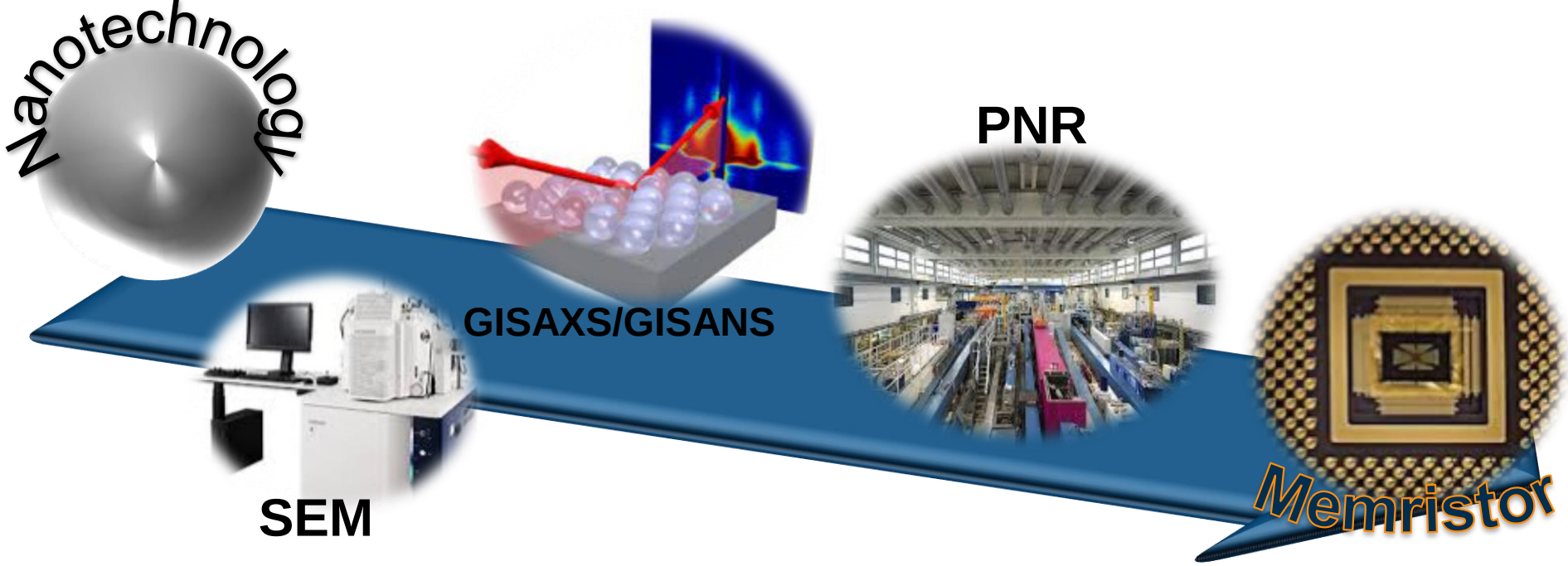

Tunable interfacial properties in Fe_3O_4 thin films/ SiO_2 nanospheres

FEBRUARY 2024 I MAI HUSSEIN HAMED

Motivation and Introduction

Oxide Interfaces??!!!

editorial

The interface is still the device

Oxide materials show an amazing variety of electronic and ionic phenomena. However, despite considerable advances in understanding and utilizing these effects, experimental and theoretical challenges still need to be addressed before the promised applications can be realized.

When Nobel laureate Herbert Kroemer coined the famous phrase that "the interface is the device", he referred to the

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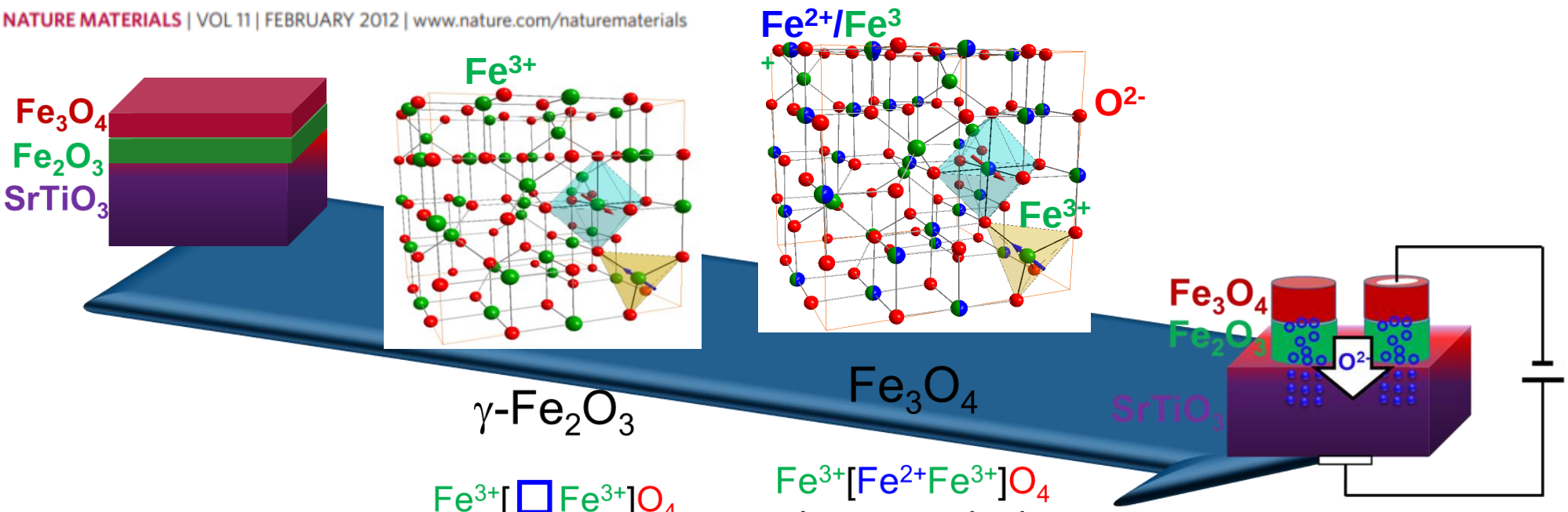


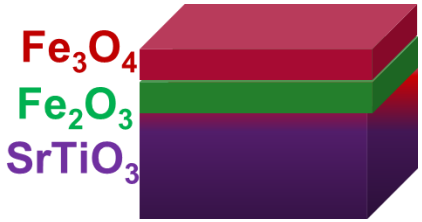
$Fe^{3+}[\square Fe^{3+}]O_4$
Defect spinel
Ferrimagnetic
$2.5\mu_B$/f.u.
Insulator

$Fe^{3+}[Fe^{2+}Fe^{3+}]O_4$
Inverse spinel
Ferrimagnetic
$4\mu_B$/f.u.
Half-metal

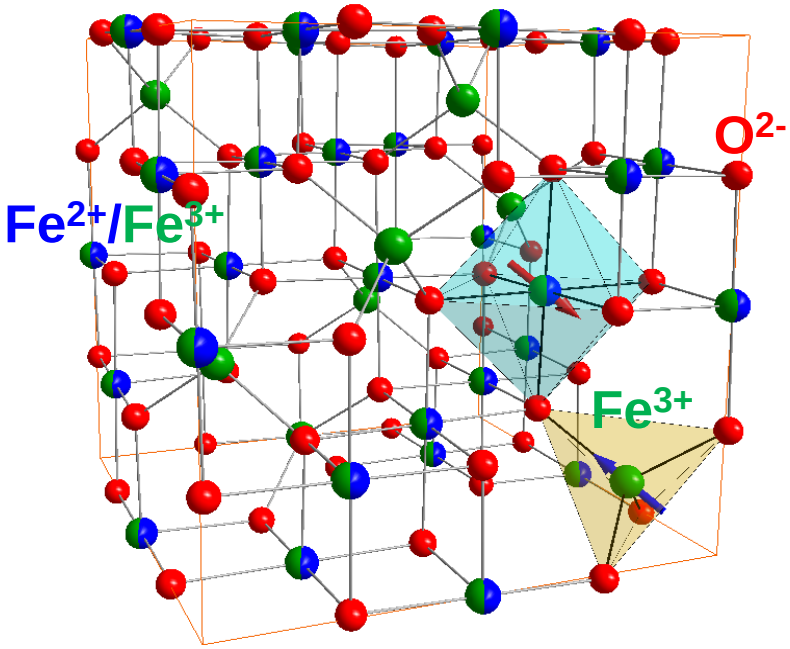
JÜLICH
Forschungszentrum

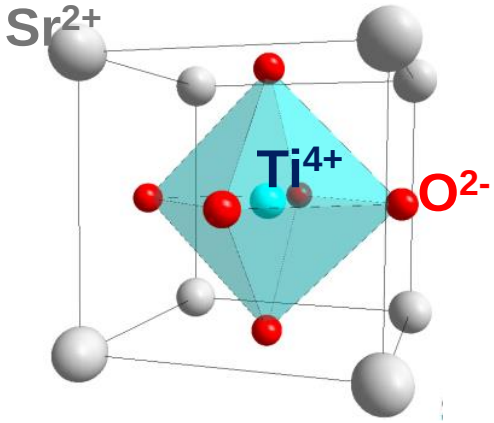
Motivation and Introduction

$SrTiO_3$ Substrate and Magnetite



$SrTiO_3$ Insulator
$Nb:SrTiO_3$ Conductor





TiO_2 terminated STO
$Ti^{4+} \rightarrow Ti^{3+}$
O^{2-}

SrO terminated STO
O^{2-}

$a_{Fe_3O_4}$=8.395 Å

a_{STO}=3.905 Å

Compressive Mismatch

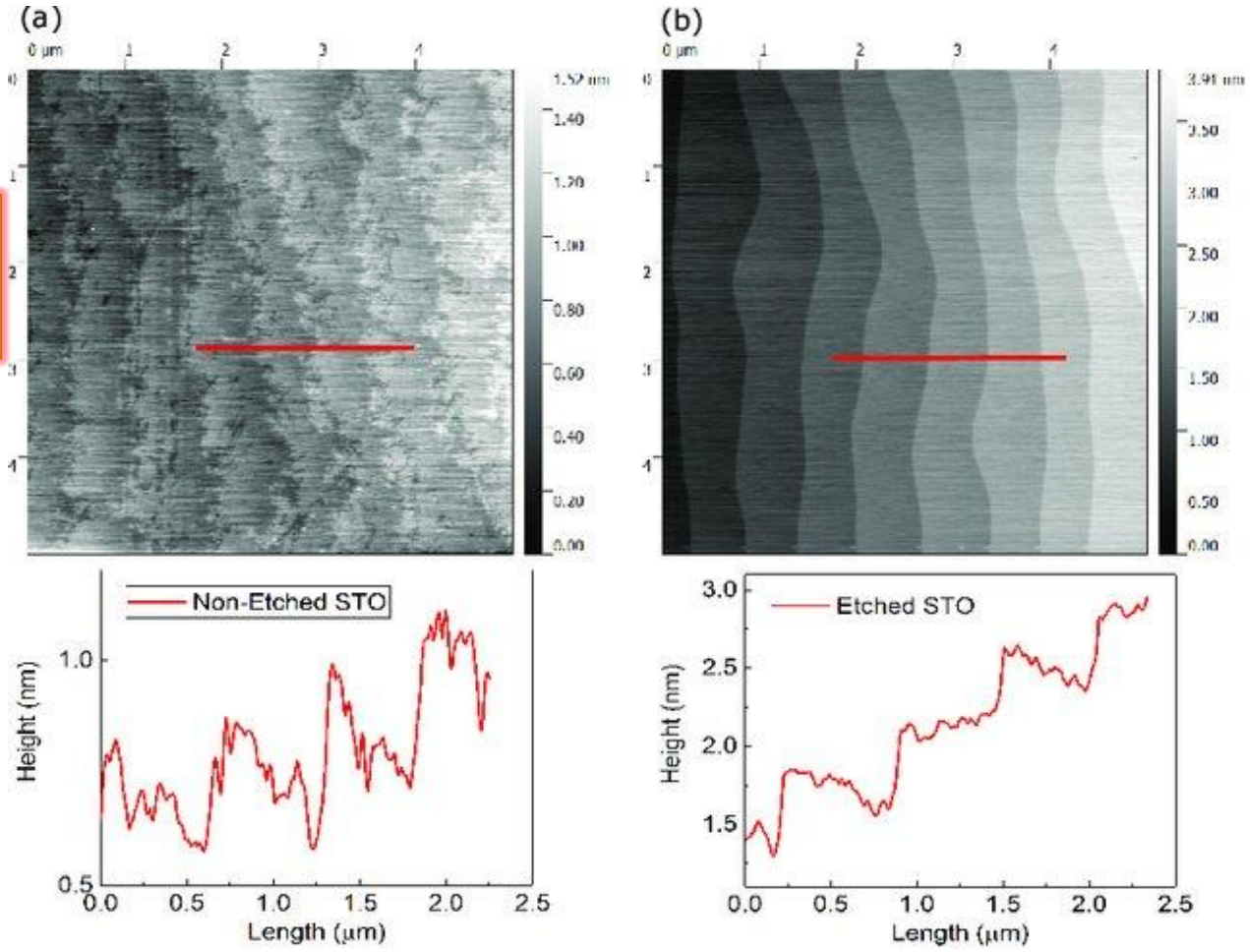
$$\varepsilon = \frac{2a_{sub} - a_{film}}{a_{film}} \approx -7.5\%$$

Terminated $SrTiO_3$: TiO_2

TiO_2 terminated STO

$Ti^{4+} \rightarrow Ti^{3+}$

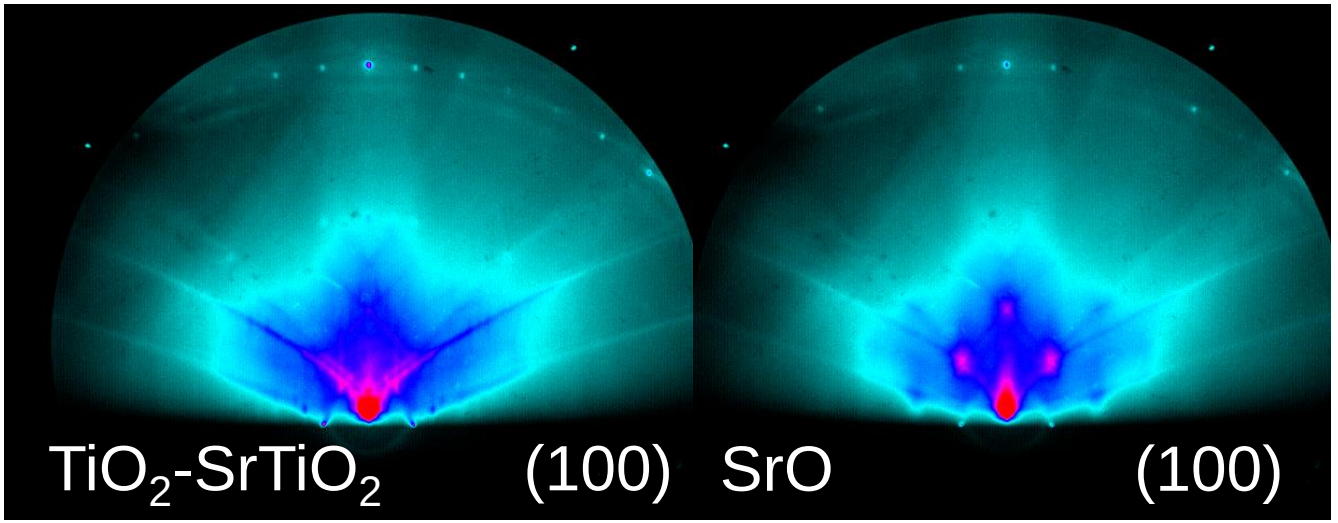
By chemical etching and annealing procedures



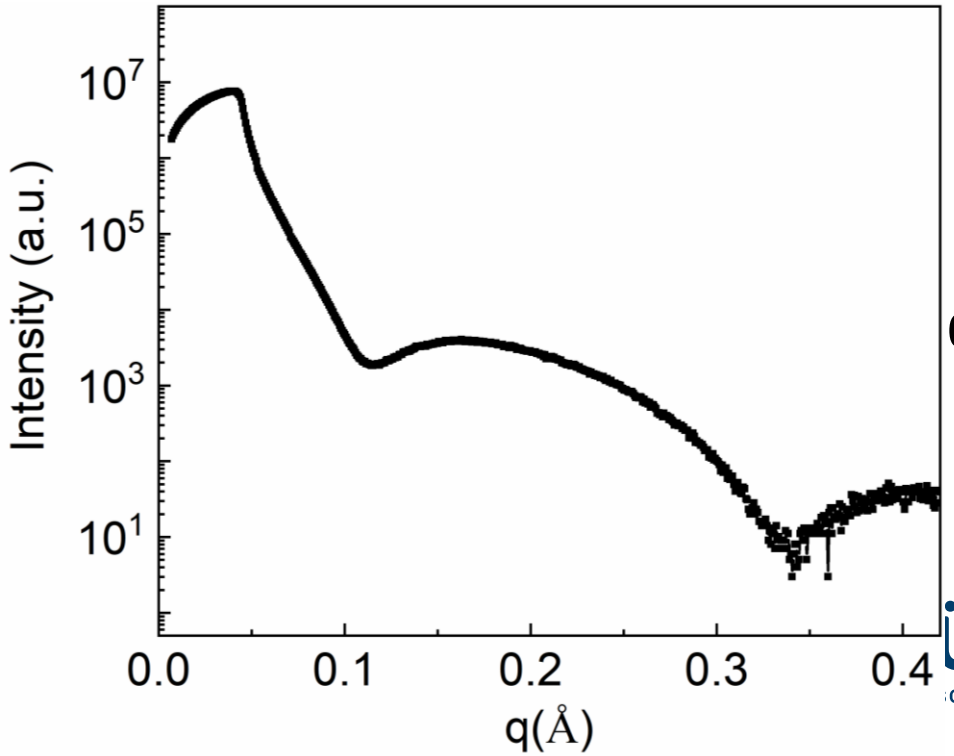
M.H. Hamed, PhD Thesis

Terminated $SrTiO_3$: SrO

SrO terminated STO

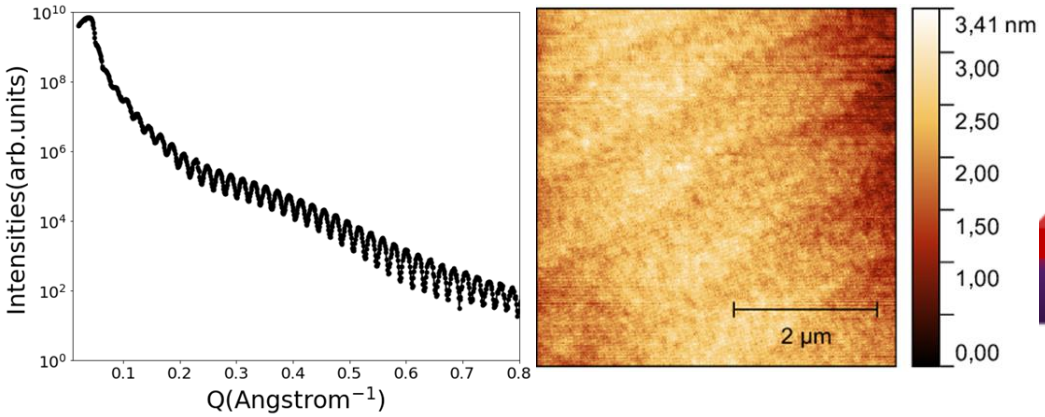


By growing one monolayer by MBE @250°C



d=1.7nm

Experimental Details



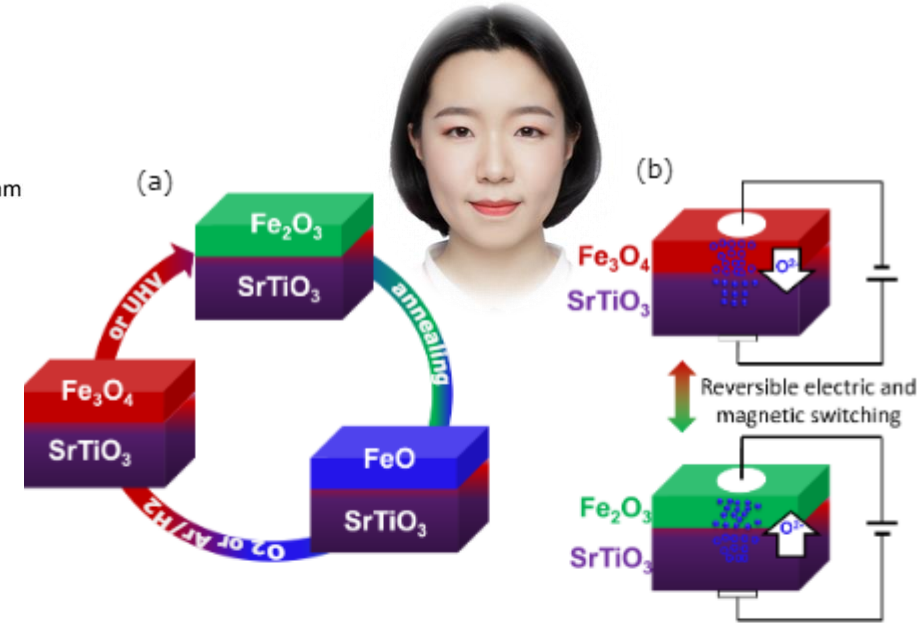
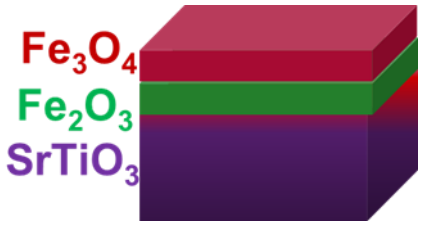
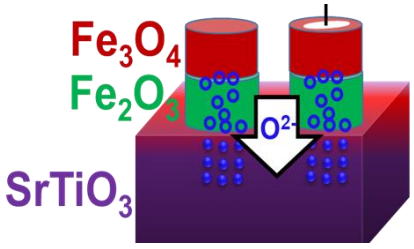
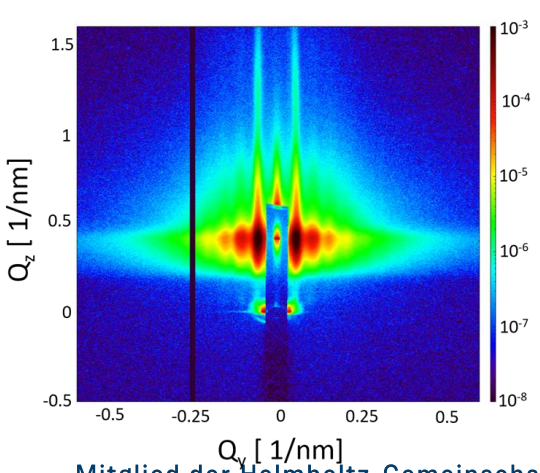
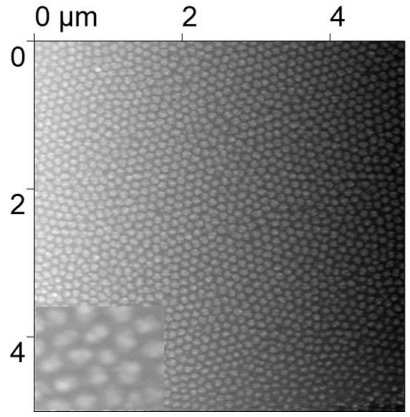


Figure 1: Interfacial oxygen exchange through the active oxide interfaces motivates a reversible switching of complex oxide heterostructures via (a) annealing at different atmosphere of O2, Ar/H2 or UHV and (b) applied electric field.







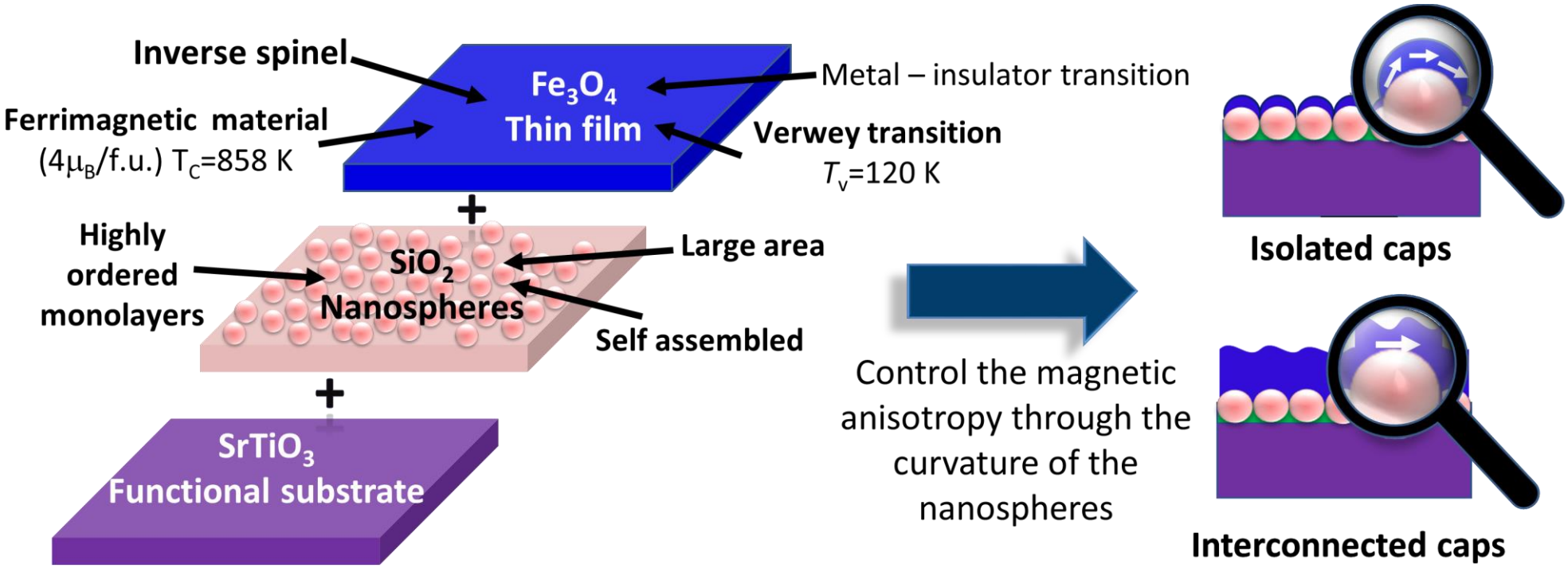


2 Timeframe

	Task	Tool	Locate	Time
(1)	Controlling the substrate surfaces:			8 months
	*Etching the STO substrate to get TiO_2 terminated surface.	Clean room	PGI7	
	*Growing one mono-layer of SrO.	MBE	JCNS2	
	Optimizing growth of Fe_3O_4.	PLD/ MBE	PGI7/ JCNS2	
	Investigating formation of 2DEG or 2DHG at the interfaces.	HAXPES	P22-DESY	
		XAS/XMCD	SOLEIL	
		PNR	MLZ	
(2)	Optimizing growth of $Fe^{57}{}_3O_4$.	MBE	JCNS2	9 months
	Characterizing the films using in-house lab techniques.	XRR/XRD	JCNS2	
		AFM/MFM		
		VSM/SQUID		
		4 Circle		

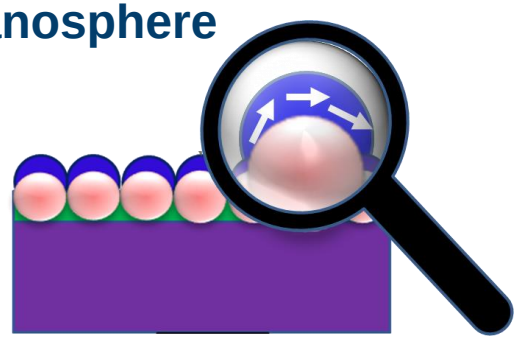
Tuning interface by curvature

Isolated vs. interconnected caps of Fe_3O_4 thin film on SiO_2 nanosphere



Tuning interface by curvature

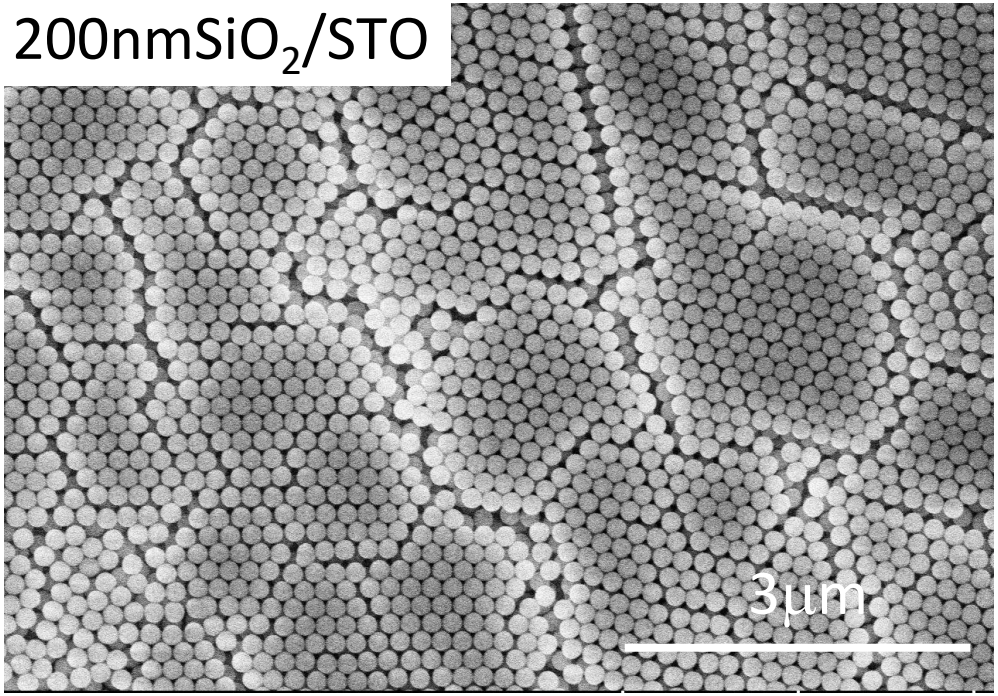
Isolated vs. interconnected caps of Fe_3O_4 thin film on SiO_2 nanosphere



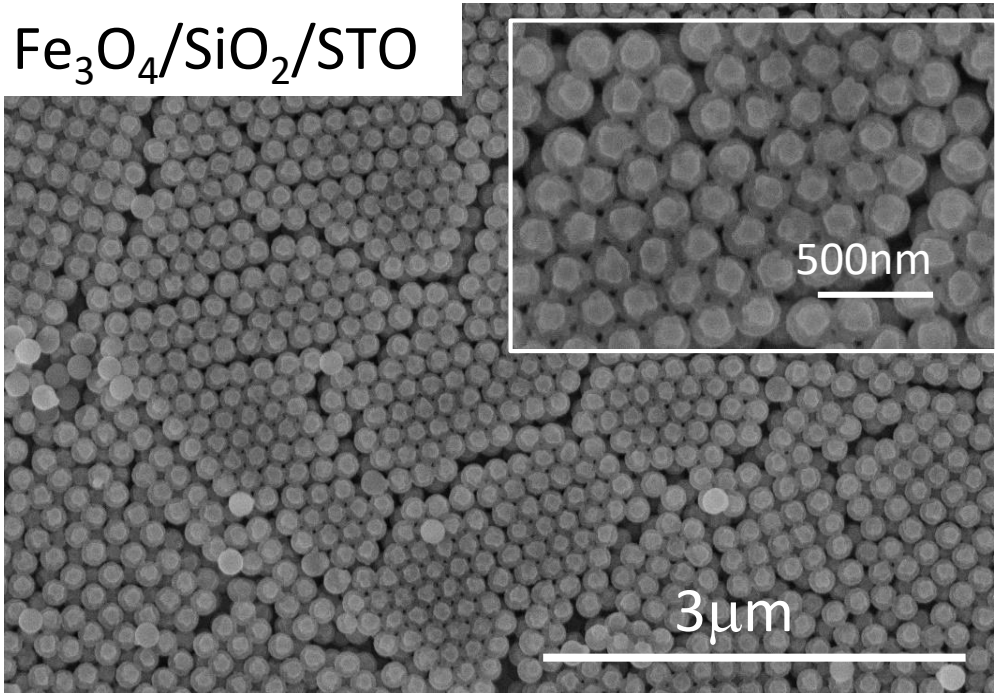
Isolated caps of 30nm Fe_3O_4 on 200nm SiO_2

SEM

$200nmSiO_2/STO$



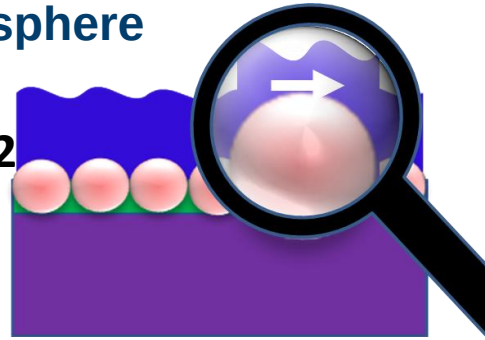
$Fe_3O_4/SiO_2/STO$



XRR, XRD, GISAXS, AFM….Poster

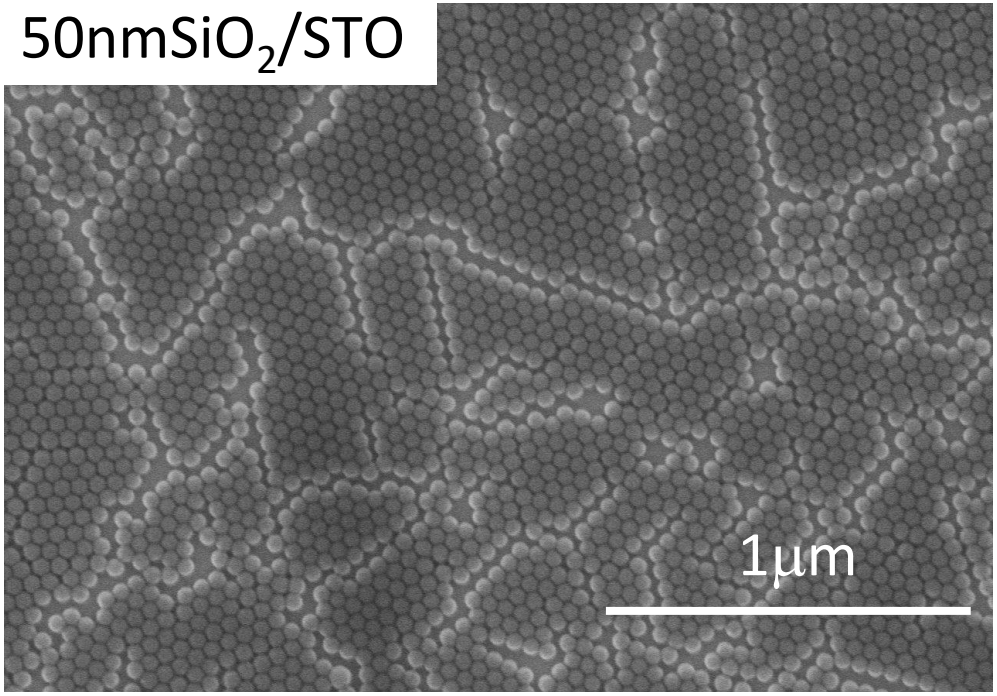
Tuning interface by curvature

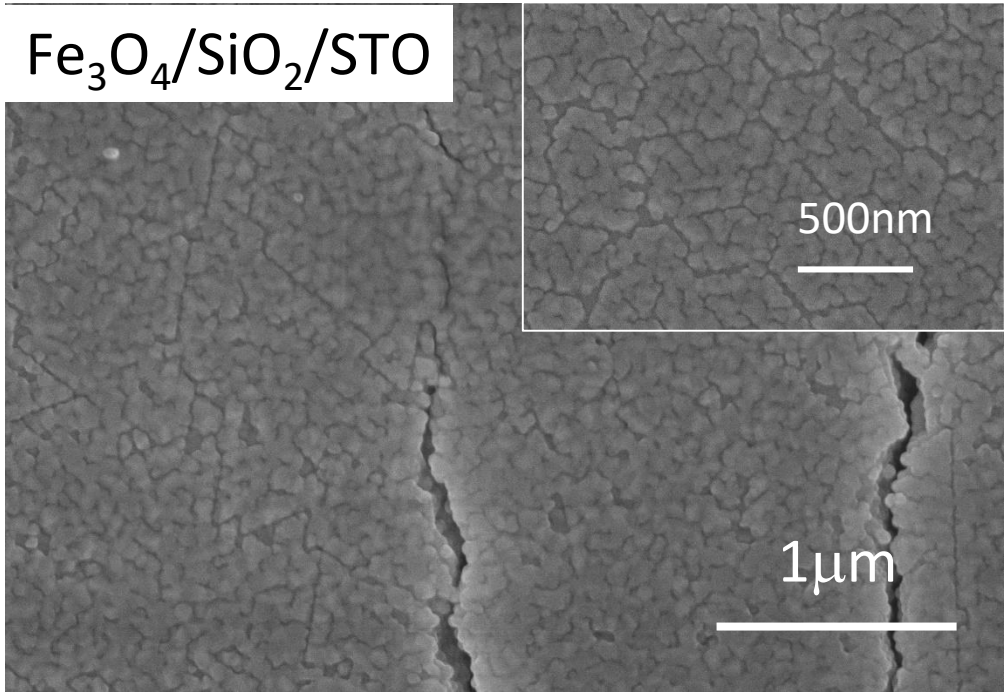
Isolated vs. interconnected caps of Fe_3O_4 thin film on SiO_2 nanosphere



Interconnected caps of 30nm Fe_3O_4 on 50nm SiO_2

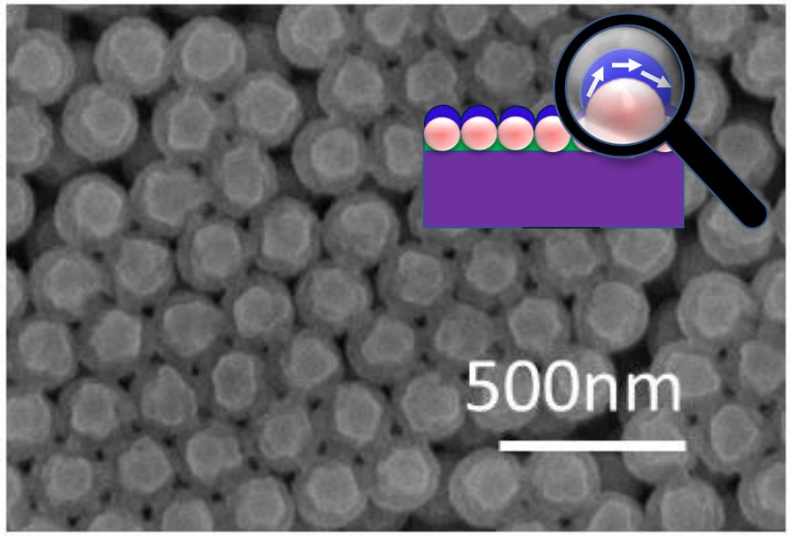
SEM

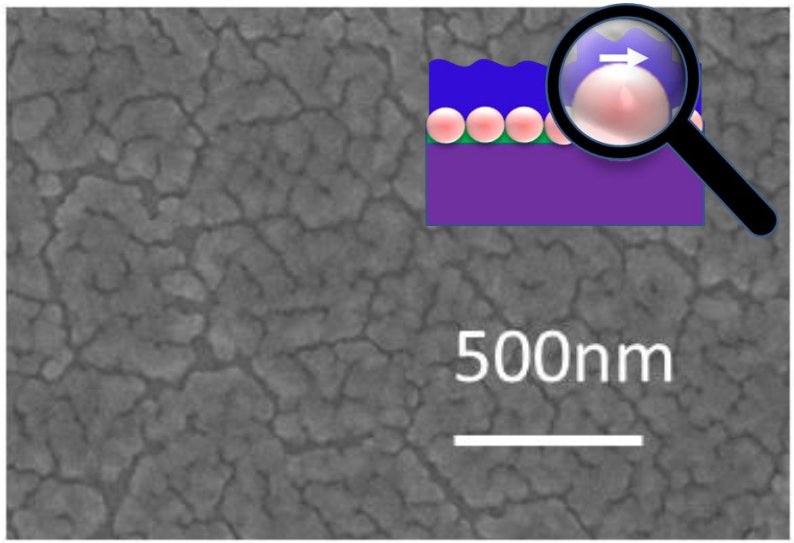


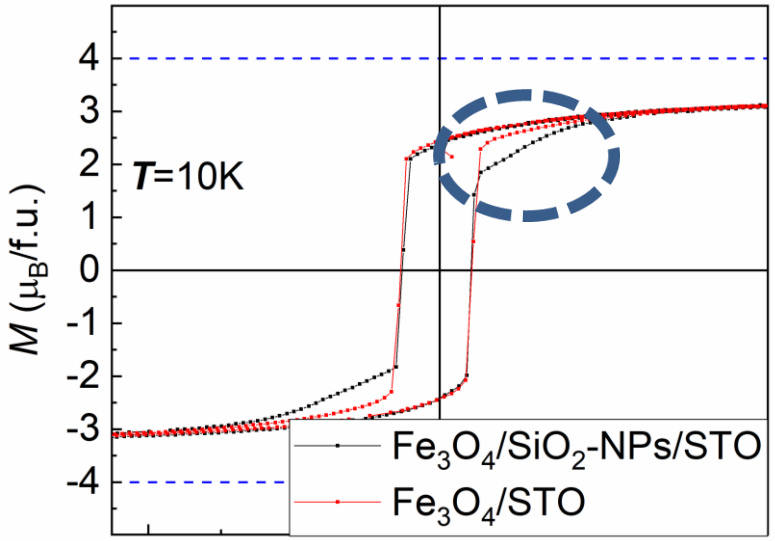


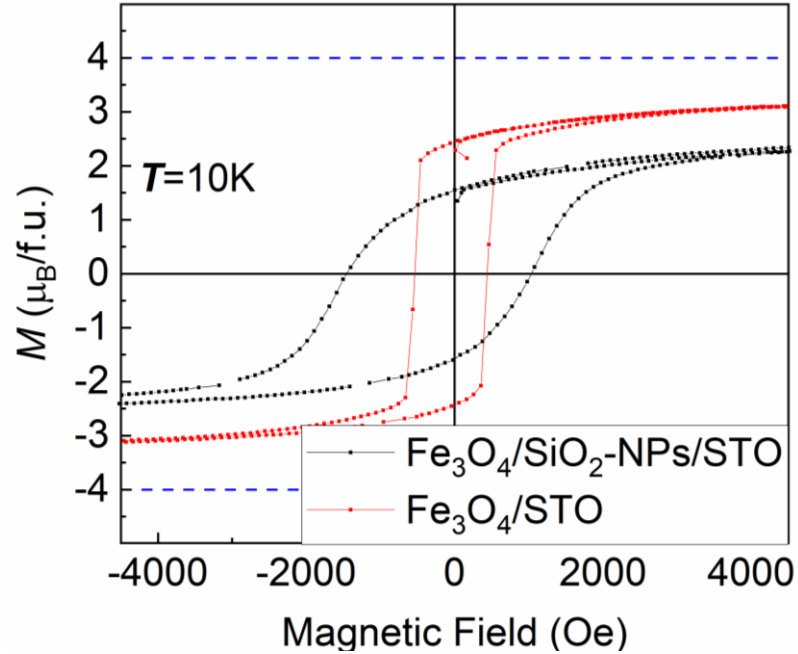
Tuning interface by curvature

Isolated vs. interconnected caps of Fe_3O_4 thin film on SiO_2 nanosphere: SQUID



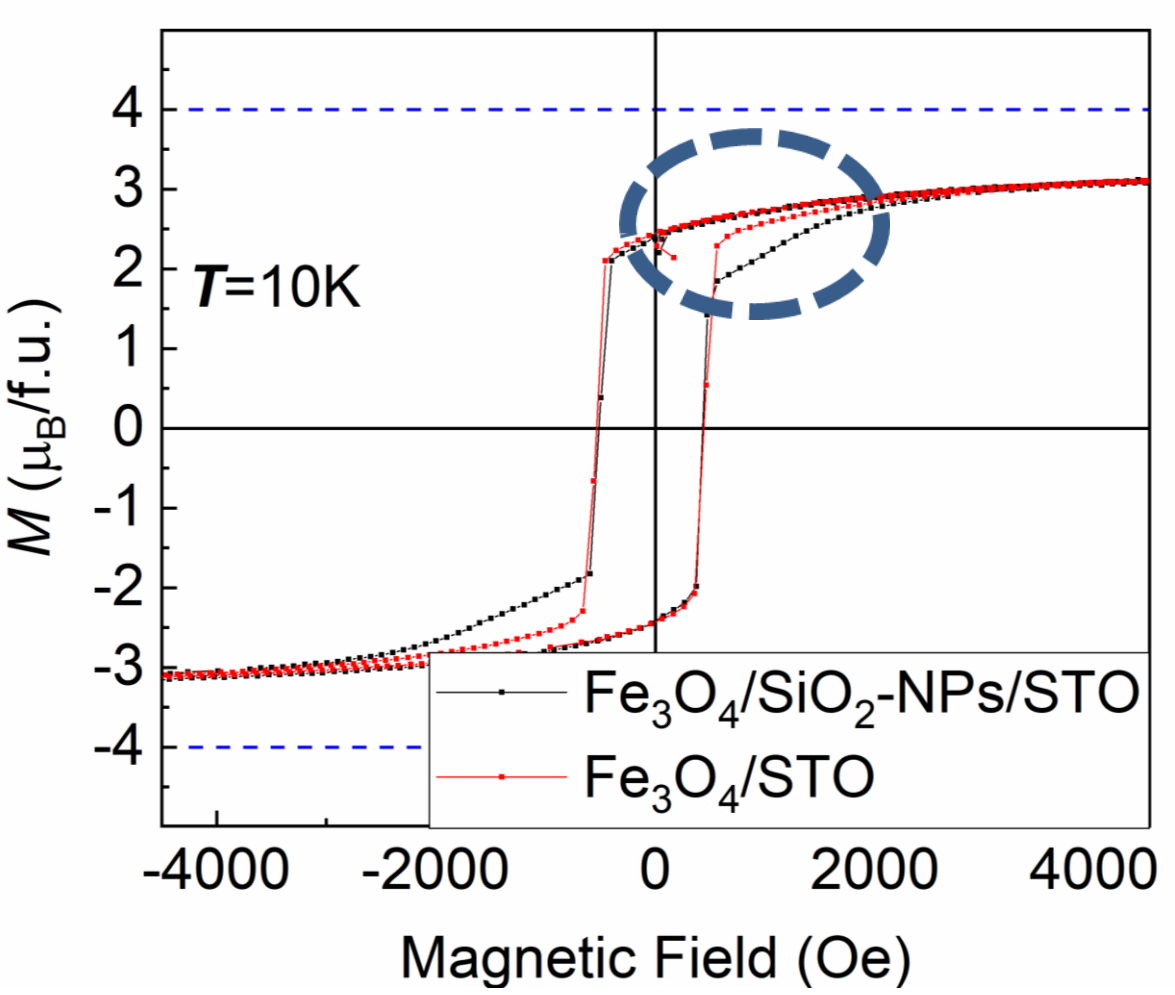


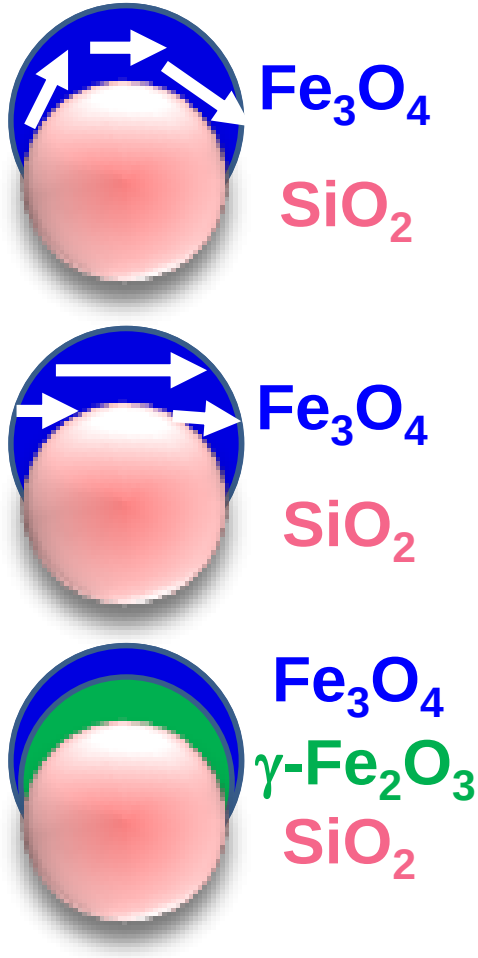




Tuning interface by curvature

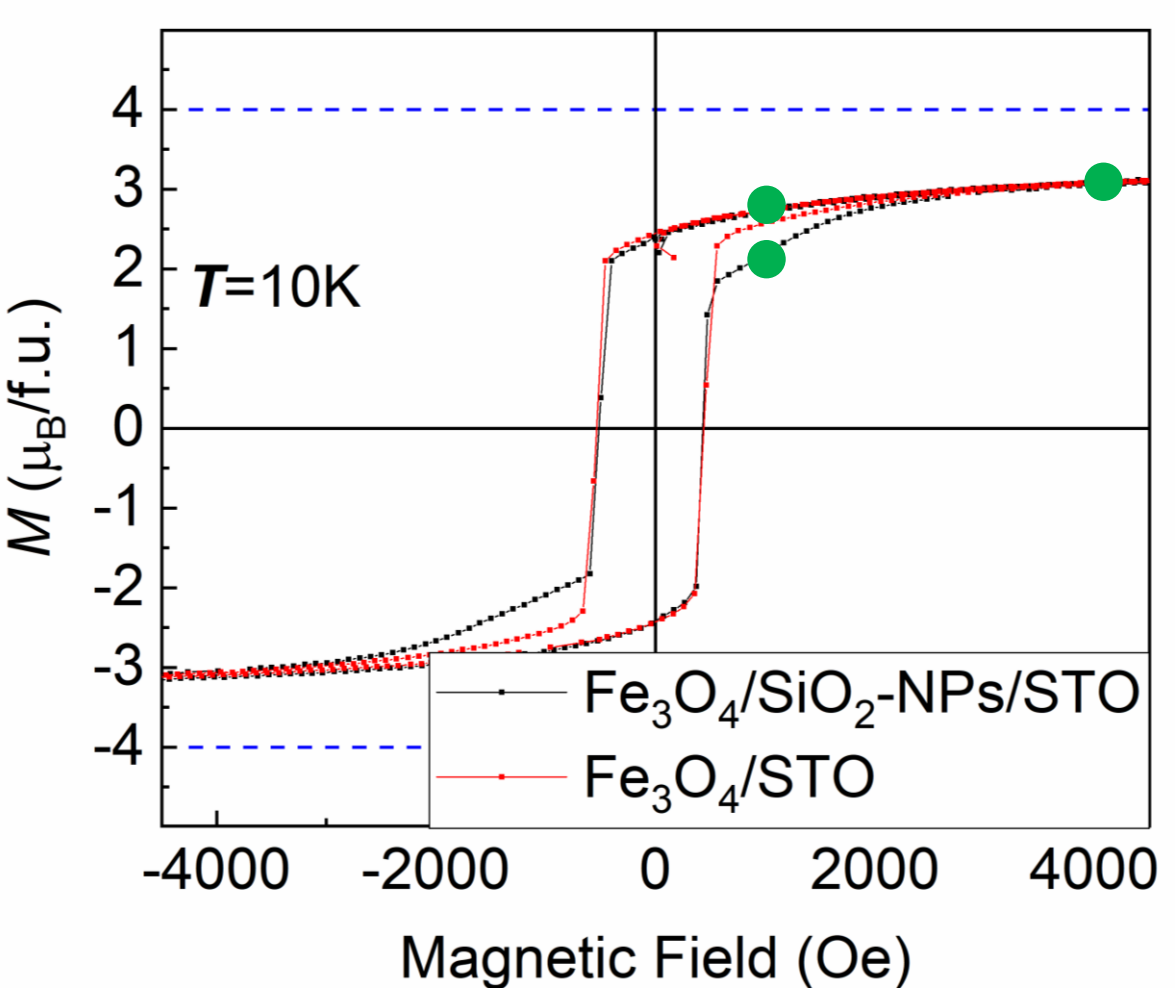
Isolated caps of 30nm Fe_3O_4 thin film on 200nm SiO_2 nanosphere: SQUID





Tuning interface by curvature

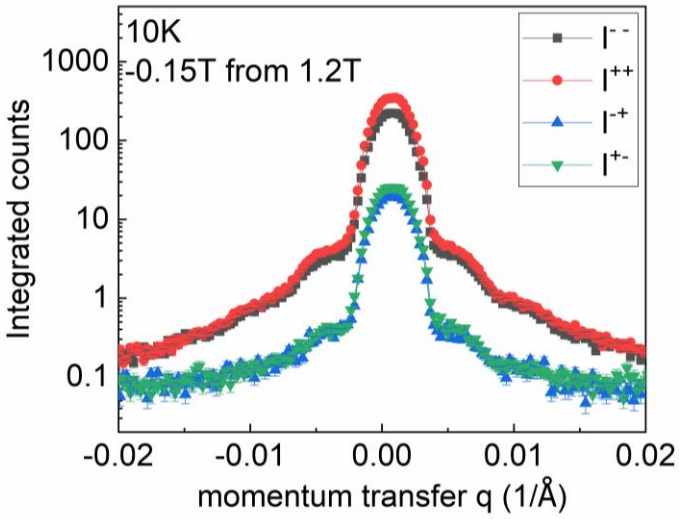
Isolated caps of 30nm Fe_3O_4 thin film on 200nm SiO_2 nanosphere
Magnetic lateral distribution: GISANS

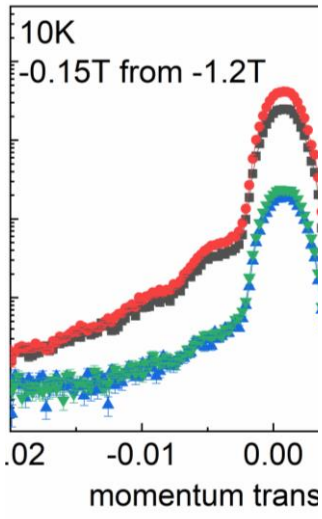


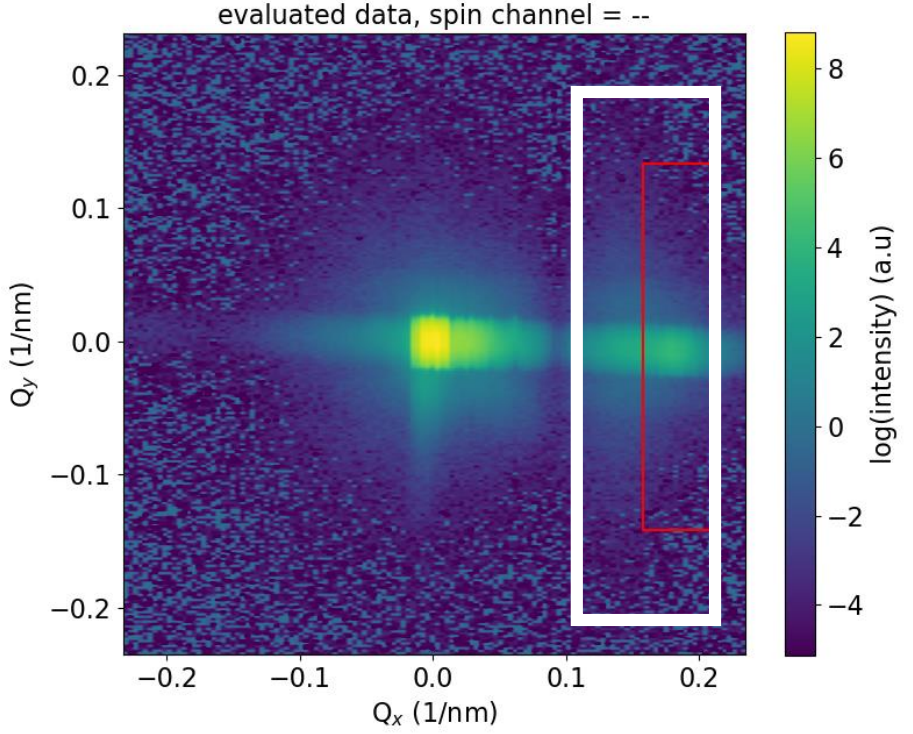
Tuning interface by curvature

Isolated caps of 30nm Fe_3O_4 thin film on 200nm SiO_2 nanosphere

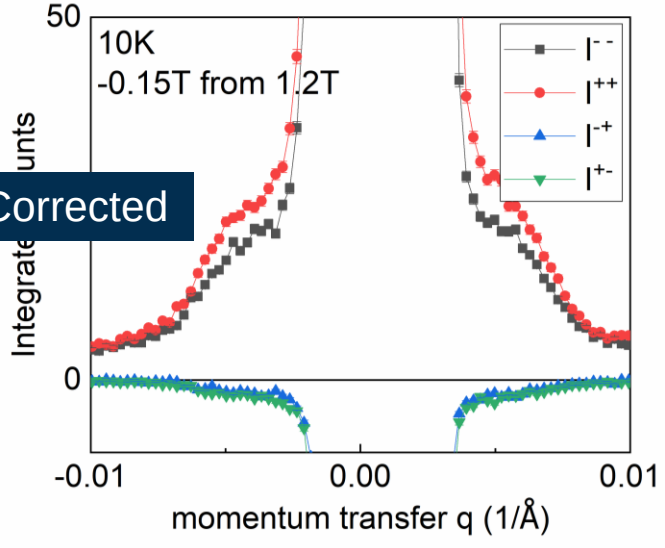
Magnetic lateral distribution: GISANS

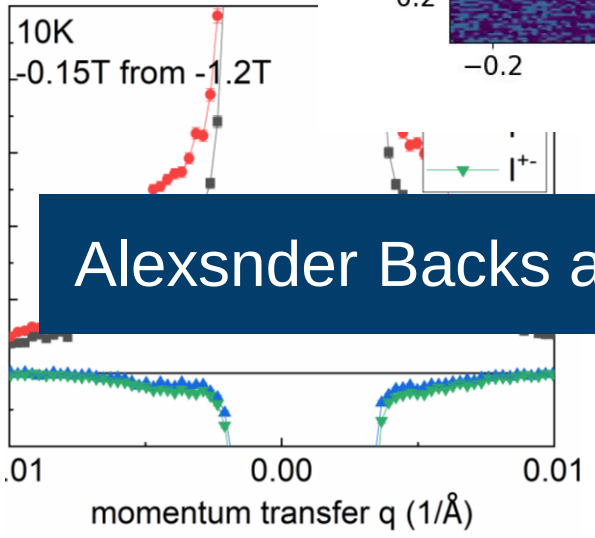


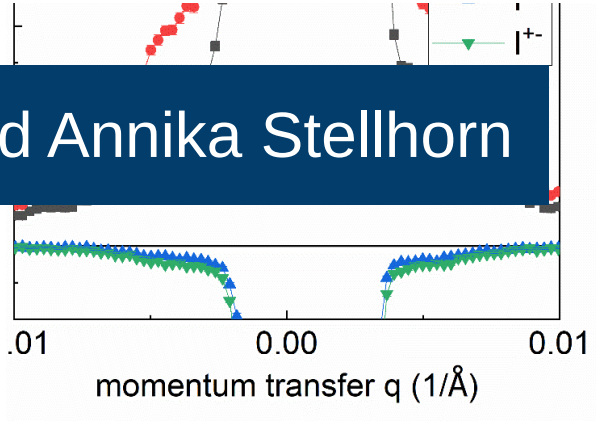




Corrected



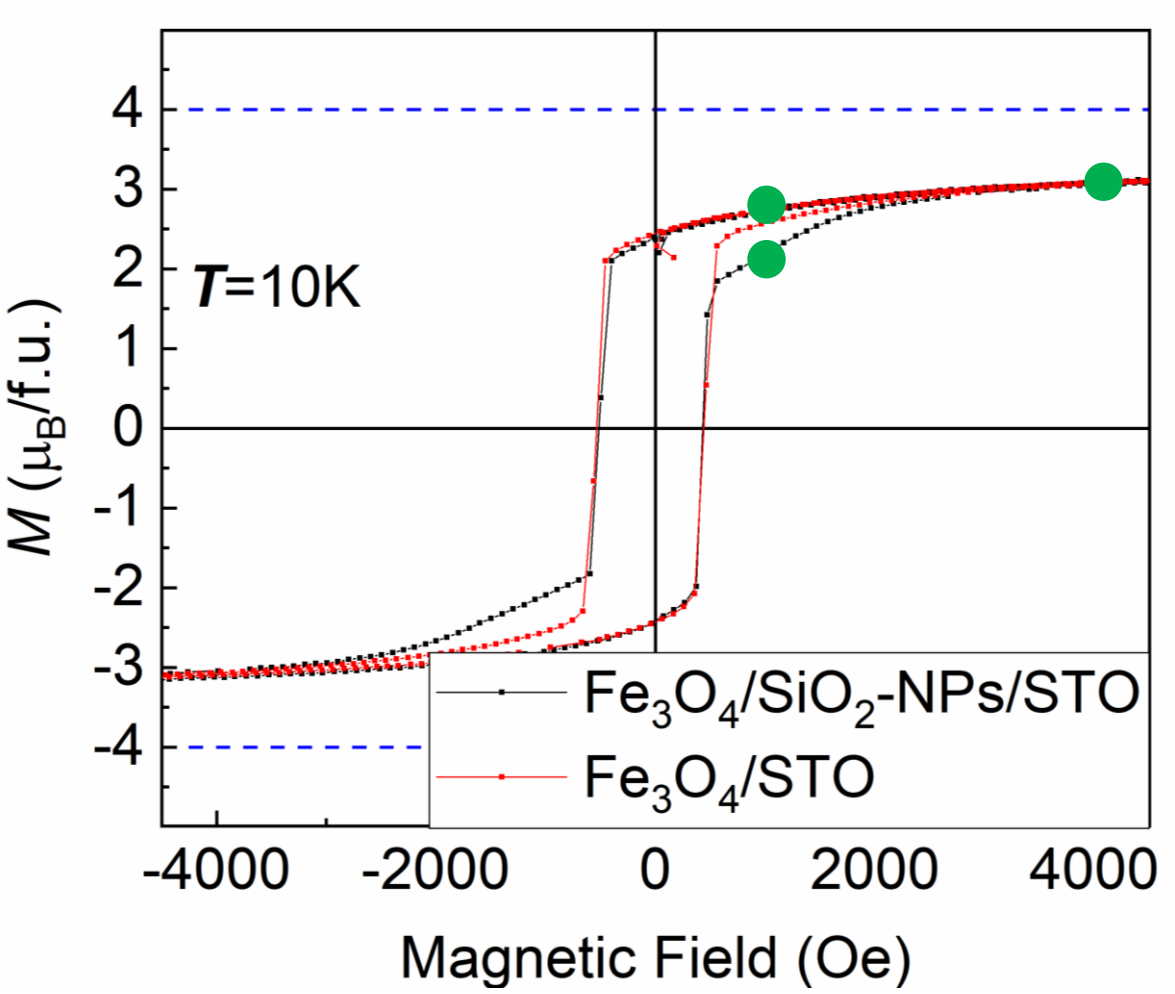


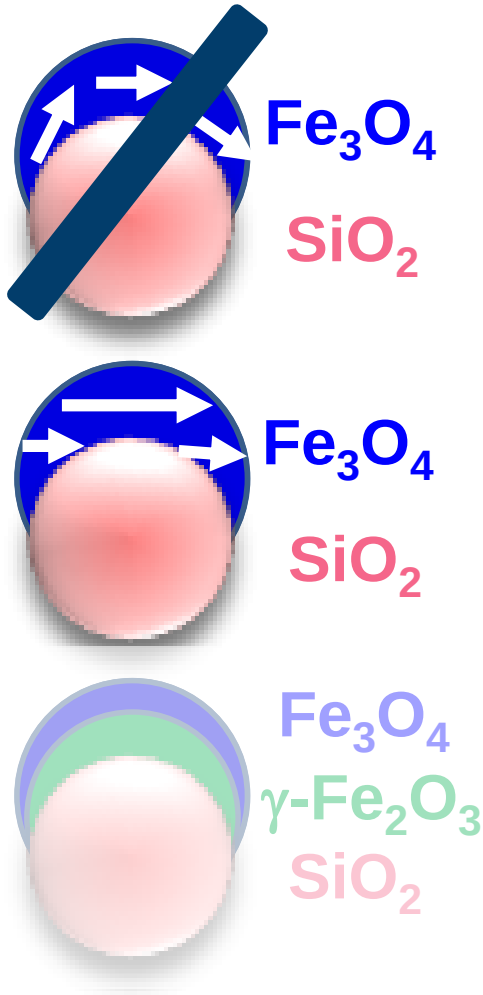


Alexsnder Backs and Annika Stellhorn

Tuning interface by curvature

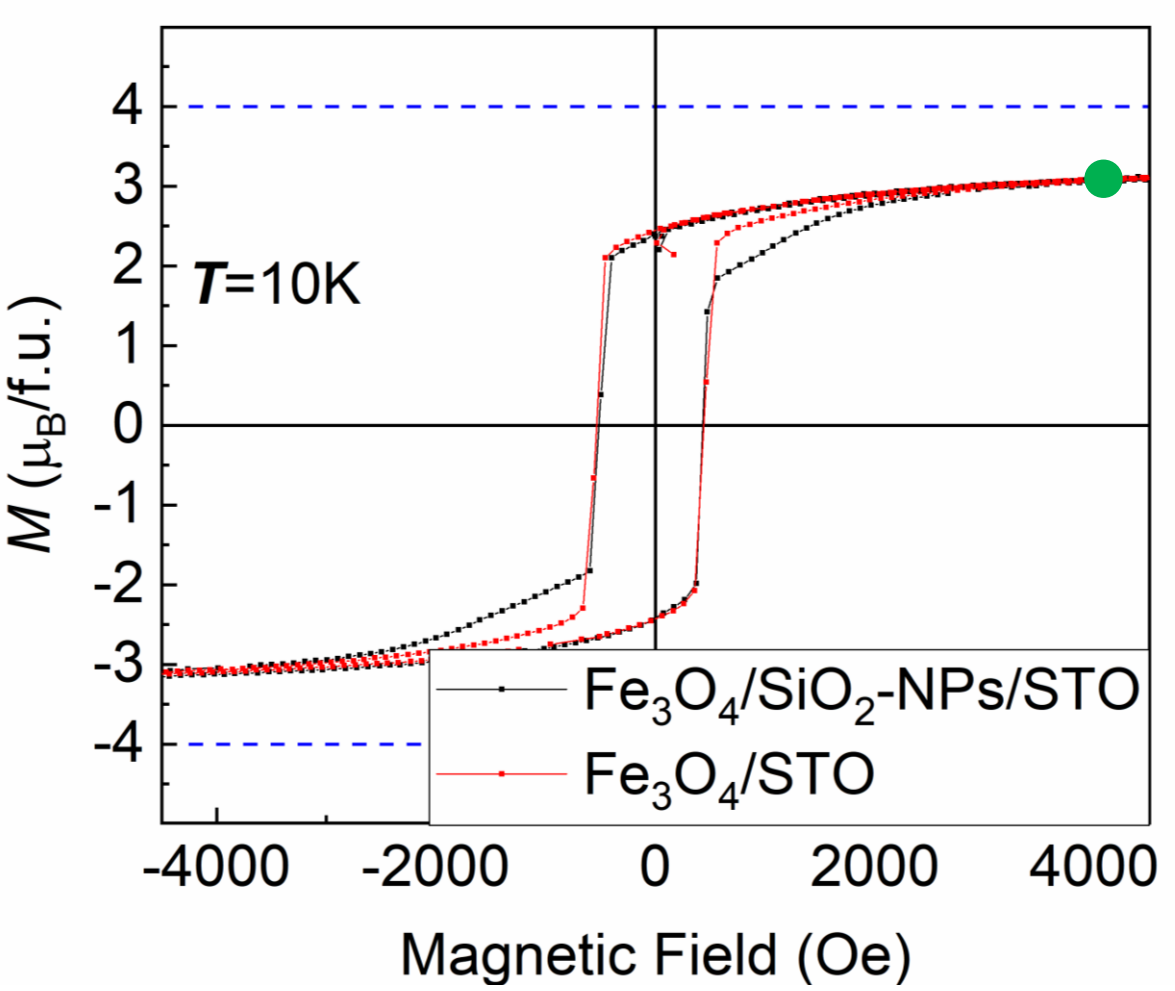
Isolated caps of 30nm Fe_3O_4 thin film on 200nm SiO_2 nanosphere
Magnetic lateral distribution: GISANS

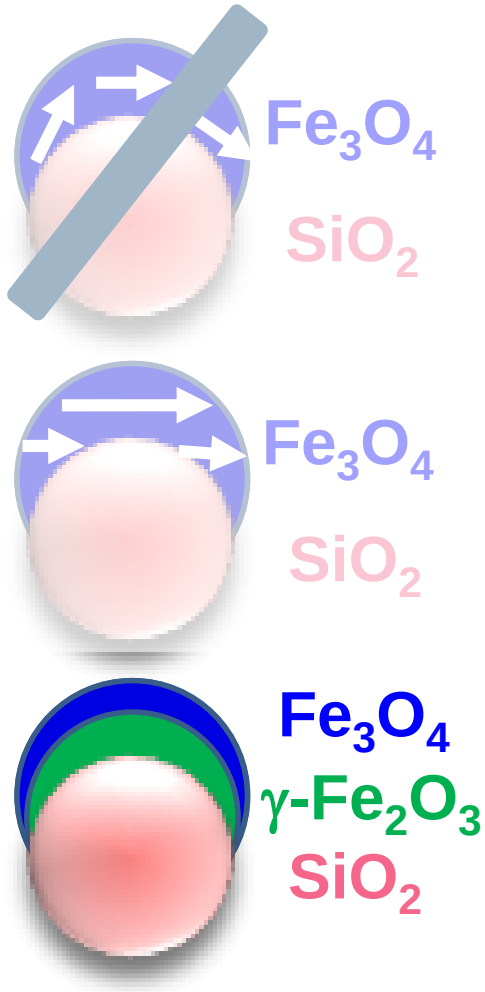




Tuning interface by curvature

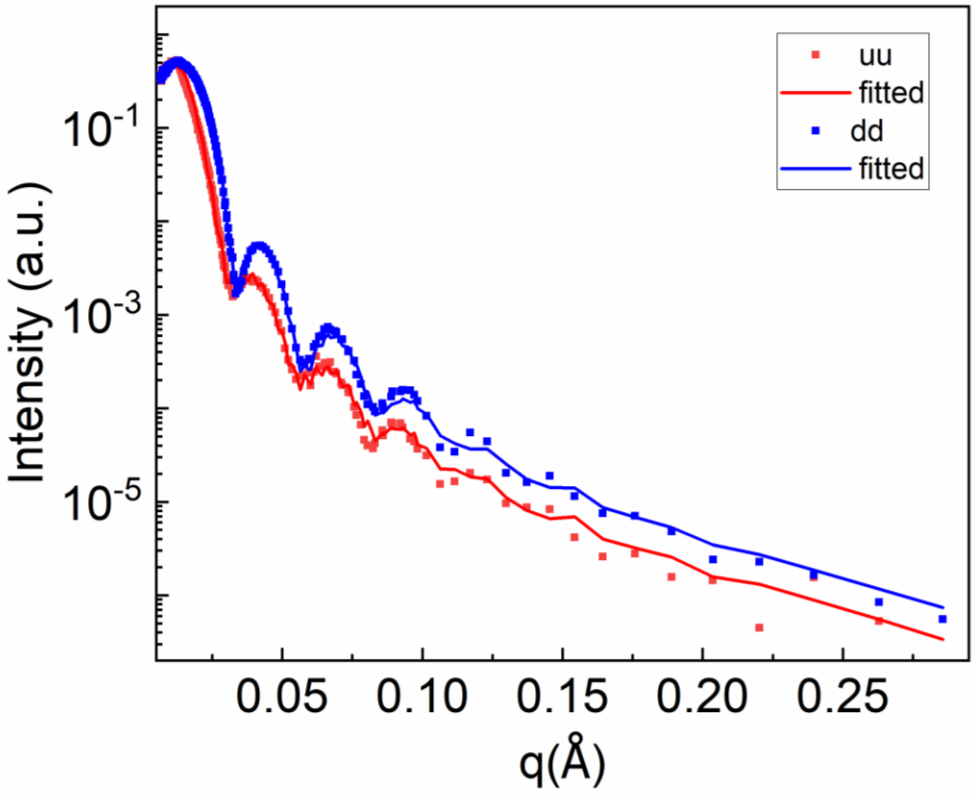
Isolated caps of 30nm Fe_3O_4 thin film on 200nm SiO_2 nanosphere
Magnetic depth resolved: PNR

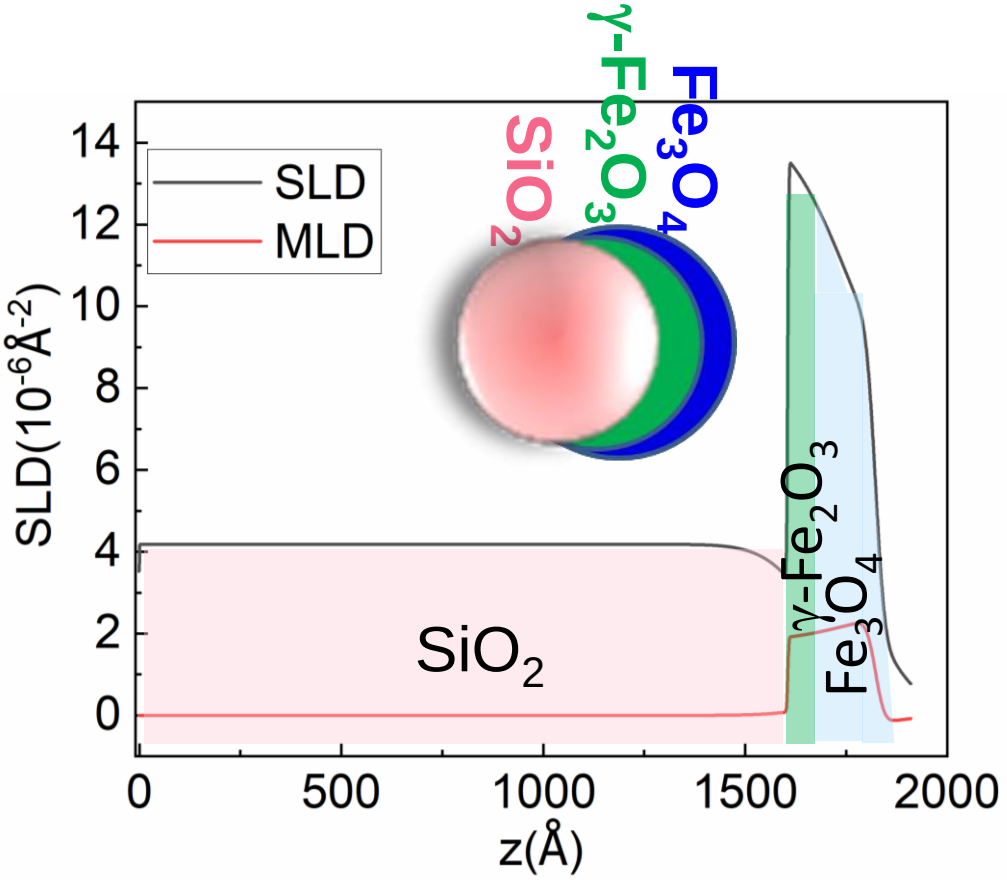




Tuning interface by curvature

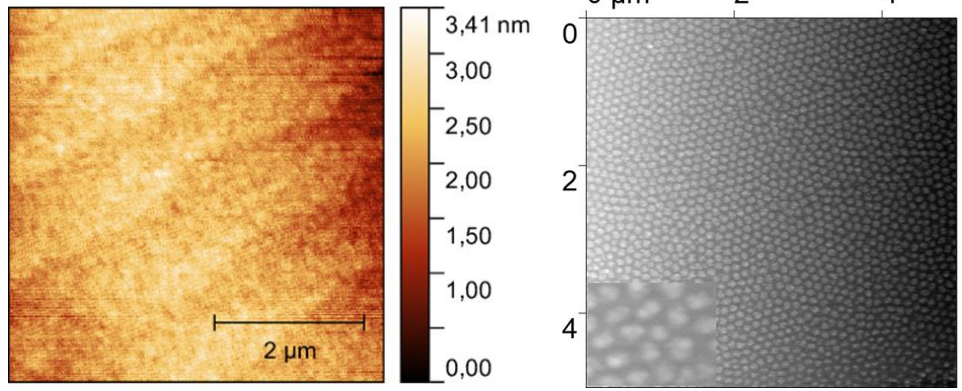
Isolated caps of 30nm Fe_3O_4 thin film on 200nm SiO_2 nanosphere
Magnetic depth resolved: PNR



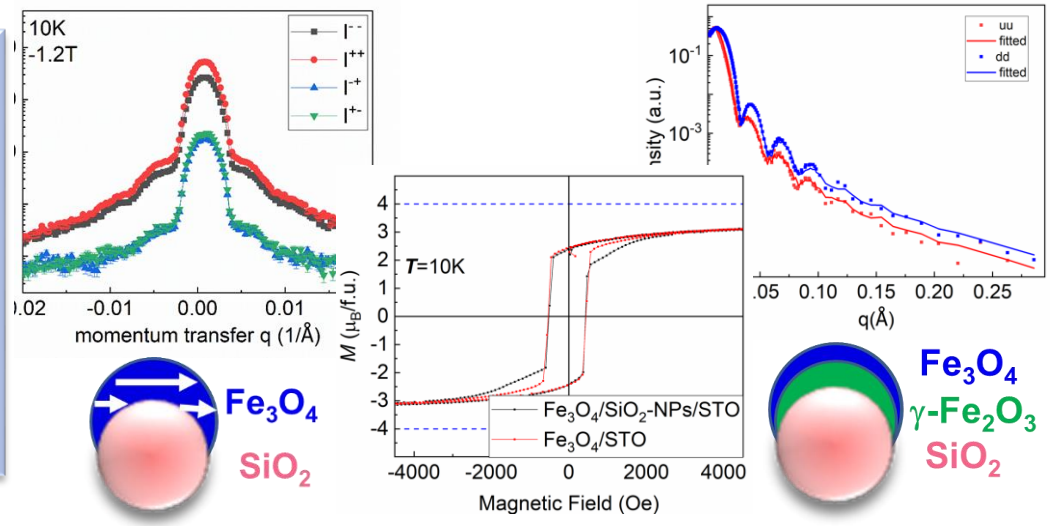


SUMMARY

- One monolayer of SrO by MBE.
- Tune the interface of Fe_3O_4 thin films and nanodots.

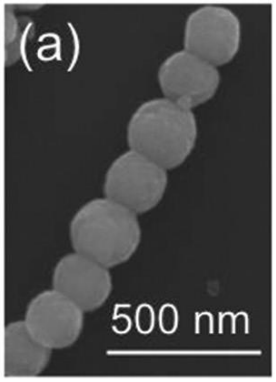


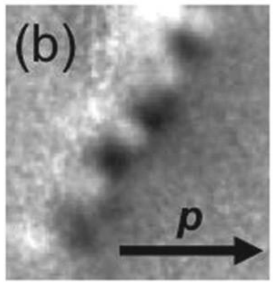
- Fe_3O_4 magnetism follow the curvature of the SiO_2 spheres.
- Redox interactions at the interfaces between the thin film and nanospheres.

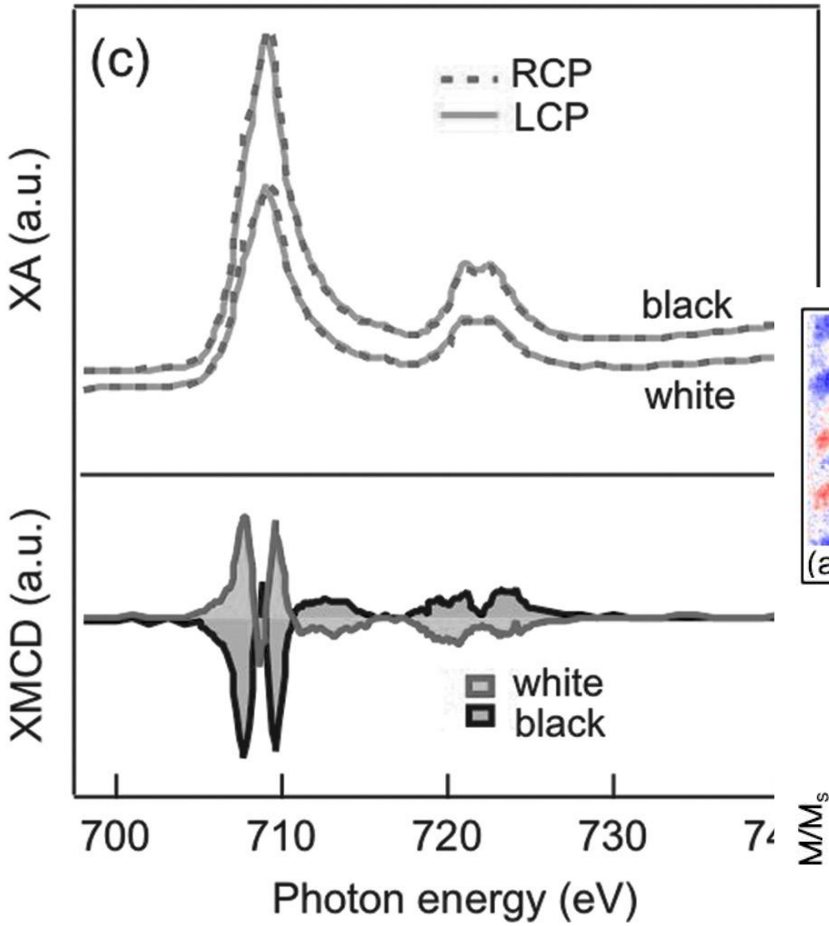


Outlook

Spin Structure: Photoemission electron microscopy (PEEM)







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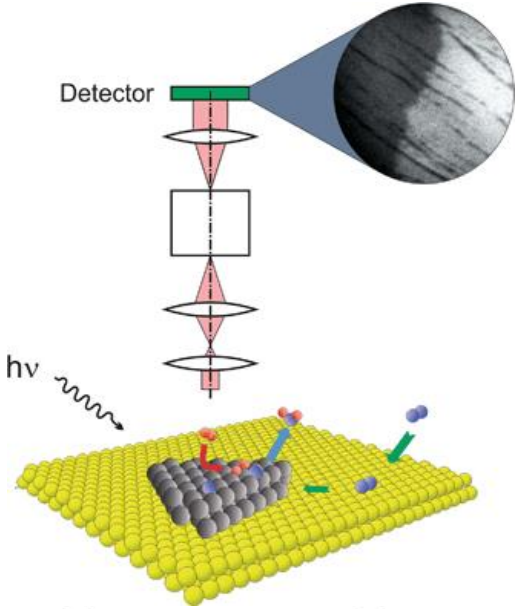

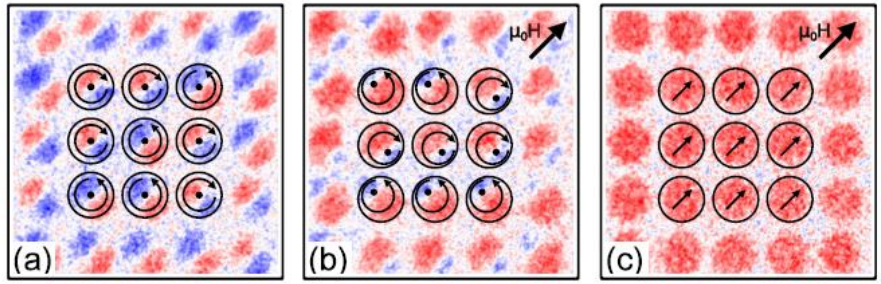

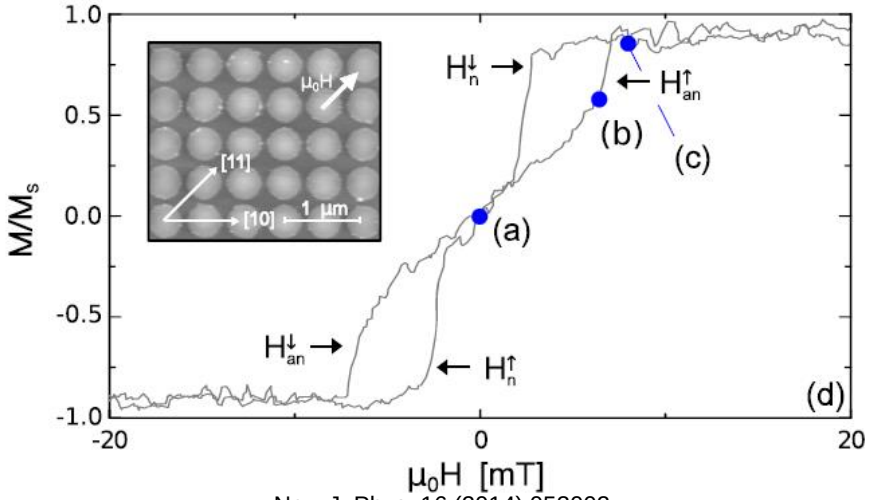

New J. Phys. 16 (2014) 053002

Scheduled PEEM 25-31 March

ACKNOWLEDGMENTS

JCNS2

Asmaa Qdemat
Yifan Xu
Connie Bednarski-Meinke
Steffen Tober
Chenyang Yin
Vitor Lima

Ulrich Rü
Emmanuel Kentzinger
Oleg Petracic
Thomas Brückel

Technical Support

Frank Gossen
Thomas Janssen
Grigory Potemkin
Georg Pickartz

DEIMOS, SOLEIL

Patrick Schöffmann

SIXS, SOLEIL

Alessandro Coati

P23, DESY

P22, DESY

Andrei Gloskovskii
Christoph Schlueter

MAGREF, SNS

Valeria Lauter

POLREF, ISIS

Andrew Caruana
Christy Kinane

L
ane Steinke

D17, ILL

Thomas Saerbeck

Thank you for your attention

Science and Technology Facilities Council
ISIS Neutron and Muon Source

SNS SPALLATION NEUTRON SOURCE

NEUTRONS FOR SOCIETY

DESY.

SOLEIL SYNCHROTRON

JÜLICH Forschungszentrum

Mitglied der Helmholtz-Gemeinschaft