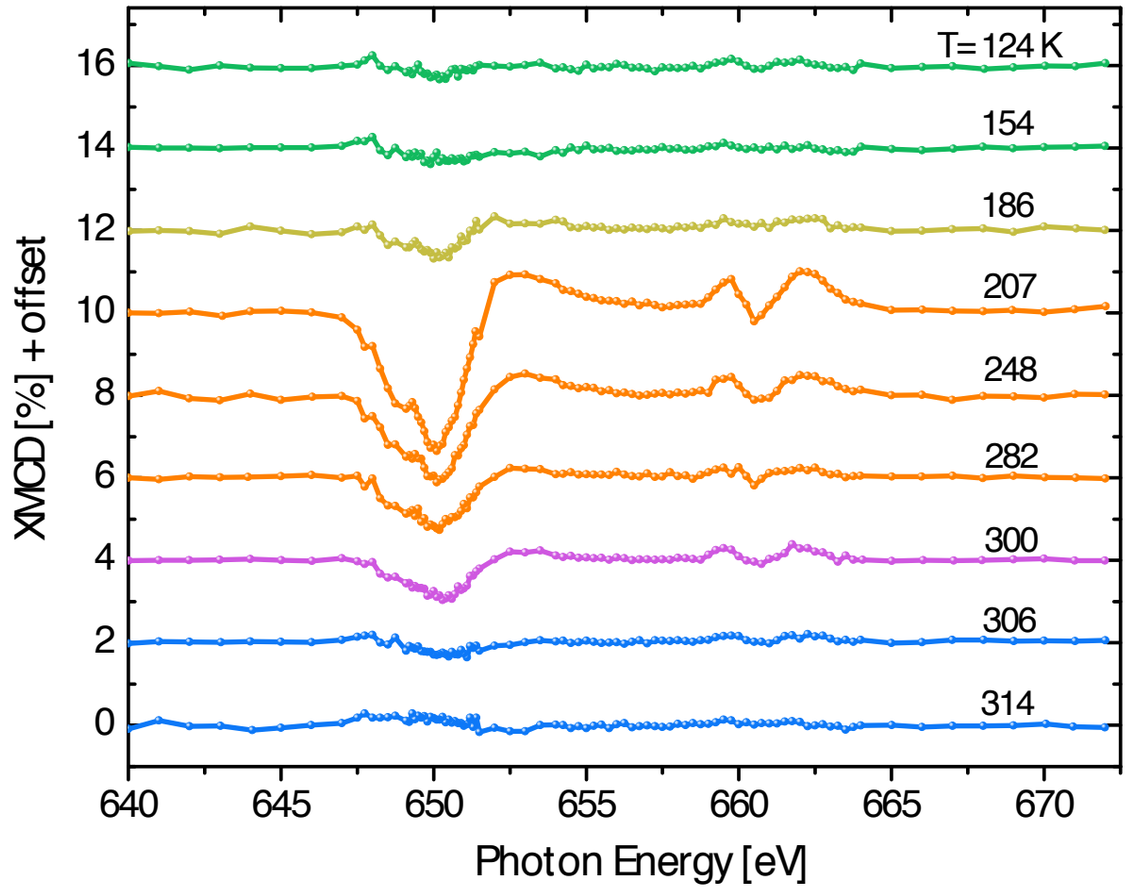
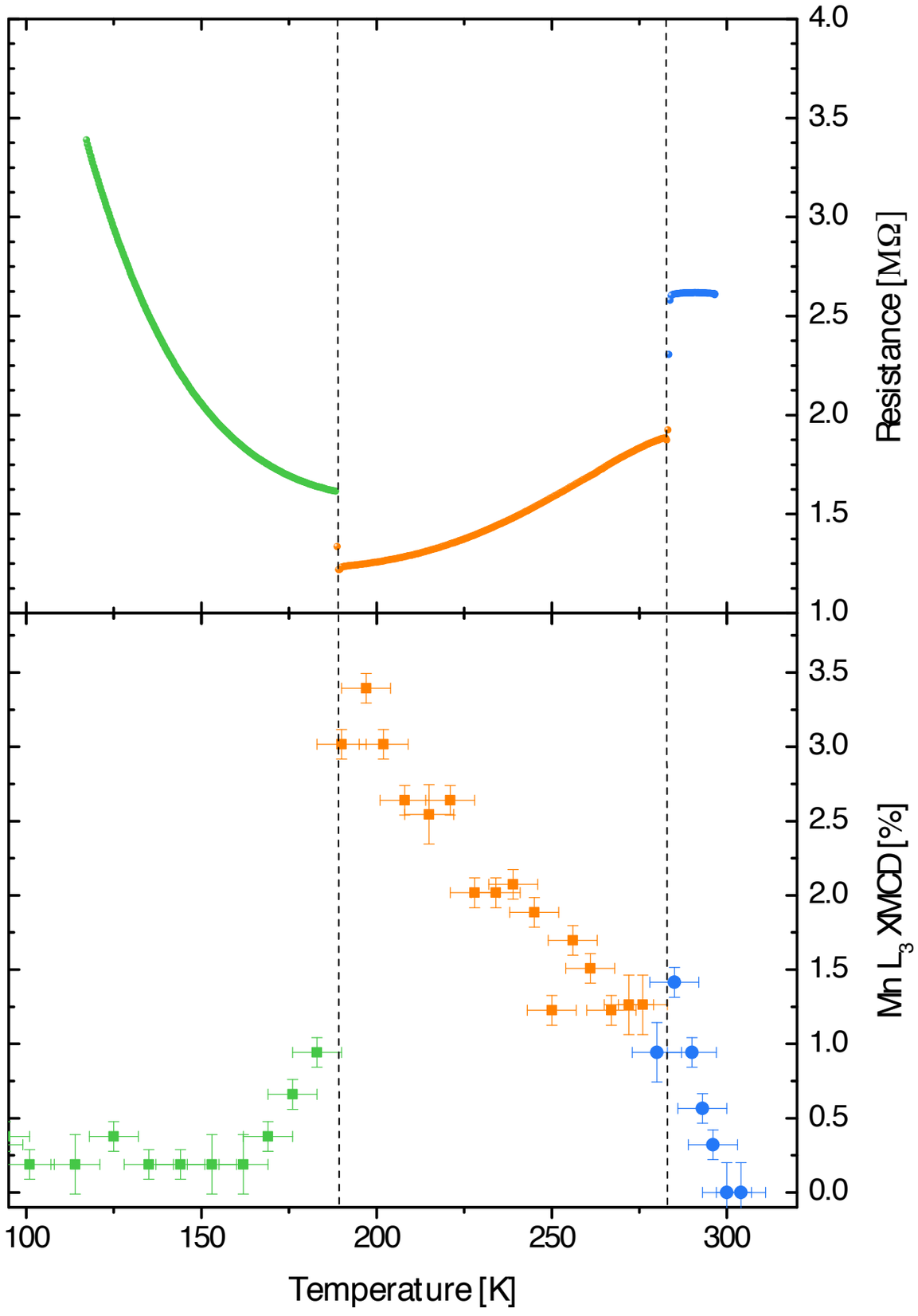
LSMO / BTO







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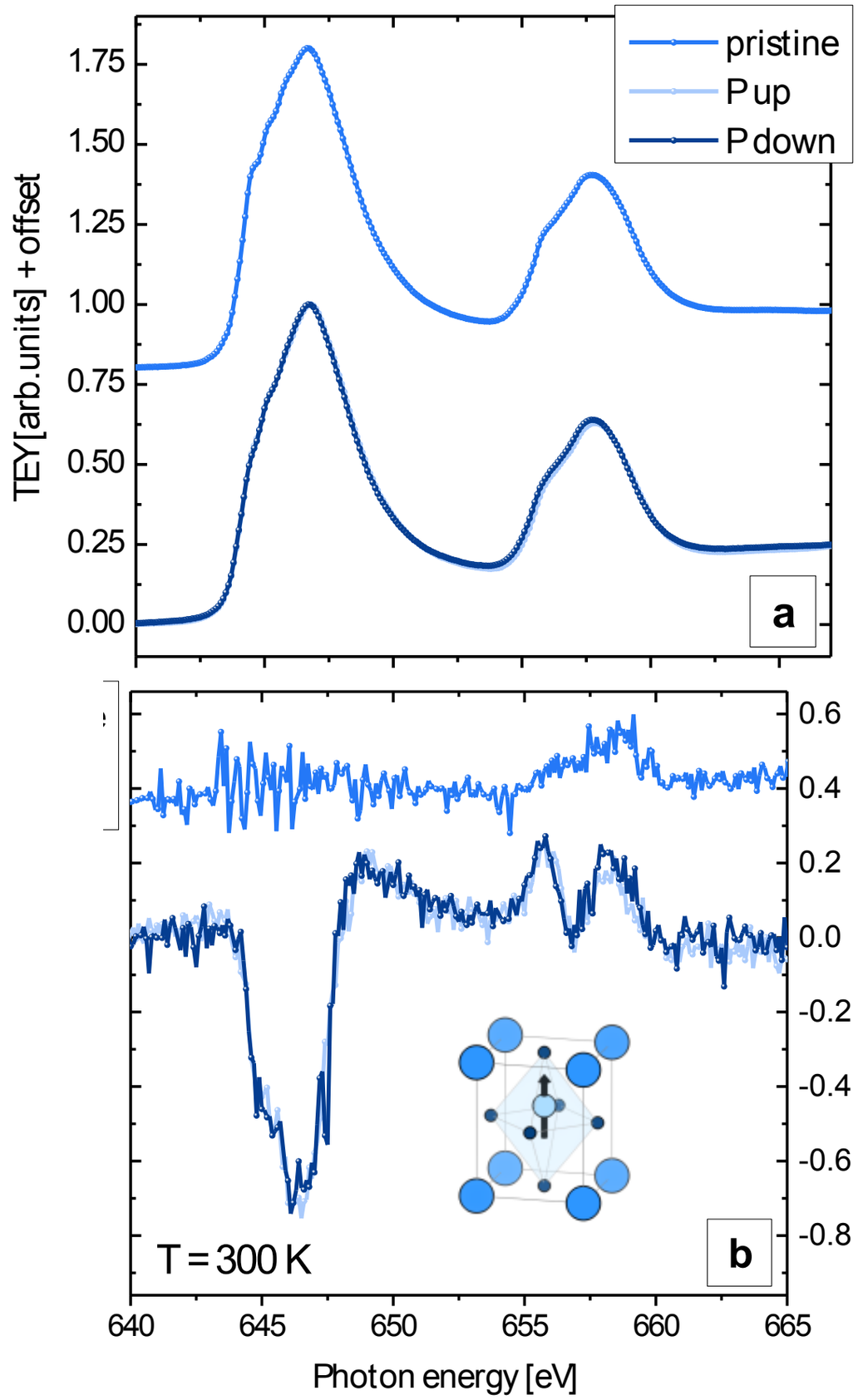
LSMO / BTO

Out-of-plane polarization

→ less strained LSMO

→ Ferromagnetic ordering



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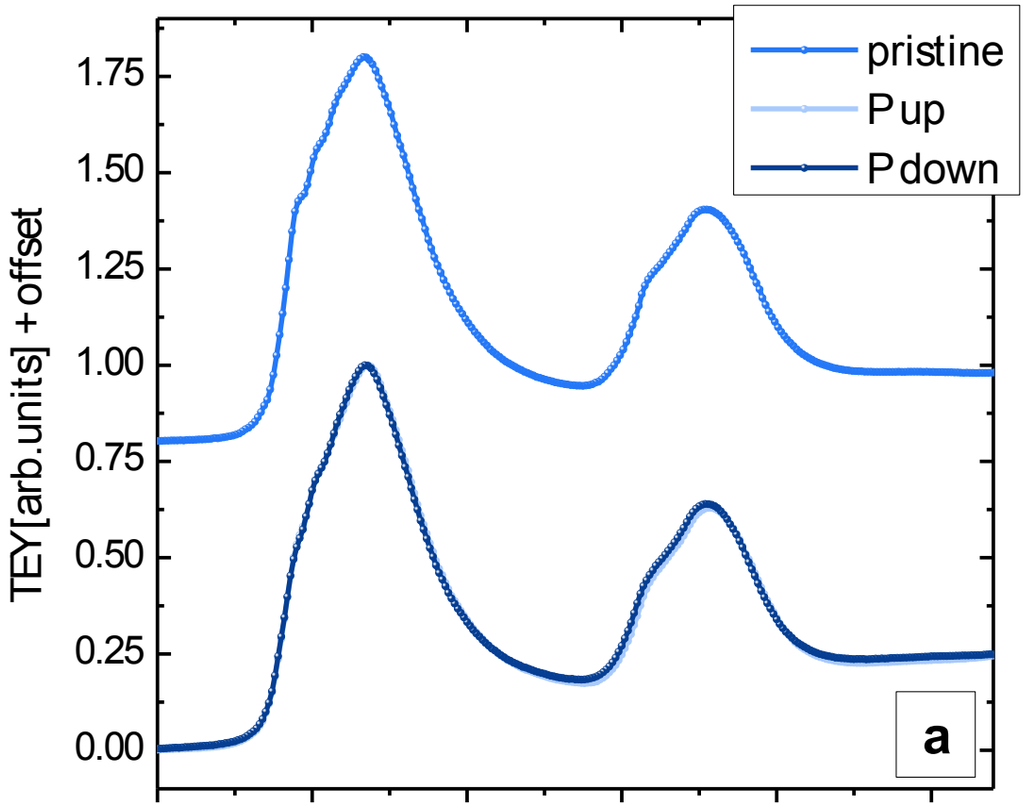

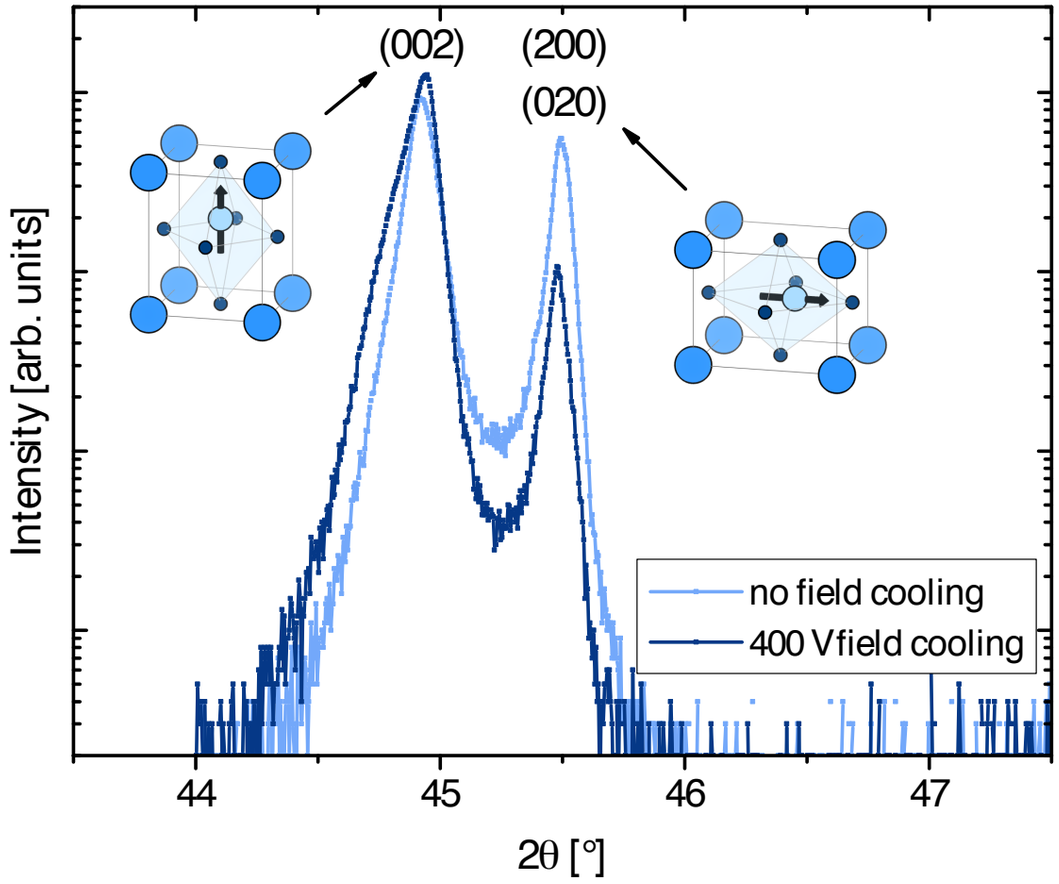

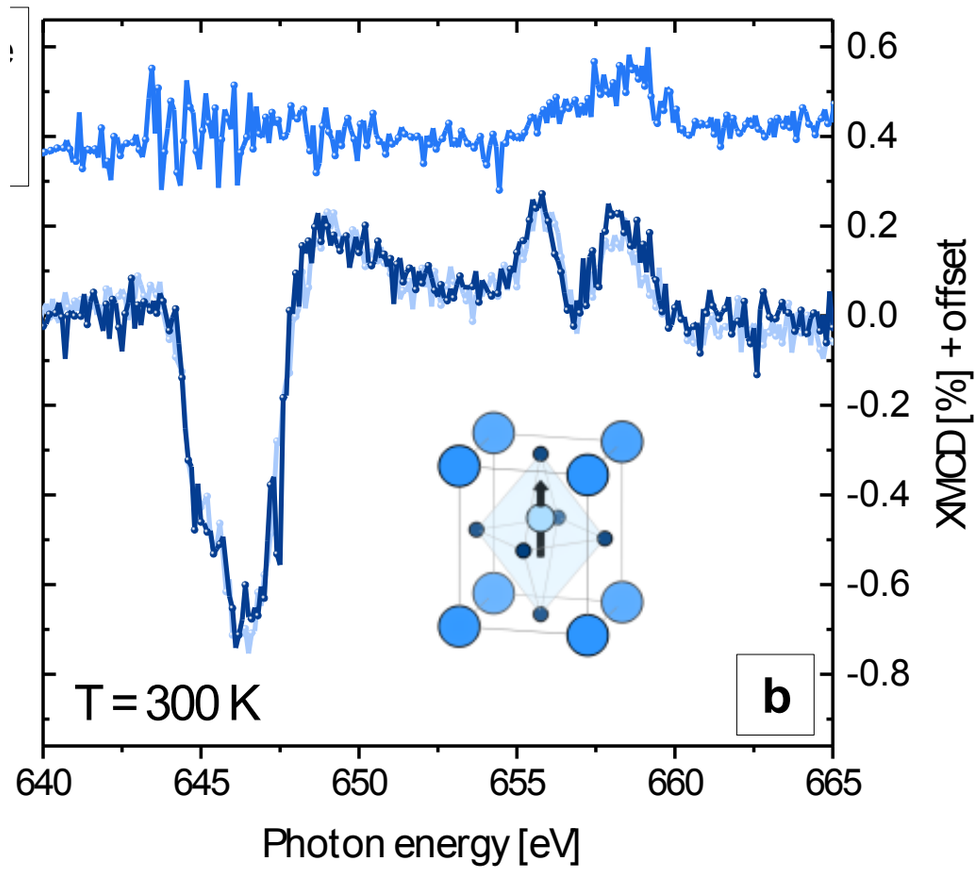

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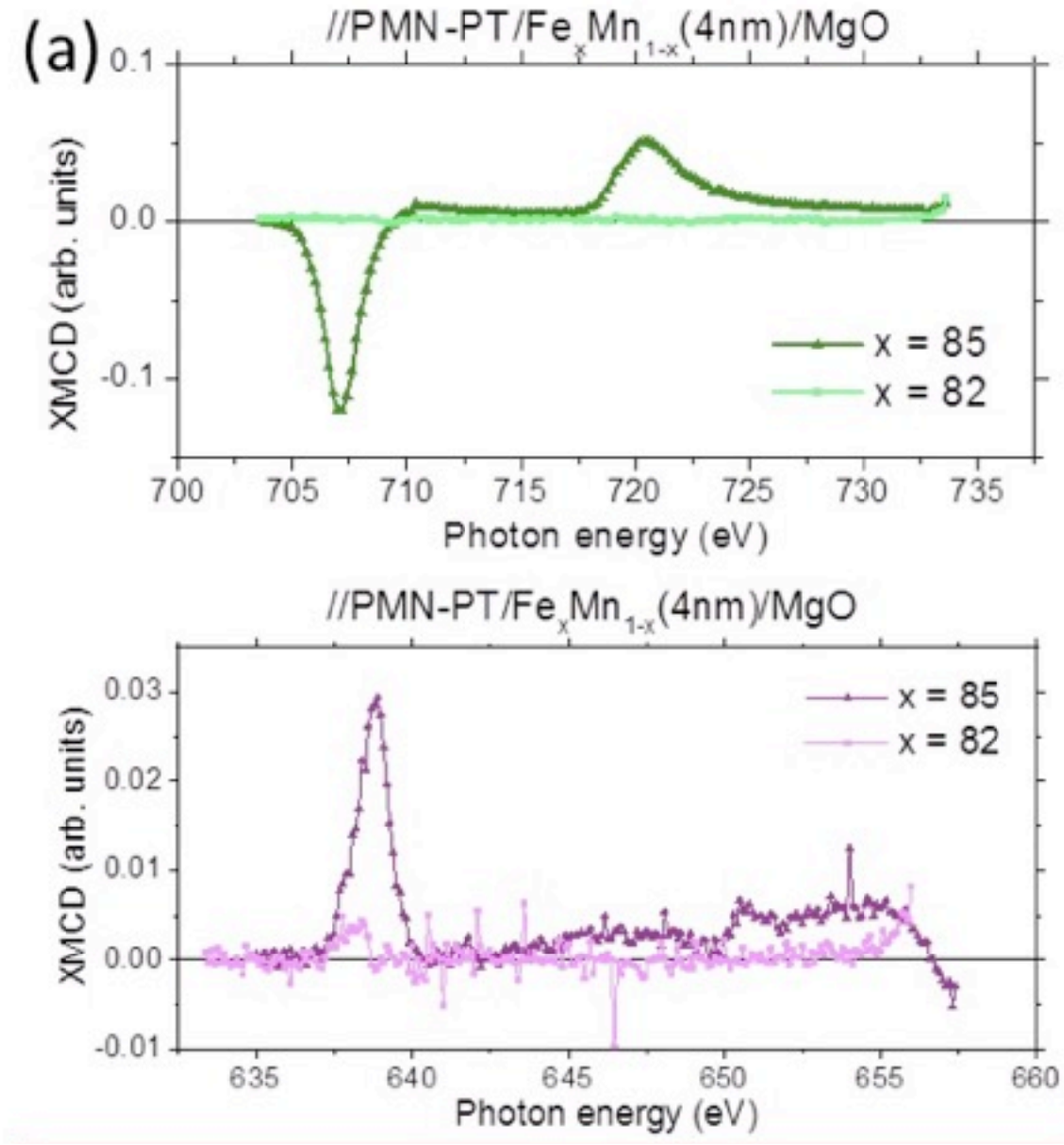
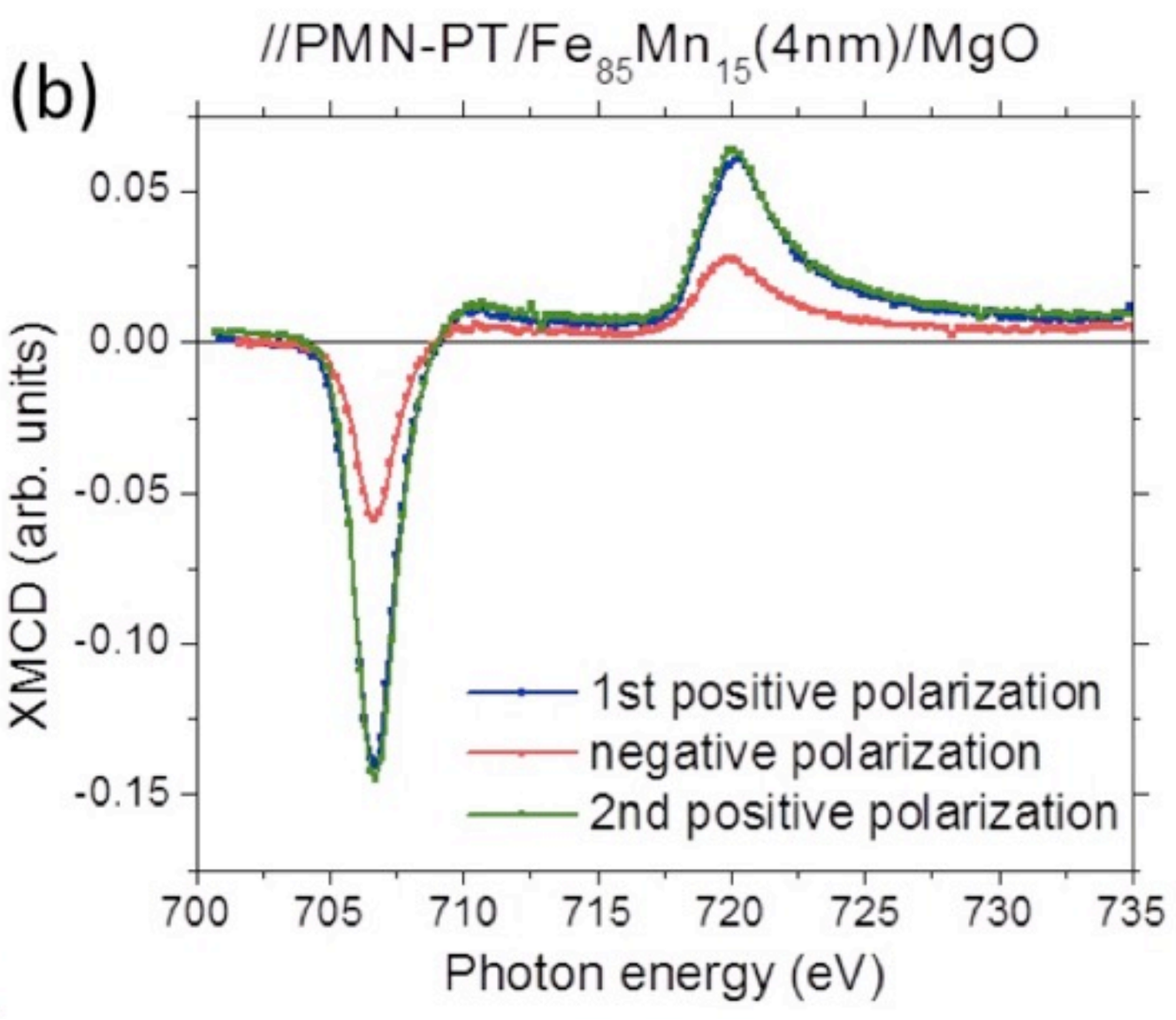
FeMn / PMN-PT





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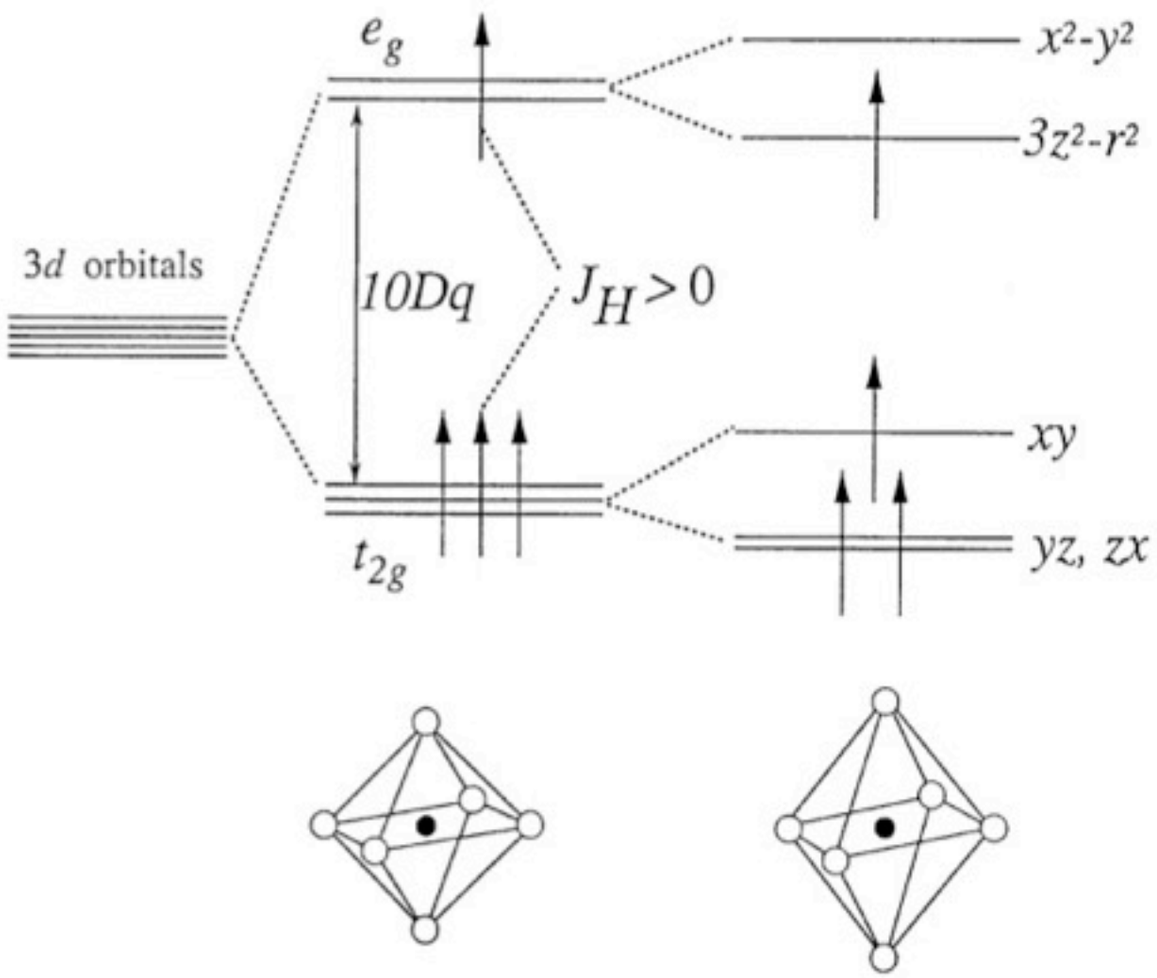
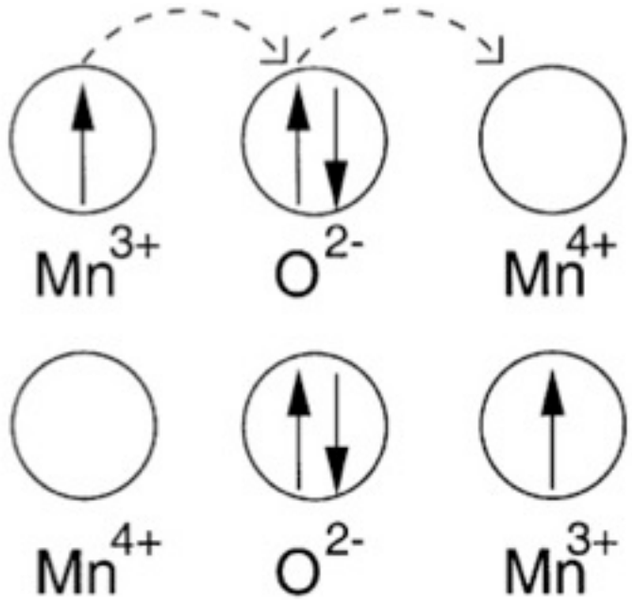
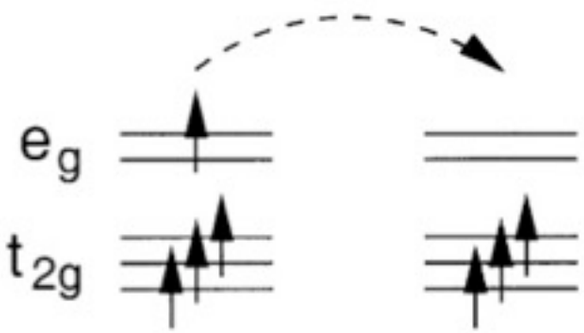
thank you for your attention

10 october 2017 - First year workshop - XXXII cycle

“Double-exchange” in manganites







E. Dagotto et al. / Physics Reports 344 (2001) 1–153

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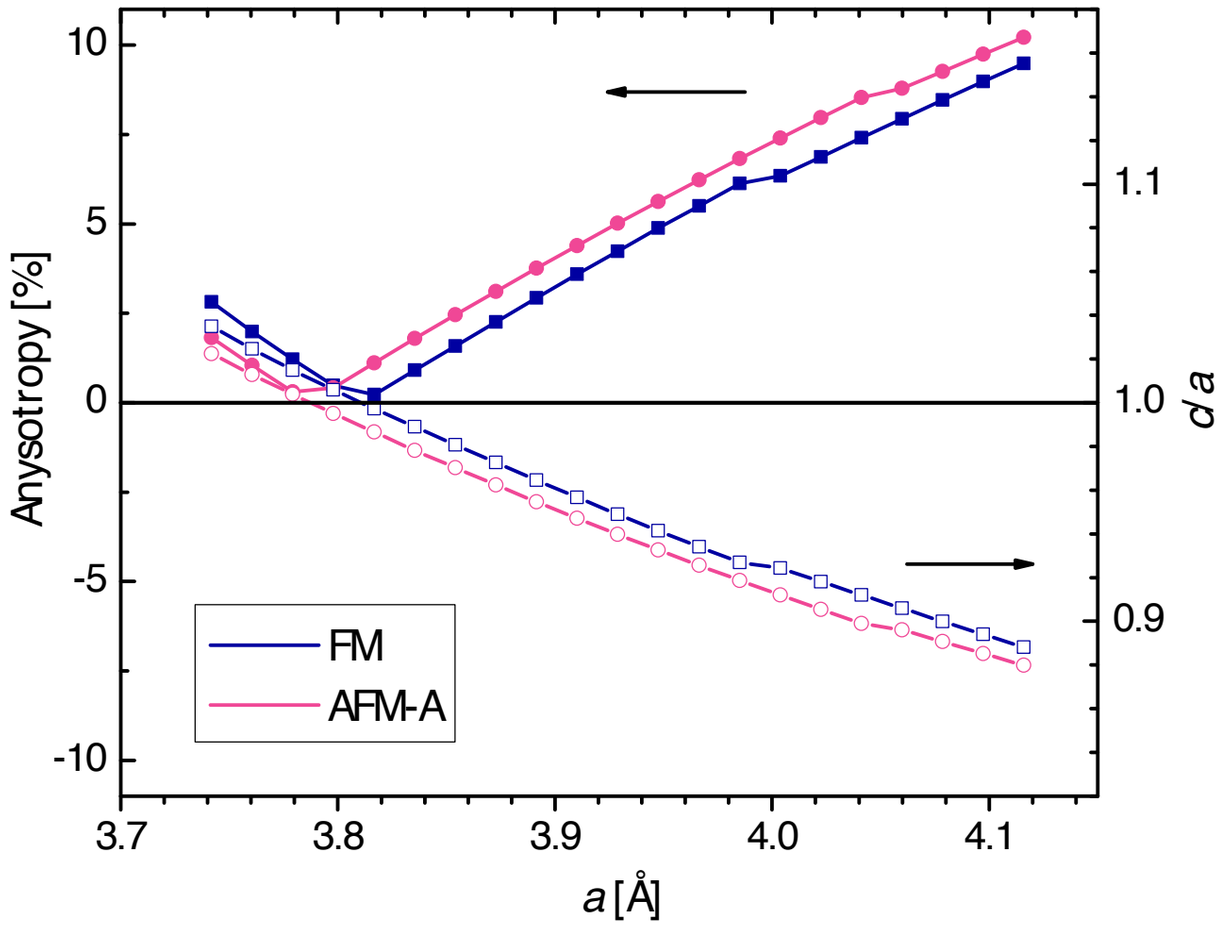
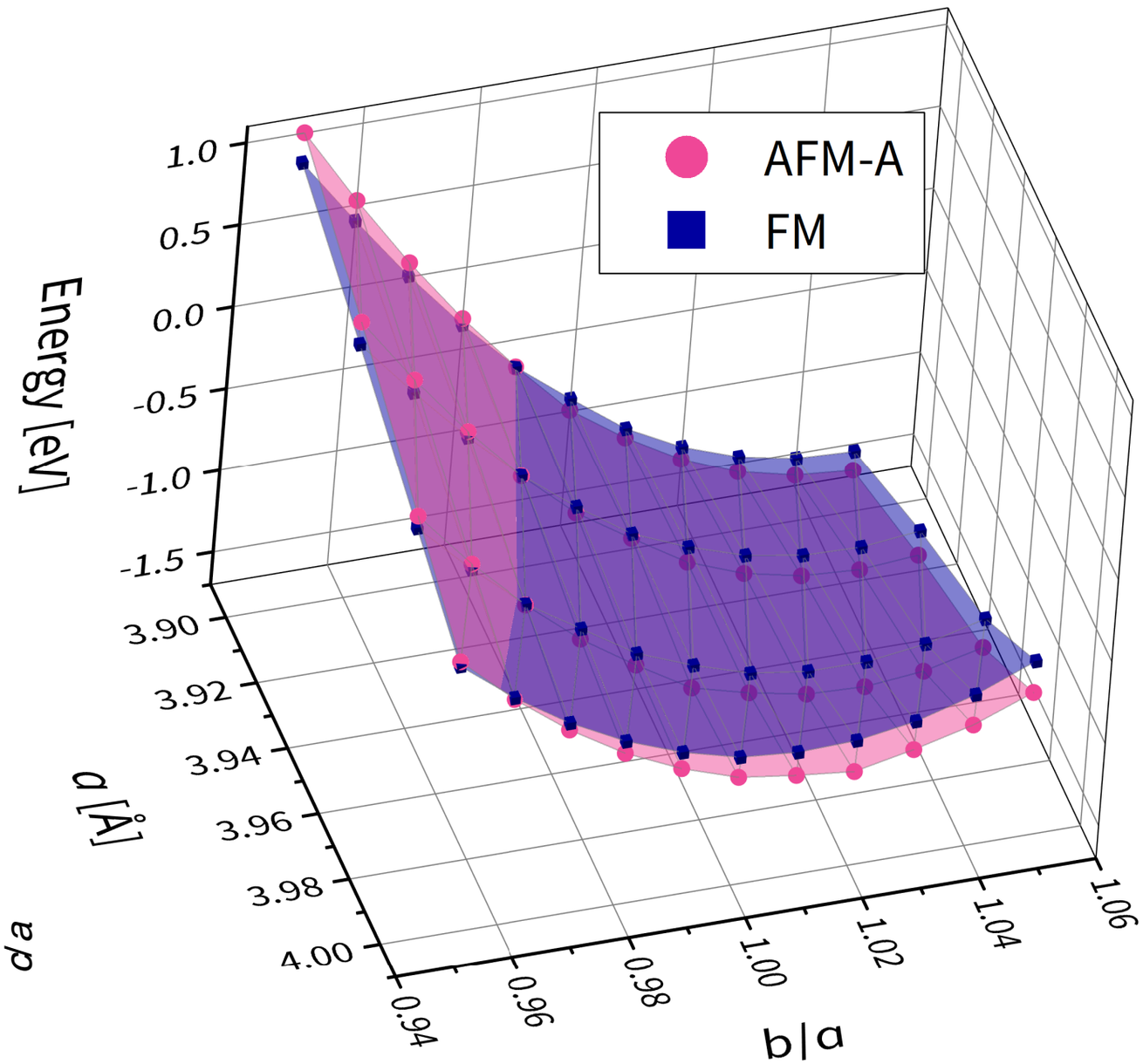
Simulations

Tight competition between strain along the three axis





FM prefers lower strain and isotropic unit cell

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