Interface Coupling in $La_{0.7}Sr_{0.3}MnO_3$ /$BiFeO_3$ Heterostructures

by
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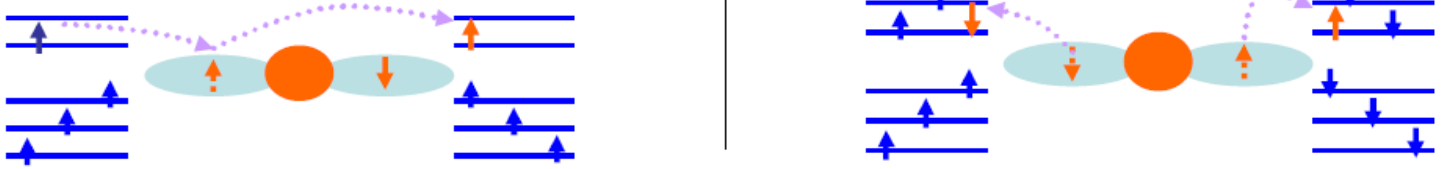
Overview

- Introduction
- Exchange Bias
- LSMO/BFO heterostructure
- Magnetic properties
- Thickness of LSMO & BFO

Introduction

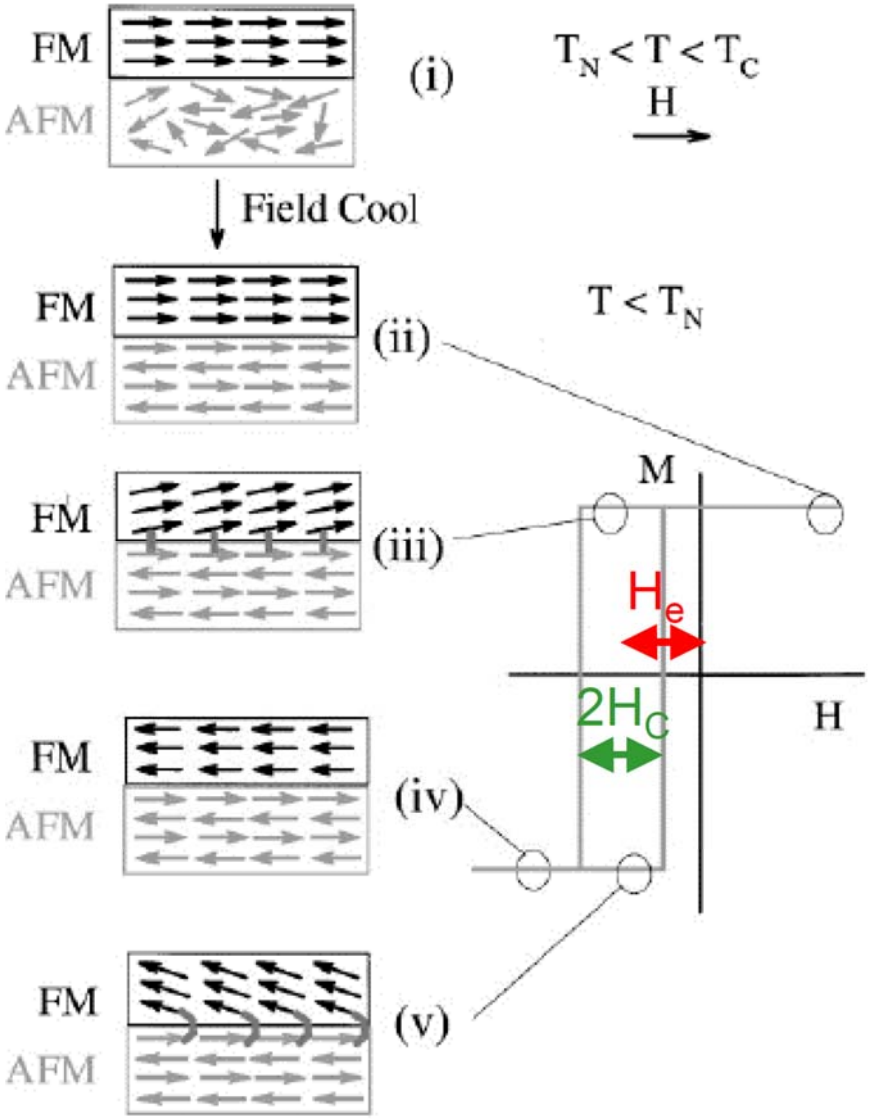
$La_{0.7}Sr_{0.3}MnO_3$	$BiFeO_3$
Ferromagnetic T_C ~ 380 K	Antiferromagnetic T_N ~ 643 K Ferroelectric T_C ~ 1103 K
Cubic: a ~3.88 Å	Rhombohedral: a_r ~3.96 Å
Double exchange interactions Mn^{3+} -- O^{2-} -- Mn^{4+}	Superexchange interactions Fe^{3+} -- O^{2-} -- Fe^{3+}



Open question:

- What kind of exchange interactions across the interface?
  - ➢ Double exchange
  - ➢ Superexchange
  - ➢ Ferromagnetic ordering
  - ➢ Antiferromagnetic ordering

Exchange Bias



➢Shift of the ferromagnetic hysteresis loop along the field axis produced by an unidirectional exchange anisotropy at the interface between FM & AFM films.

➢ ***Shift*** and ***broadening*** of hysteresis loop when FM/AF field cooled below T_N

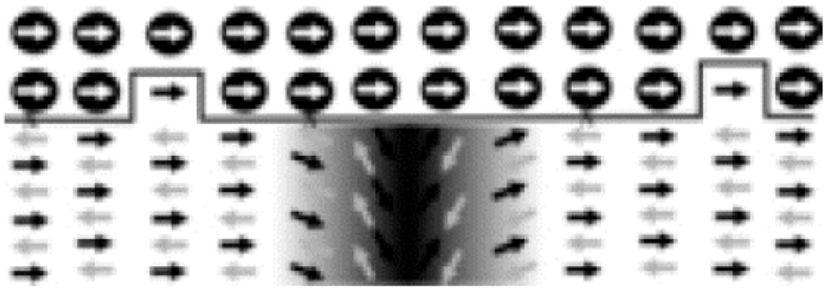
➢ Interaction between interfacial spins : ***effective field***

➢In magnetic recording, exchange bias is used in the pin state of the readback heads of hard disk drives exactly their point of max. sensitivity

Reviews : Noguès et al, *JMMM* **192**, 203 (1999)
Noguès et al, *Phys. Rep.* **22**, 65 (2005)

Malozemoff Model for Exchange Bias

Atomic roughness at the interface



AF domain wall

AF domain size

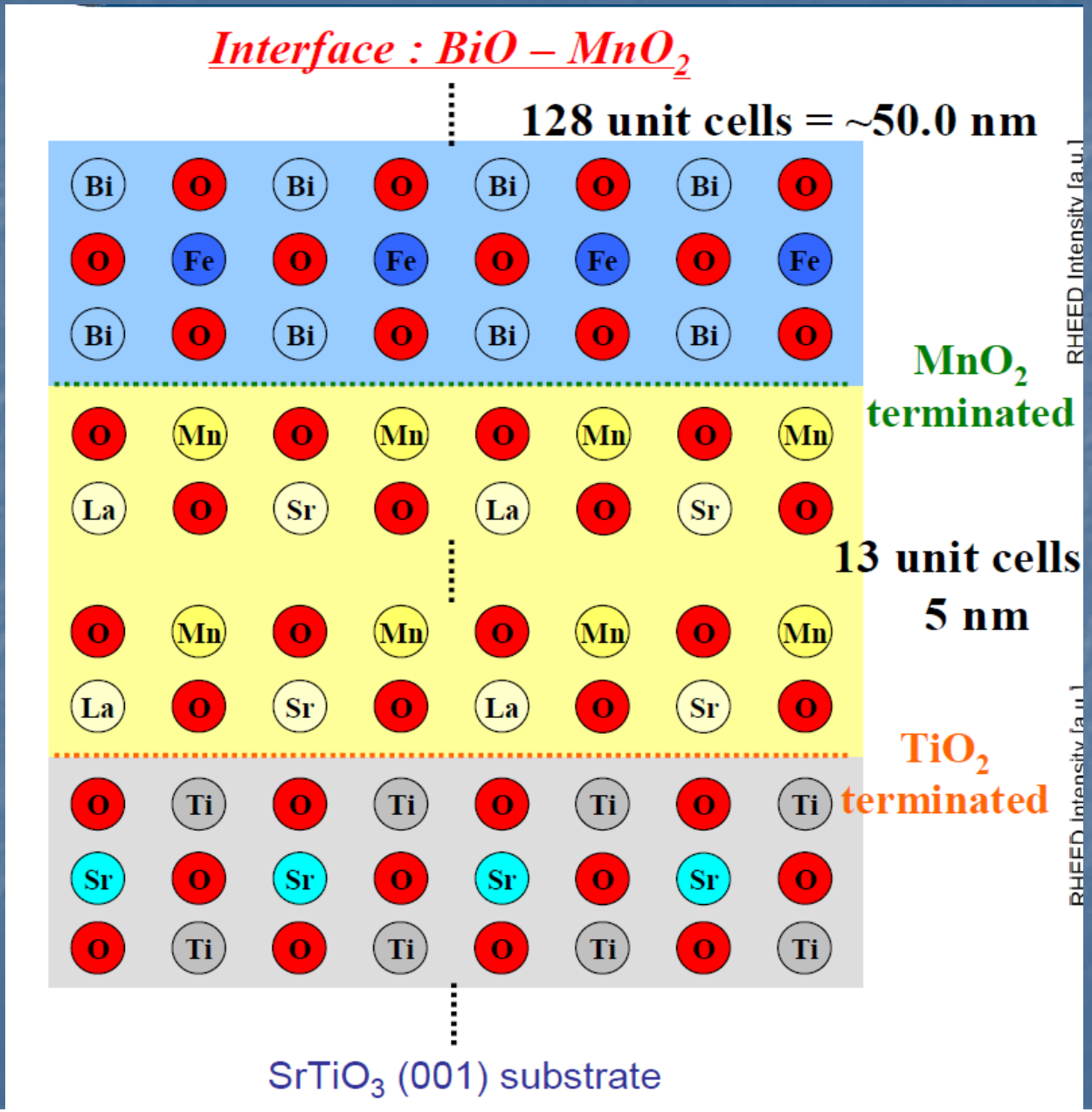
J_{eb}	Exchage interaction
J_{ex}	Exchange constant
M_{FM}	FM magnetization
t_{FM}	FM thickness
S_{AF}	interfacial moment in AF
S_{FM}	interfacial moment in FM
a	Lattice parameter
L	AF domain size
z	Number of frustrated interaction paths

$$H_e = -\frac{J_{eb}}{\mu_0 M_{FM} t_{FM}} = -\frac{2zS_{AF}S_{FM}J_{ex}}{\mu_0 M_{FM} t_{FM} aL}$$

Malozemoff, *Phys. Rev. B,* **35,** 3679 (1987)
Radu and Zabel, *Condmat*/0705.2055 (2007)

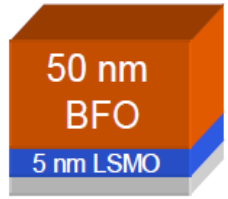
H_e varies as inverse of L, as observed in several systems:
Takano et al., *Phys. Rev. Lett.*, **79**, 1130 (1998), Scholl et al., *Appl. Phys. Lett.*, **85,** 4085 (2004)

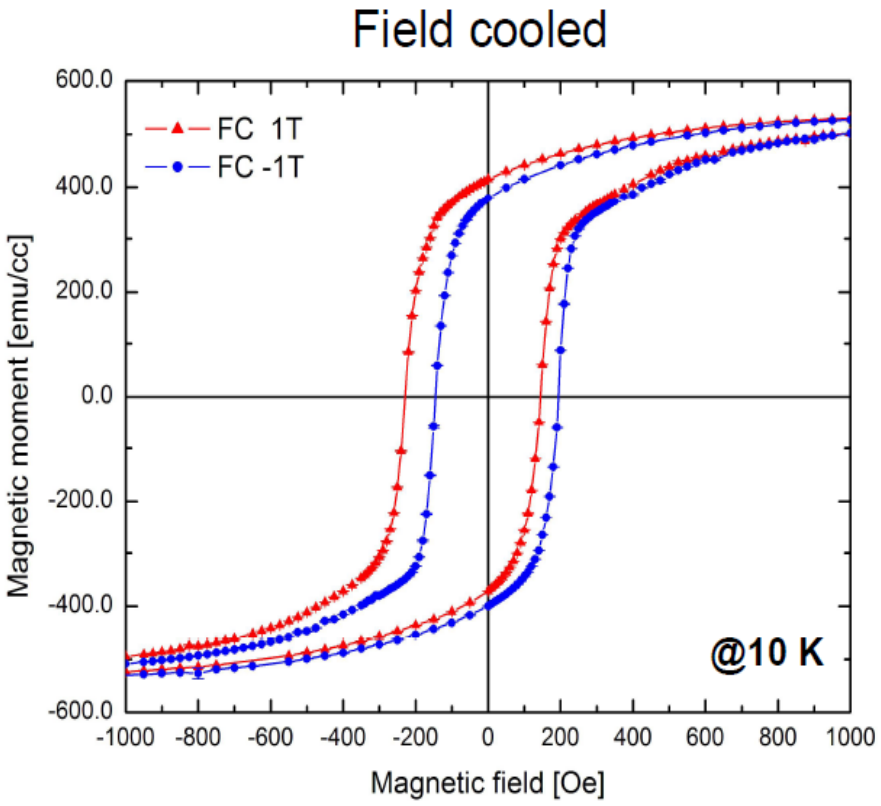
LSMO/BFO heterostructure

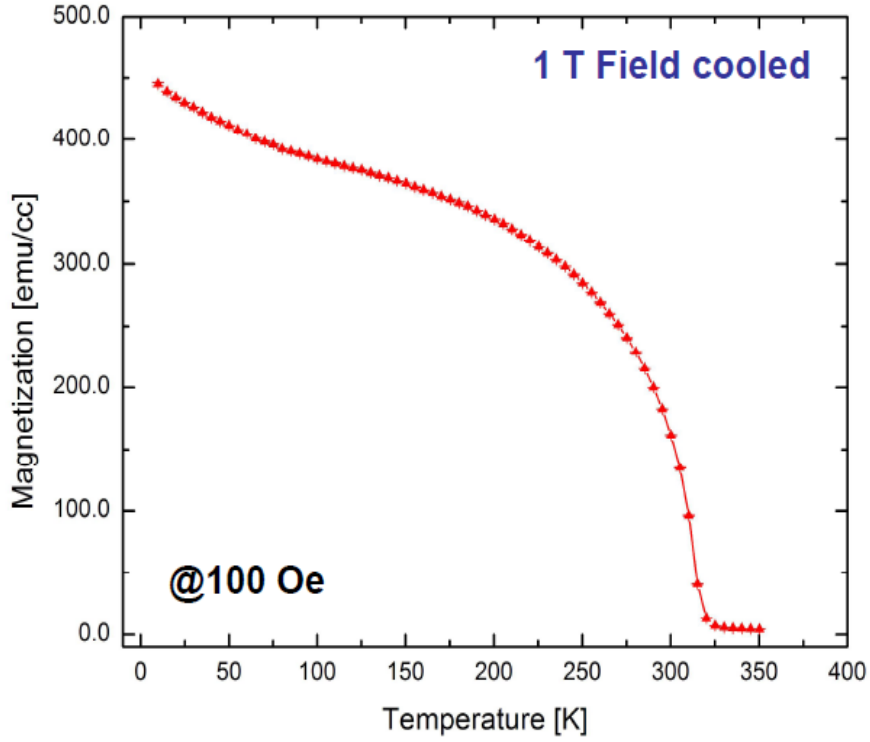


Magnetic Properties

5 nm $La_{0.7}Sr_{0.3}MnO_3$ / 50 nm $BiFeO_3$ Heterostructure





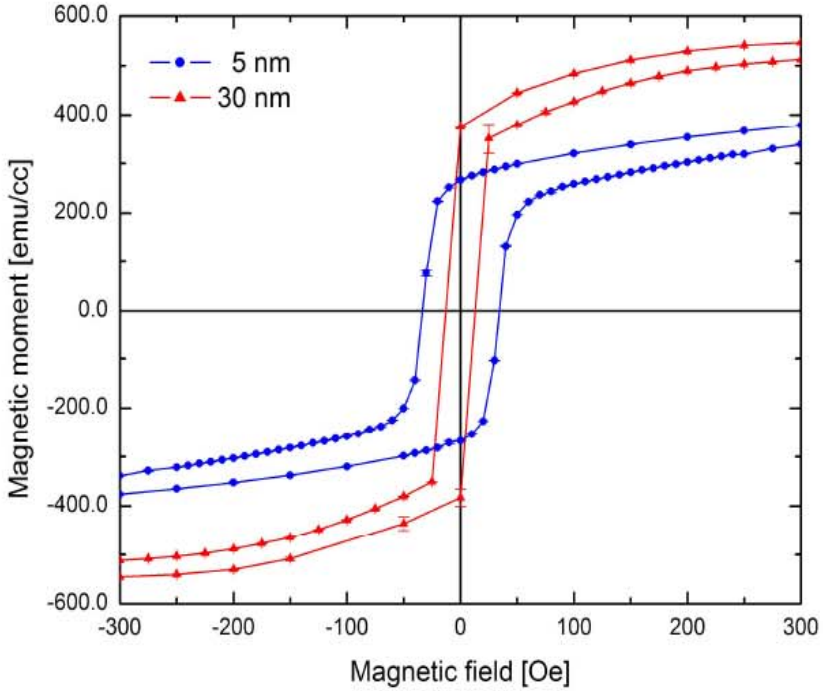


Shifts in hysteresis loops !

T_C ~320 K

Thickness dependence of LSMO growth

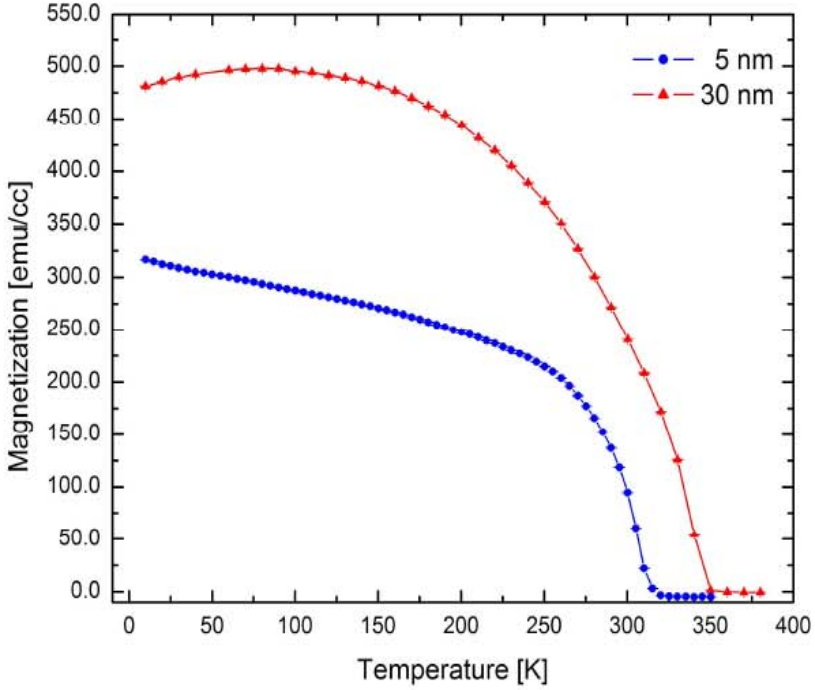
1 T field cooled



- Magnetization decreases
- Hc increases:

15 Oe → 40 Oe

1 T field cooled



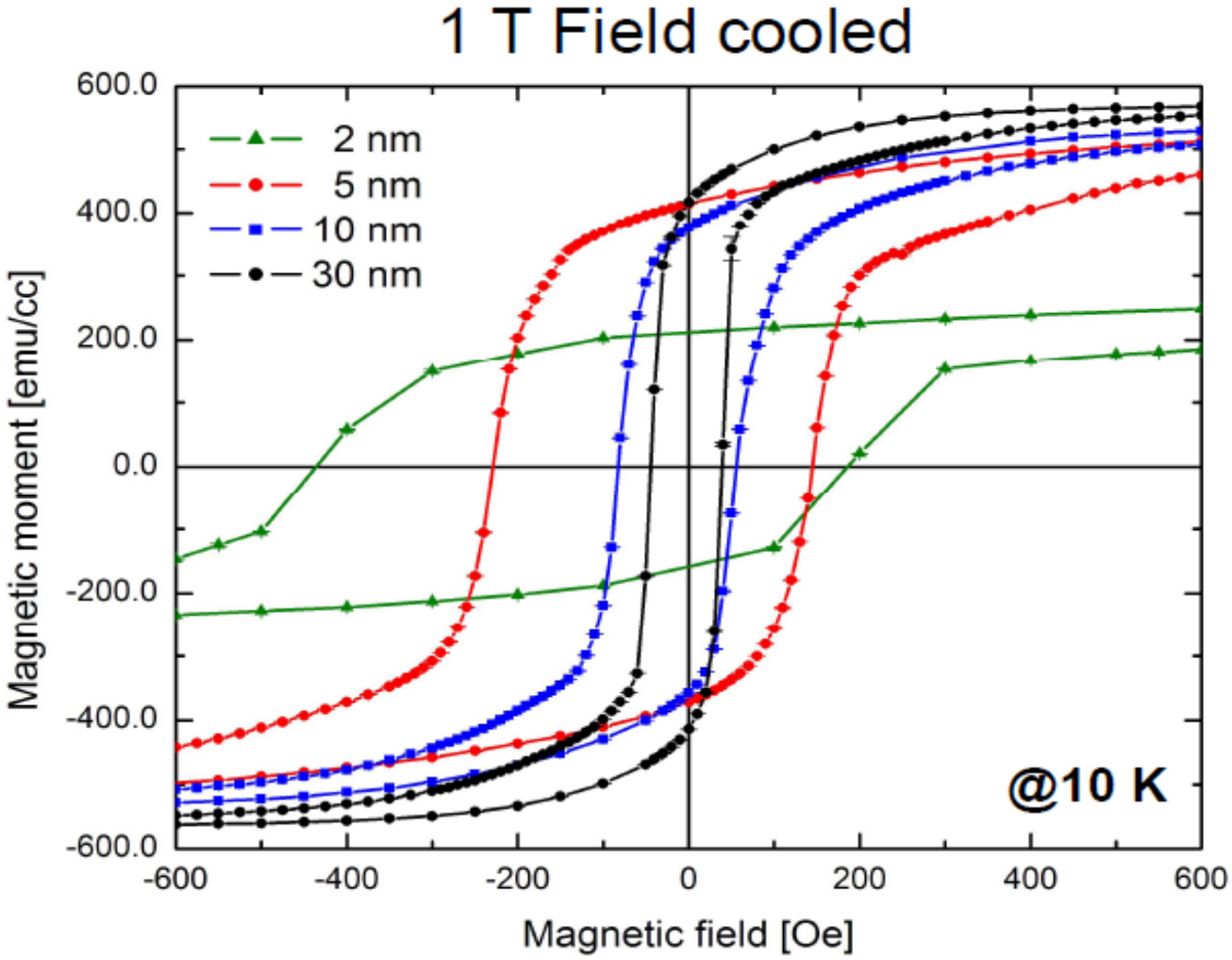
- T_N decreases:

345 K → 315 K

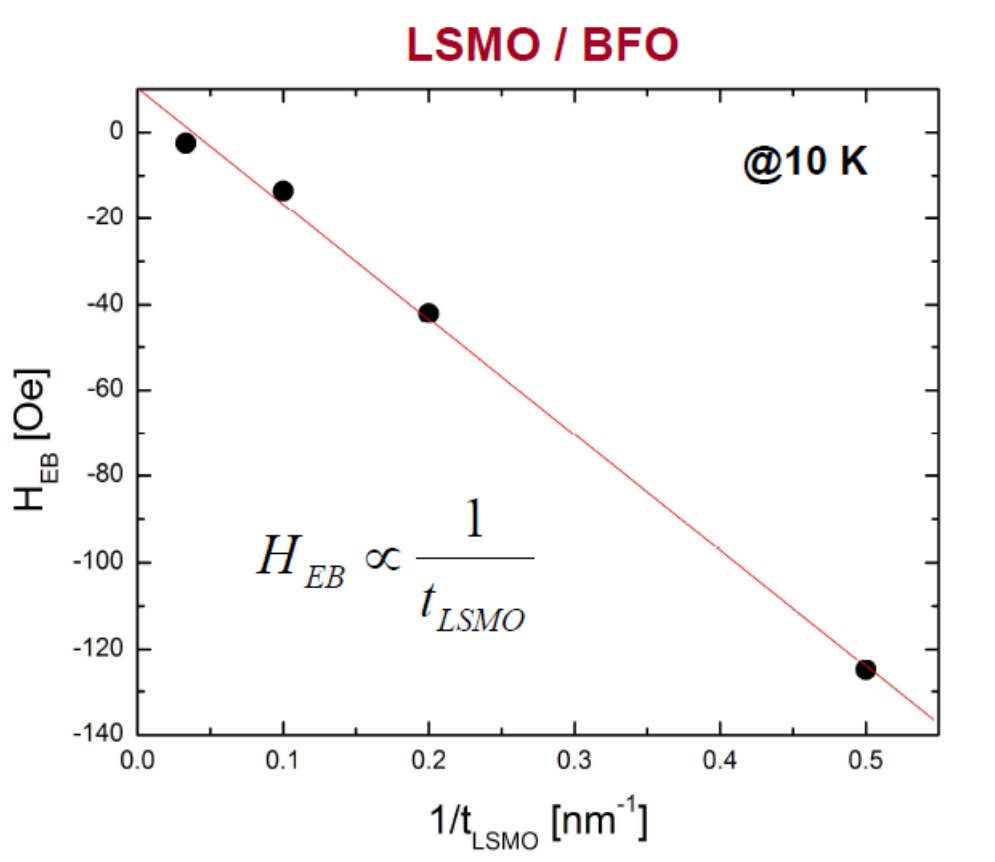
Normal LSMO thickness dependence

Thickness dependence of LSMO

? nm $La_{0.7}Sr_{0.3}MnO_3$ / 50 nm $BiFeO_3$



Thickness dependence of LSMO

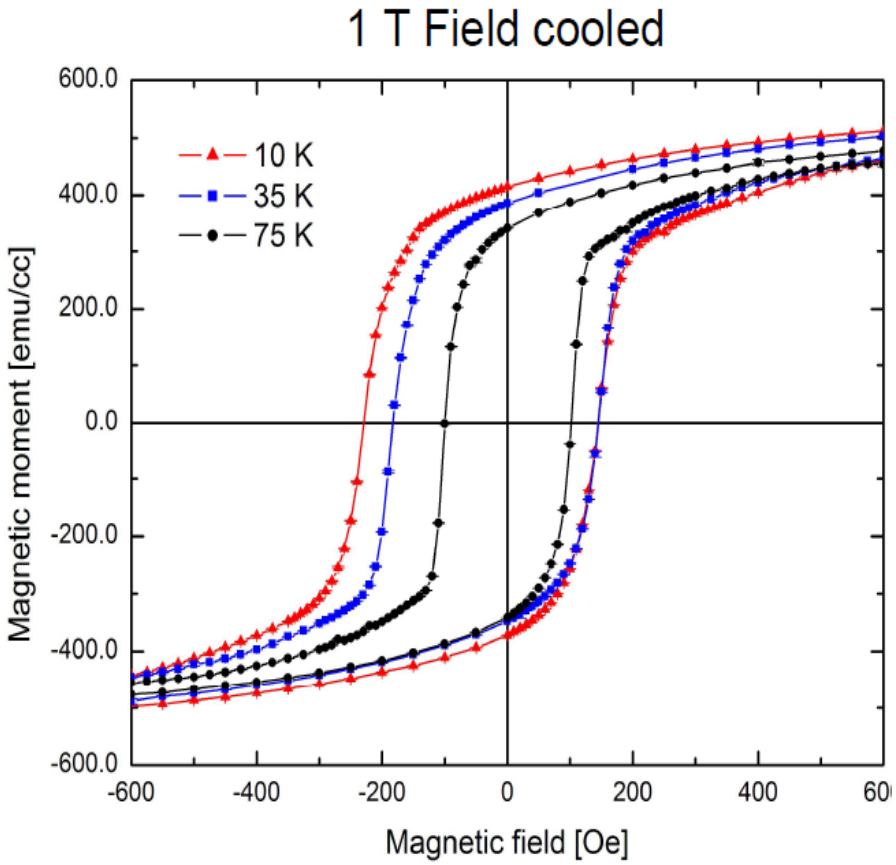


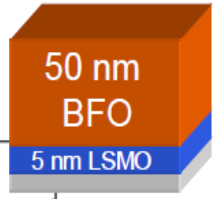
Exchange Bias interaction between $La_{0.7}Sr_{0.3}MnO_3$ and $BiFeO_3$

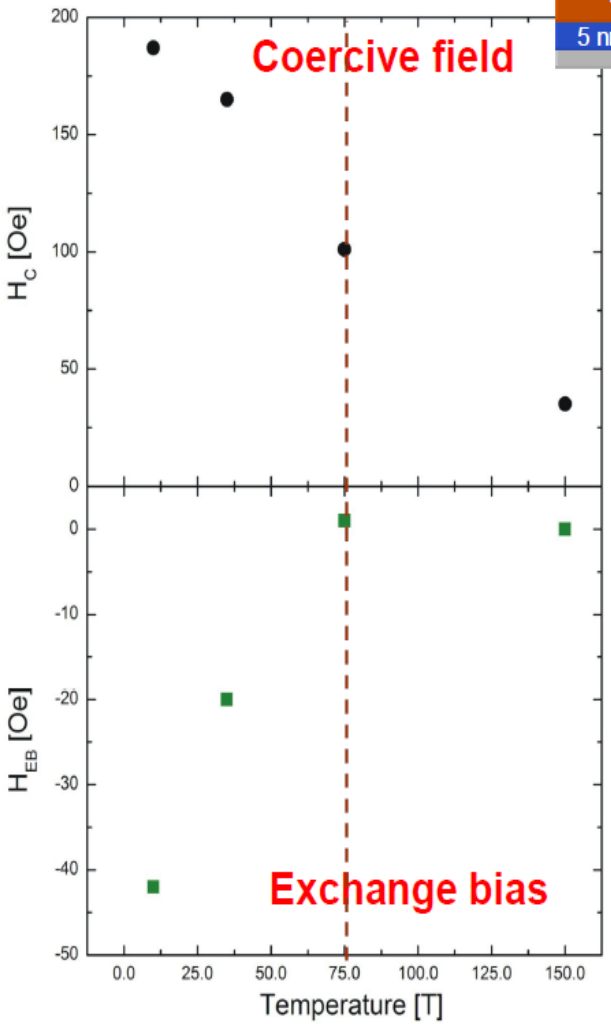
Nogués, J & Schuller, I.K., J. Magn. & Magn. Mater. 192, 203 (1999)

Temperature dependence

5 nm $La_{0.7}Sr_{0.3}MnO_3$ / 50 nm $BiFeO_3$ Heterostructure



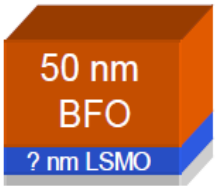


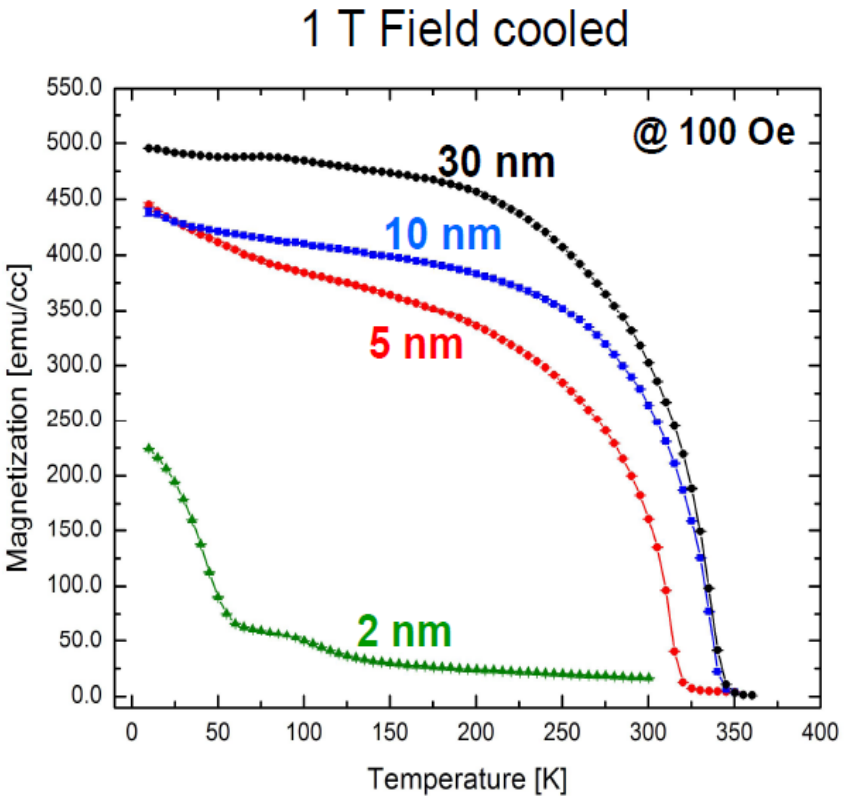


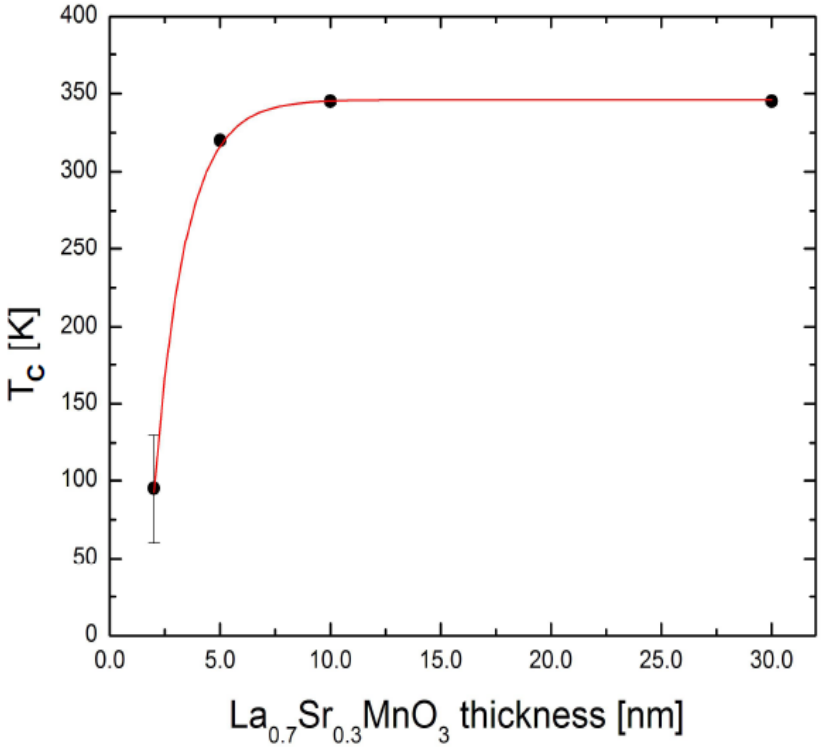
Blocking temperature : ~75 K

LSMO Thickness dependence

? nm $La_{0.7}Sr_{0.3}MnO_3$ / 50 nm $BiFeO_3$ Heterostructure

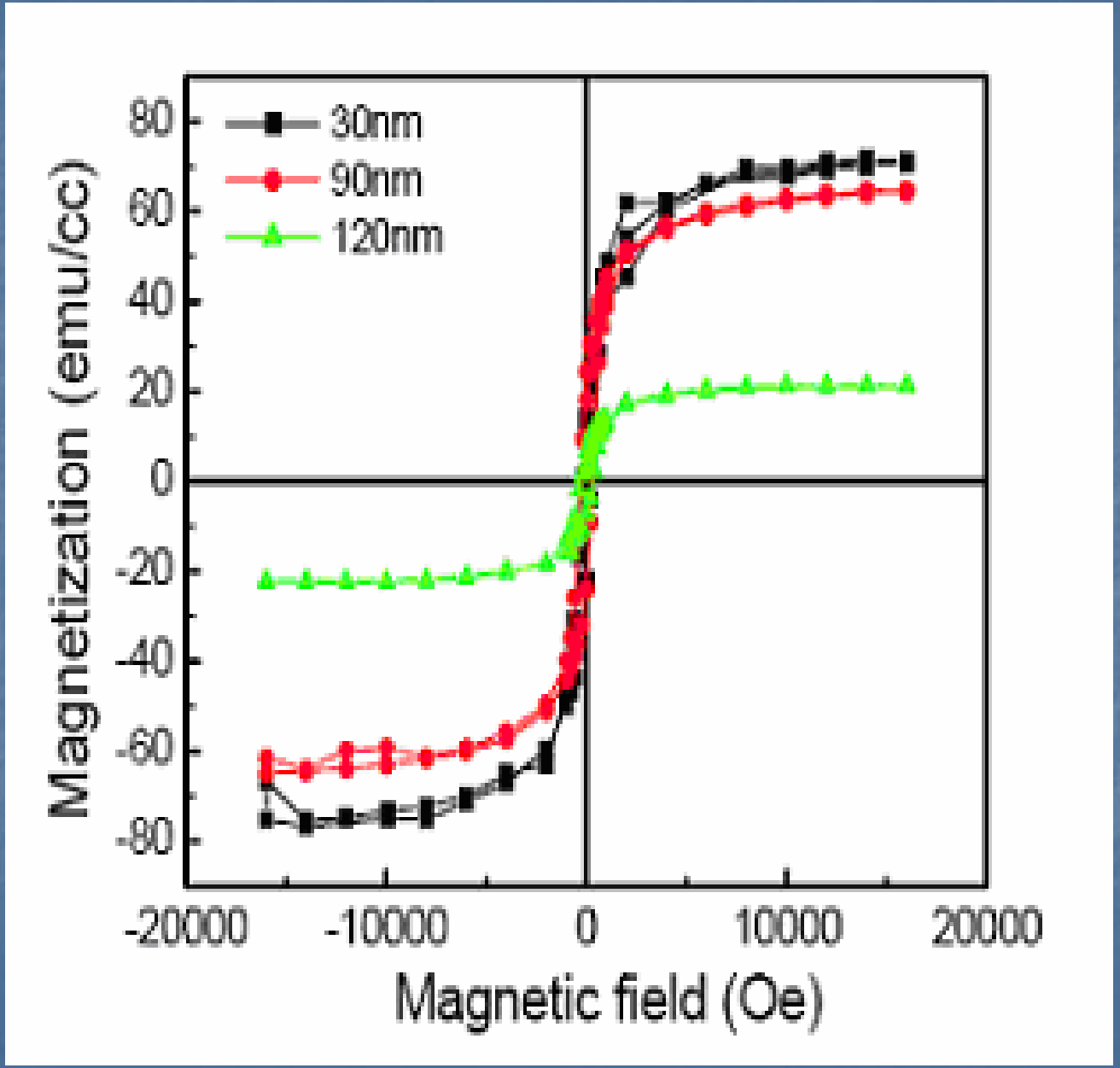




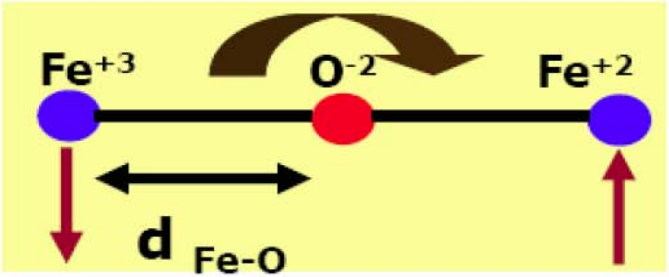


Minimum LSMO thickness: ~5 nm

Magnetization measurements in BFO

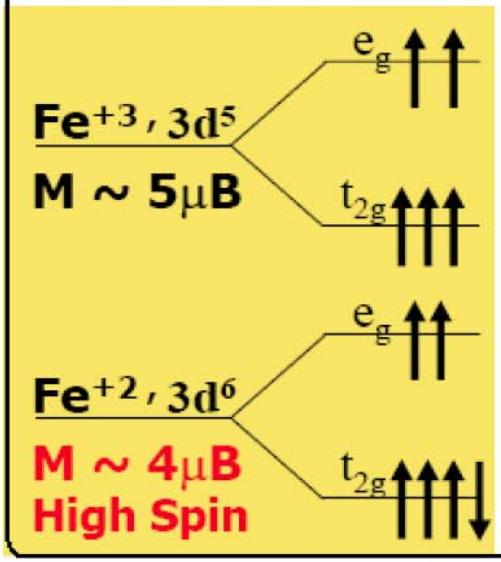


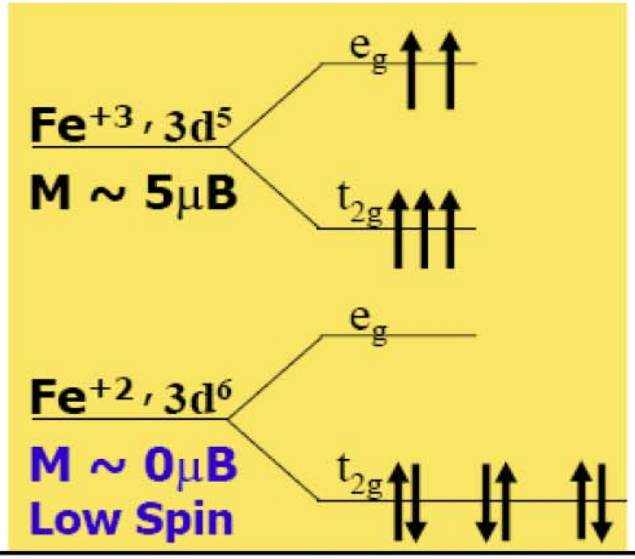
Possible Origins of Magnetism

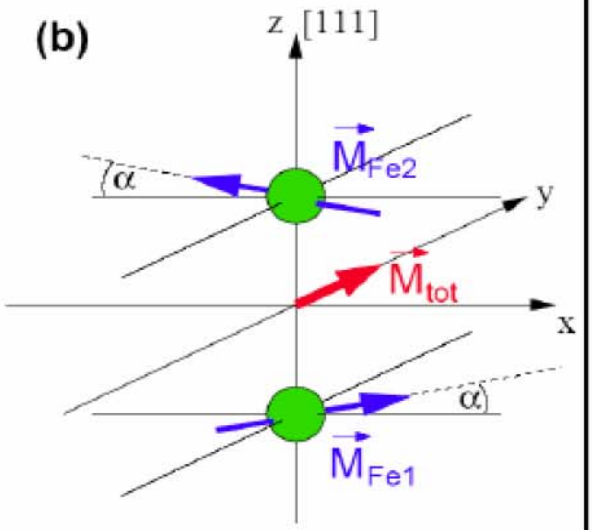


Antiferromagnetic
Super-exchange

- Need to understand Fe-O defect chemistry under heteroepitaxial constraints
- Electronic structure of Fe+3/Fe+2 under Heteroepitaxial stresses
- Spin canting effects under combined oxygen defect-electronic structure effects

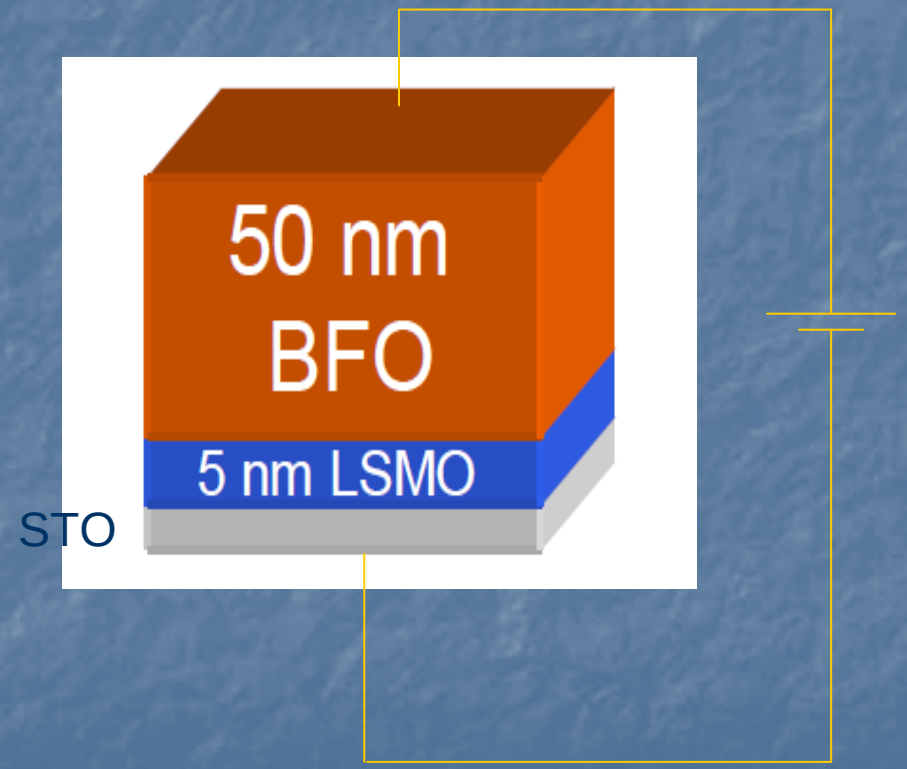






My Goal

- To apply electric field on LSMO/BFO



Thanks for your attention