How cobalt drives spin orientation in hematite

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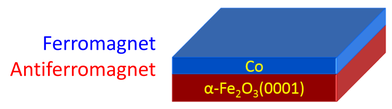
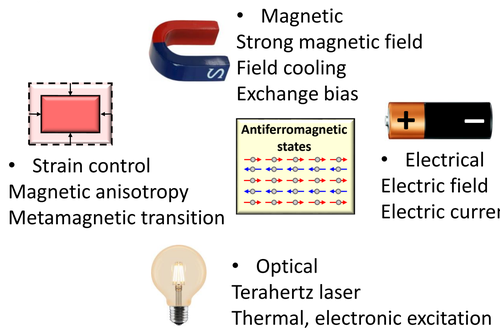
Motivation

Antiferromagnetic materials, which have drawn considerable attention as an active element in spintronic devices, have unique properties:
- ✓ robust against magnetic field perturbation
- ✓ exhibit ultrafast spin dynamics (AFM –terahertz; FM-gigahertz)
- ✓ produce no stray fields

Aim: How does ferromagnetic cobalt drive the spin orientation in antiferromagnetic hematite?

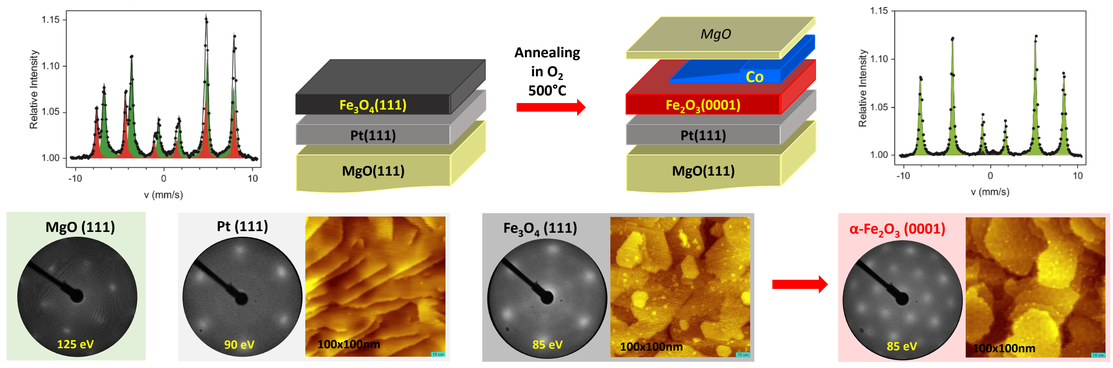


Understanding how to efficiently manipulate the magnetic state of an antiferromagnet is key to the development of antiferromagnetic spintronics.



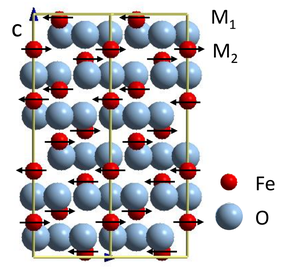
Preparation

Samples prepared in a multi-chamber, ultrahigh vacuum (UHV) system by molecular beam epitaxy (MBE).
Controlled *in situ* by Low Energy Electron Diffraction (LEED), Scanning Tunneling Microscopy (STM), Conversion Electron Mossbauer Spectroscopy (CEMS).
Hematite α-Fe_2O_3 prepared by magnetite oxidation. Magnetite prepared by iron reactive deposition.

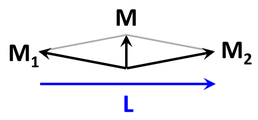


Hematite α-Fe_2O_3

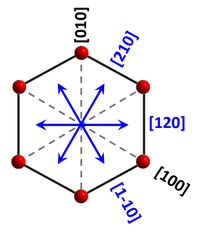
Corundum structure - hexagonal unit cell
T_M = 250 K, T_N = 953 K



Spins FM aligned in basal plane arranged AFM along c axis „ABBA" stacking

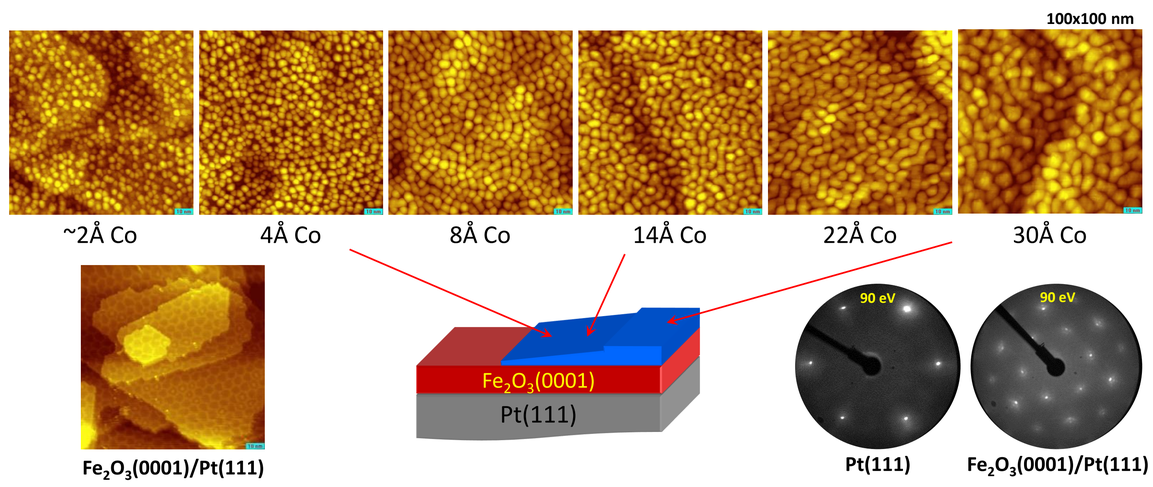


Slight canting of two AFM sublattices (0.057°), leads to the appearance of a weak ferromagnetism.
Uncompensated magnetic moment M lies in the same basal plane perpendicular to the AFM order direction.

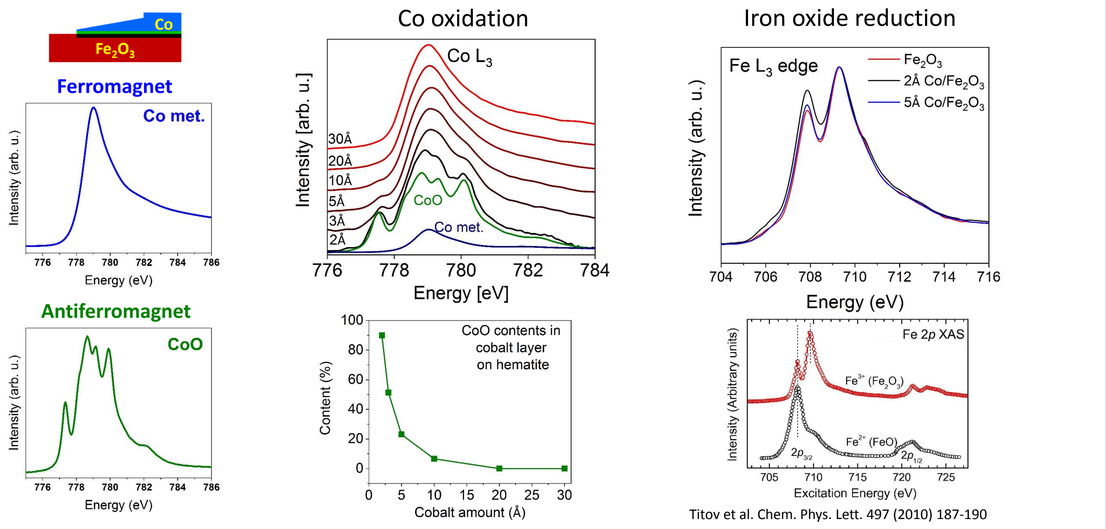


Basal plane with three easy axes [210], [120], [1-10] of the AFM order direction.

Morphology of Co on α-Fe_2O_3



Chemical structure at the Co/hematite interface µXAS-PEEM measurements



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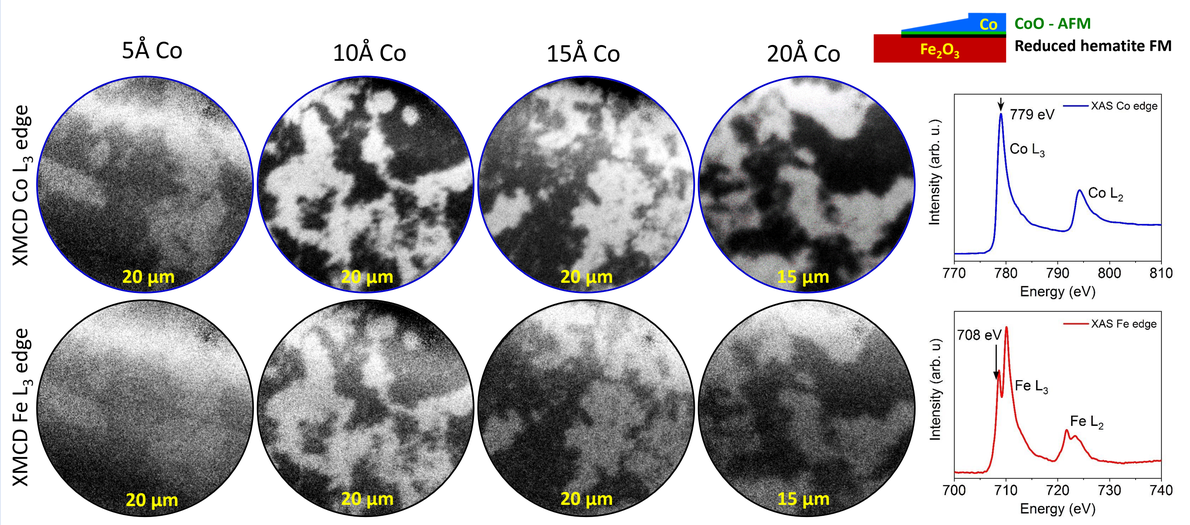
Magnetic domain structure - Co/α-Fe_2O_3 XMCD-PEEM imaging



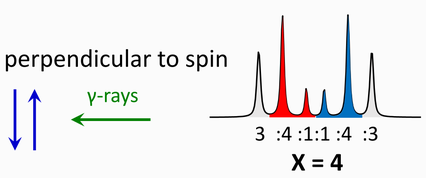
Conversion Electron Mossbauer Spectroscopy

- chemical, electronic and magnetic information
- direct *in-situ* probe of magnetism direction
- isotope sensitive – probe only ^{57}Fe atoms
- short characteristic time

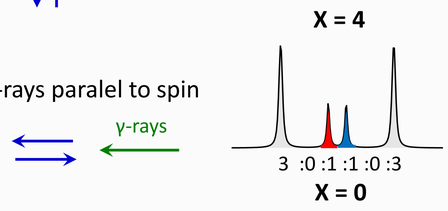
Relative intensity of spectrum lines

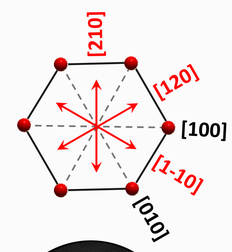
$$X = \frac{I_2}{I_3} = \frac{I_5}{I_4} = \frac{4\sin^2\Theta}{2-\cos^2\Theta}$$

γ-rays perpendicular to spin



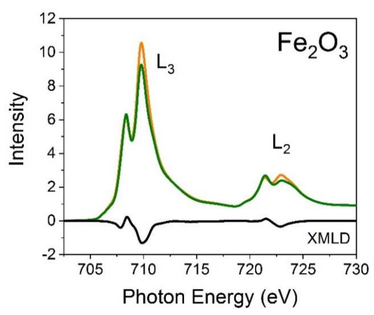
γ-rays paralel to spin

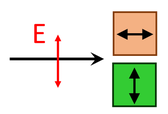




Hematite
Random occupation of three possible orientation of AFM order directions

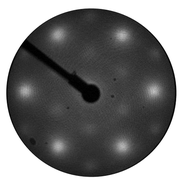
Magneto-crystalline anisotropy





XMLD is sensitive to the orientation of the linear polarization of X-ray relative to the AFM order direction

X-ray Magnetic Linear Dichroism

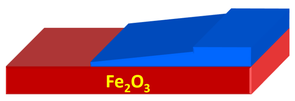


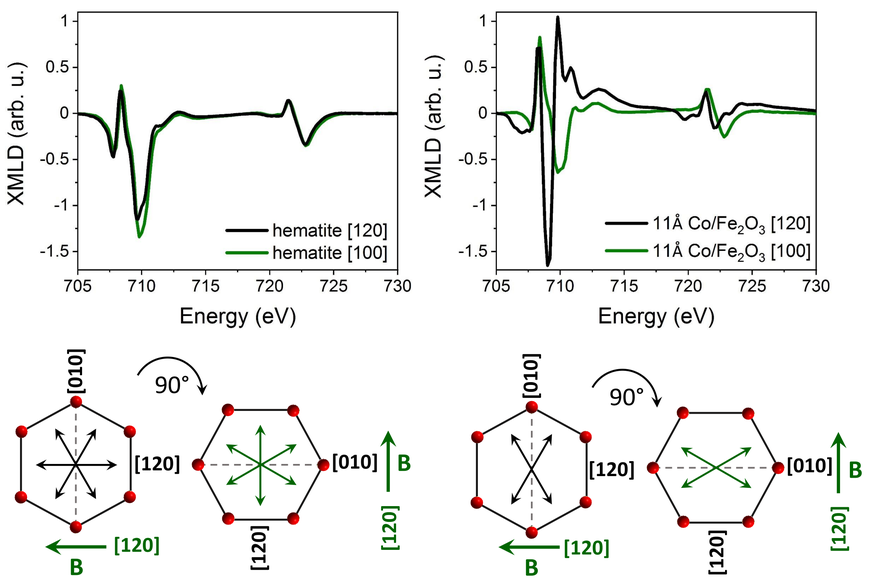
B (125 mT)

External magnetic field applied in [120] direction

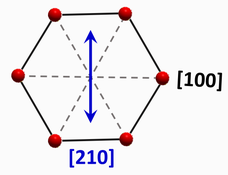
To determine the AFM order direction in hematite, we measured the XMLD spectra for two azimuthal angles of the sample.

XMLD spectrum change after 90° sample rotation if AFM order direction has preferential orientation

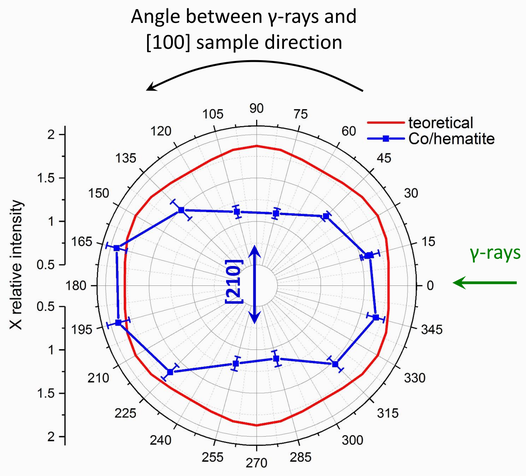




External magnetic field applied in [100] sample direction



Cobalt covered hematite
Weak ferromagnetic moment in hematite aligned parallel to external magnetic field (B). AFM order direction perpendicular to B.



Conclusions

- ✓ The interactions at the Co/Fe_2O_3 interface influenced magnetism in studied system.
- ✓ Due to cobalt oxidation, there is no magnetism for 2-4Å Co/Fe_2O_3
- ✓ Uncompensated magnetic moment appears in AFM hematite after cobalt deposition.
- ✓ Cobalt enforces domain structure in hematite
- ✓ Due to the proximity of the cobalt layer, we can force the spin orientation in the hematite using a low external magnetic field.