

Short Review of the Last Two Years of Magnetic Carriers / 2016-2018

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UNIVERSITY OF
COPENHAGEN



THE UNIVERSITY OF BRITISH COLUMBIA

12th

International Conference on the
SCIENTIFIC AND CLINICAL
APPLICATIONS OF
MAGNETIC CARRIERS

COPENHAGEN, DENMARK
MAY 22-26 2018



FH KREMS
UNIVERSITY OF APPLIED
SCIENCES / AUSTRIA

WOLFGANG SCHÜTT
KREMS, AUSTRIA



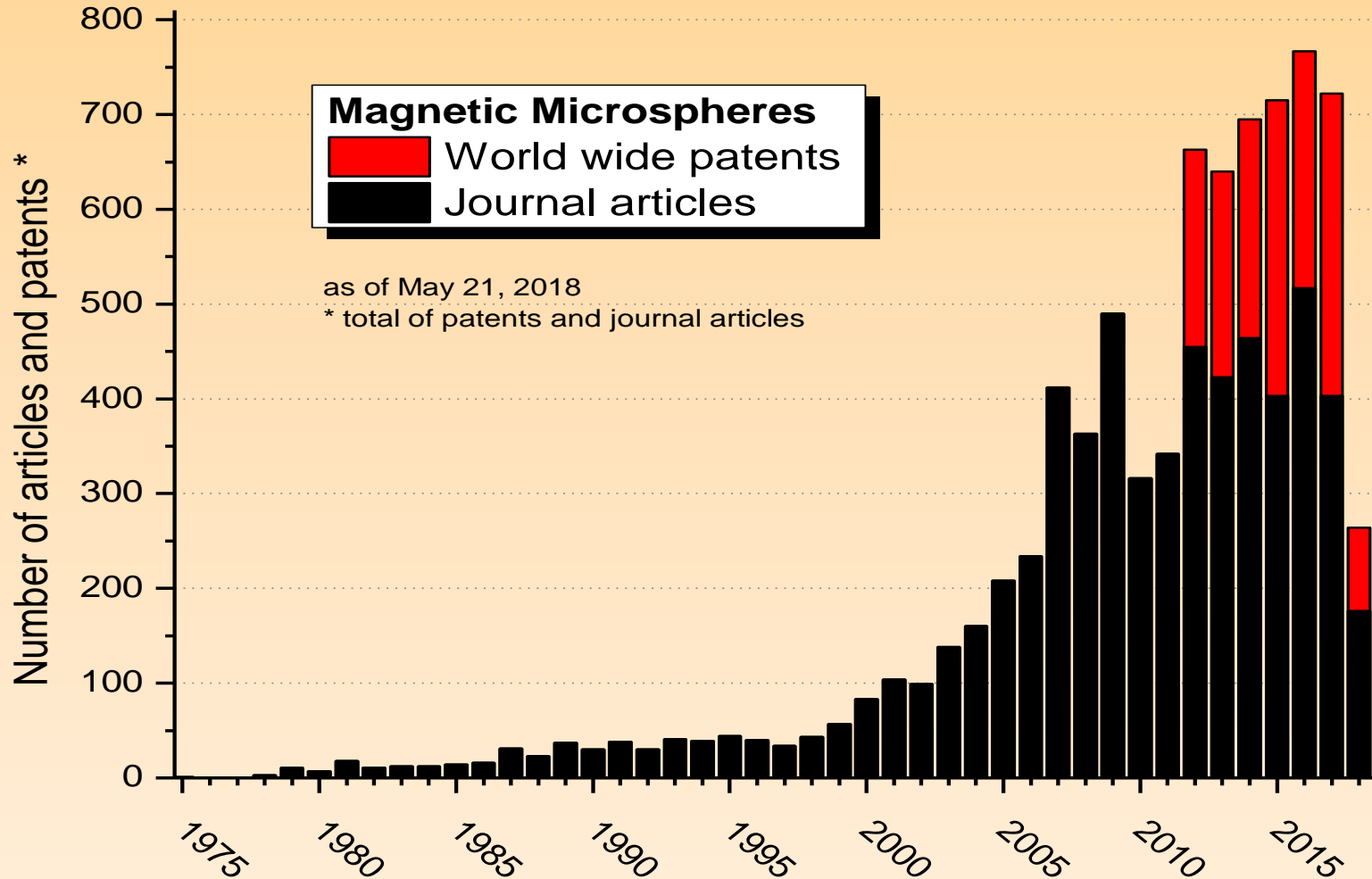
Cleveland Clinic
MACIEJ ZBOROWSKI
CLEVELAND, OHIO, U.S.A.



URS HAFELI
VANCOUVER, CANADA
COPENHAGEN, DENMARK

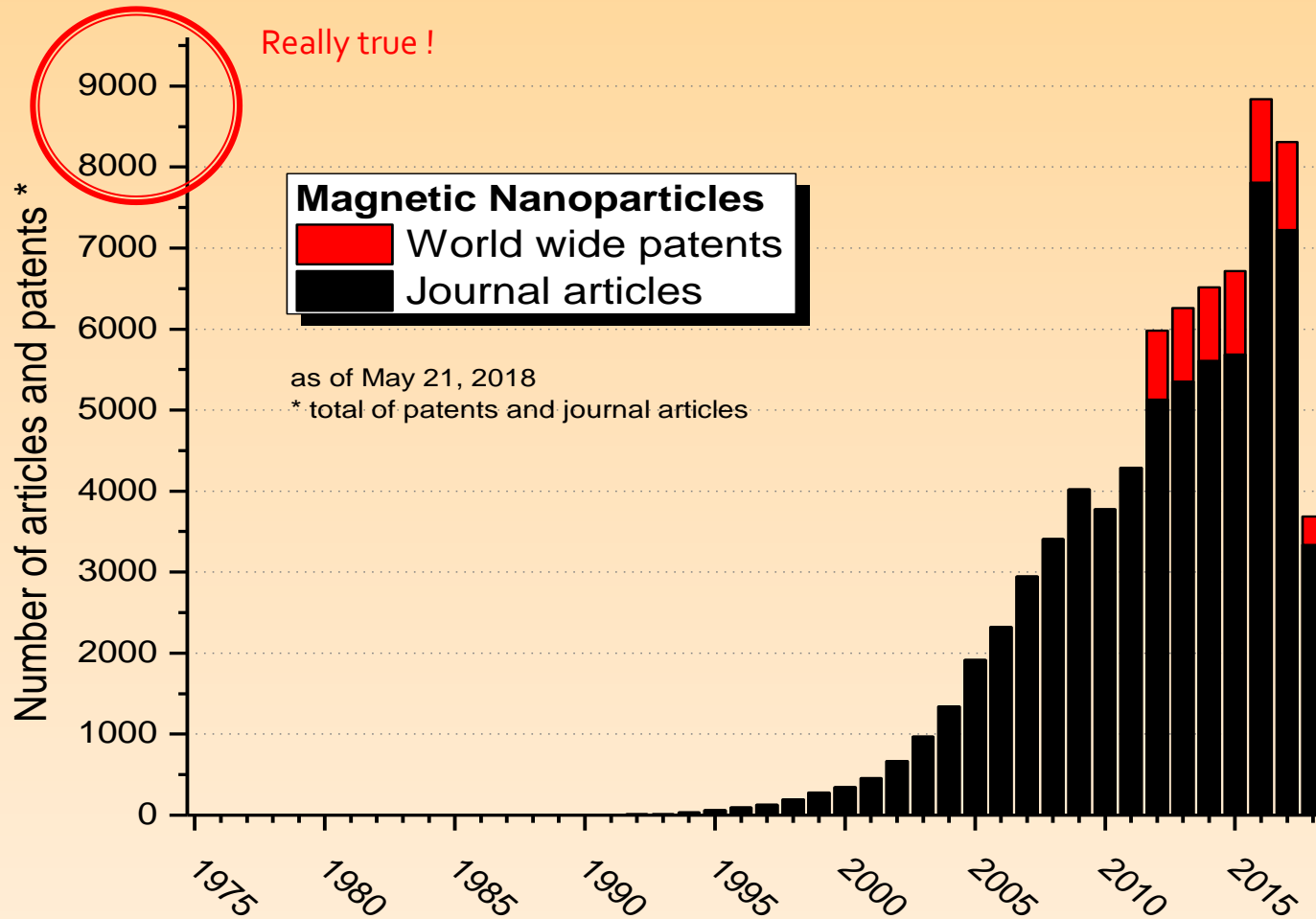
Journal Update:

Is Publishing about Magnetic Microspheres Still Trendy ?



Journal Update:

Publishing about Magnetic Nanoparticles, That's Trendy !



Christian Bergemann

- Left us much too early at the age of 54
- Was with us since the very first conference



Christian Bergemann



Magmeet 1996 in Rostock, Germany

Christian Bergemann



Magmeet 1998 in Cleveland, OH, USA

Christian Bergemann

- He supported many of us with magnetic nanoparticles to try out all the crazy “things” we do
- He will be missed!



chemicell
NEW TOOLS IN BIOSCIENCES

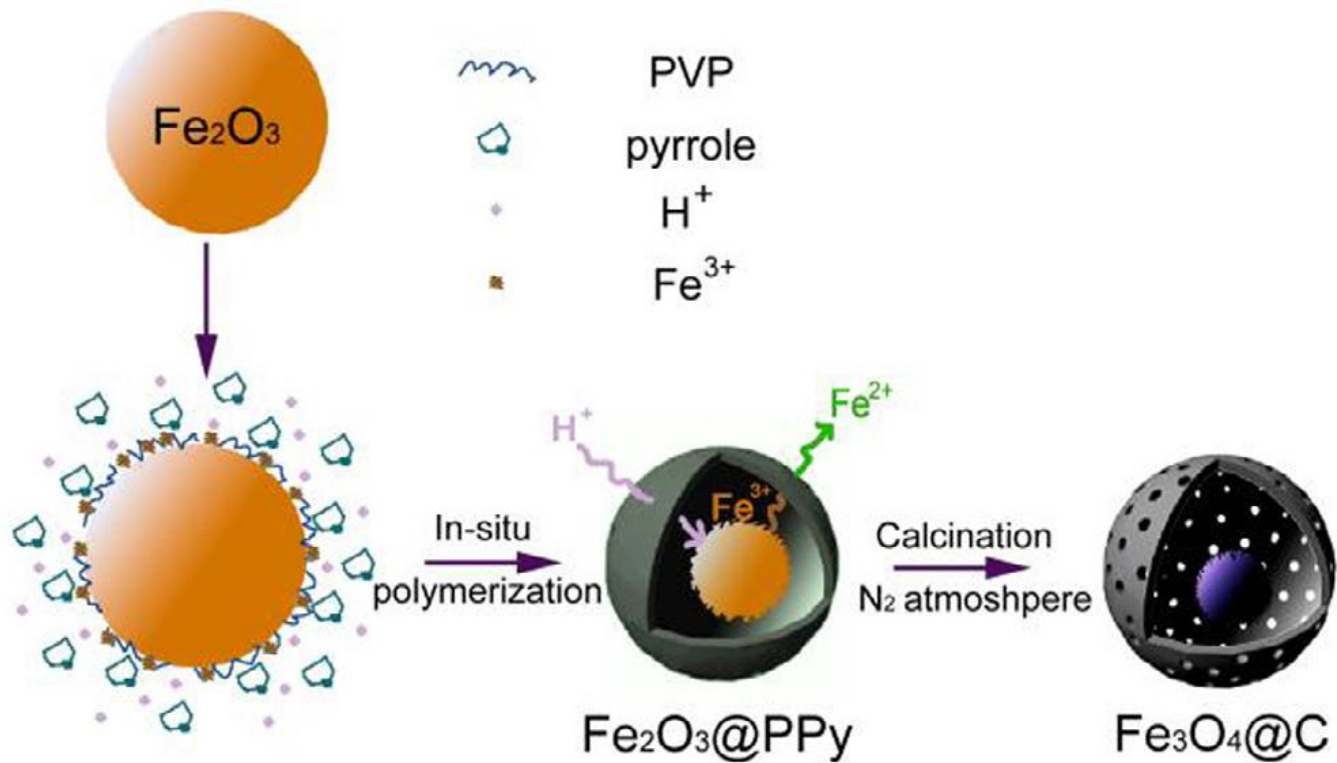
DISCLAIMER

- This presentation is rather incomplete, opinionated, one-sided, and might NOT mention your research
- But that's why you have to stay around for the next 4 days ...

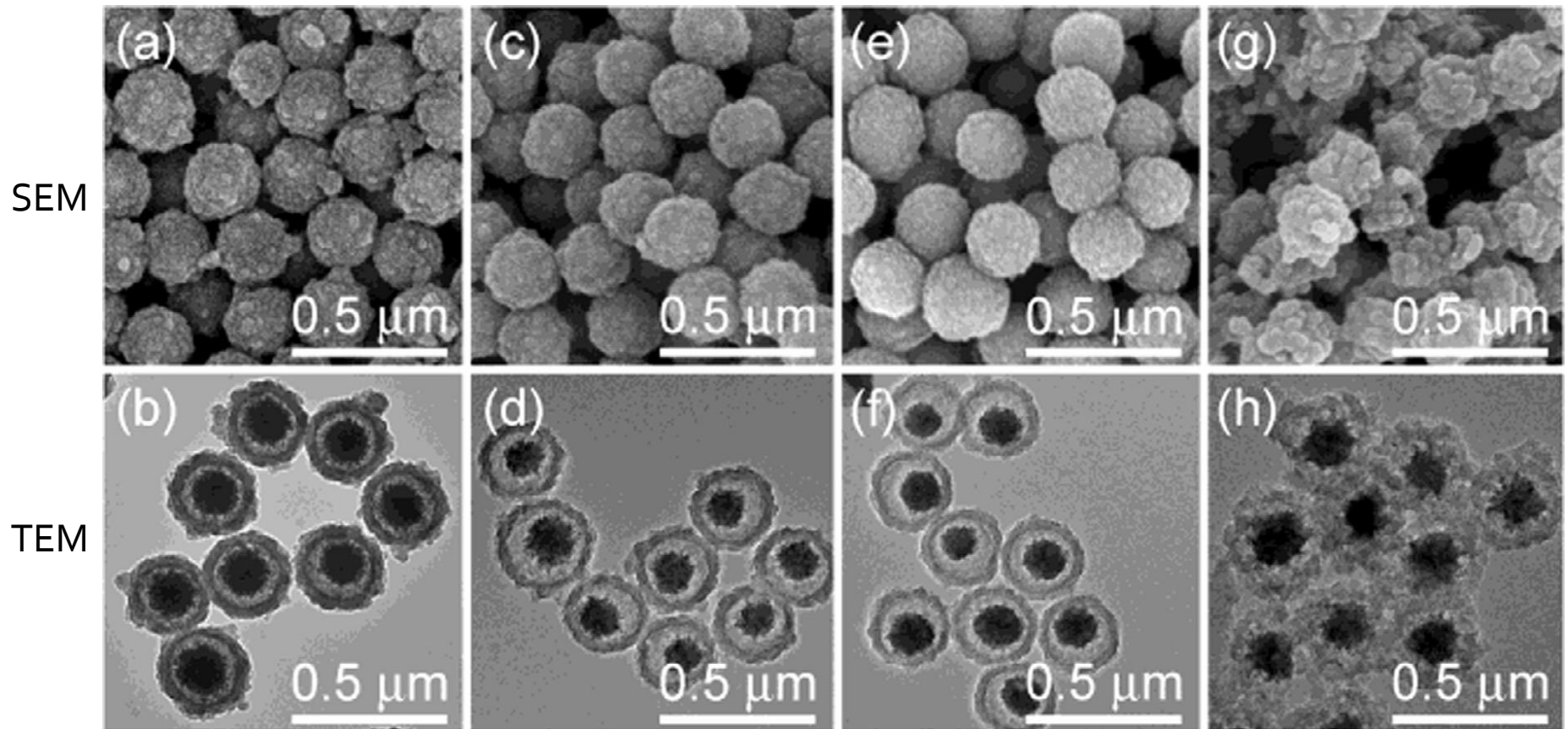


Synthesis

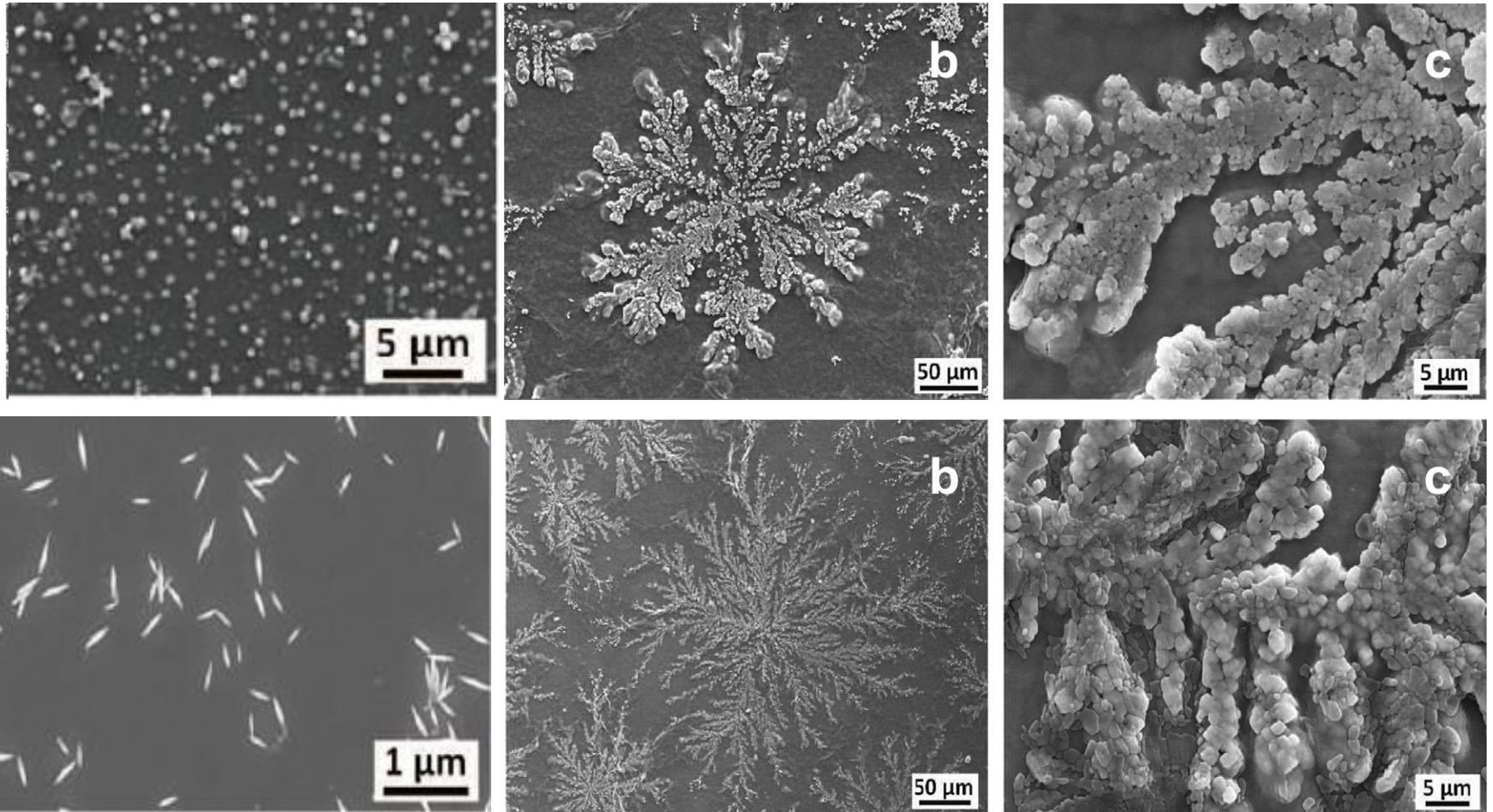
The Magnetic Rattle



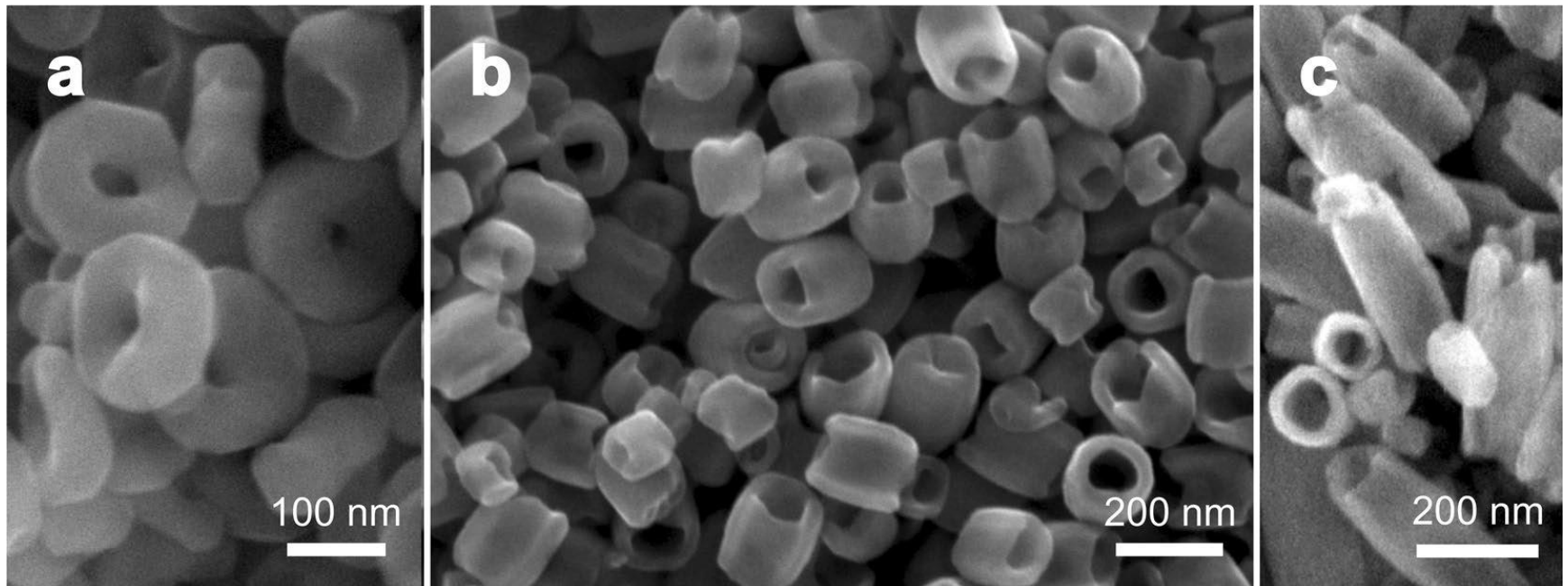
The Magnetic Rattle



Liquid Crystalline Magnetic Microflowers



Magnetic Nanorings

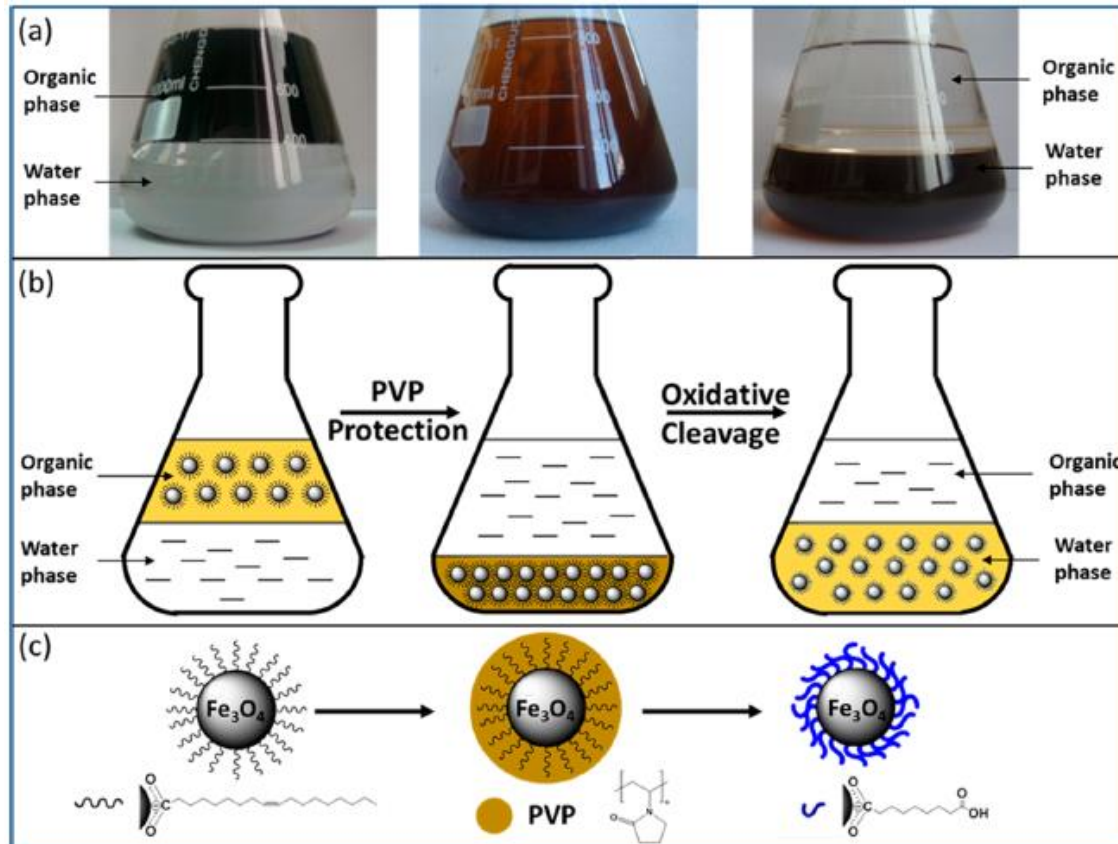


Dias et al., Scientific reports (2018) 7:14843

Coatings

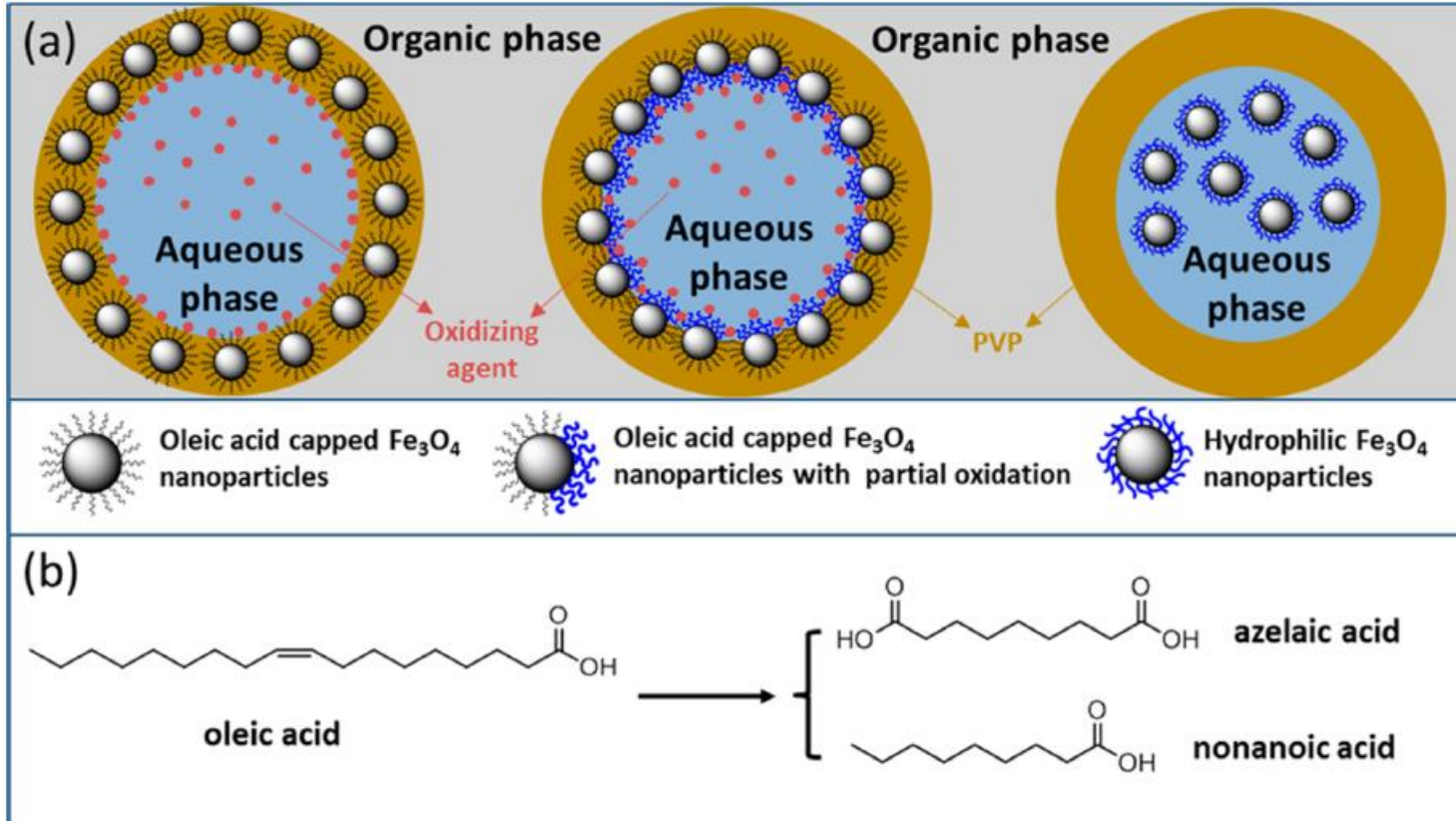
Coatings Are Crucial

- But coatings are still tricky

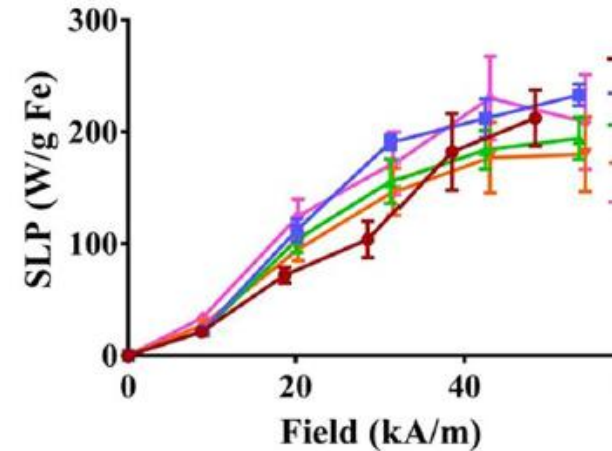
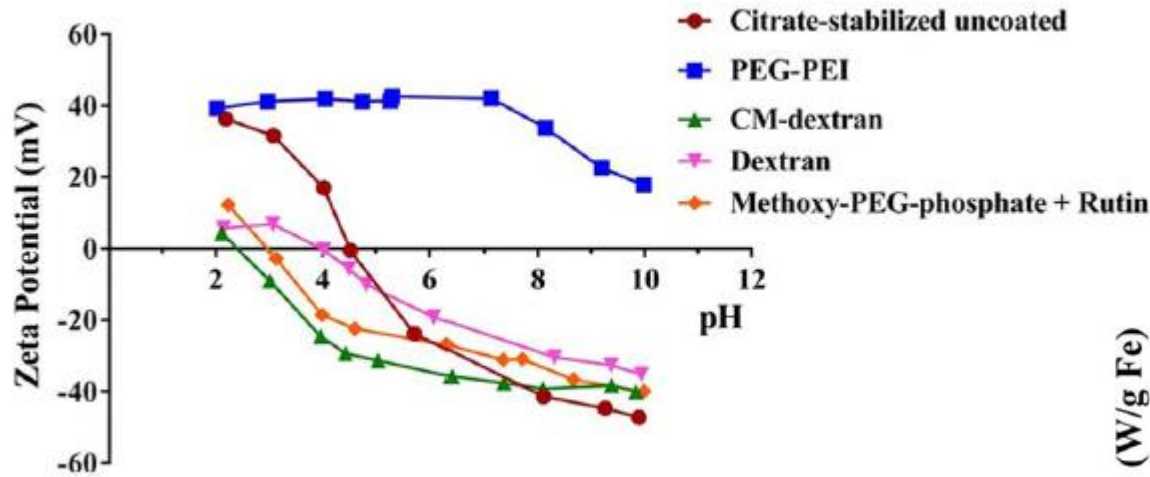


Coatings Are Crucial

- But coatings are still tricky

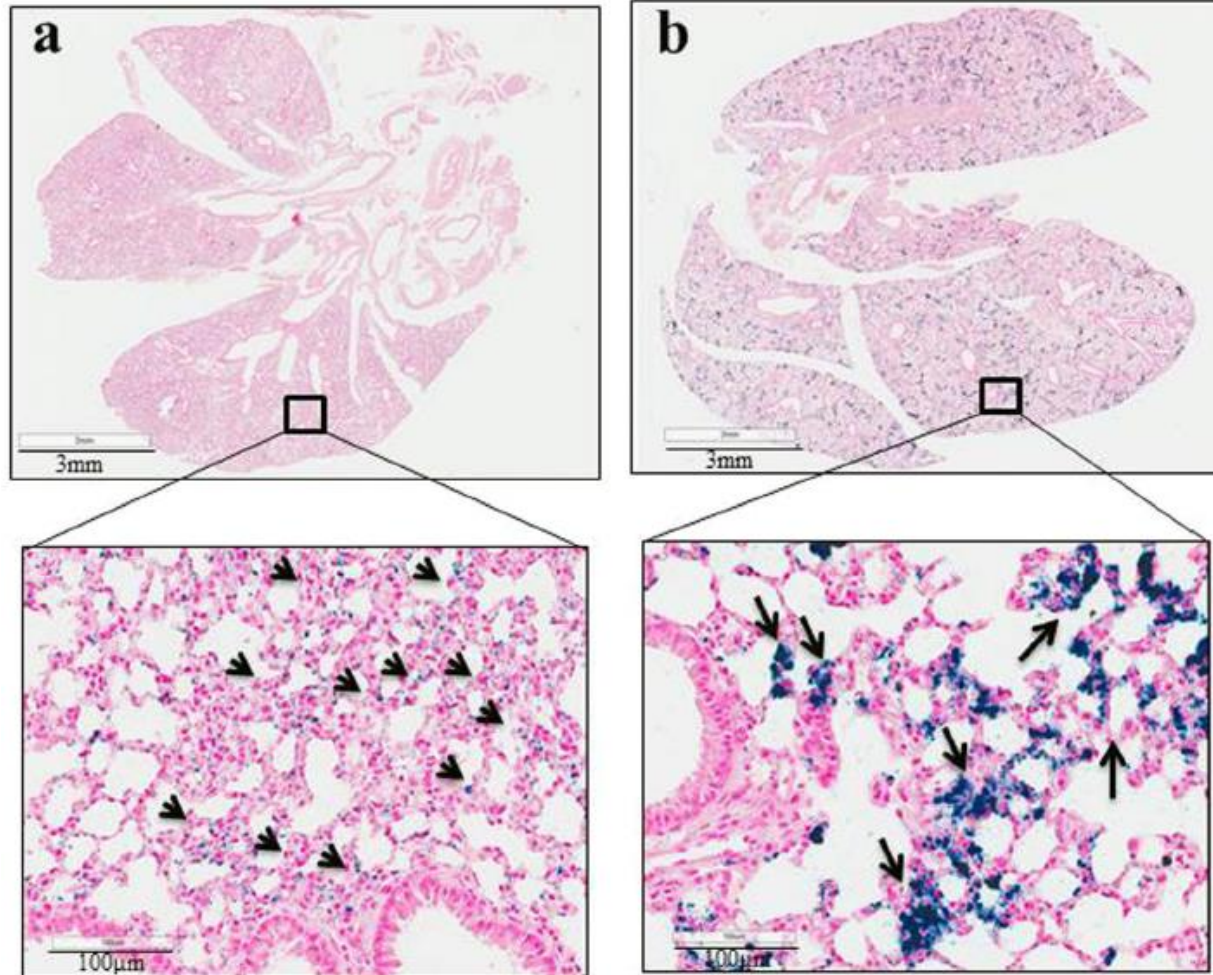


In Vivo Biodistribution of Coated MNPs



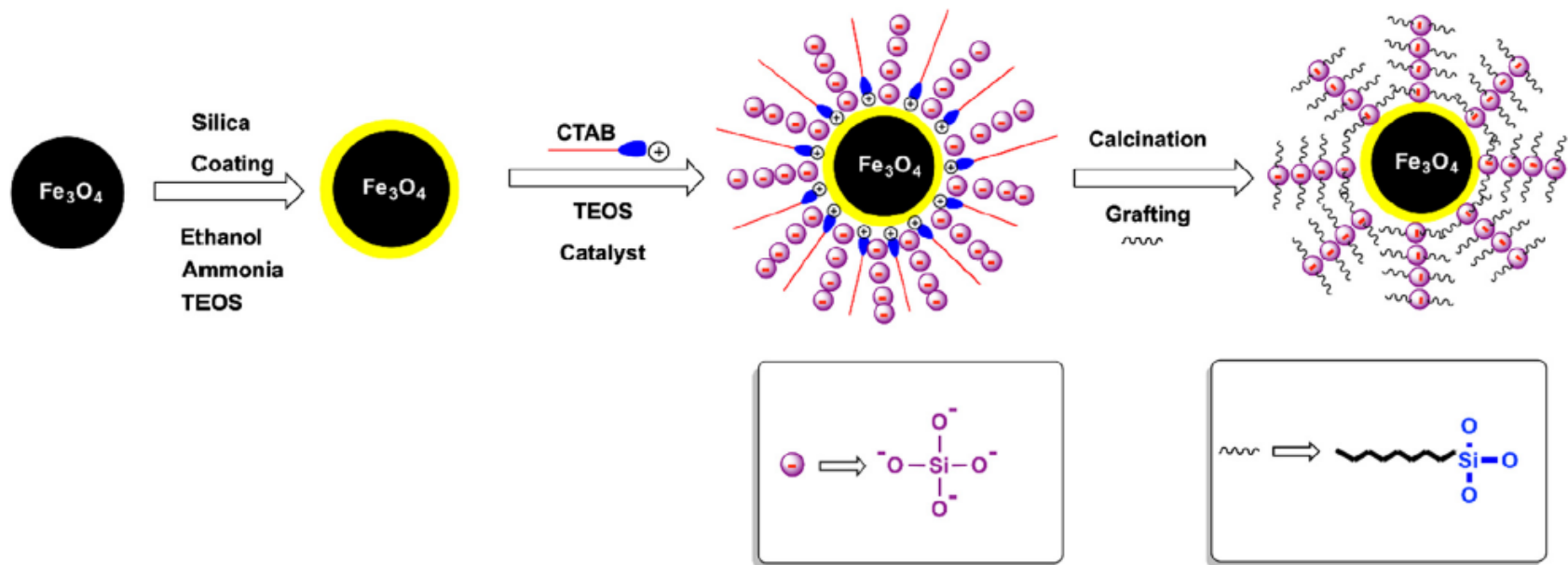
Coating	c(Fe) [mg/ml]	Z(Ave) [nm]	P.I.	Z(Ave) [nm] in PBS	P.I. in PBS	Zeta potential (mV)
(Lot)		in H ₂ O	in H ₂ O			at pH 7
CM-dextran [0451745-001]	22.8	171	0.153	272	0.405	-38
PEG-PEI [0461745-001]	23.4	166.6	0.115	136.4	0.123	28

In Vivo Biodistribution of Coated MNPs



Feathery Superhydrophobic Surface

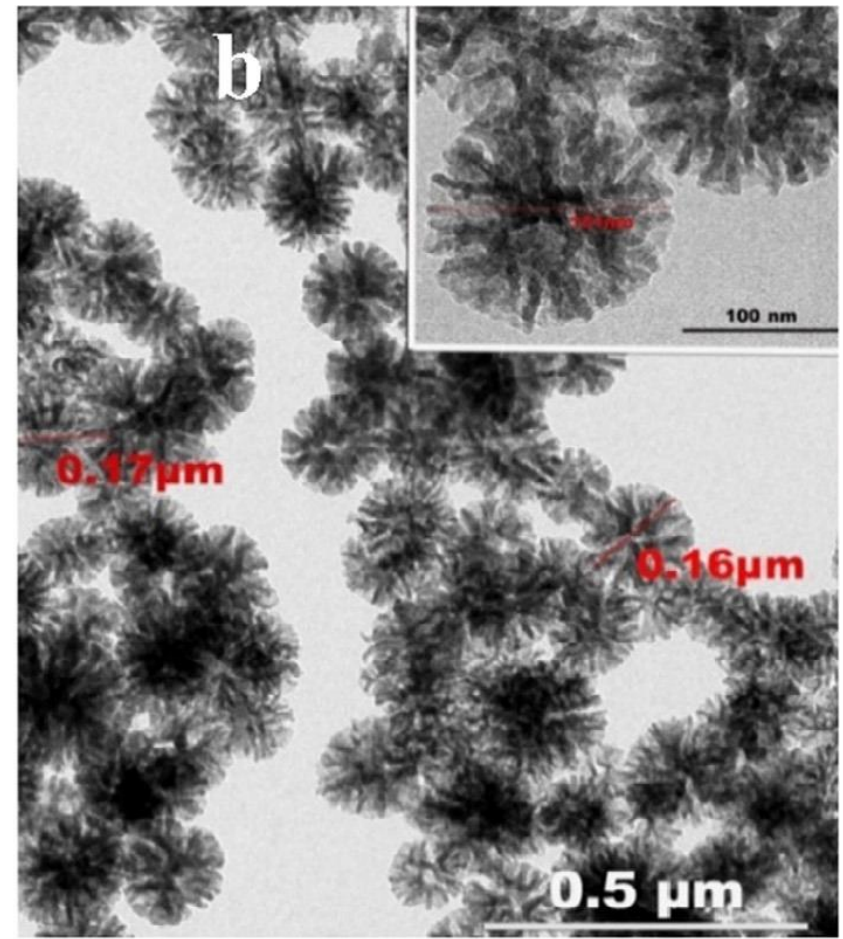
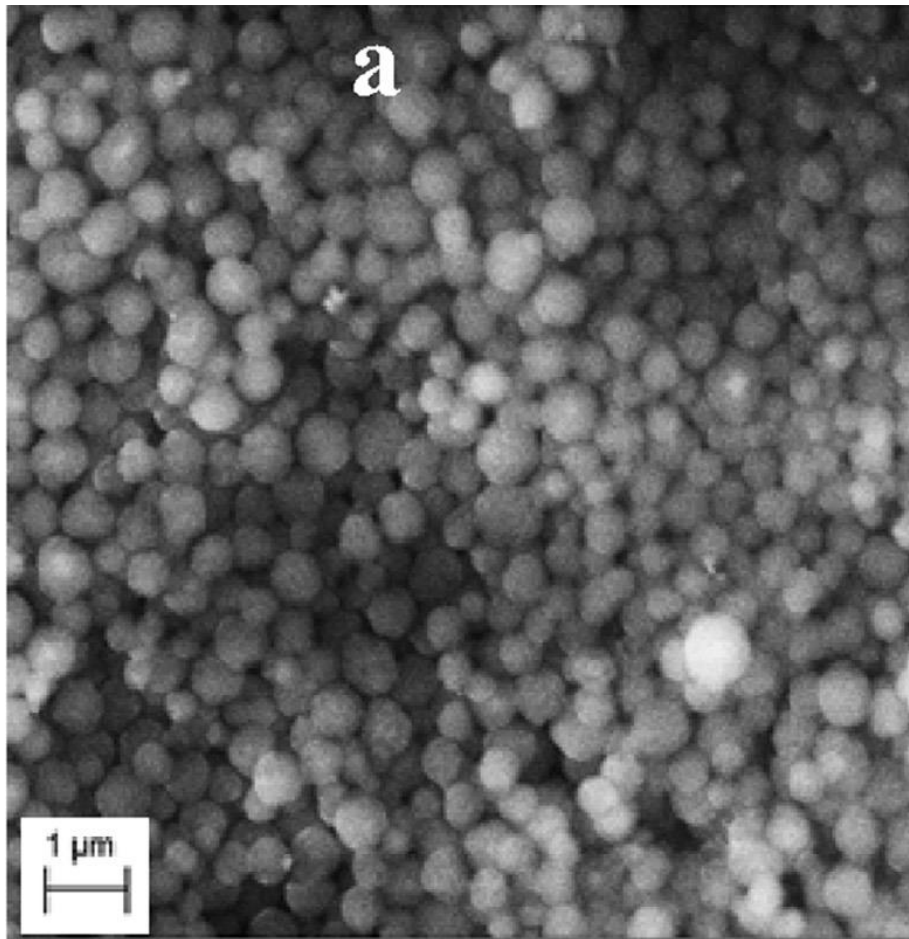
- Inexpensive approach of making particles with superhydrophobic silica shell



Scheme 1. Schematic representation of the $\text{Fe}_3\text{O}_4@H\text{-SiO}_2/\text{KCC-1}$ preparation process.

Feathery Superhydrophobic Surface

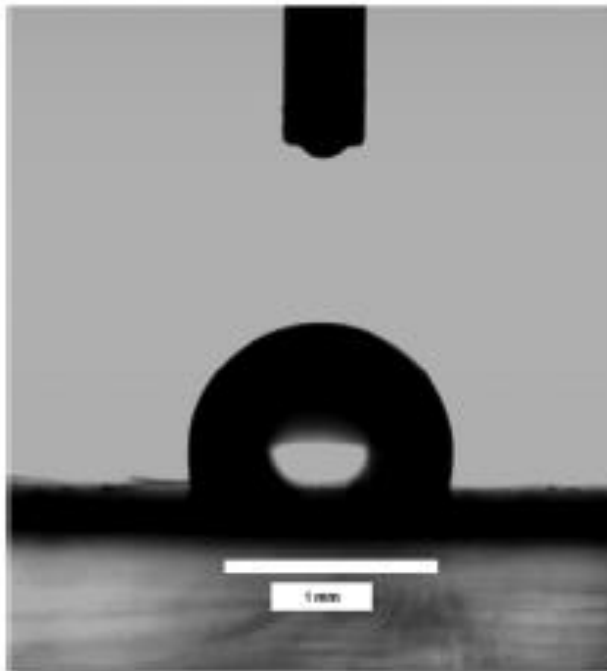
SEM and TEM of superhydrophobic MNPs; contact angle 175°



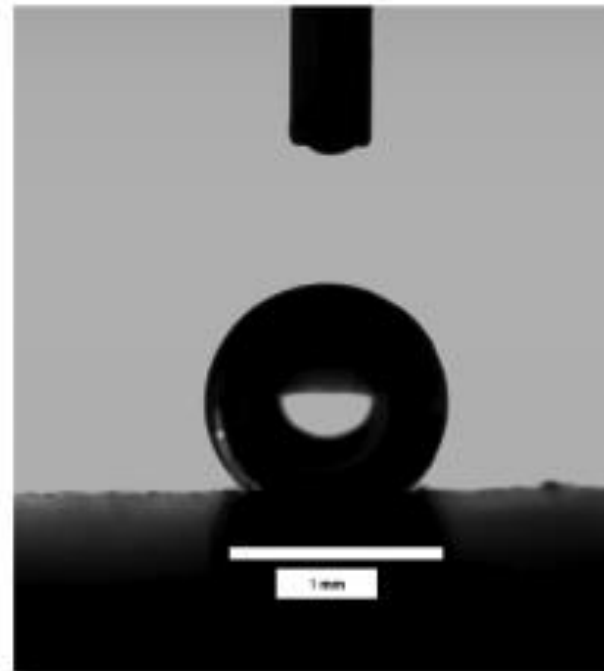
Magnetic Change of Hydrophobicity

- Contact angle of magnetoactive elastomers can be changed by a magnetic field

Earth mag field 112°



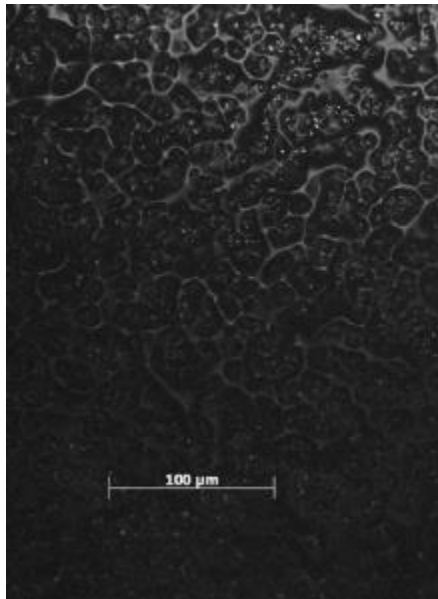
~ 500 mT 138°



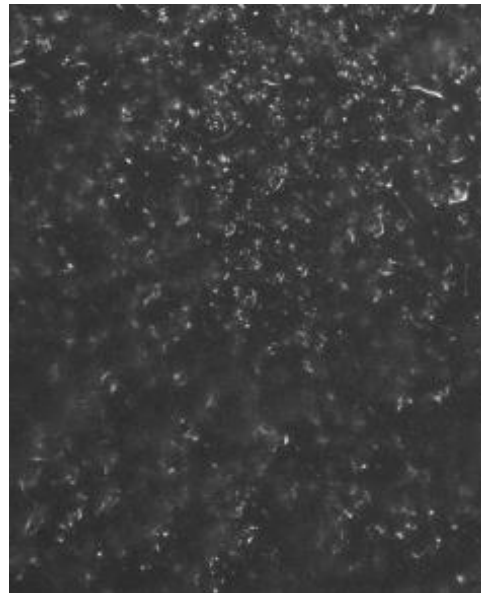
Magnetic Change of Hydrophobicity

- Seems to happen through surface structure changes

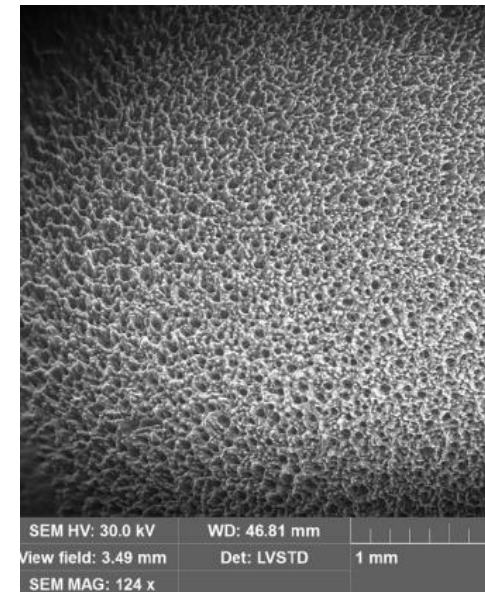
Earth mag field 112°



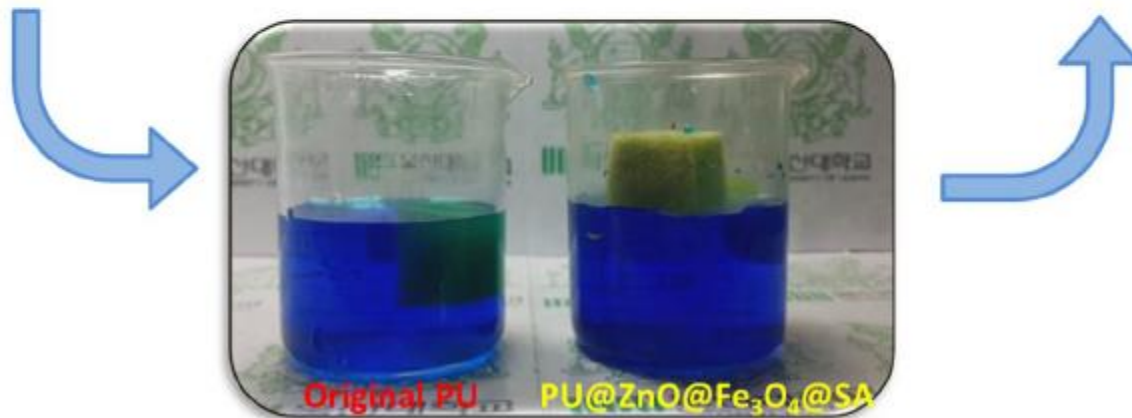
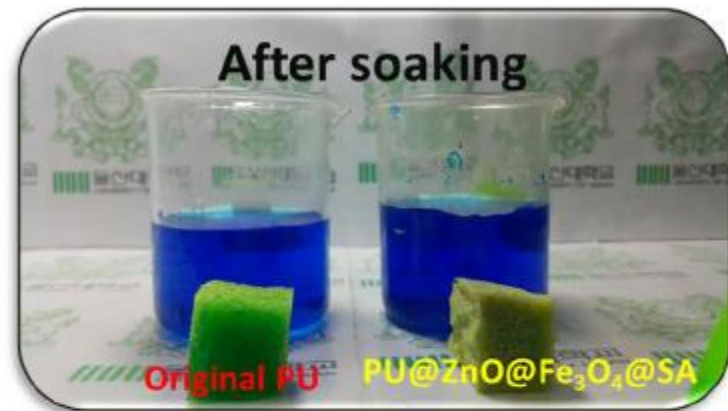
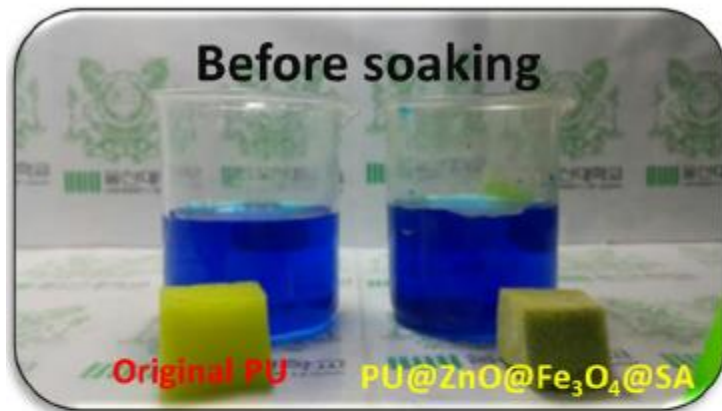
~ 500 mT 138°



70% carbonyl iron MNP



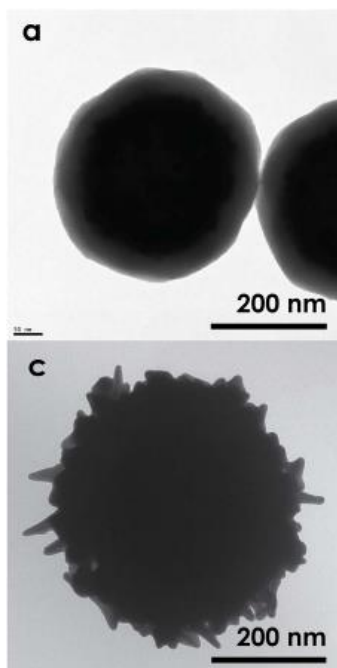
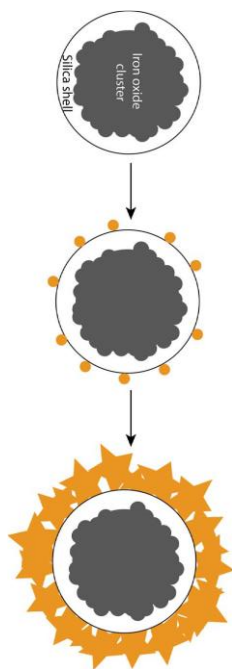
Superhydrophobic Sponge for Oil Cleanup from Spills in the Water



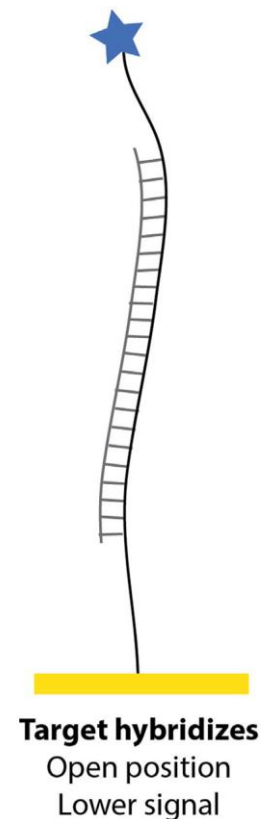
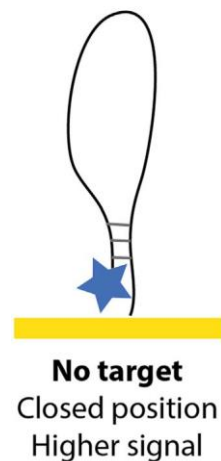
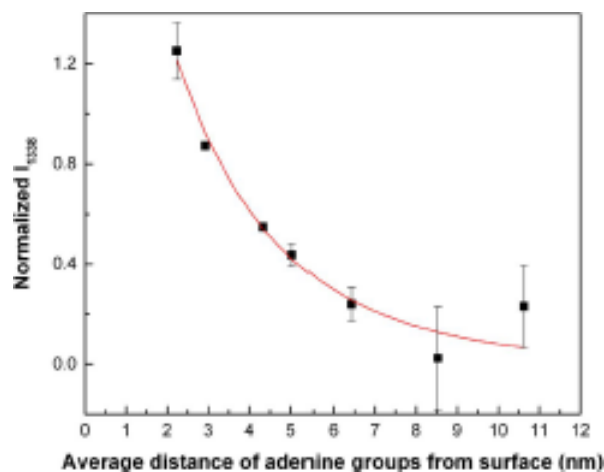
Assays and Diagnostics

DNA Biosensor Assay

- Assay does not need an extrinsic tag or secondary hybridization step
- Surface enhanced Raman spectroscopy

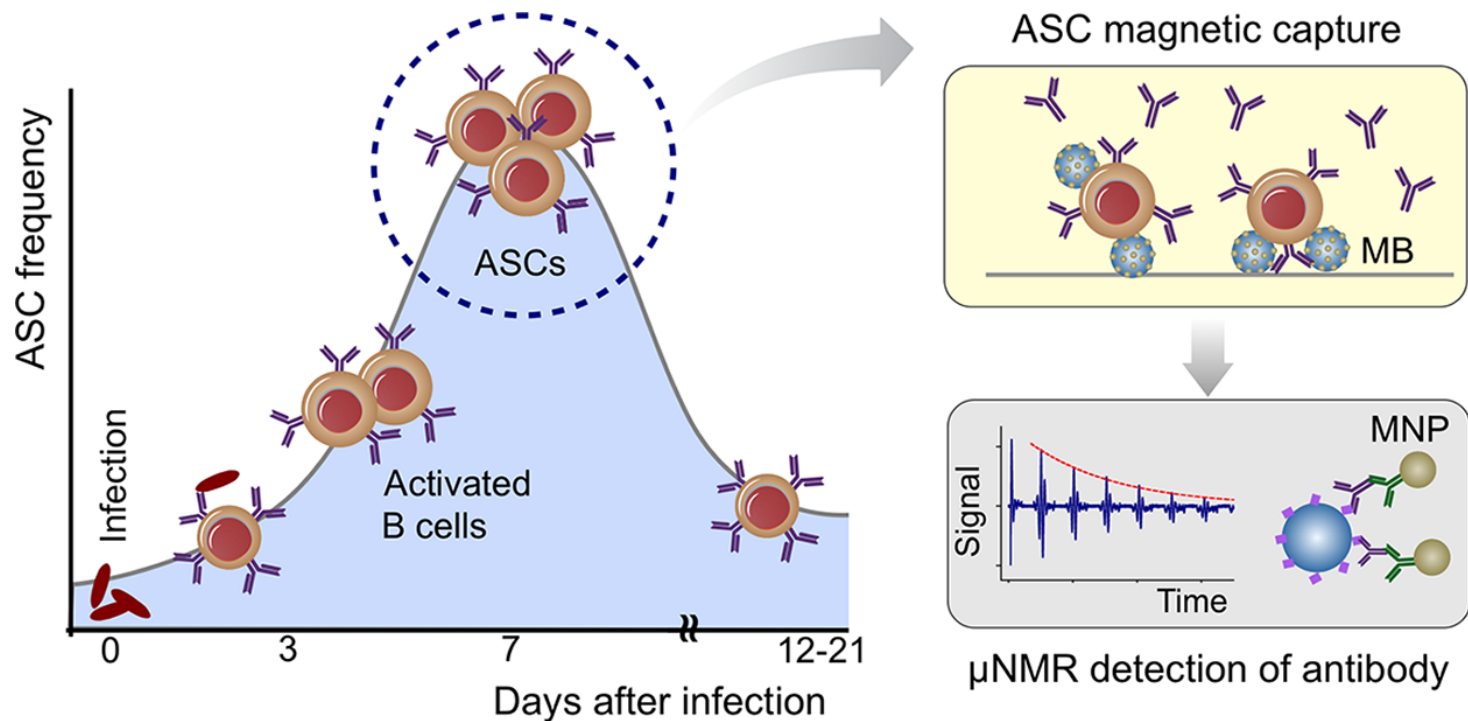


Bedford and Gu et al., *Talanta* 182 (2018) 259–266

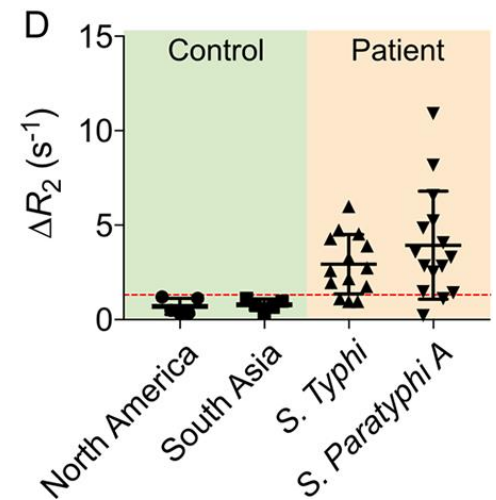
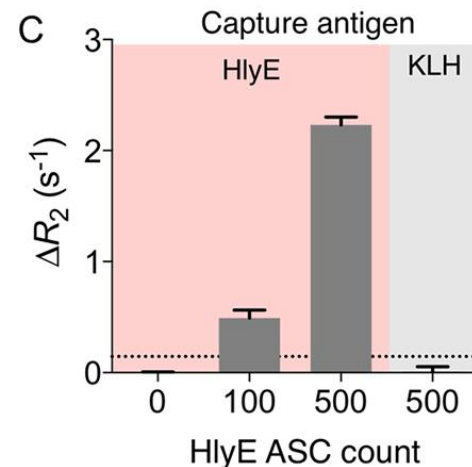
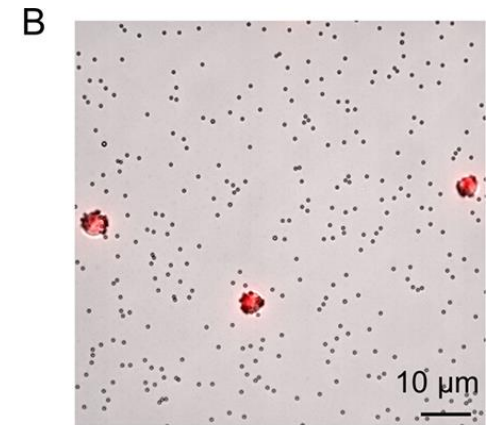
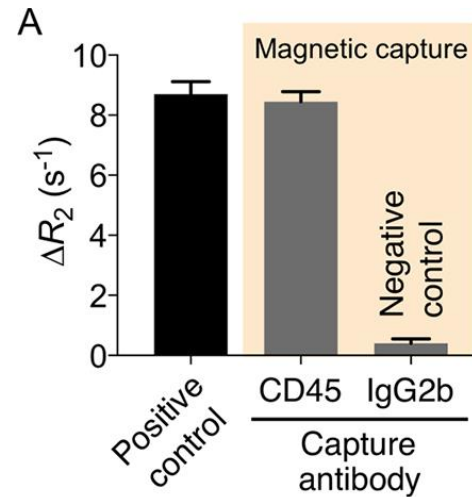
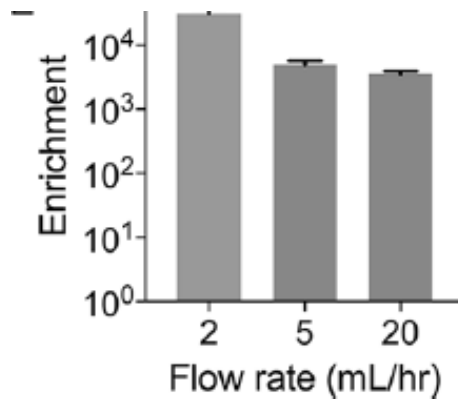
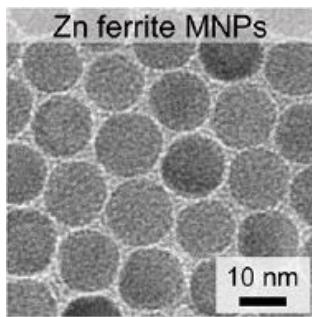
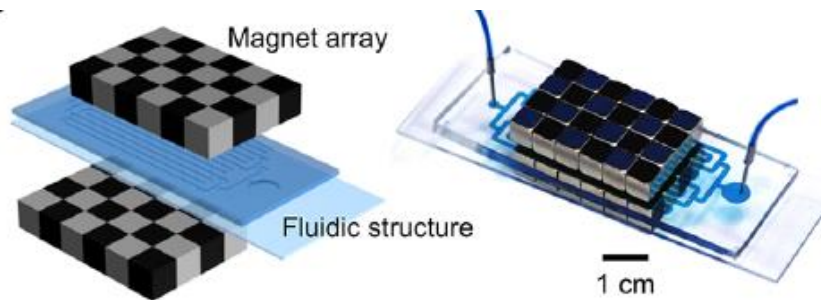


Rapid Diagnosis of Acute Infection with Nanomagnetic System

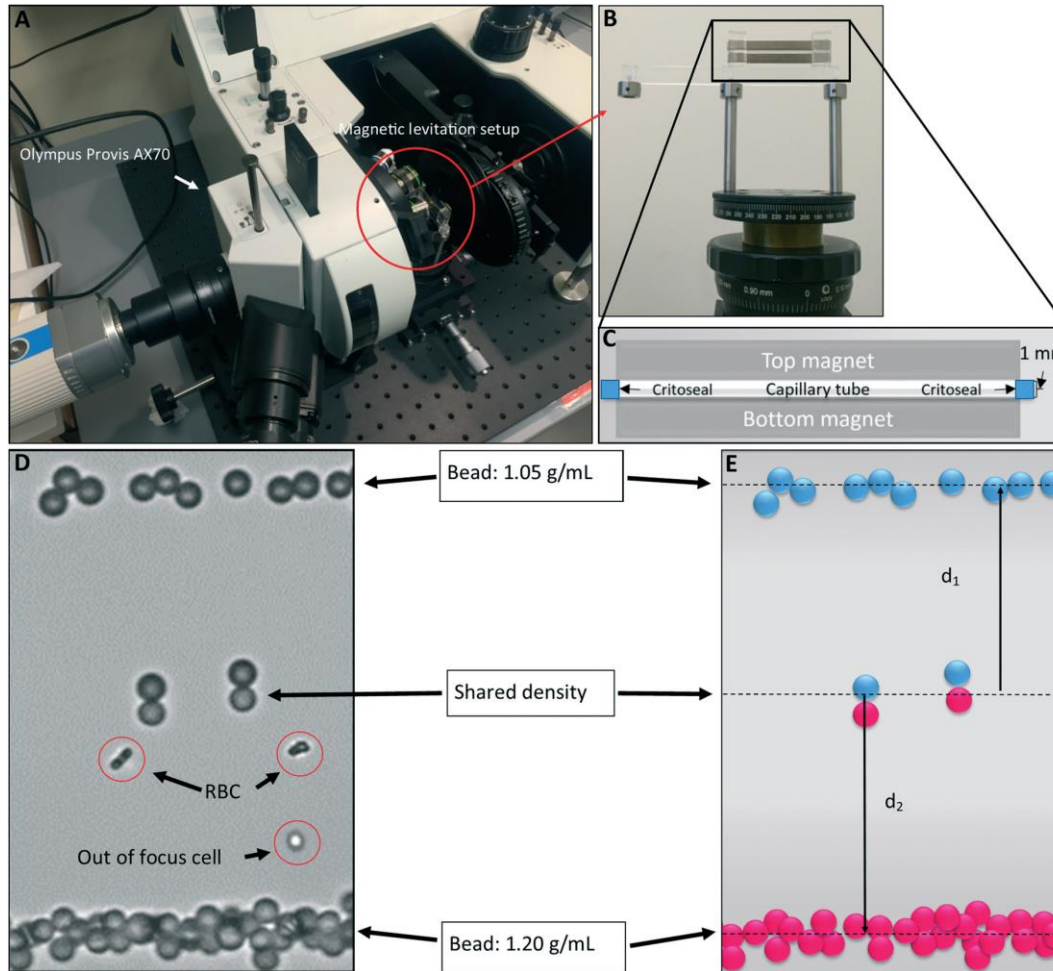
- Detection of antibody-secreting cells (ASCs) in the peripheral blood 3-7 days after infection



Rapid Diagnosis of Acute Infection with Nanomagnetic System

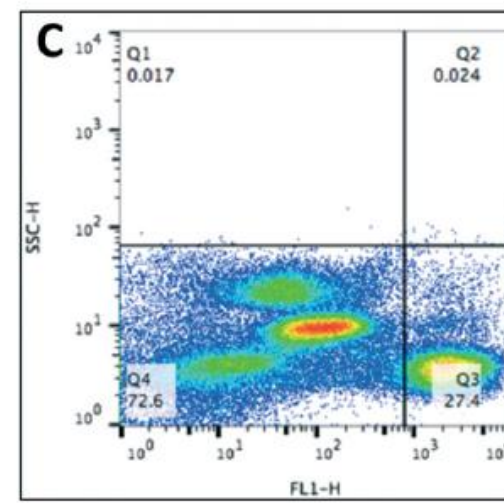
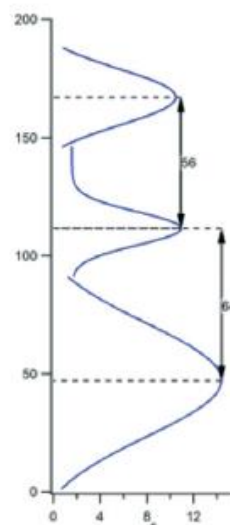
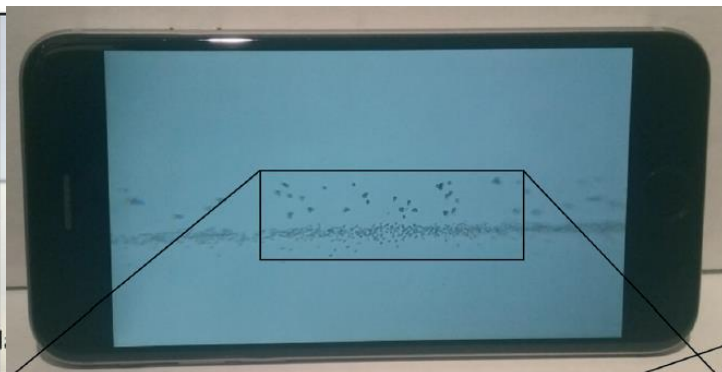
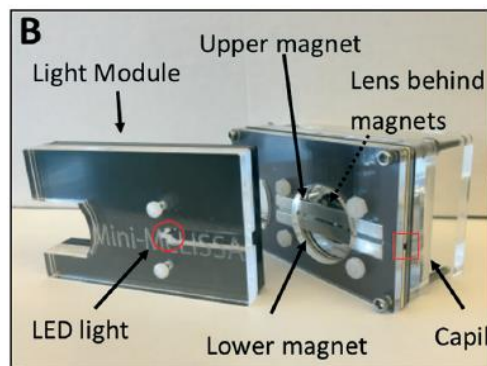
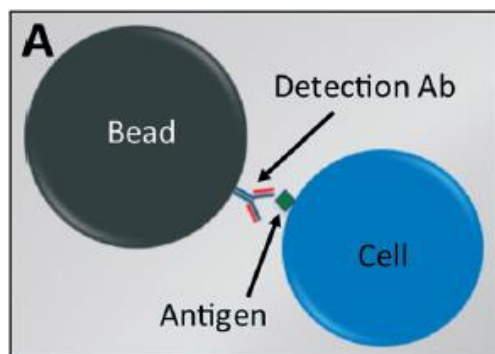


Levitation Based Antigen Detection



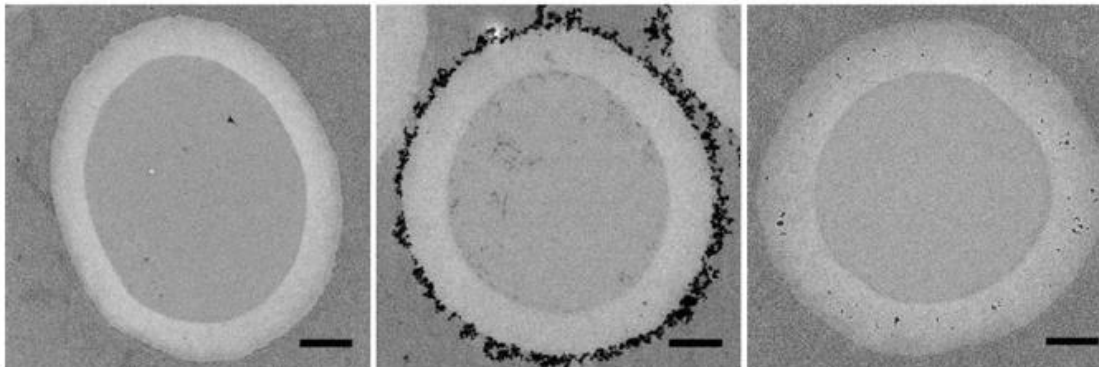
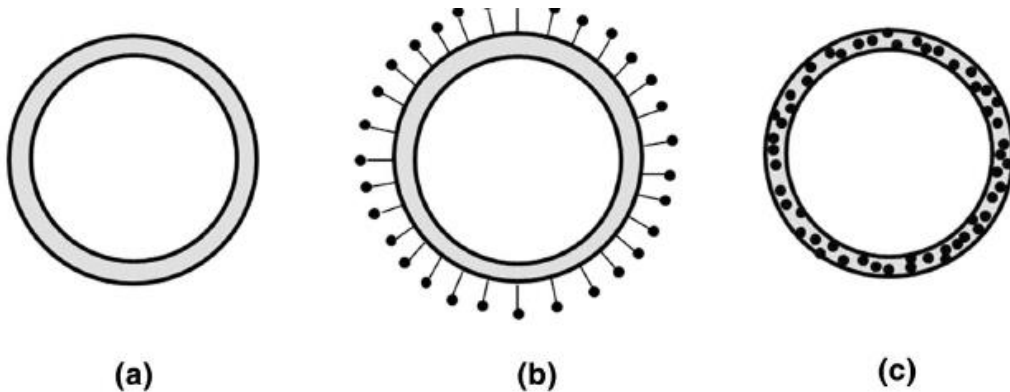
Andersen et al., Lab Chip, 2017,17, 3462-3473

Levitation Based Antigen Detection

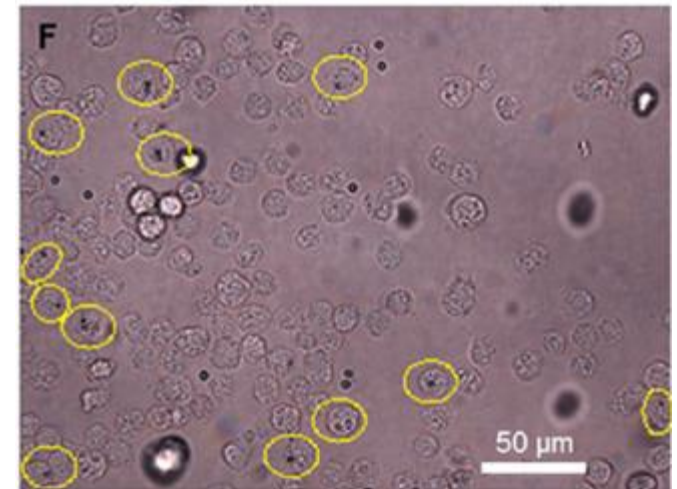


Bubbles Make Good US Contrast

- Uptake speed into macrophages is bubble type dependent – external MNP are fastest

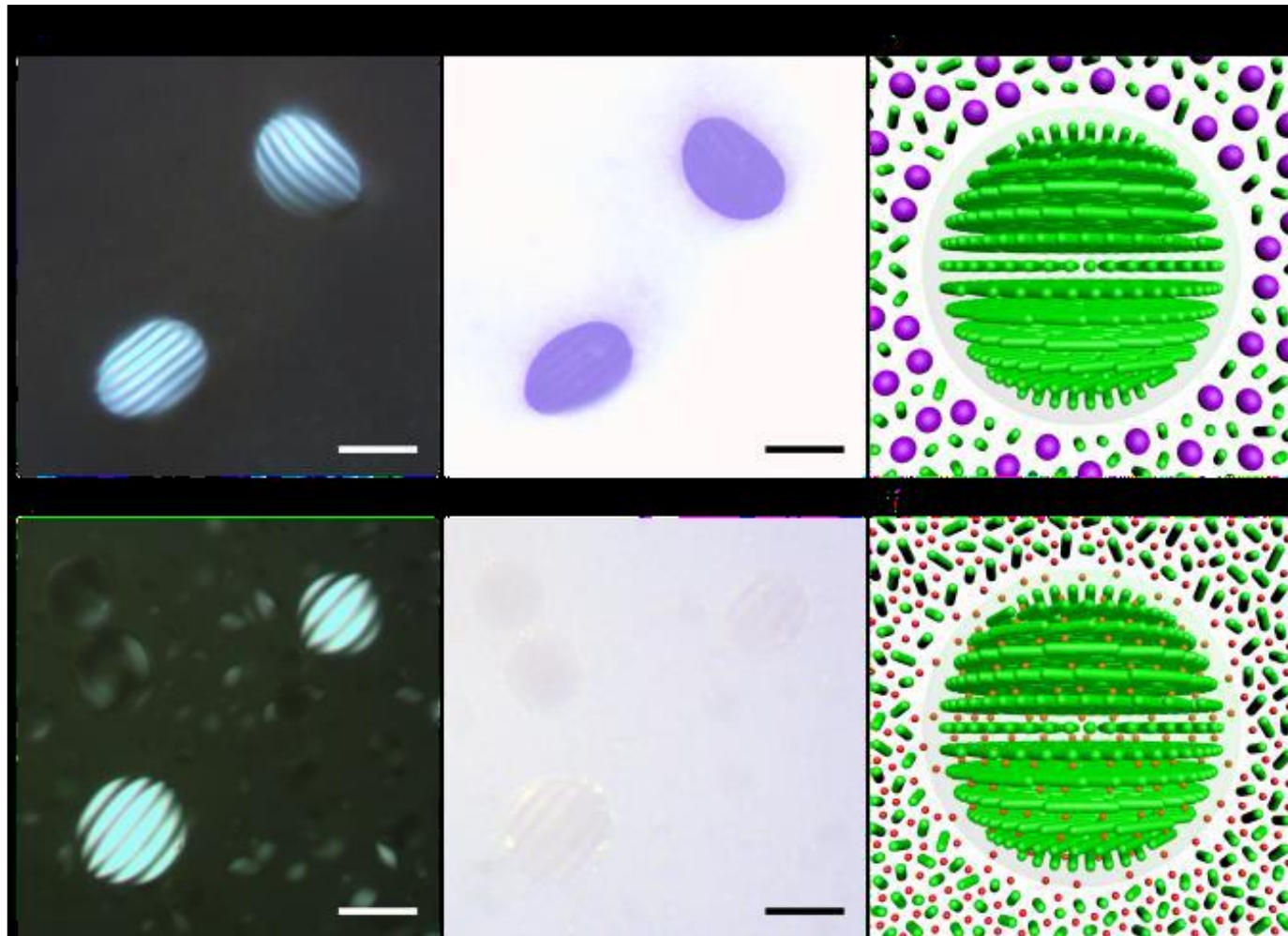


- Endothelial cells do not take up PVA bubbles

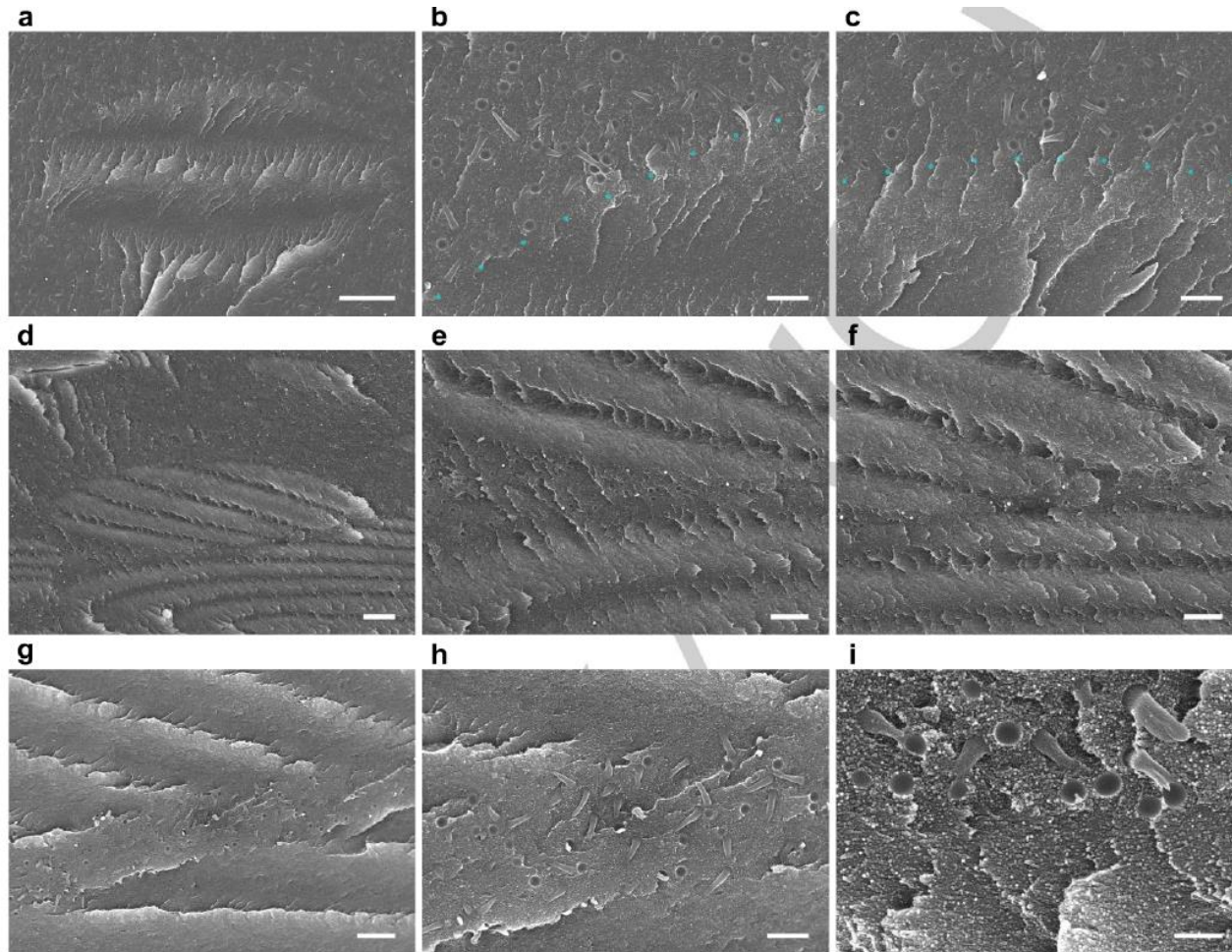


Technical Applications

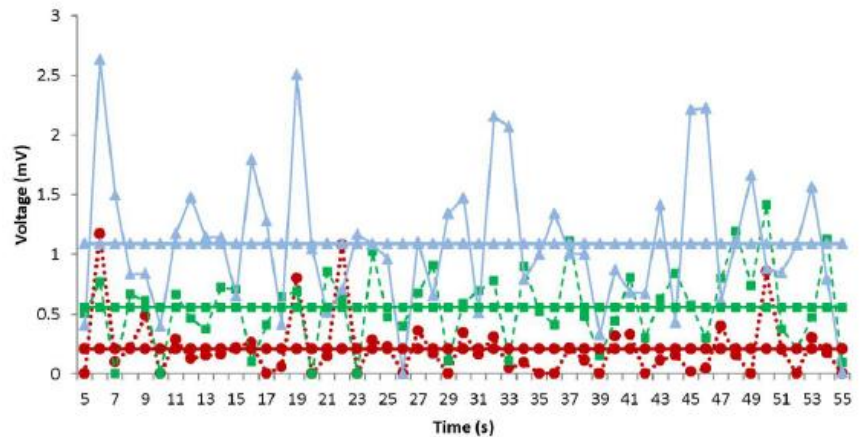
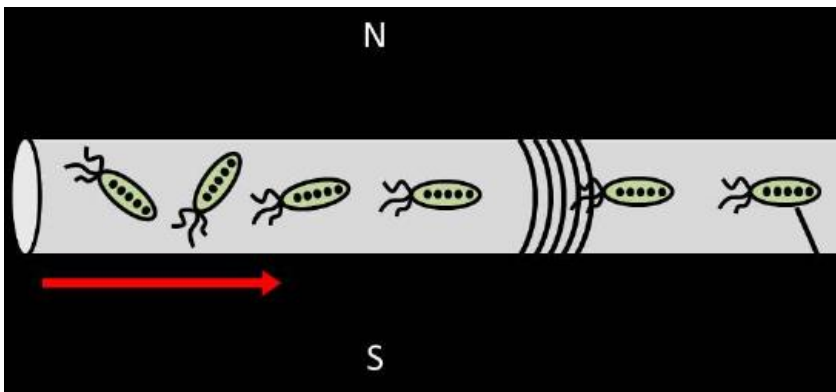
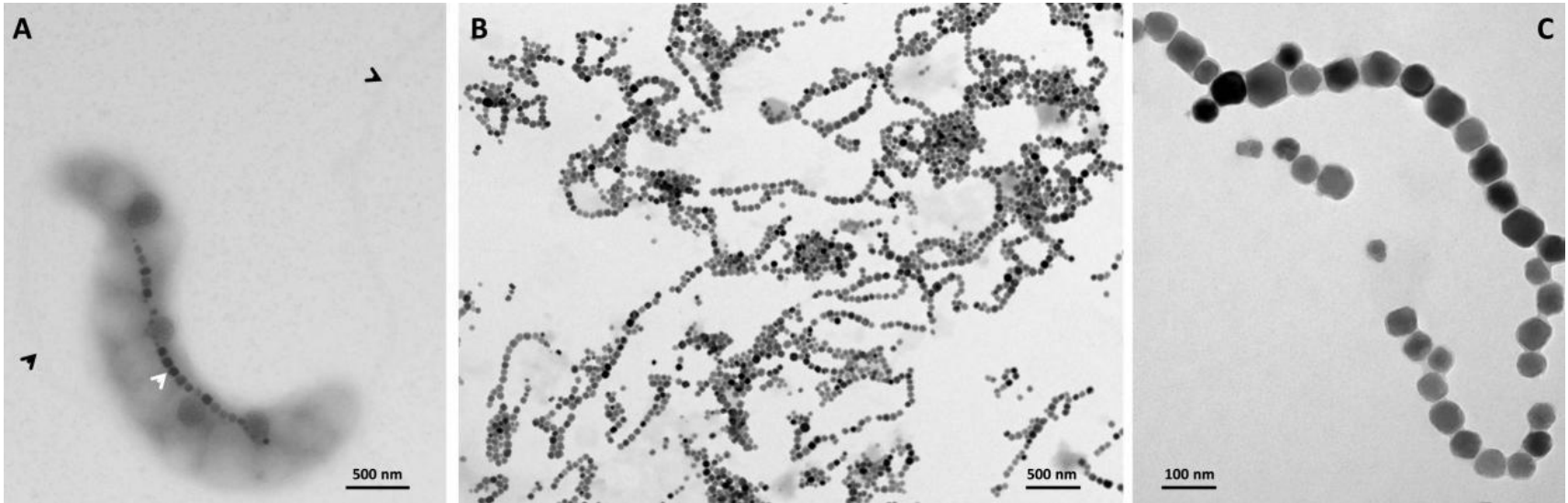
Size-Selective Exclusion Effects of Liquid Crystalline Tactoids on MNPs



Size-Selective Exclusion Effects of Liquid Crystalline Tactoids on MNPs

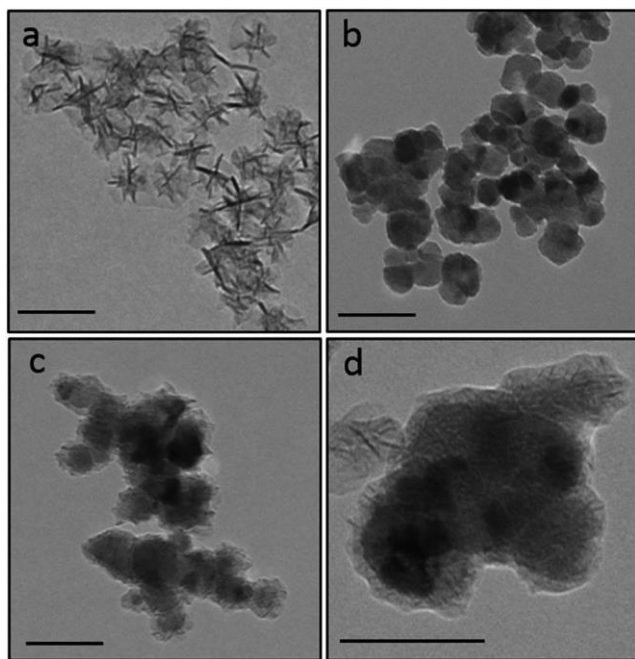


Green Energy with Magnetotactic Bacteria (or Magnetosomes)

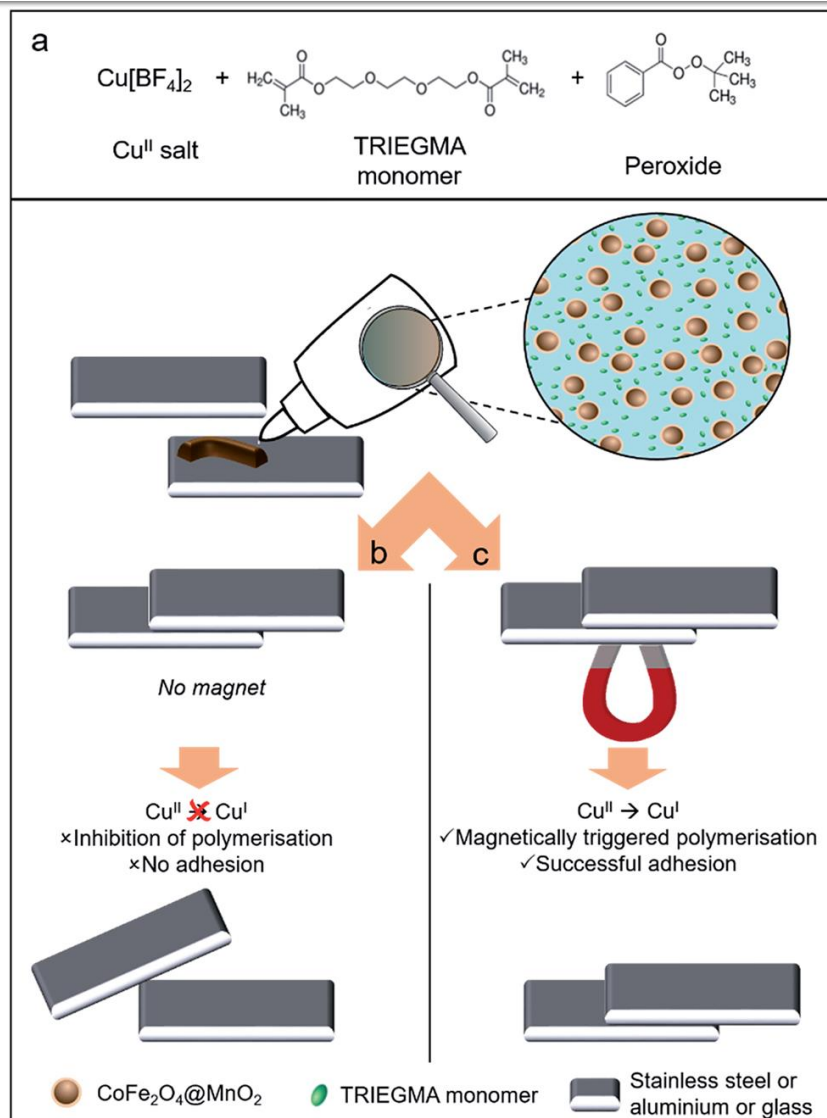


Magnetically Activated Adhesive

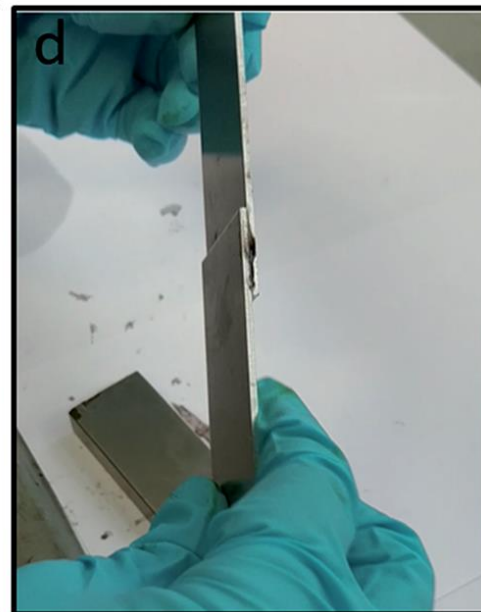
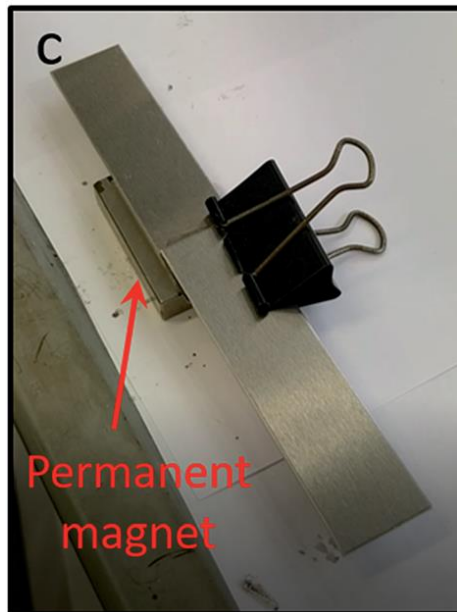
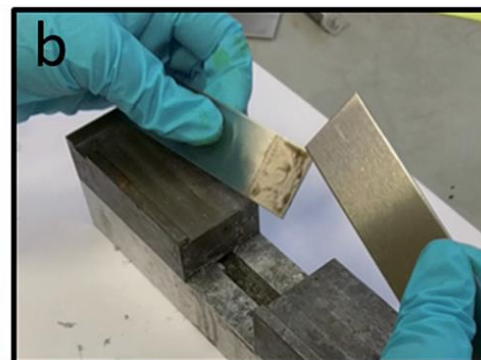
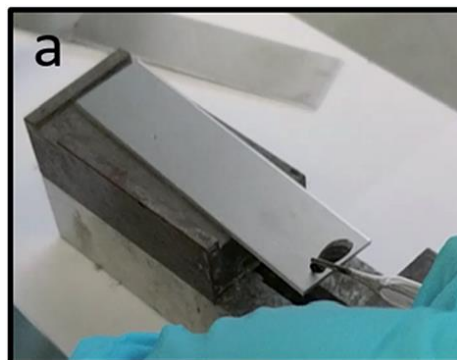
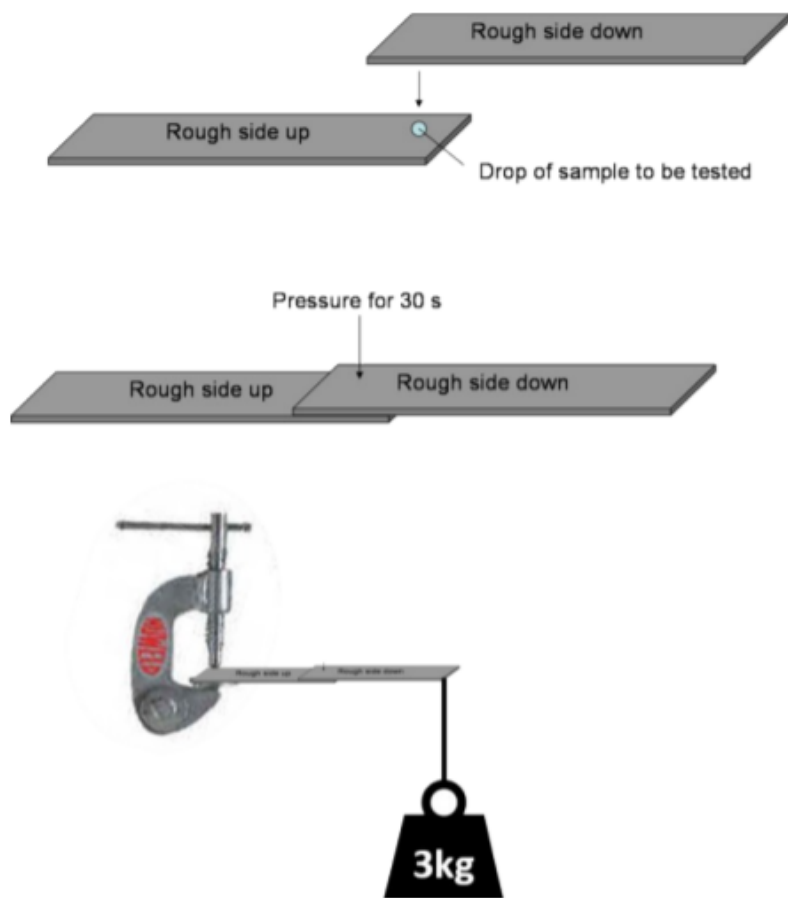
- MNP prevent in sub% concentration the reduction of Cu(II) in the adhesive



Davies et al., Chem. Sci., 2017, 8, 7758–7764



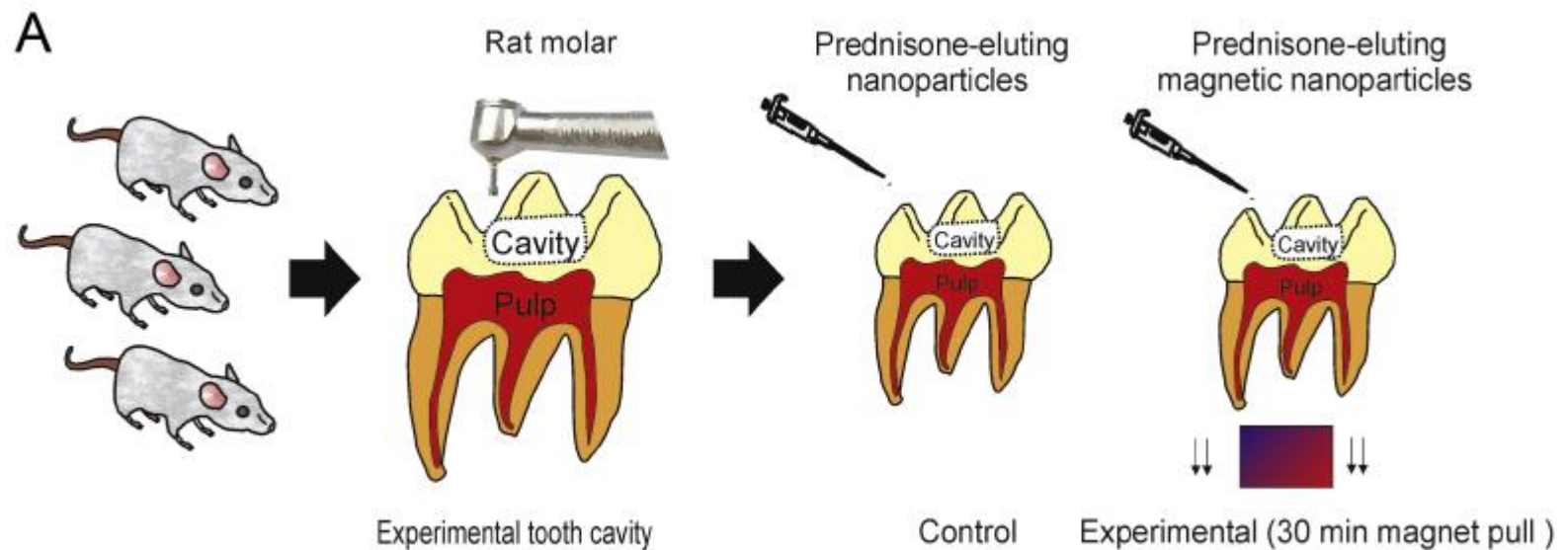
Magnetically Activated Adhesive



Magnetic Force

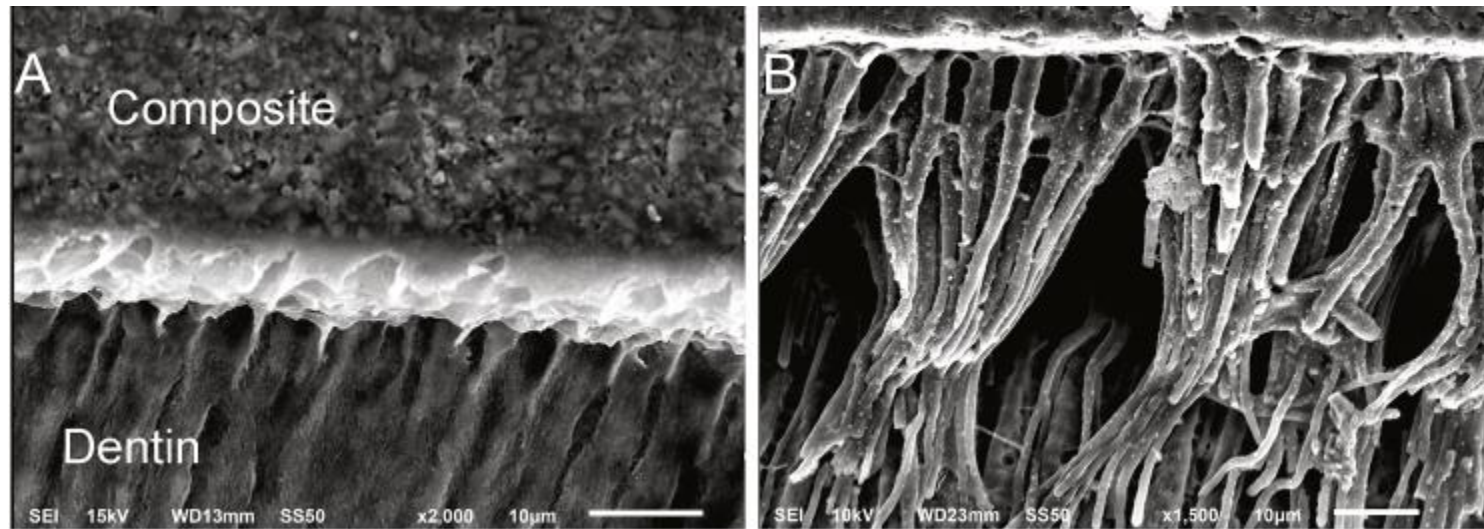
Magnetic Tooth Repair

- Active steering of MNP to the dental pulp through naturally occurring channels in the dentin



Magnetic Tooth Repair

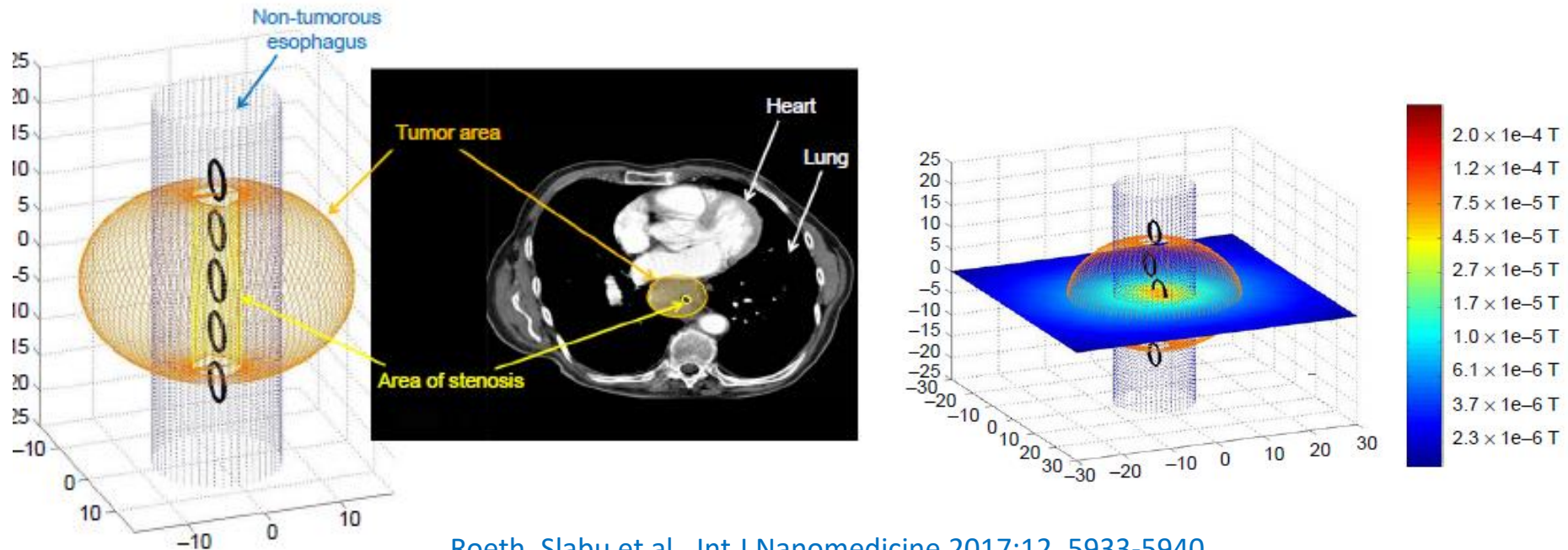
- Active steering of MNP to the dental pulp through naturally occurring channels in the dentin



Endoscopic Targeting of MNP

- Modeling was performed to figure out if endoscopic magnetic targeting deep in the body is potentially useful

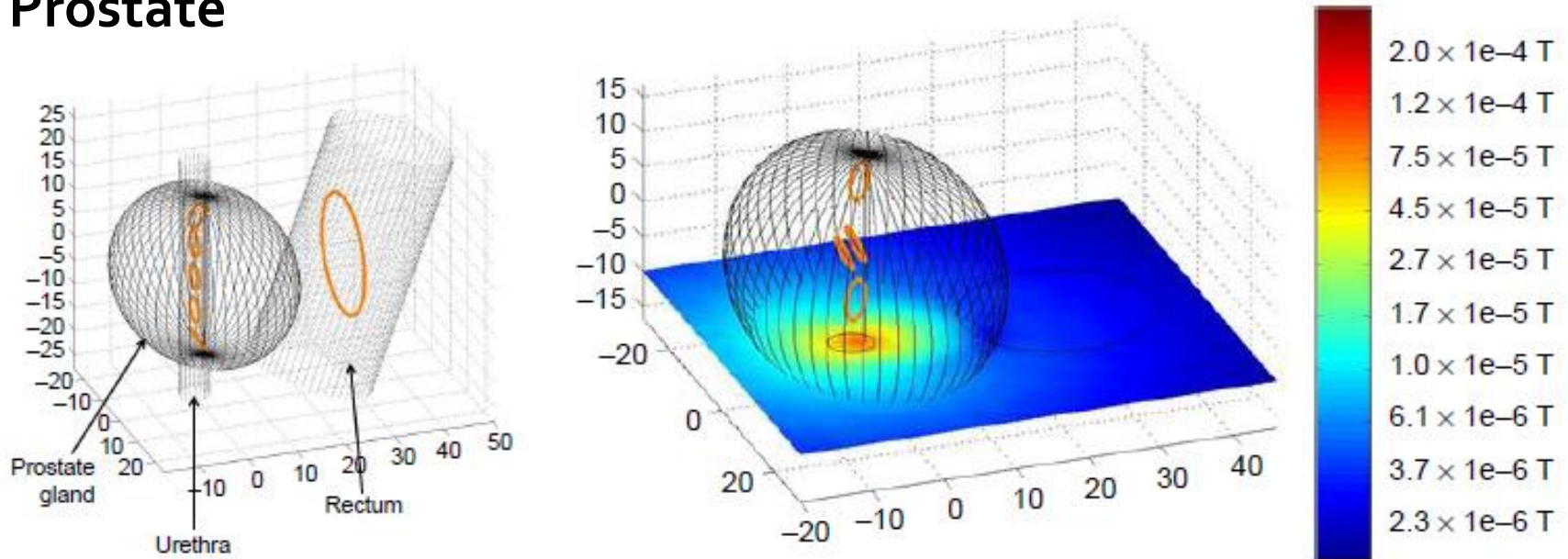
Esophageal Cancer



Endoscopic Targeting of MNP

- Modeling was performed to figure out if endoscopic magnetic targeting deep in the body is potentially useful

Prostate



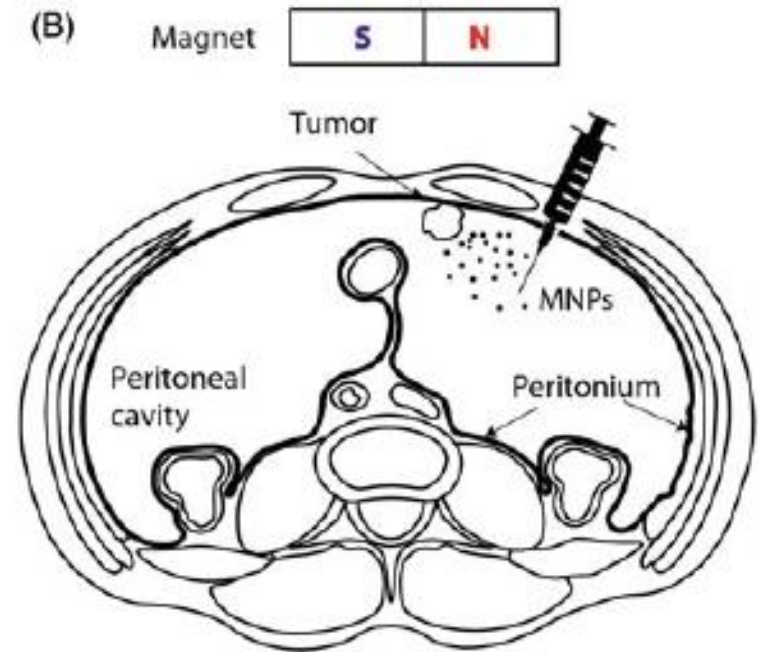
Intraperitoneal Magnetic Concentration of Chemotherapeutic Drugs

- Intraperitoneal infusion of chemotherapeutic drug
- Optimization of tumor drug exposure with MNP

(A)

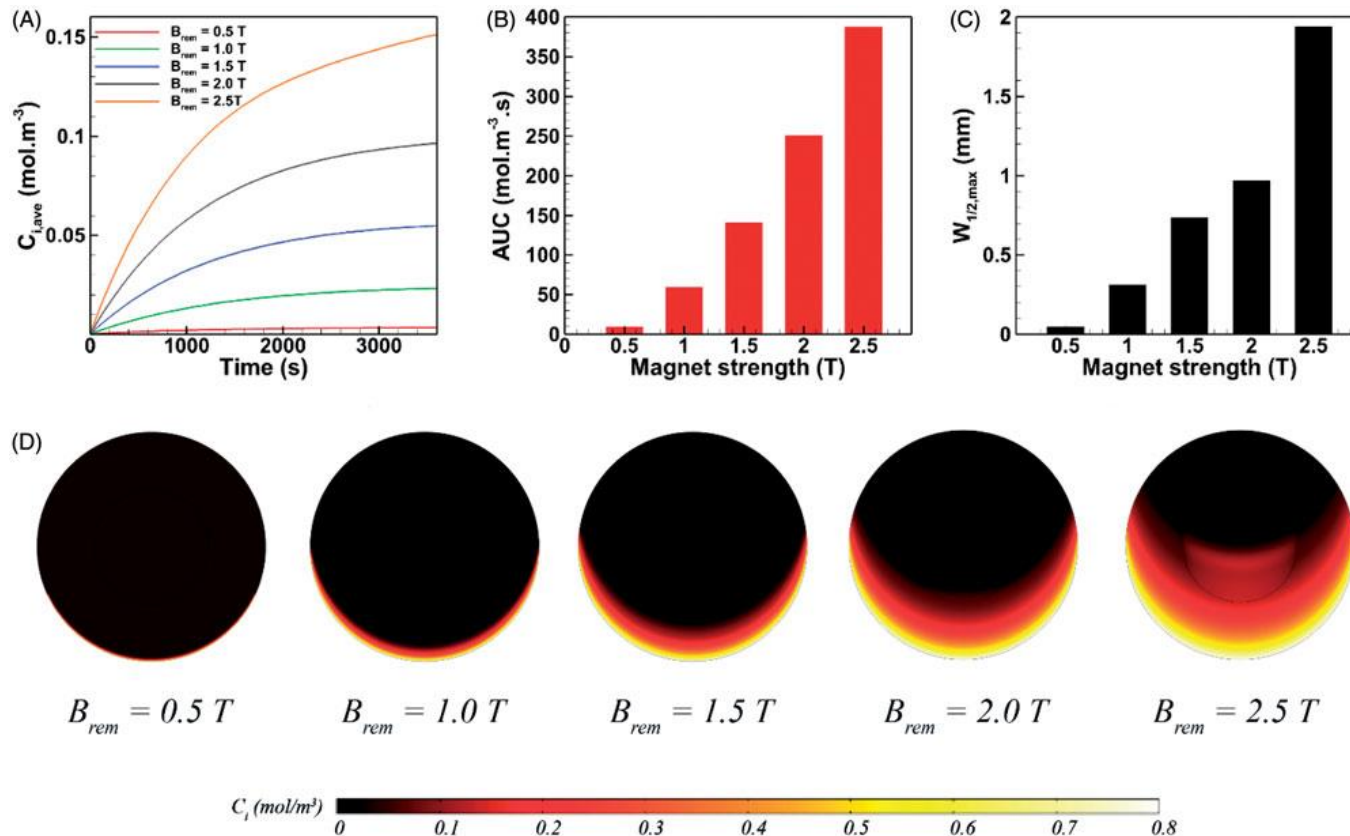


(B)



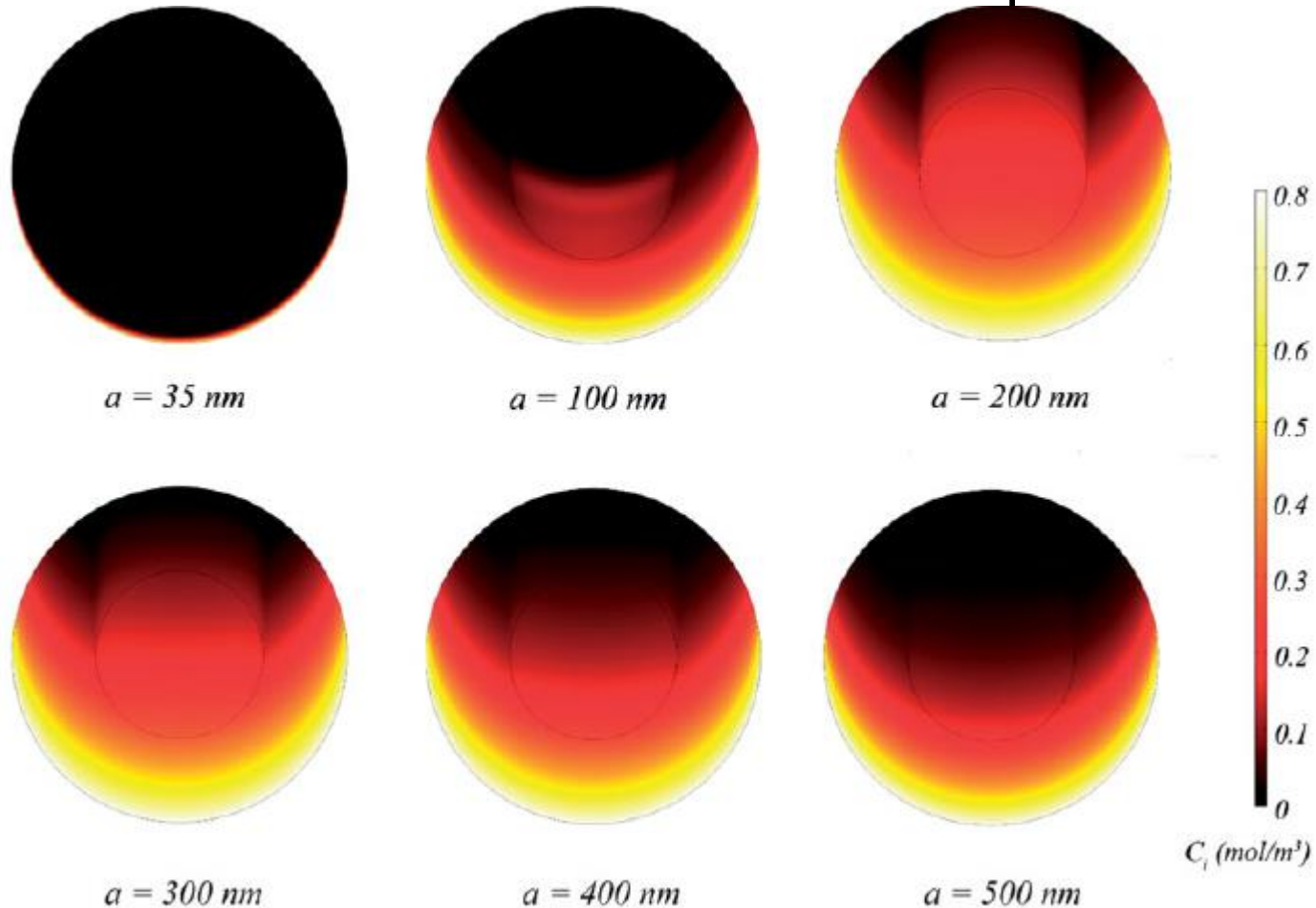
Intraperitoneal Magnetic Concentration of Chemotherapeutic Drugs

- Magnetic force increases concentration in tumor, as well as length of exposure



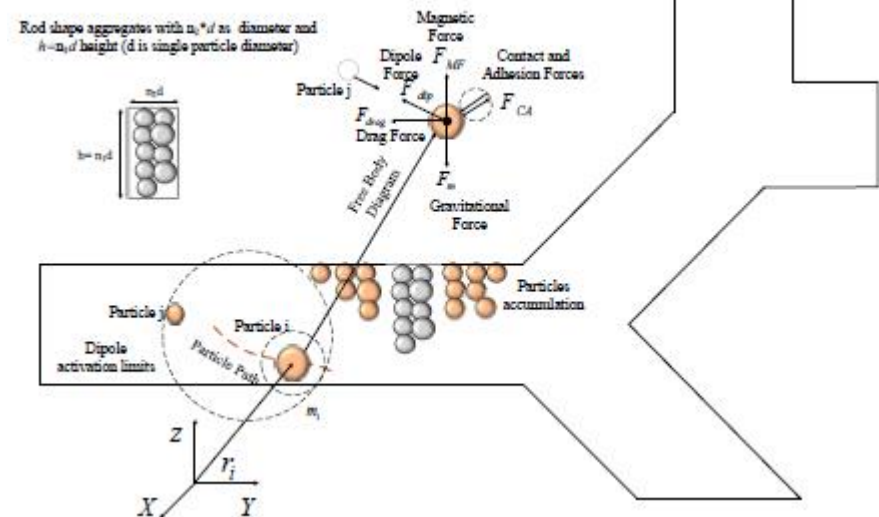
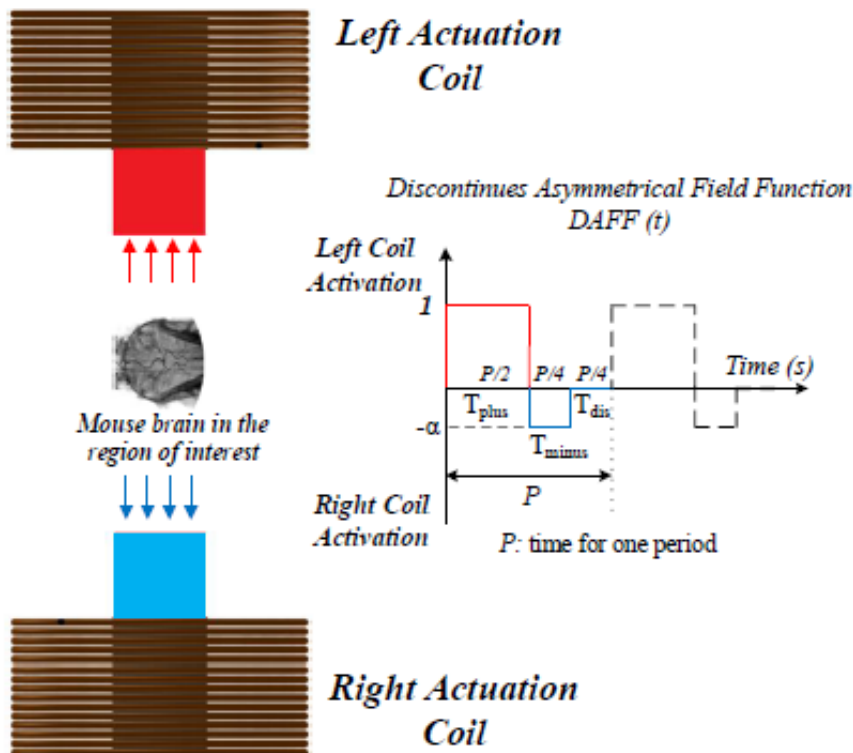
Intraperitoneal Magnetic Concentration of Chemotherapeutic Drugs

- MNP size is also crucial and should be optimized

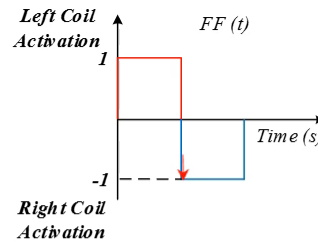


Magnetic Actuation to Disaggregate MNP and Pass the Blood-Brain Barrier

- Delivery of MNPs to BBB requires control over aggregation and disaggregation
- Only possible by discontinuous magnetic field function

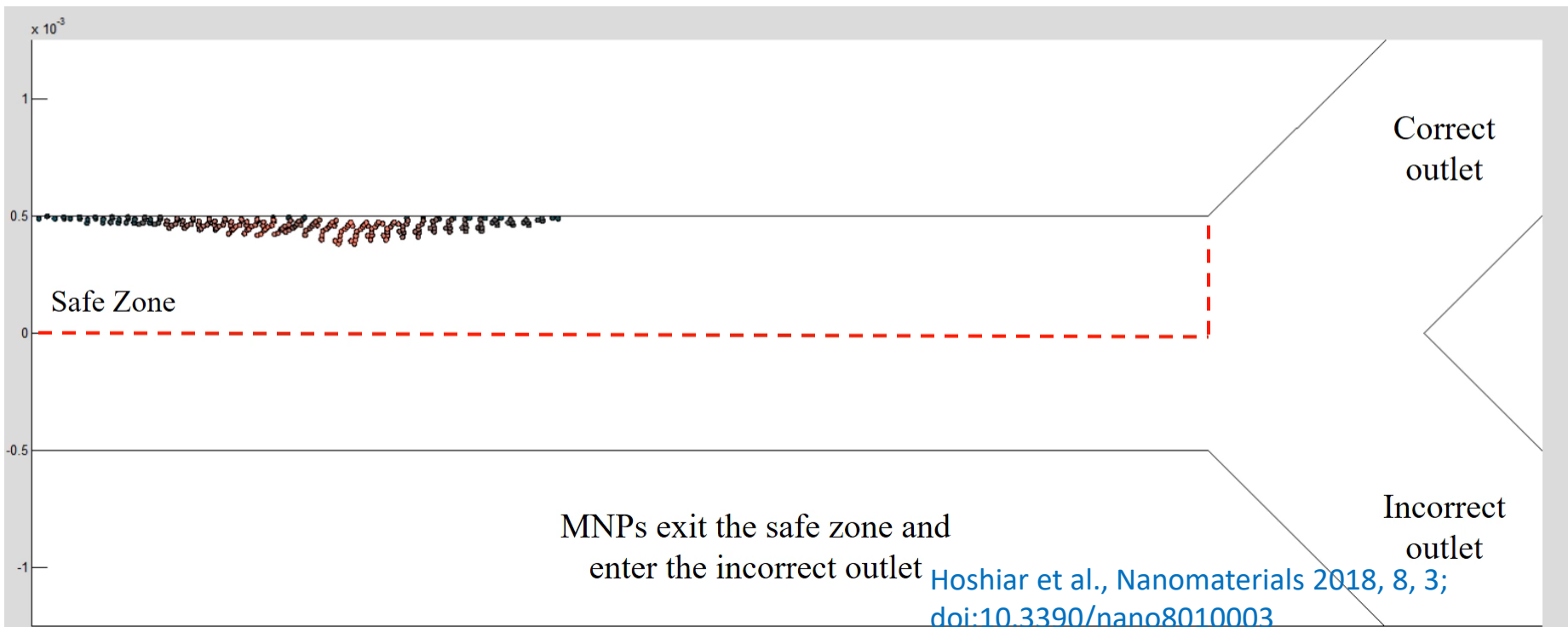


Magnetic Actuation to Disaggregate MNP and Pass the Blood-Brain Barrier



Magnetic Field: 6A, Fr. 0.5

Flow velocity: 1 mm/s

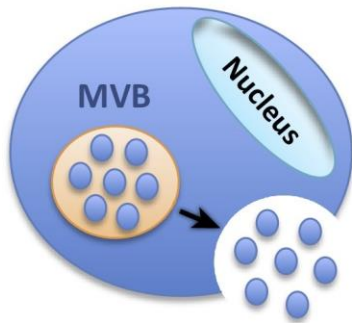


Biological Applications

Targeting of Cell-Derived Magnetic Microvesicles

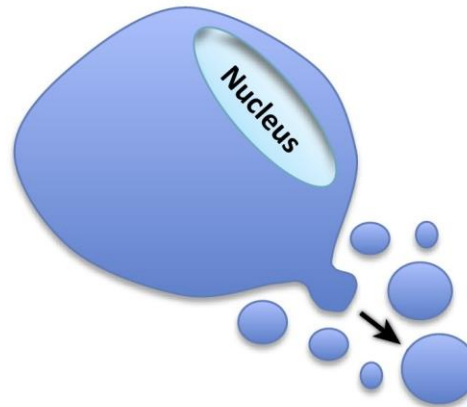
- Microvesicles are nanosized (100-1000 nm) membrane-bound vesicles secreted by many cell types
- Can transport cargos including protein, RNA, DNA

(A) Exosomes



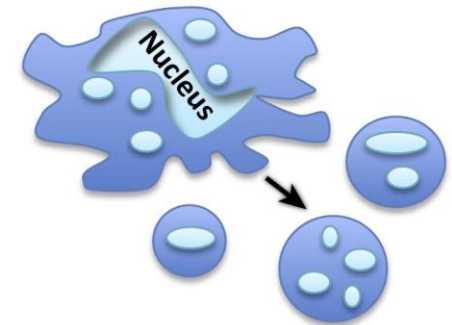
Internal budding followed by secretion

(B) Microvesicles



Budding at the cell surface

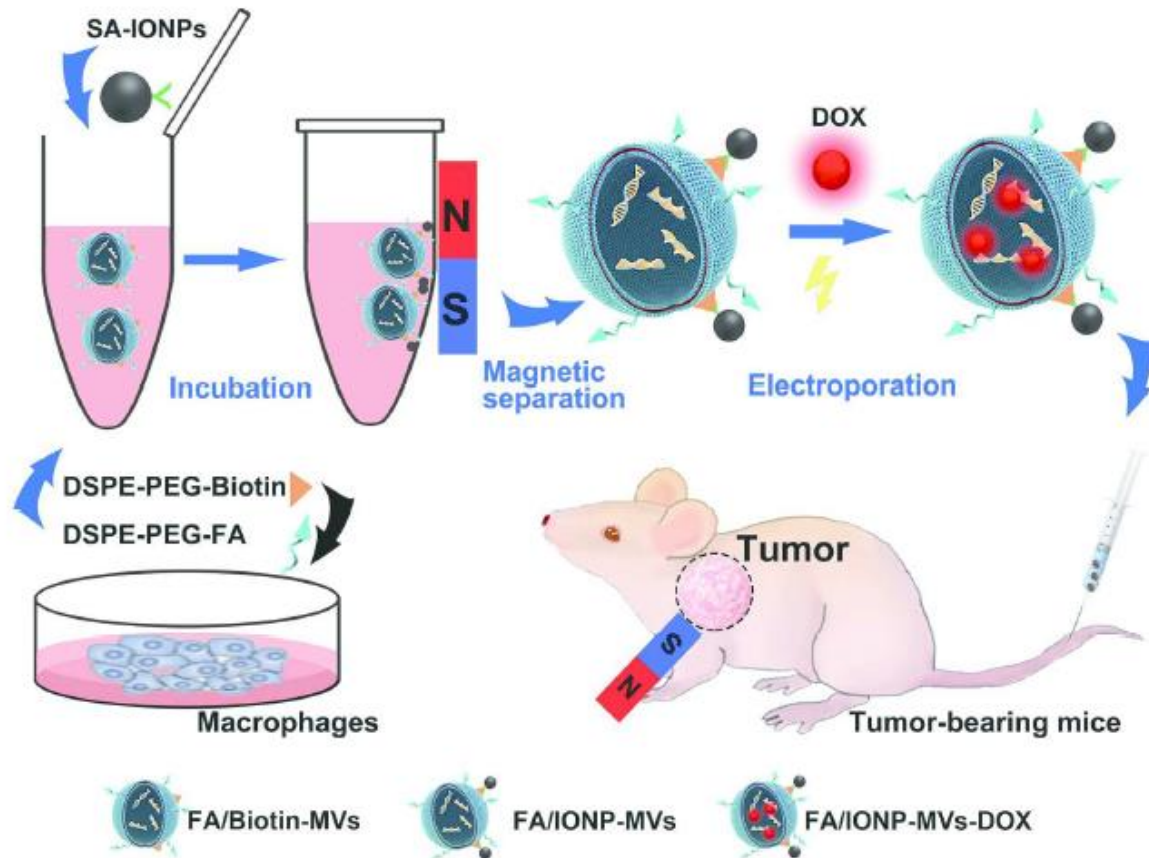
(C) Apoptotic bodies



Cell fragmentation

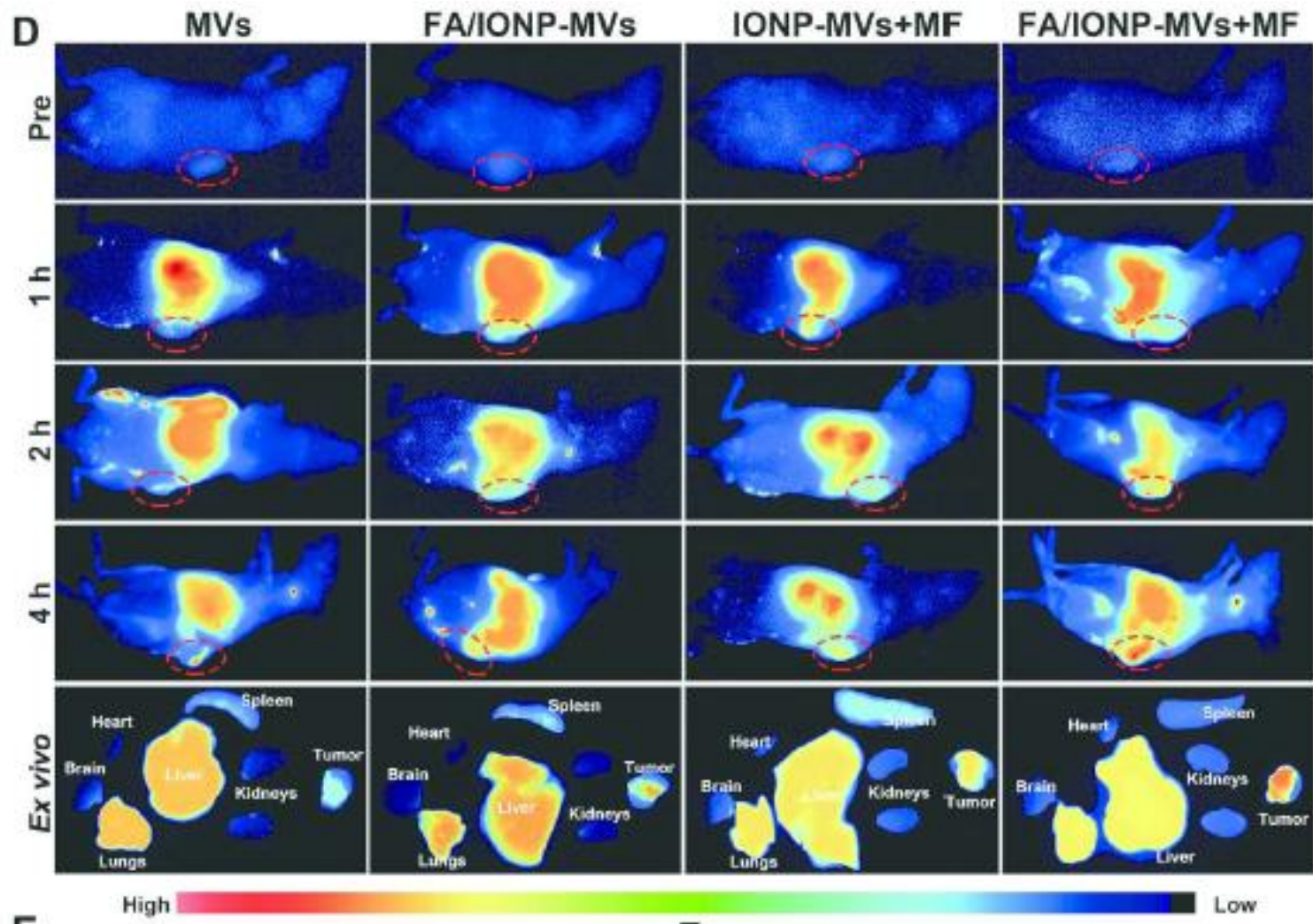
Targeting of Cell-Derived Magnetic Microvesicles

- Biotin- and folic acid modified microvesicles were used to make magnetic targeting microvesicles

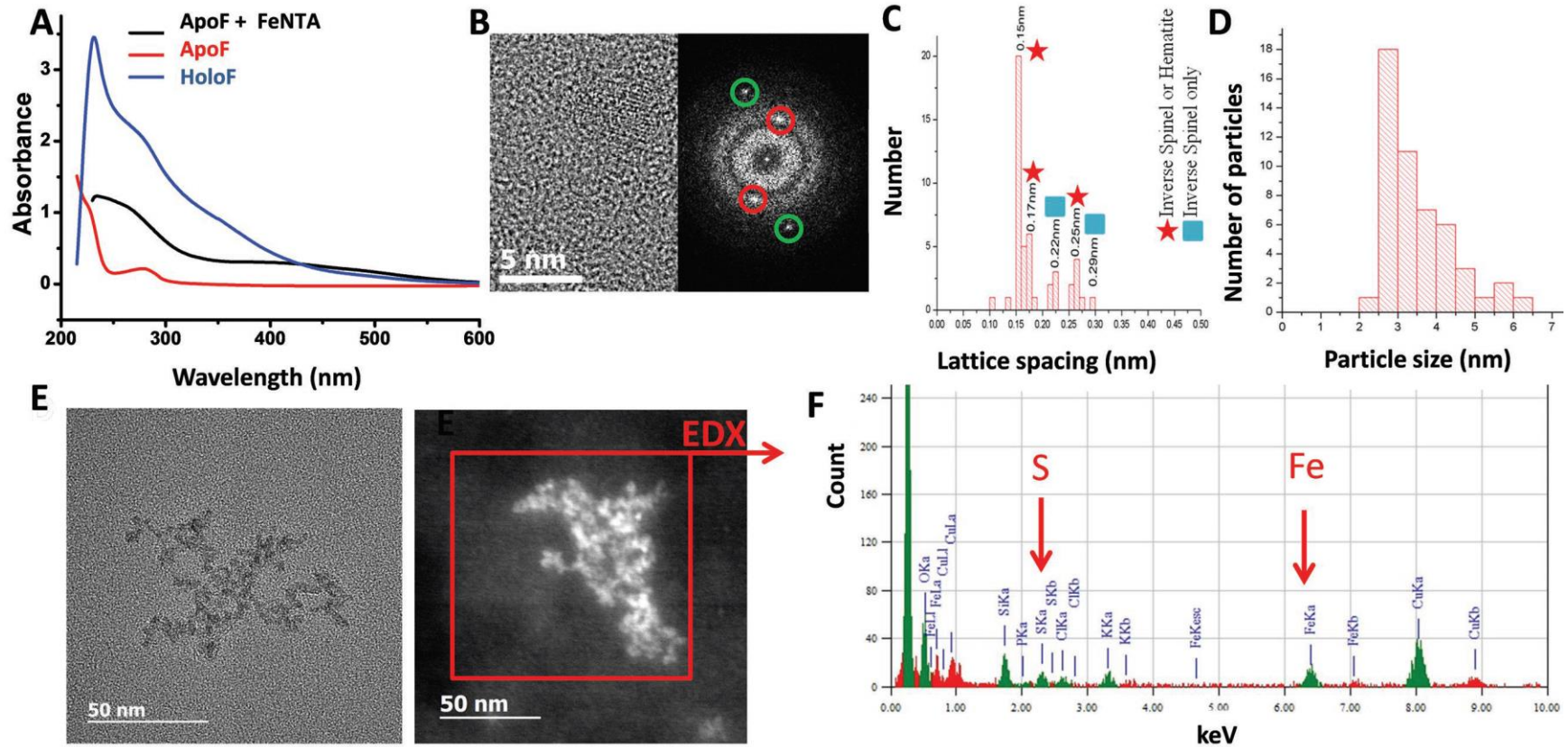


Zhang et al. (2018) ACS Nano
DOI:
[10.1021/acsnano.6b05630](https://doi.org/10.1021/acsnano.6b05630)

Targeting of Cell-Derived Magnetic Microvesicles



Ferritin Protein Controls Degradation of Iron Oxide Nanoparticles



Medical Applications

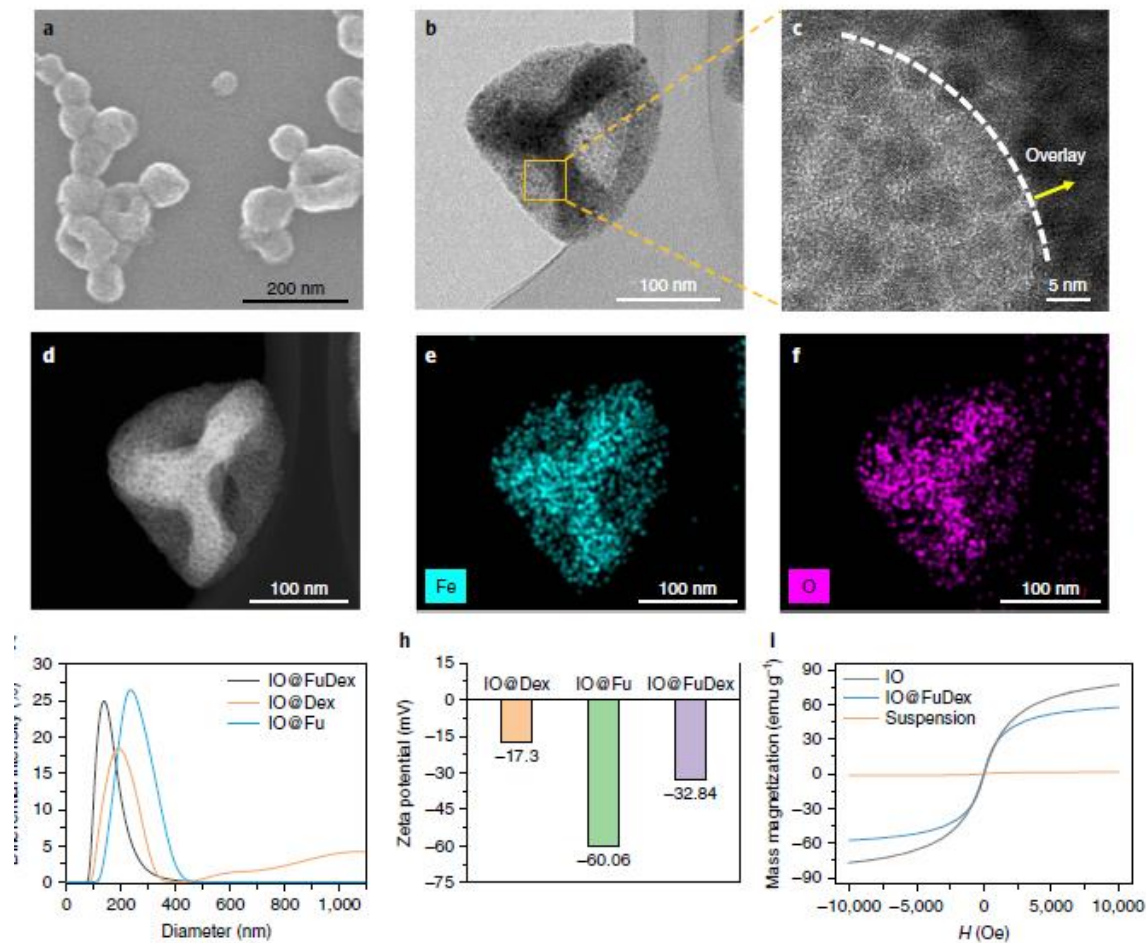
Niels Kaj Jerne Auditorium



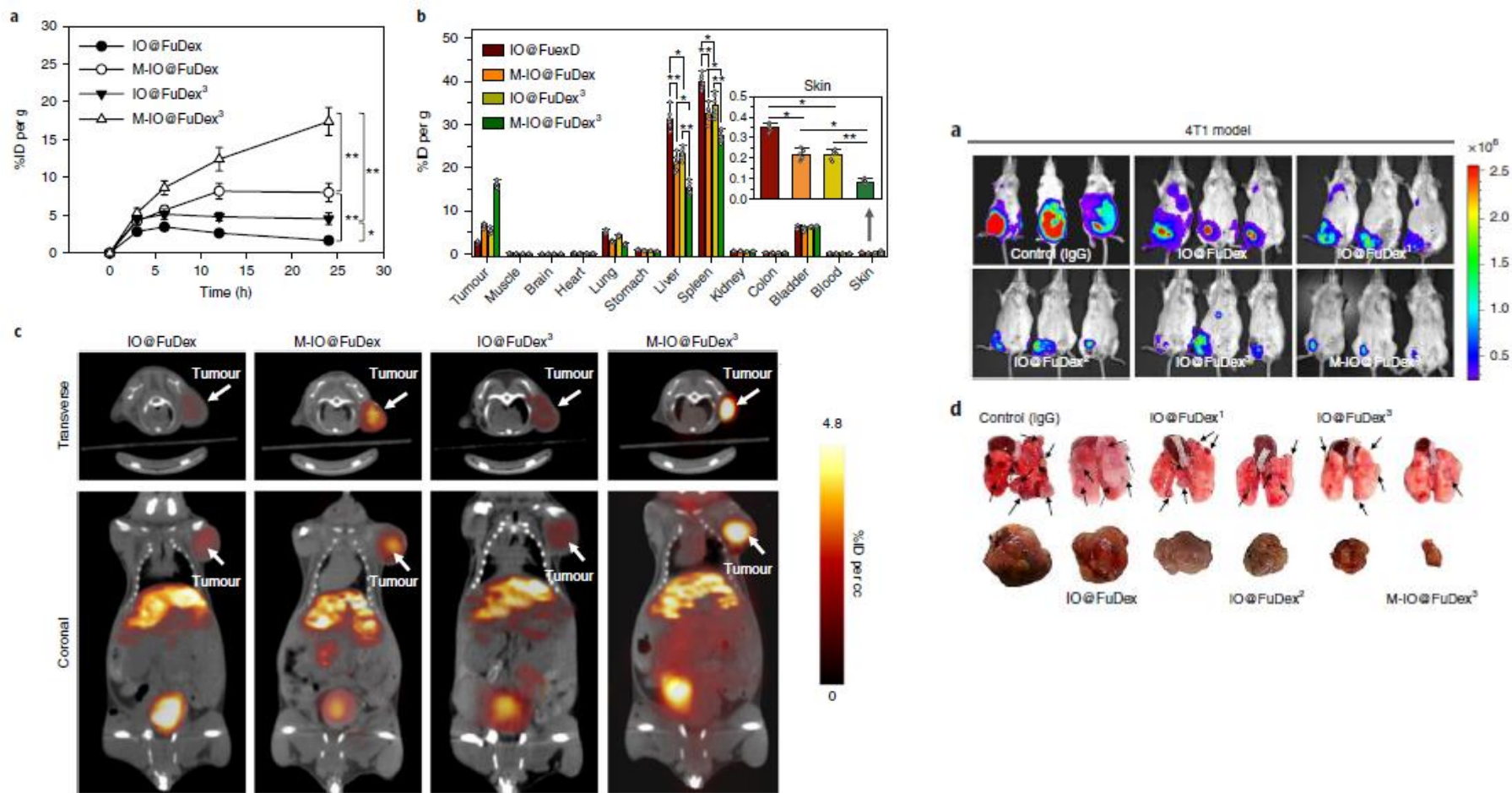
1911-1994

- Was a Danish immunologist
- Shared Nobel Prize in Physiology or Medicine in 1984 with Georges J. F. Köhler and César Milstein "for theories concerning the specificity in development and control of the immune system and the discovery of the principle for production of monoclonal antibodies"

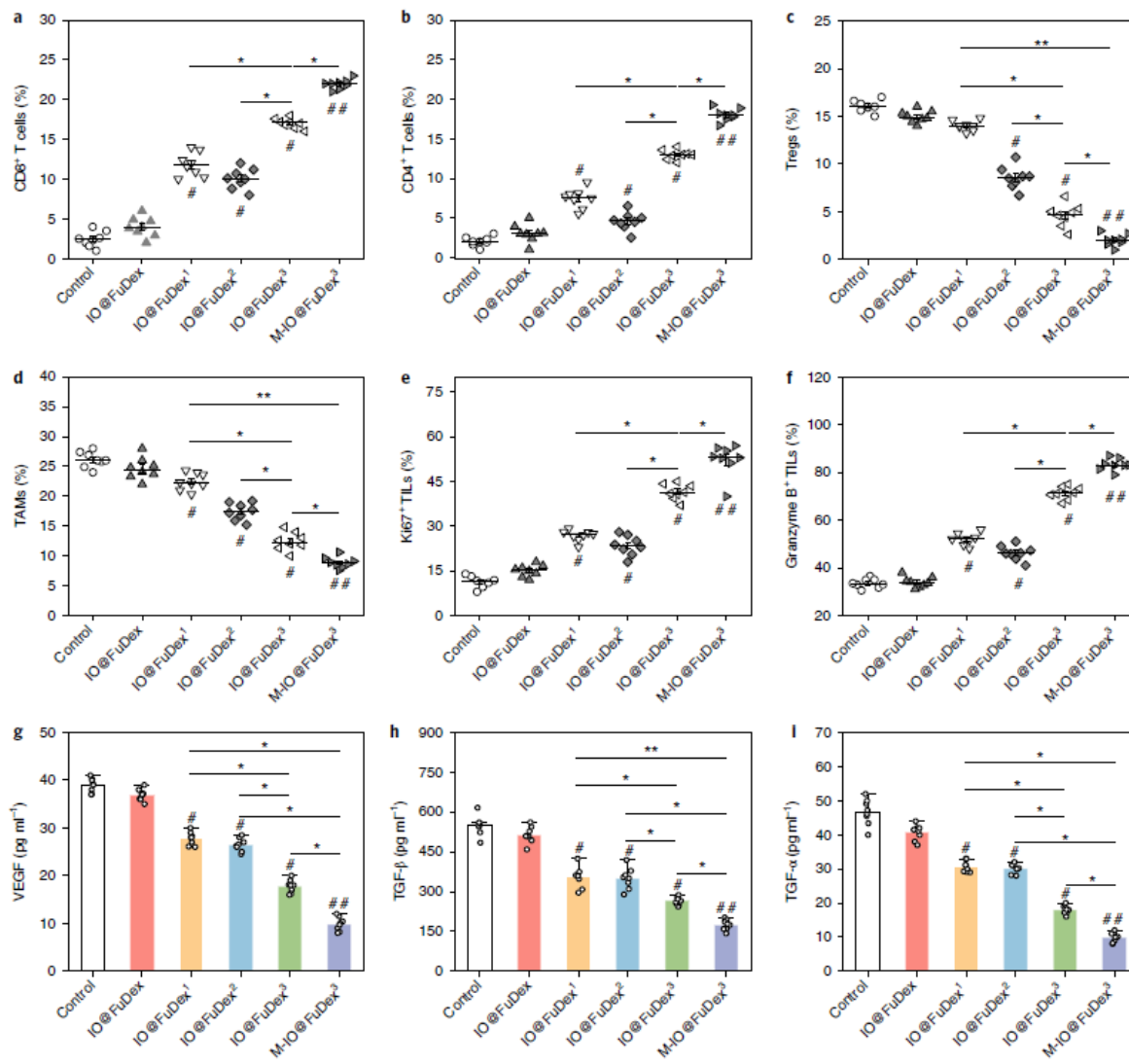
Fucoidan-Based Magnetic Nanoparticles Enhance Immunotherapy



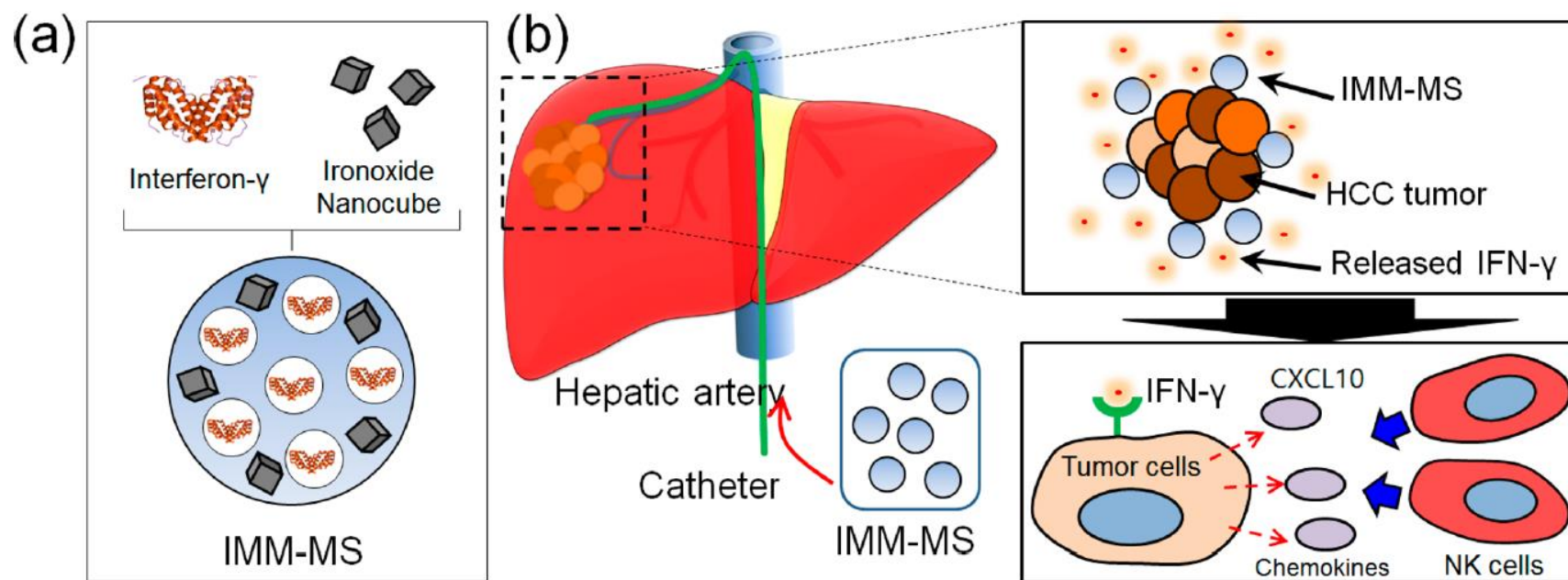
Fucoidan-Based Magnetic Nanoparticles Enhance Immunotherapy



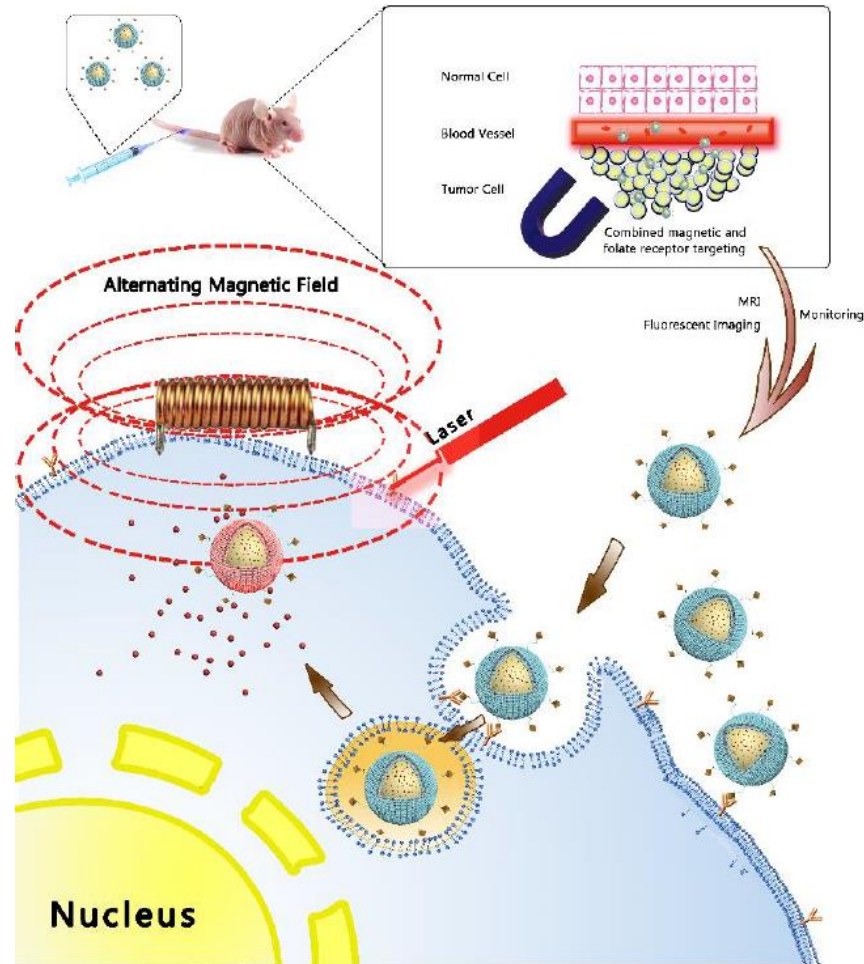
Fucoidan-Based Magnetic Nanoparticles Enhance Immunotherapy



Immunomodulatory Microspheres

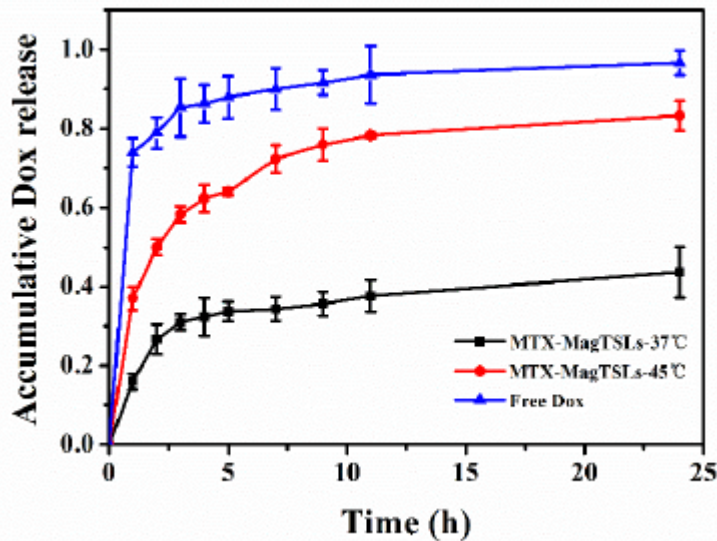


Thermo-Sensitive Magnetoliposomes

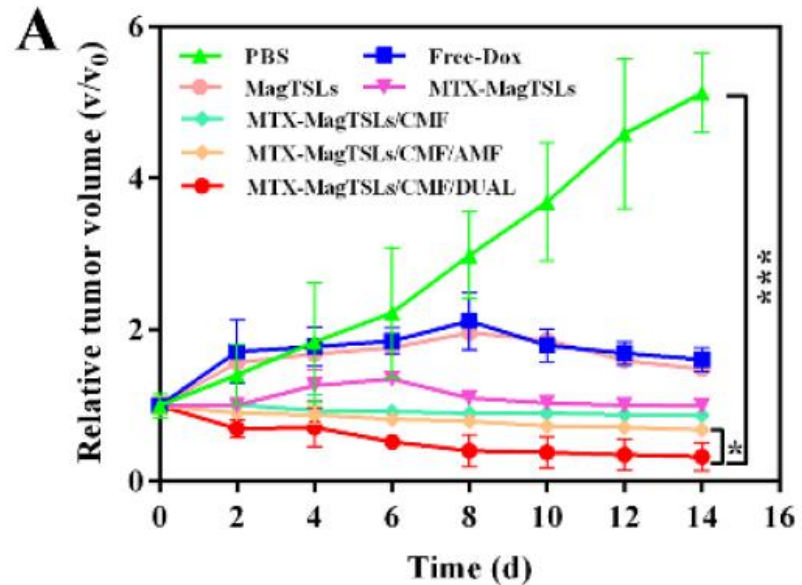


Thermo-Sensitive Magnetoliposomes

Just by heating (water bath)



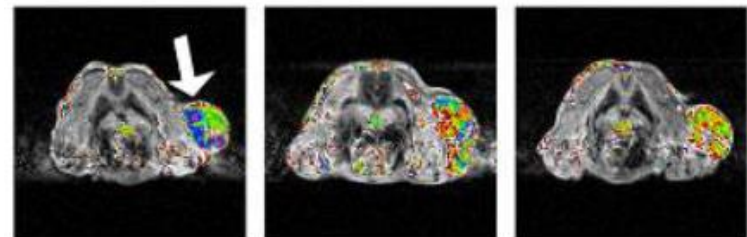
In vivo in tumor bearing mice



0h

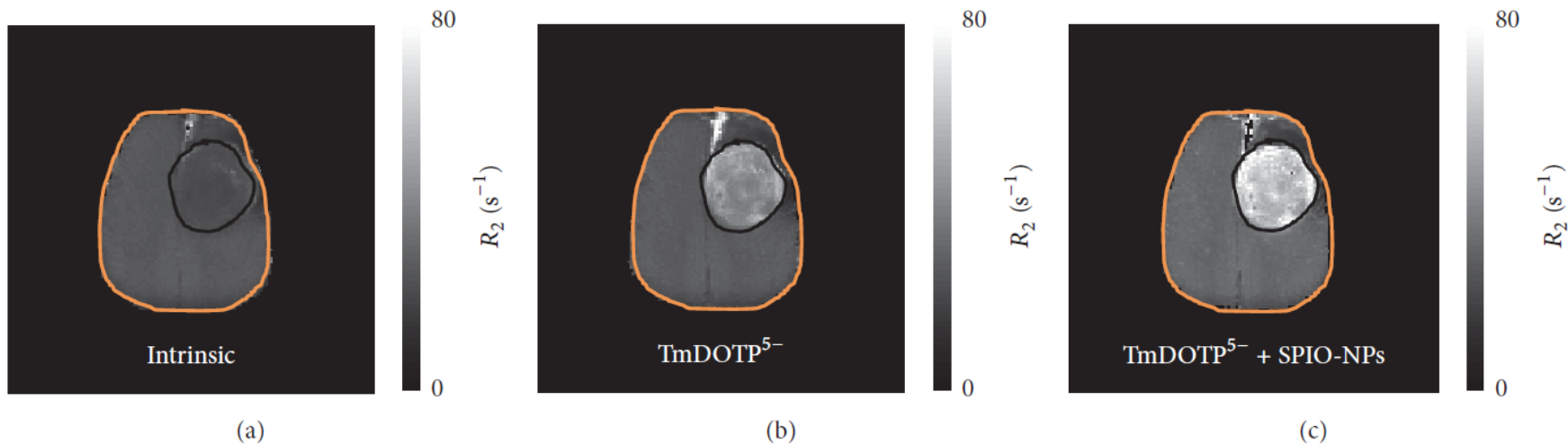
4h

8h

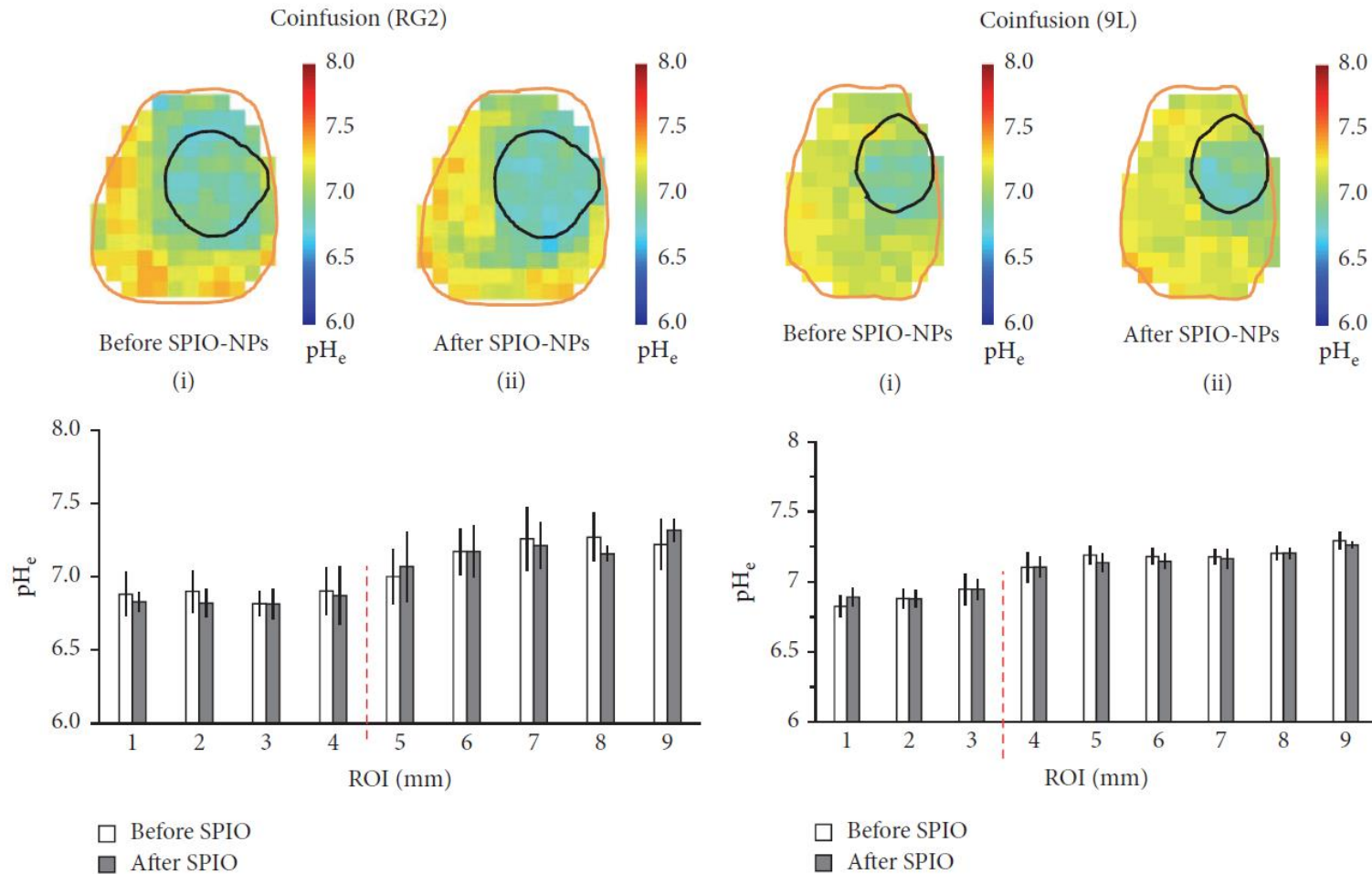


Tumor pH and Particle Mapping

- R2 Mapping of brain tumors
- Additional mapping of MNP as drug carrier
- Mapping of the intra- and peri-tumoral pH as a therapeutic outcome control



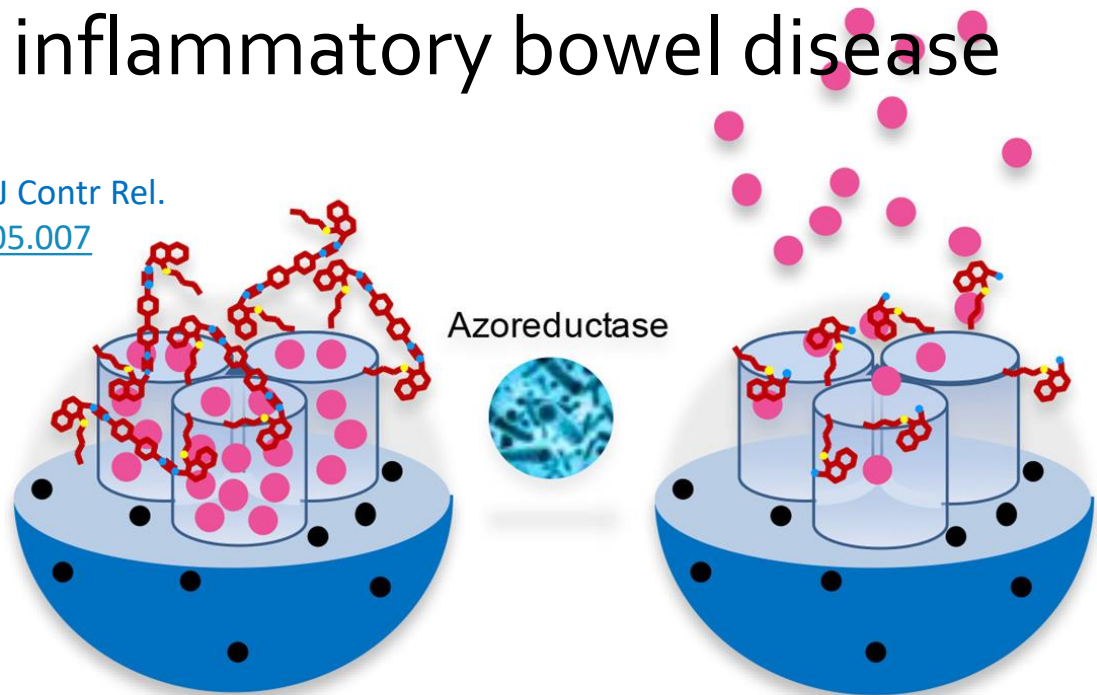
Tumor pH and Particle Mapping



Magnetically Enhanced Colon Targeting

- Azoreductase in the colon could be used for drug release in inflammatory bowel disease

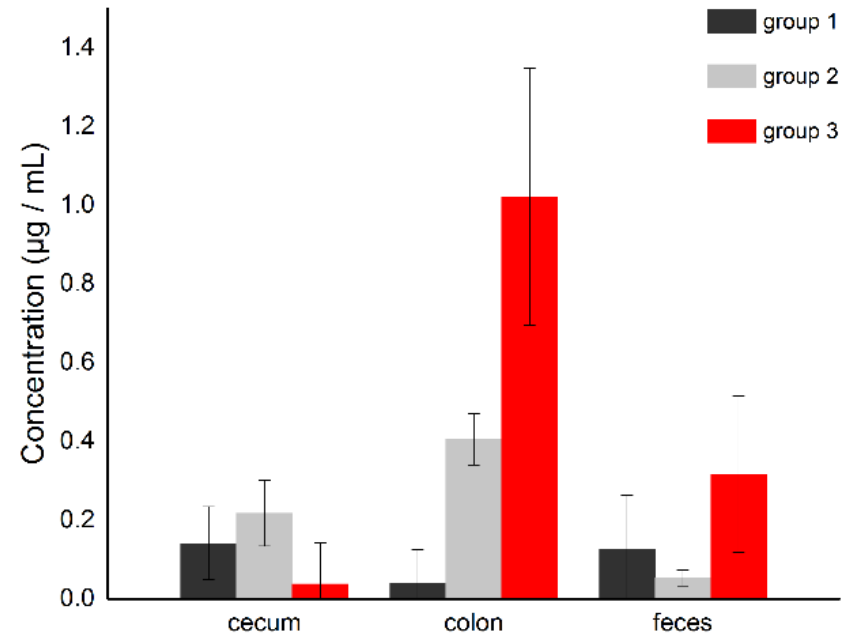
Teruel AH, Pérez-Esteve É, et al. (2018). *J Contr Rel.*
<https://doi.org/10.1016/j.jconrel.2018.05.007>



- ⇒ Safranin O (S1) / Hydrocortisone (S2)
- ⇒ Oleate Fe₃O₄ nanoparticles

Magnetically Enhanced Colon Targeting

- Safranin O concentration in colon when given in magnetic particles suspension plus a magnetic belt is highest



Teruel AH, Pérez-Esteve É, et al. (2018). J Contr Rel.
<https://doi.org/10.1016/j.jconrel.2018.05.007>

There is Much More



... from your colleagues during
the next few days here at the
meeting !

*And don't forget to check (and
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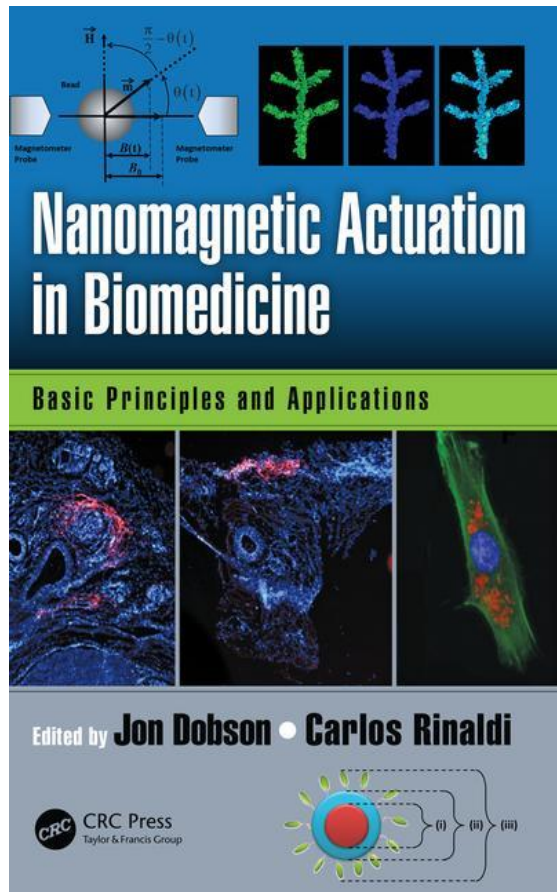
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New Books (I)



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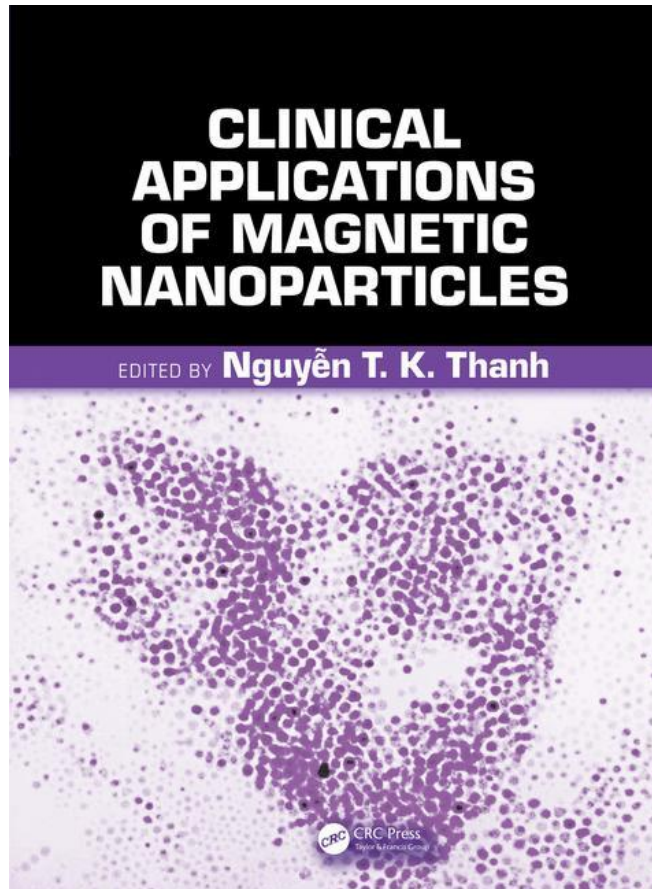
Jon Dobson, Carlos Rinaldi

January 5, 2018 by CRC Press

Reference - 256 Pages - 71 Color & 26 B/W Illustrations

ISBN 9781466591219 - CAT# K20502

New Books (II)



Clinical Applications of Magnetic Nanoparticles

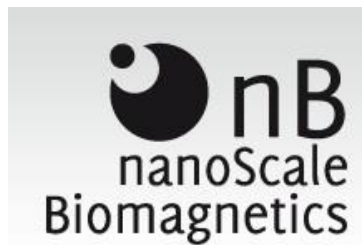
CRC Press, 2018

ISBN: 9781138051553. 490 Pages

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