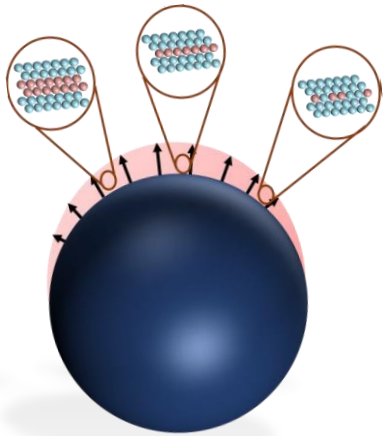
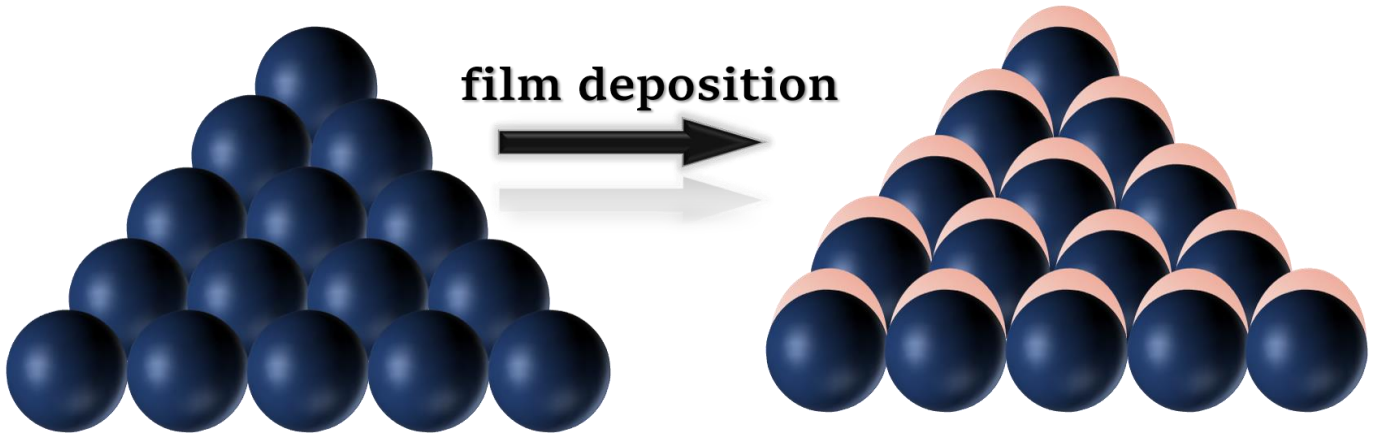
Curvature-modulated structural and magnetic properties of thin films deposited onto highly ordered nanosphere arrays

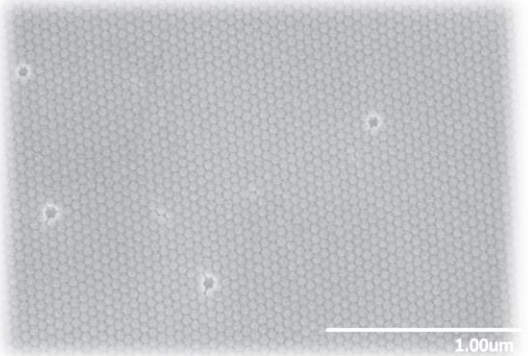
Asmaa Qdemat, Emmanuel Kentzinger, Johan Buitenhuis, Sabine Pütter, Mai Hussein Hamed, Connie Bednarski-Meinke, Oleg Petracic, and Thomas Brückel

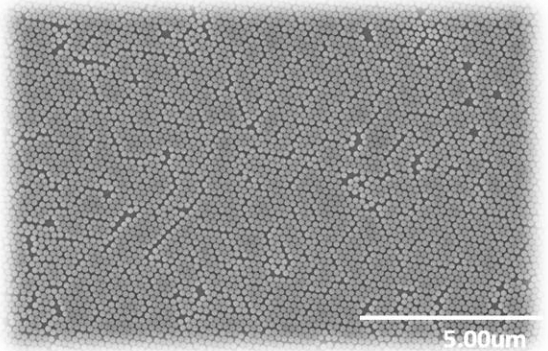


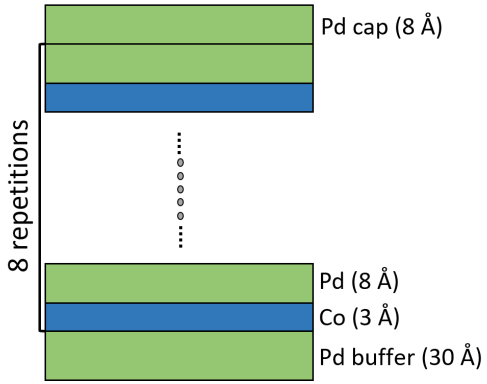


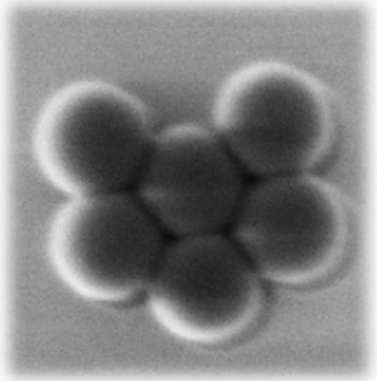
Outline

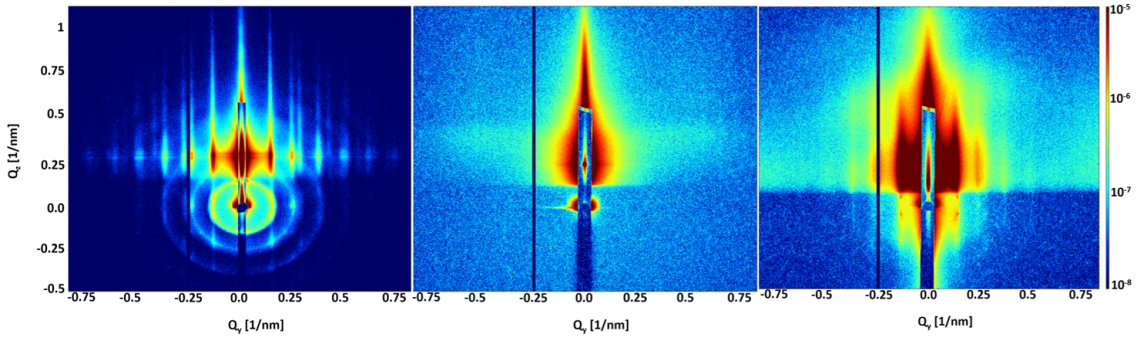
- Introduction & Motivation
- Magnetic nanocaps fabrication
  - Monolayer formation
  - Film deposition
- $[Co/Pd]_8$
  - 50 nm SiO_2 nanospheres
  - 200 nm SiO_2 nanospheres
- Summary & Outlook

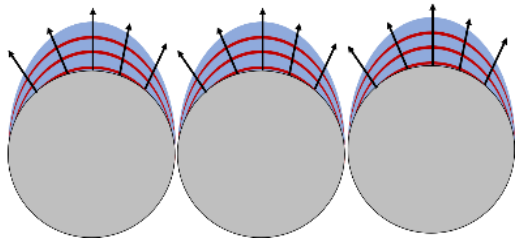












Introduction & Motivation

Jülich Centre for Neutron Science

Magnetic Nanostructures

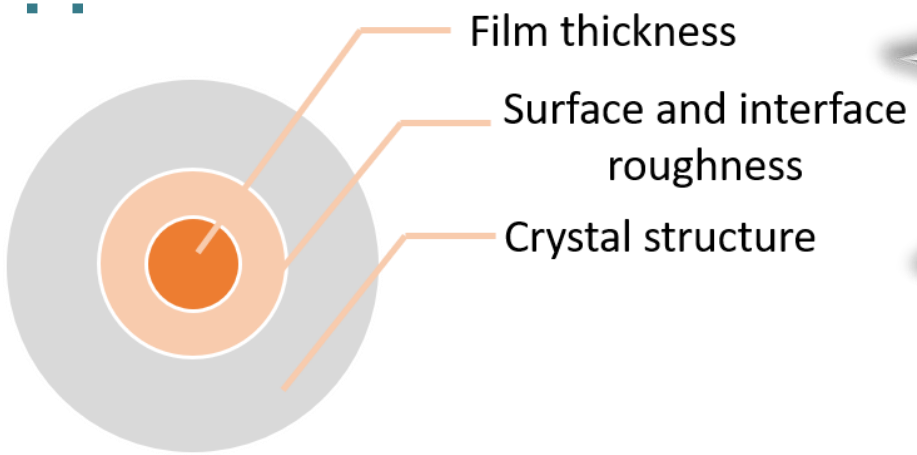
- fundamental science
- Industrial applications

Why???

novel magnetic properties

How properties of magnetic films can be tailored ????

Microstructural parameters

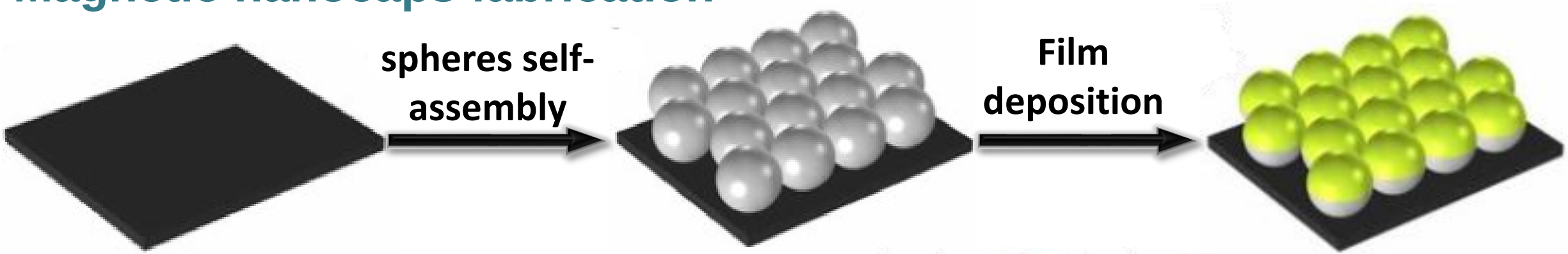


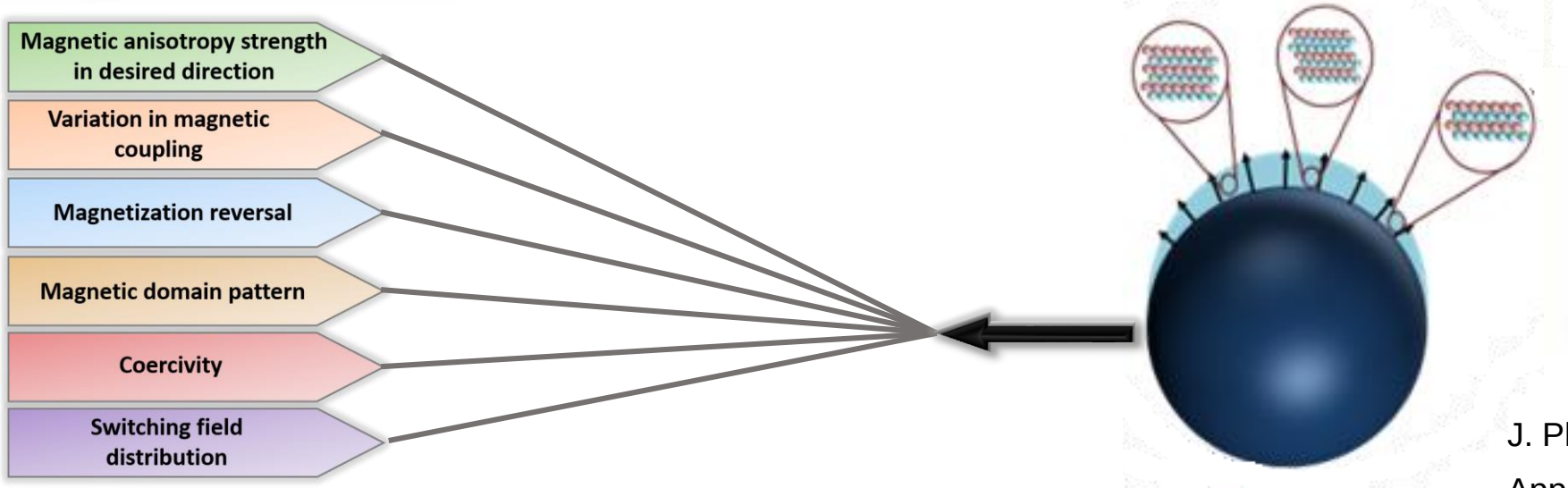
Nanosphere Lithography

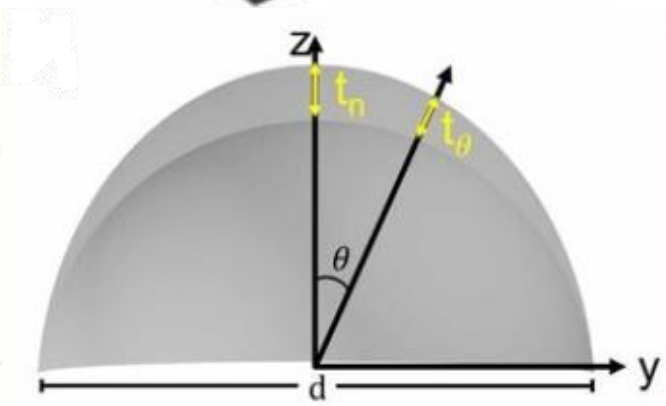
Introduction & Motivation

Nanosphere Lithography

Magnetic nanocaps fabrication







J. Phys. D Appl Phys 49 (2016), 363001

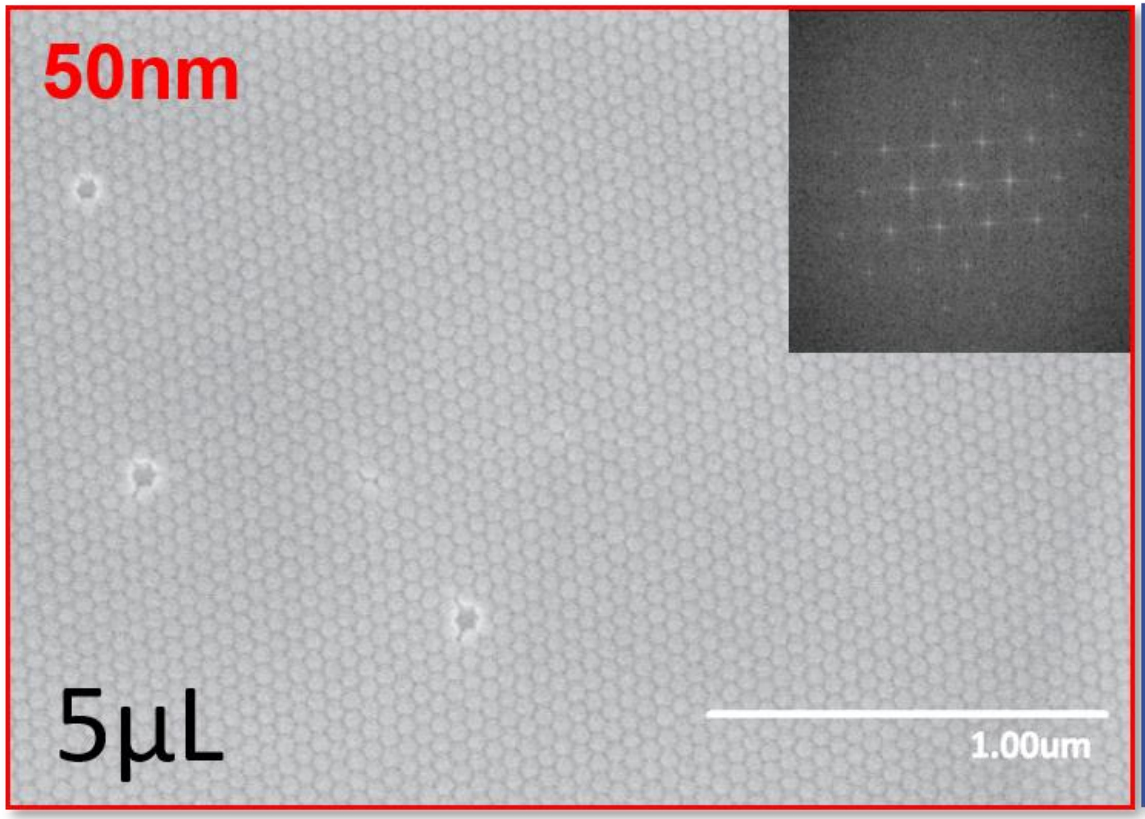
Appl. Phys. Lett 105 (2014), 022405

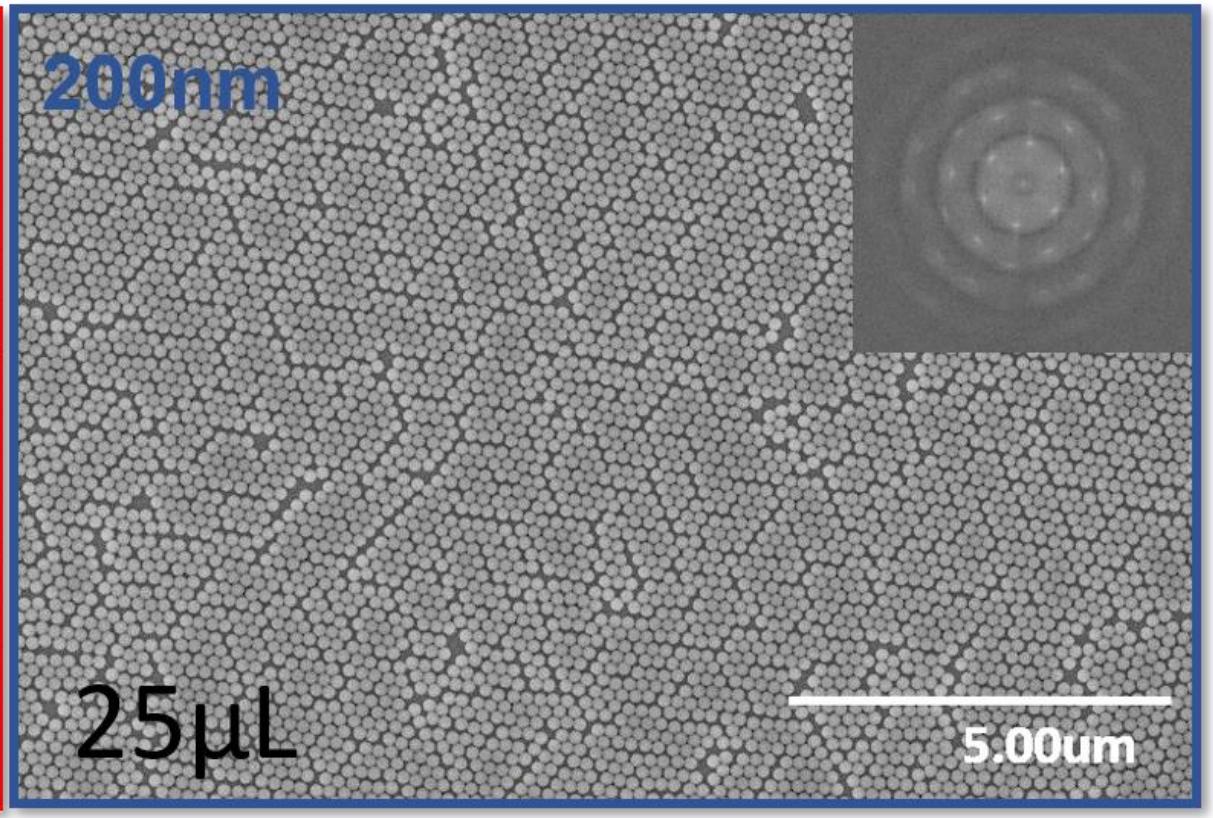
IEE Mag. Lett. 6 (2015), 670030

Magnetic nanocaps fabrication

Monolayer formation

- Silica nanospheres (50nm & 200nm)
- In-House Synthesis @ IBI-4
- Porous (non-coated) & Mesoporous (coated)
- Amorphous materials
- Dispersed in toluene & Ethanol





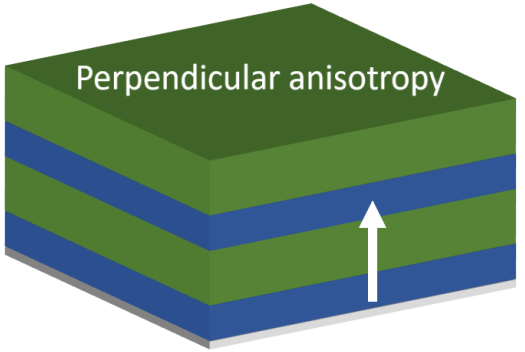
RSC Adv., 2020,10, 18339-18347

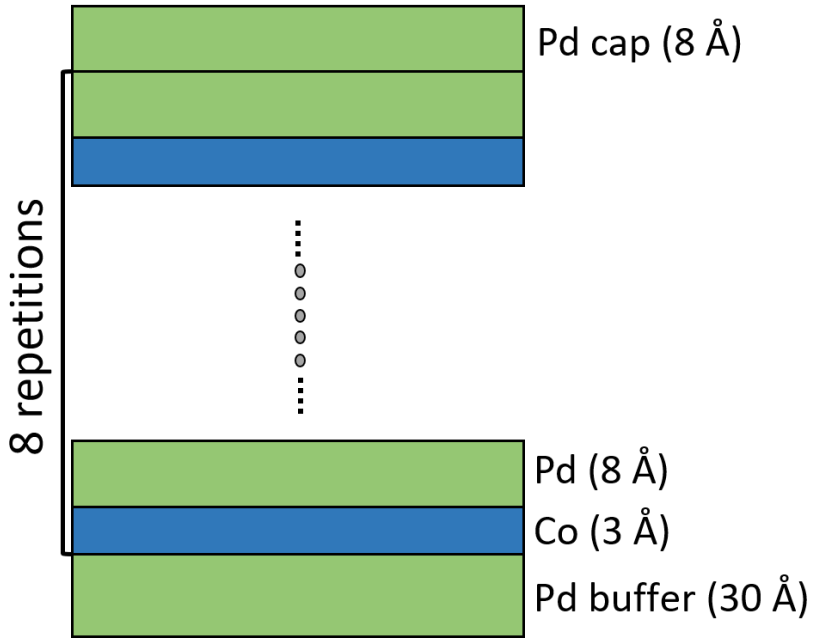
Magnetic nanocaps fabrication

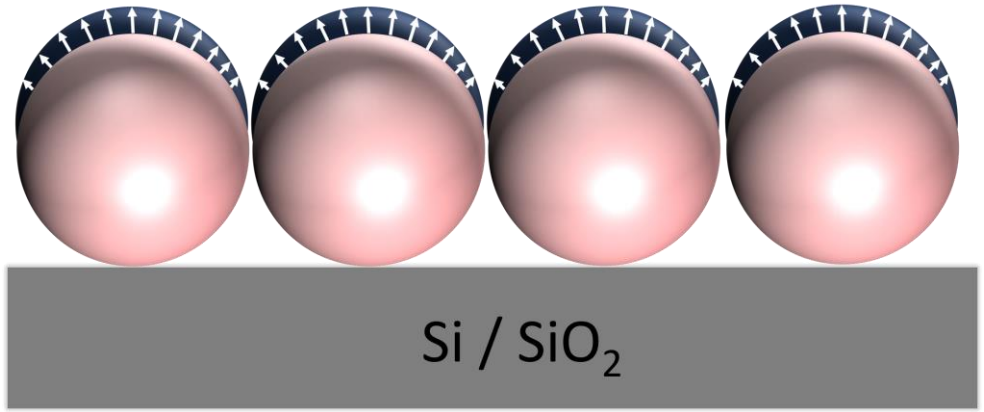
Film deposition @ MBE - Garching

- Co/Pd multilayers
- Co/Pt multilayers

Strong magnetic anisotropy pointing perpendicular to the surface







Anisotropy points radially outward, leading to altered magnetic reversal properties

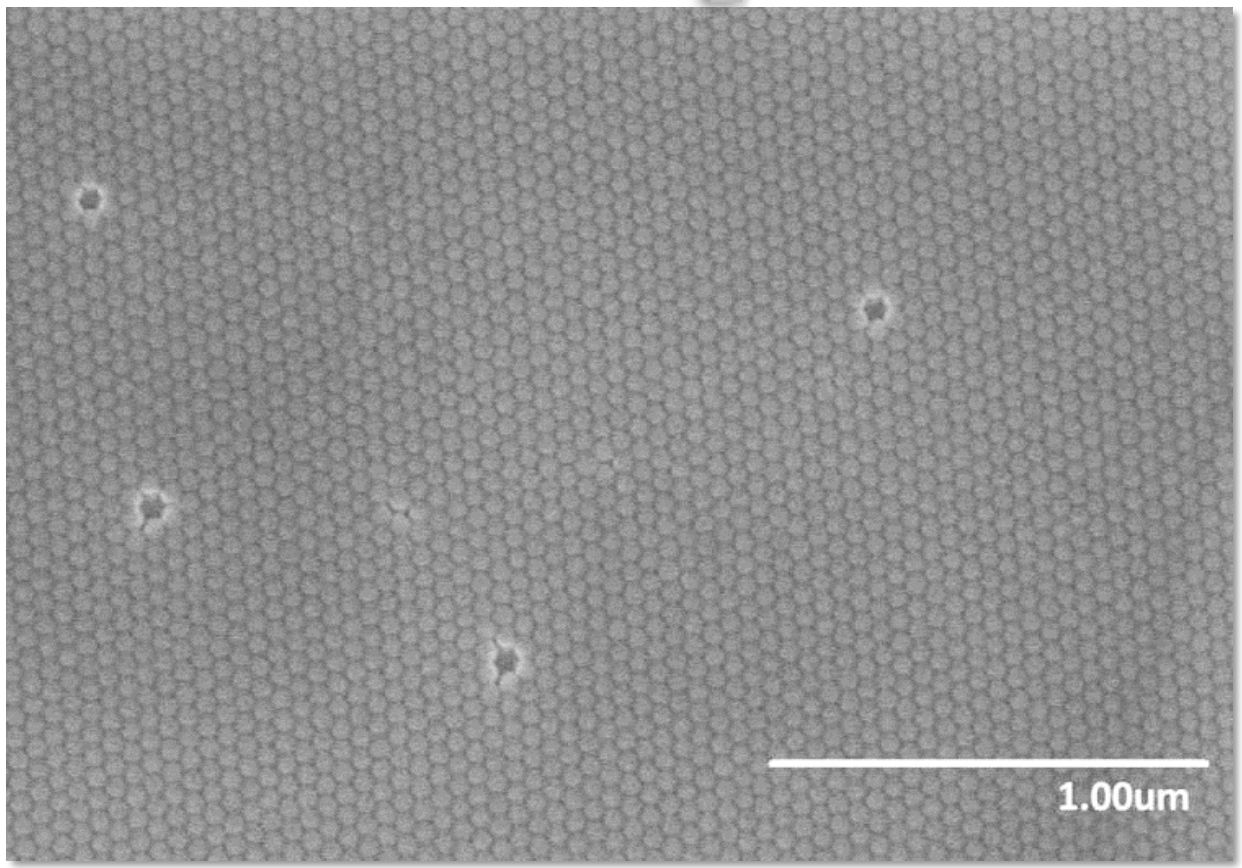
Nature Materials. 2005, 4(3), 203-206

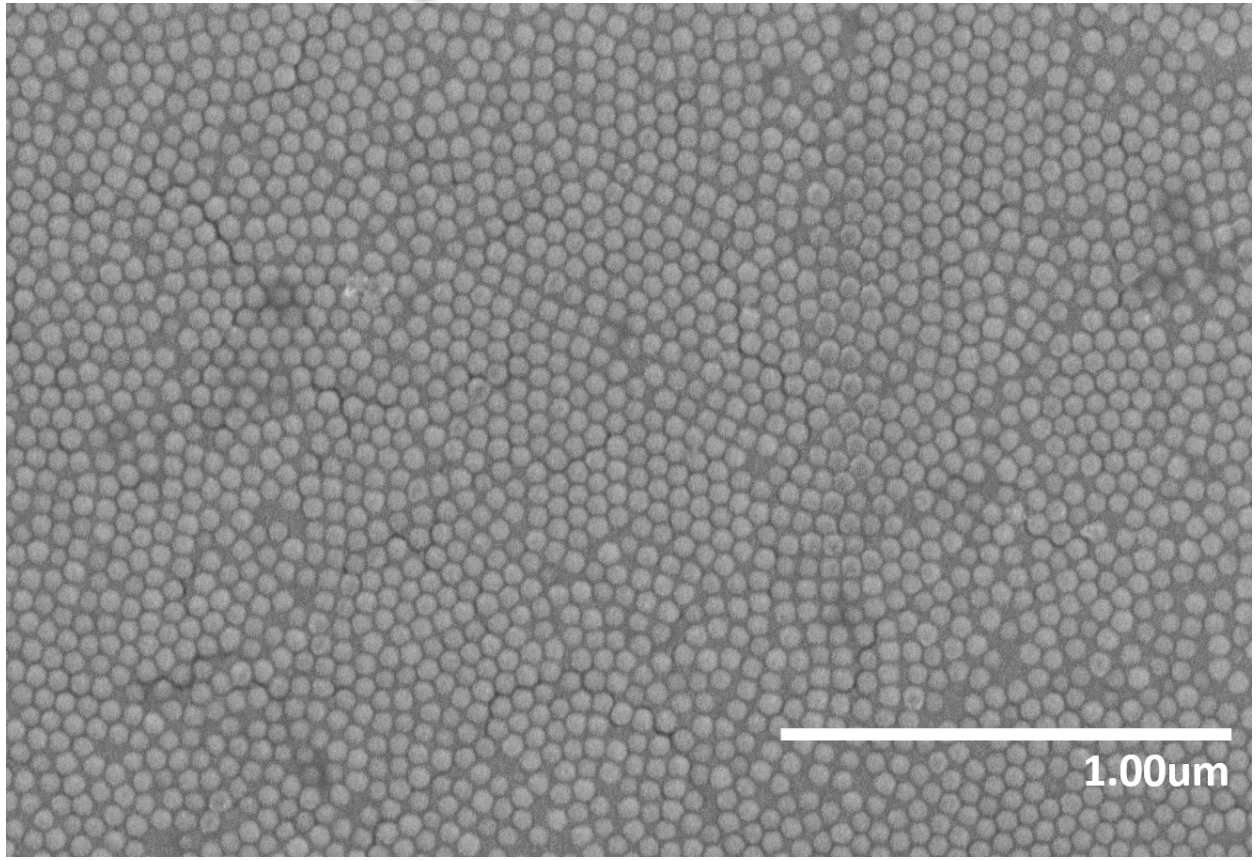
Cobalt Palladium multilayers

$[Co/Pd]_8$ on 50nm SiO_2 nanospheres

- SEM

After film deposition

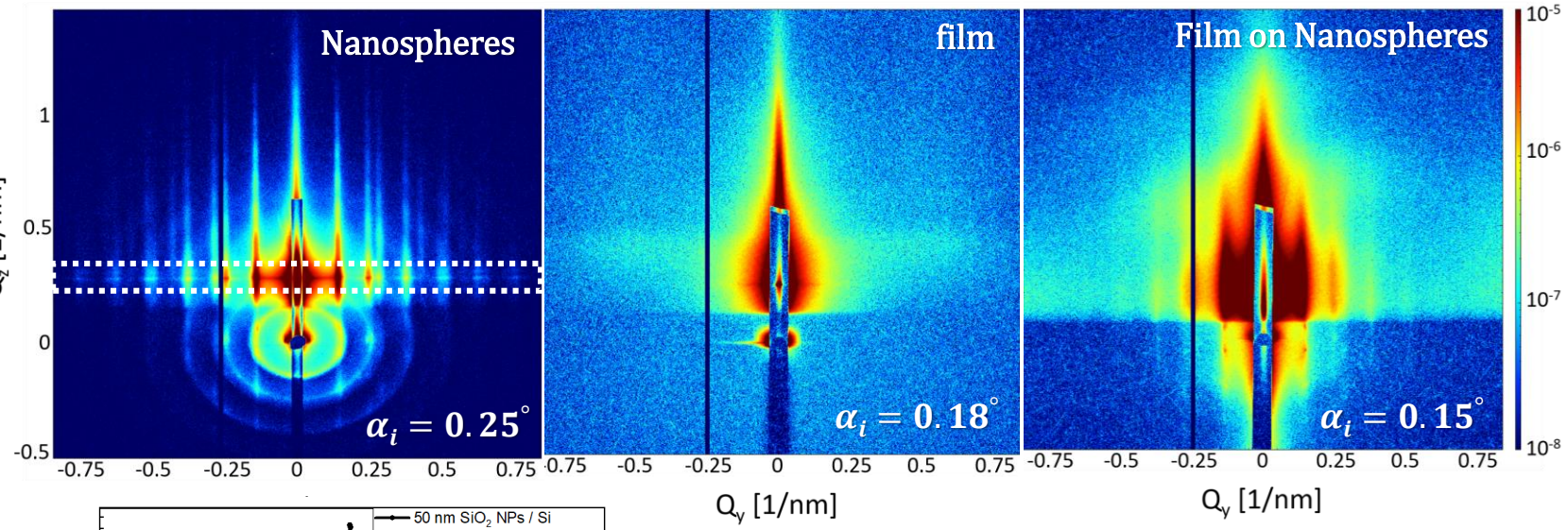


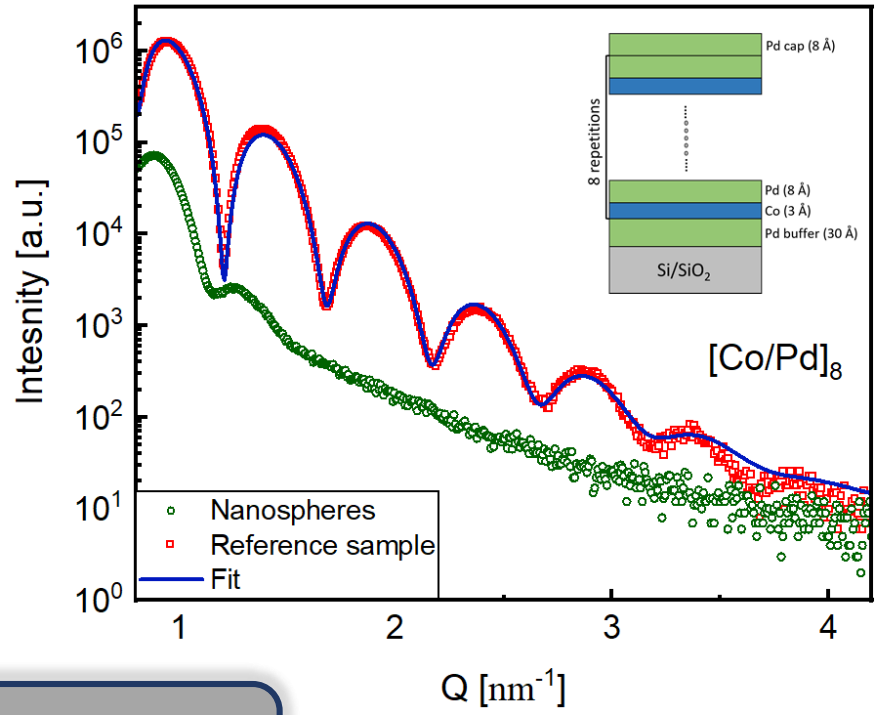


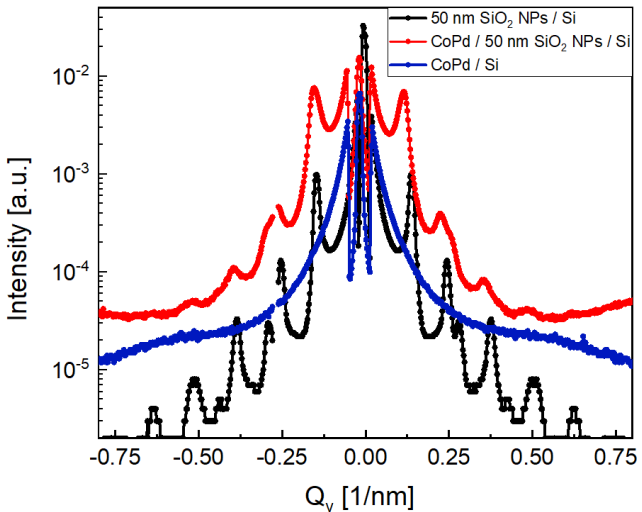
Cobalt Palladium multilayers

$[Co/Pd]_8$ on 50nm SiO_2 nanospheres

- XRR & GISAXS





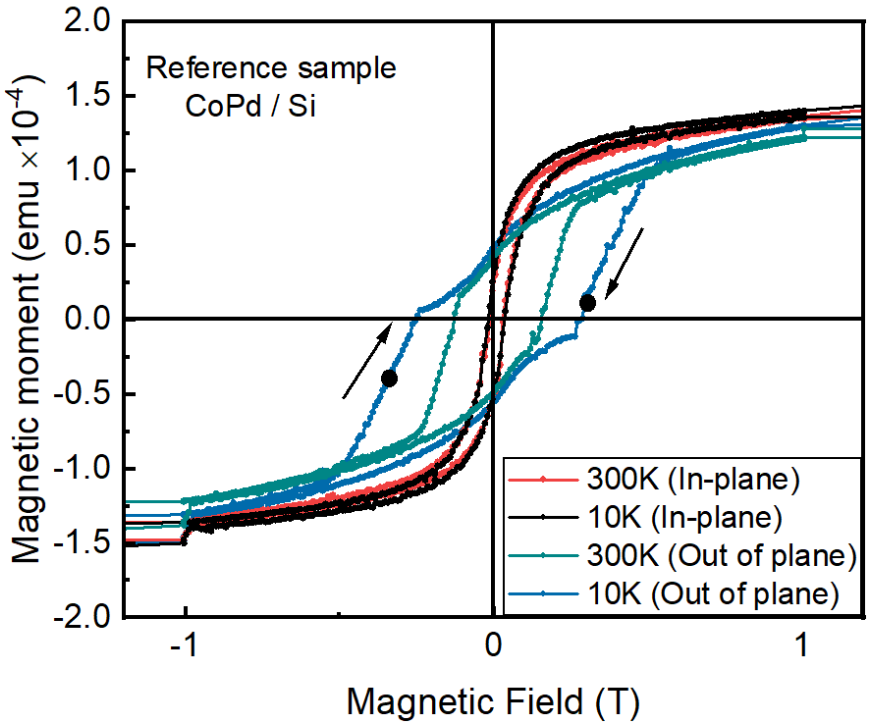


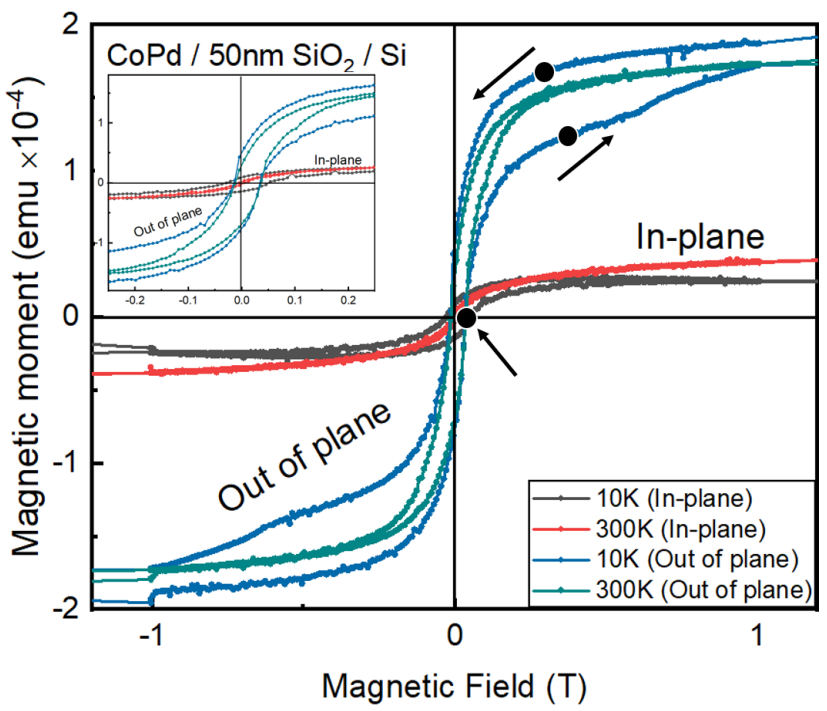
- Distinct vertical Bragg → long-range periodic order of the nanospheres
- Formation of isolated nanocaps on the nanospheres

Cobalt Palladium multilayers

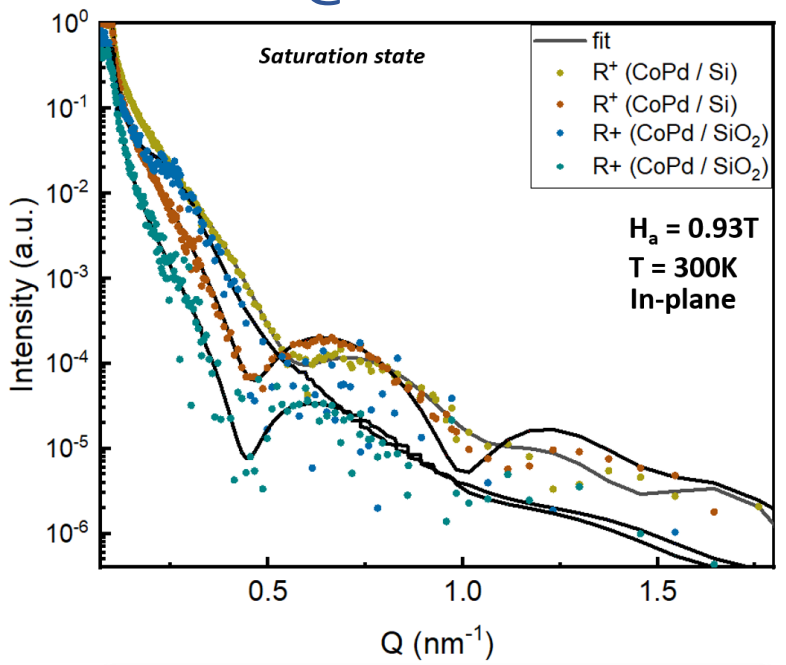
$[Co/Pd]_8$ on 50nm SiO_2 nanospheres

- M-H @ SQUID





- PNR @ D17 (Test measurement)



Magnetic moment parallel to the field

(Co/Pd)8 / Si: soft/hard system with strong antiferromagnetic interface coupling

(Co/Pd)8 / NS: two uncoupled phases as the coercivity is reduced to zero

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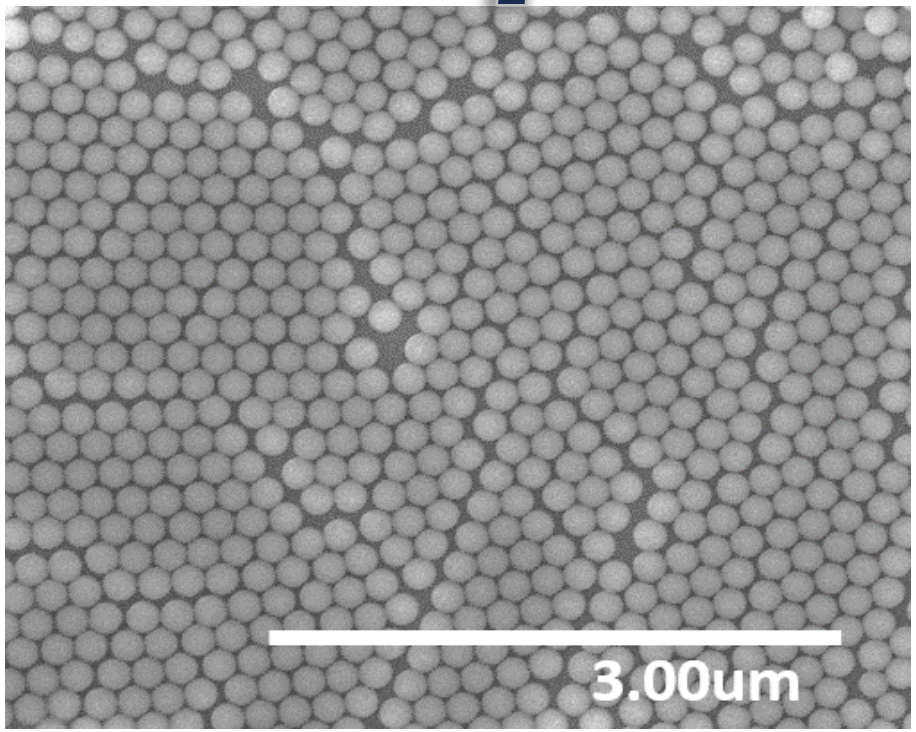
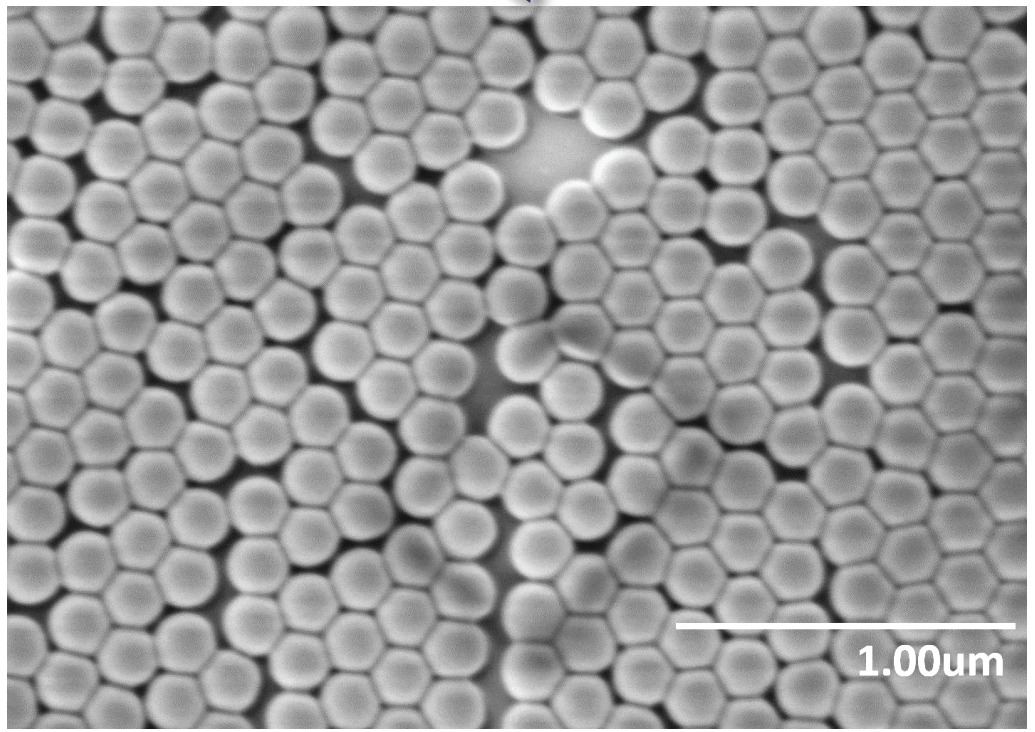
Cobalt Palladium multilayers

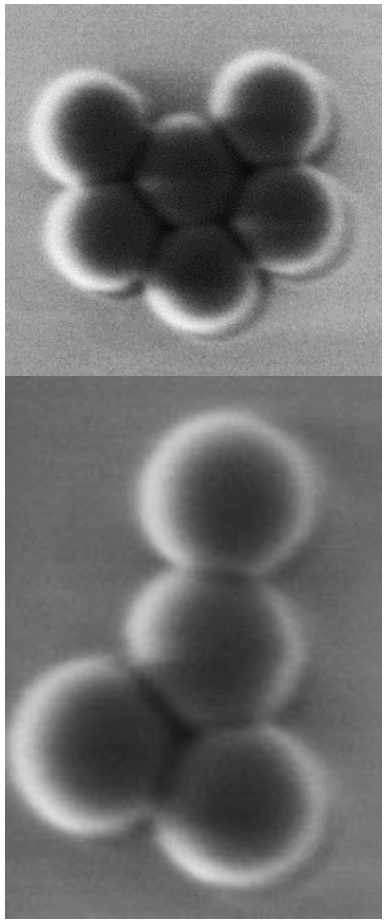
$[Co/Pd]_8$ on 200nm SiO_2 nanospheres

- SEM

After film deposition



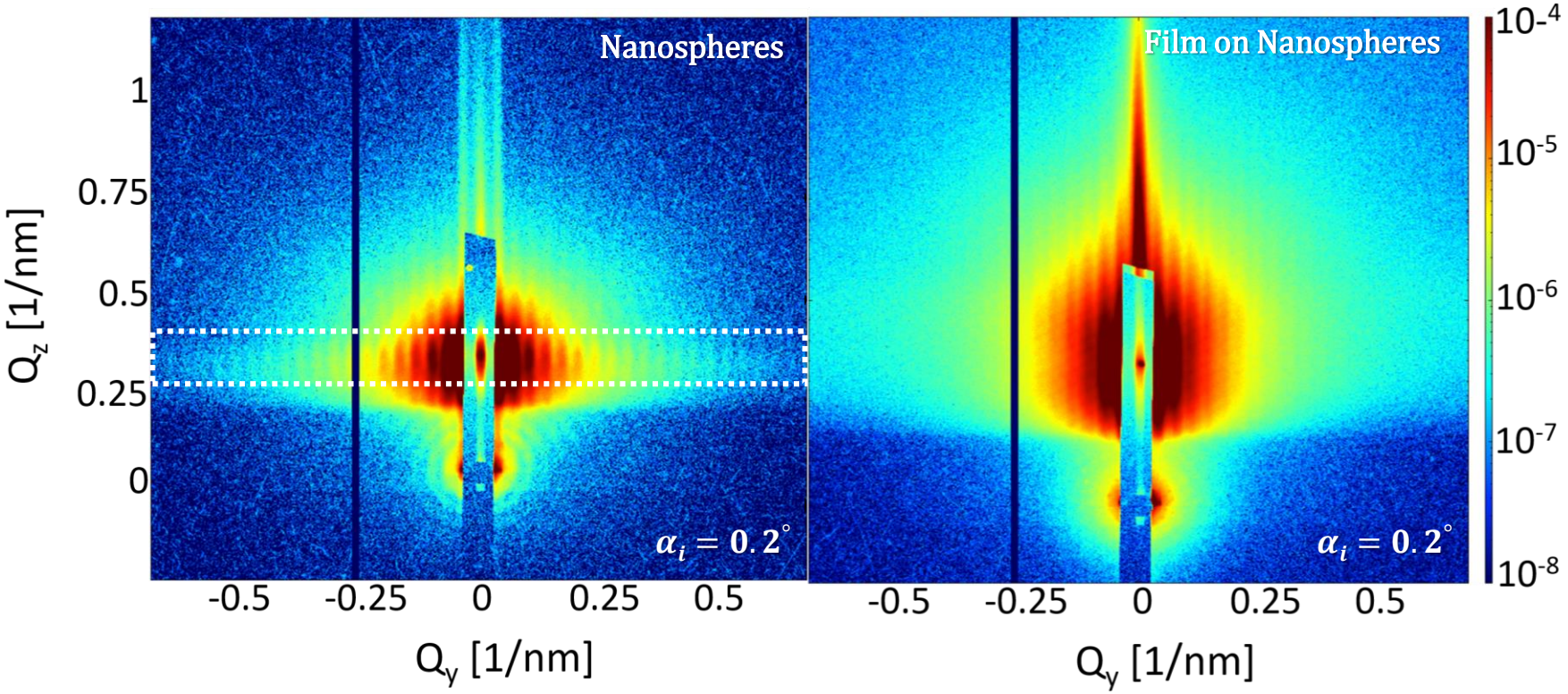


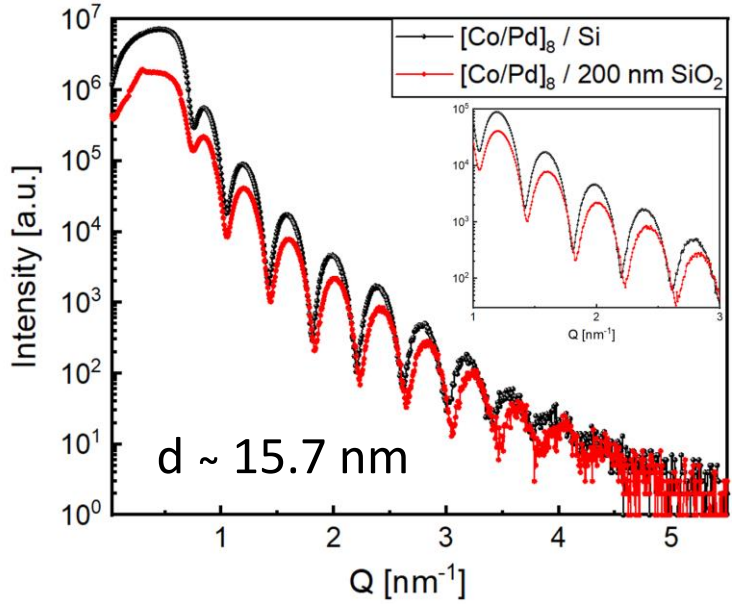


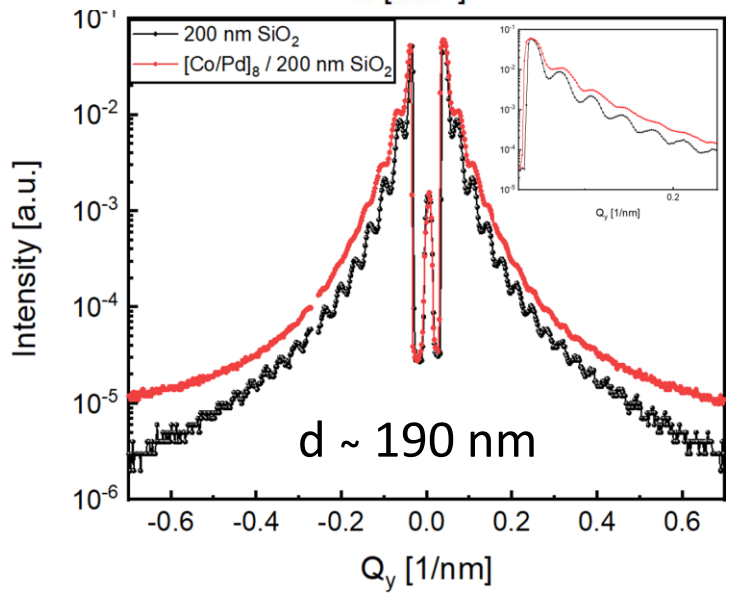
Cobalt Palladium multilayers

$[Co/Pd]_8$ on 200nm SiO_2 nanospheres

- XRR & GISAXS





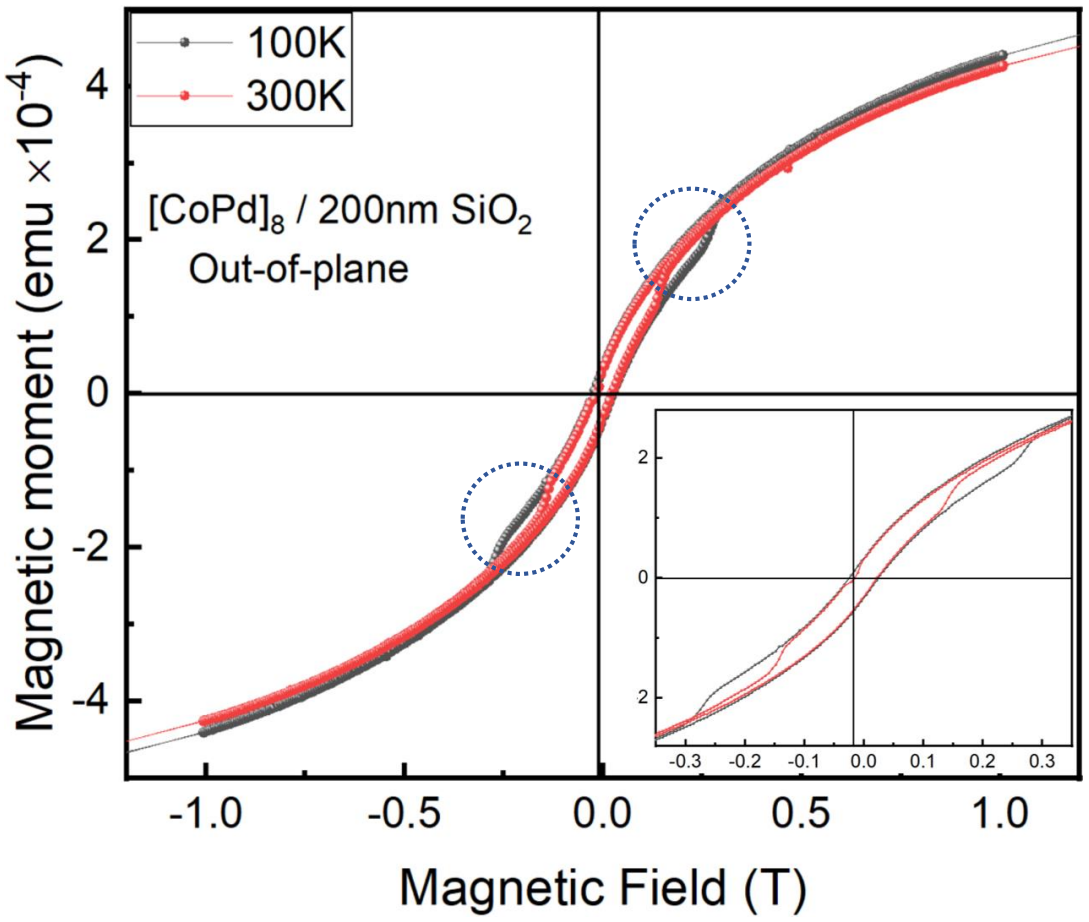


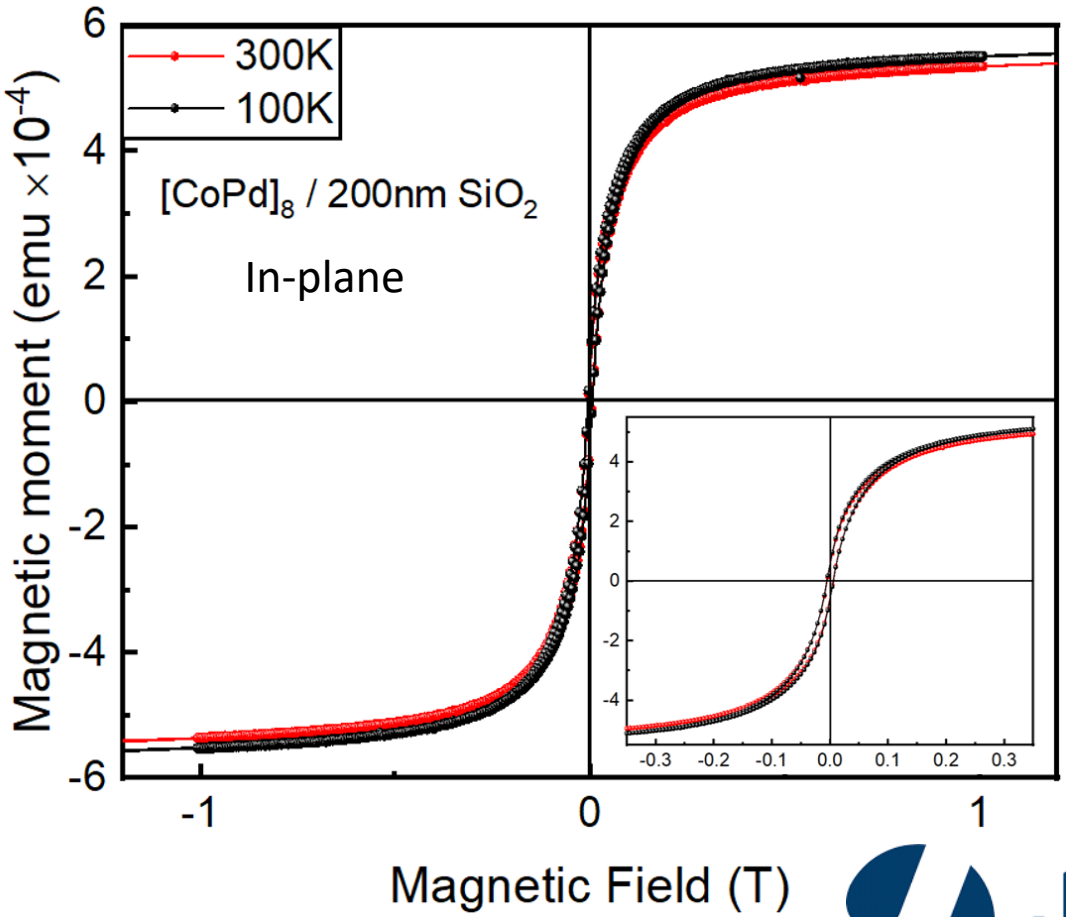
- long-range periodic order of the nanospheres

Cobalt Palladium multilayers

$[Co/Pd]_8$ on 200nm SiO_2 nanospheres

- M-H @ SQUID





?????

Summary

- Nanosphere lithography → new catalog of nanostructures → produced easily, inexpensively
- Thin film magnetic properties can be tailored by depositing on a curved substrate
- Isolated or interconnected caps → Film thickness, nanospheres radius

Outlook

- Grow Co/Pt multilayers with in-plane and out-of-plane easy axis of magnetization / different Co thickness
- Changing the number of bilayers of the deposited Co/Pd multilayers
- AFM, MFM, TEM, MOKE
- GISANS (accepted proposal @ D33-ILL / 04th – 7th of March)
- PNR (submitted proposals / D17 and SuperADAM @ ILL)

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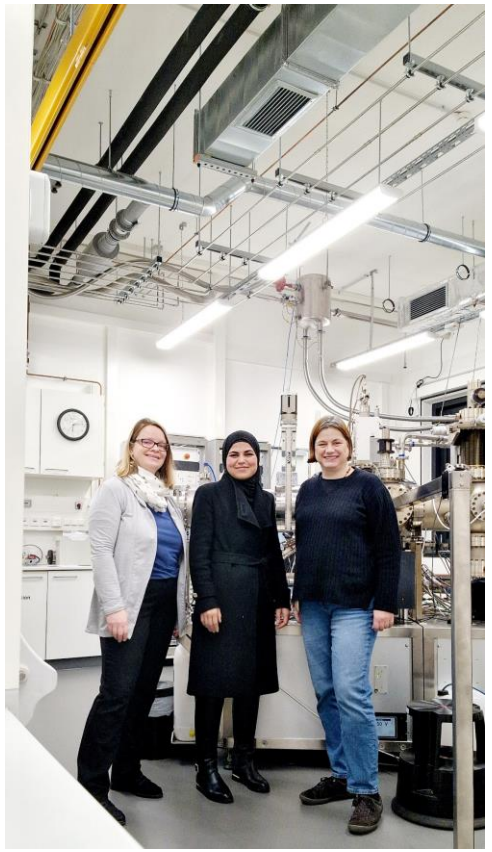
- Dr. Mai Hussein Hamed
- Dr. Connie Bednarski-Meinke
- Dr. Oleg Petracic
- Dr. Grigory Potemkin
- Dr. Thomas Saerbeck

Electronic Materials (PGI-7)

Institute for Biological Information Processes (IBI-4)



THANK YOU