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Fakulteta za farmacijo

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Highly Porous Core-Shell Nanostructures

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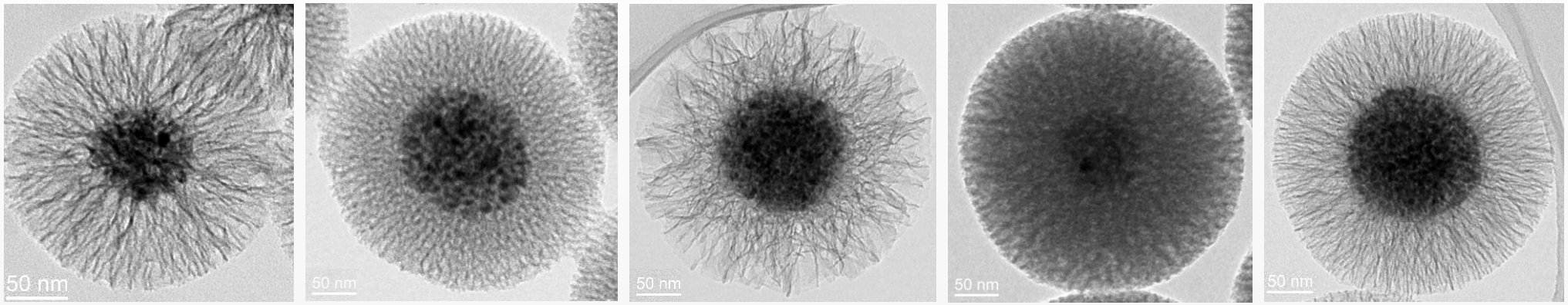
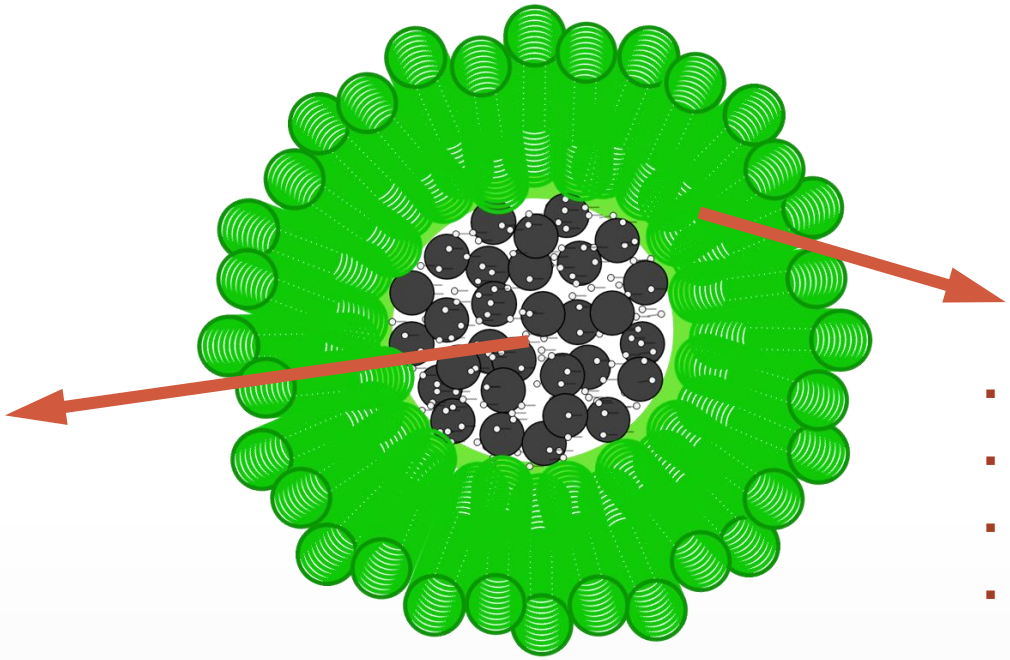


Outline

- Core-shell nanoparticles
- Synthesis
- Results
  - Tunability
  - Versatility
- Conclusions

Core-shell nanoparticles

- Combining properties and capabilities of both systems
- **Radially oriented** pore structure with **large** pores



Core: iron oxide multi-core nanoparticle

$F_m = \uparrow$

Enhanced magnetic properties

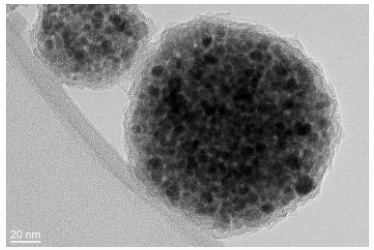
Shell: mesoporous silica

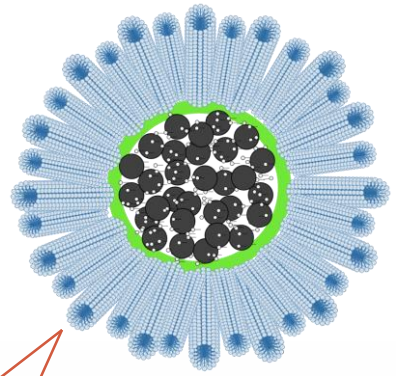
- Mesoporous silica (amorphous SiO_2)
- Biocompatible, surface functionalization
- Applications (molecule carrier, catalyst-support)
- Challenges
  - **Large pores**
  - **Selective formation of silica on nanoparticle cores**

Q. Pankhurst, (2003), Applications of magnetic nanoparticles in biomedicine, Journal of Physics D: Applied Physics, 36, 167-181, H. Markides, (2012), Biocompatibility and toxicity of magnetic nanoparticles in regenerative medicine, Journal of nanomaterials, 2012, 1-11,N. Vallabani, (2018), Recent advances and future prospects of iron oxide nanoparticles in biomedicines and diagnostics, 3 Biotech, 8, 279. S. Kralj, (2014), The chemically directed assembly of nanoparticle clusters from superparamagnetic iron-oxide nanoparticles, RSC Advances, 4, 13167-13171, R. Narayan, (2018), Mesoporous silica nanoparticles: a comprehensive review on synthesis and recent advances, Pharmaceutics, 10, 118.

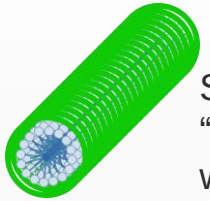
Synthesis · soft-templating method (Stöber process modification)

Magnetic multi-core nanoparticle

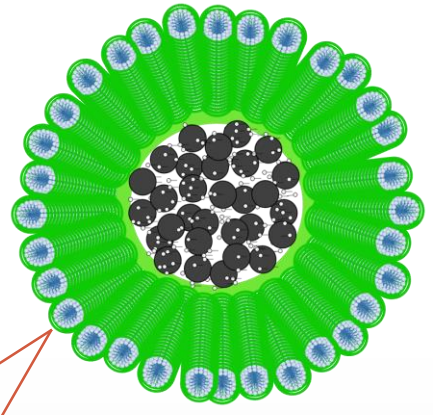


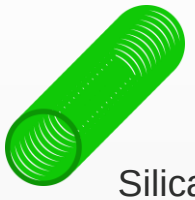


Surfactant “soft-template”

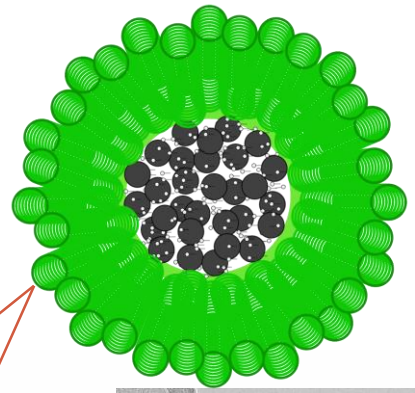


Surfactant “soft-template” with deposited silica

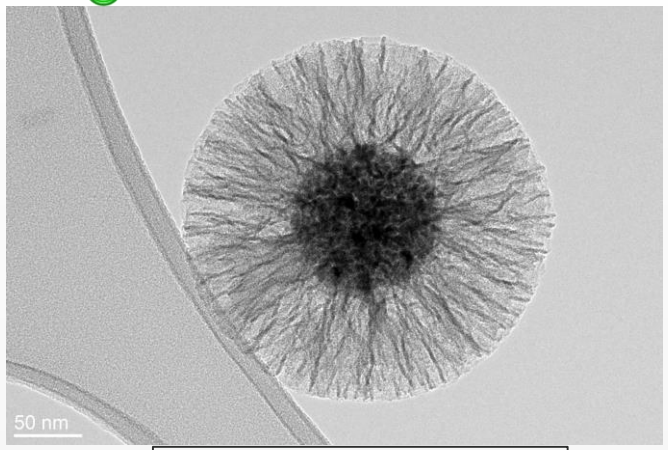




Silica pore



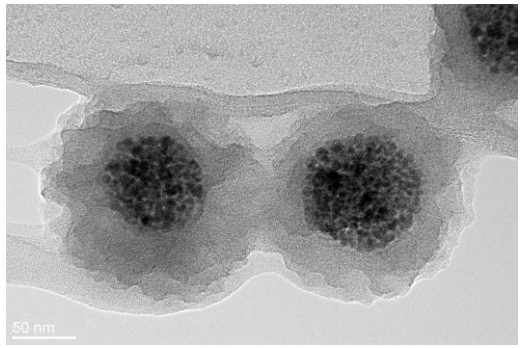
Mesoporous silica coated magnetic multi-core nanoparticle



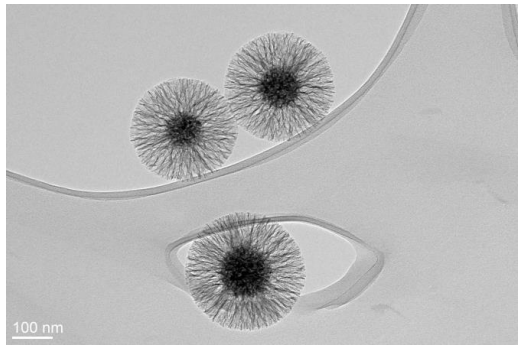
TEM micrograph
Shell thickness 80 nm;
Pore diameter 17 nm

Shell tunability · Adjusting shell thickness and pore size

- Surfactant (SOFT-TEMPLATE BUILDING BLOCK)

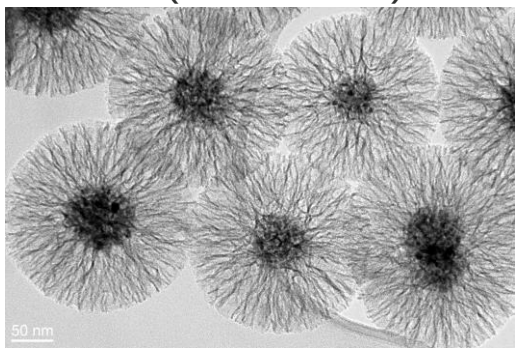


CTAB – one-sixth amount;
49 nm; compact

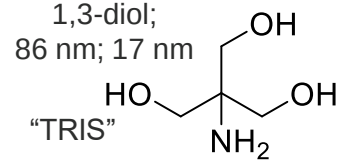


CTAB;
80 nm; 17 nm

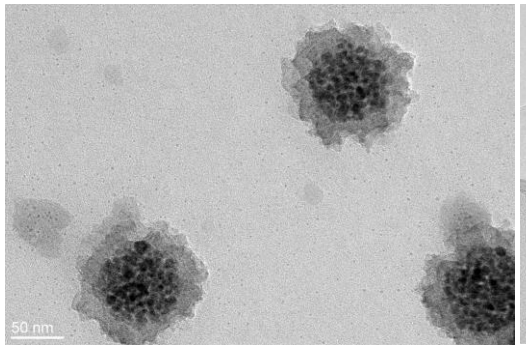
- Base (CATALYST)



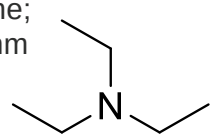
2-amino-2-(hydroxy methyl) propane-1,3-diol;
86 nm; 17 nm

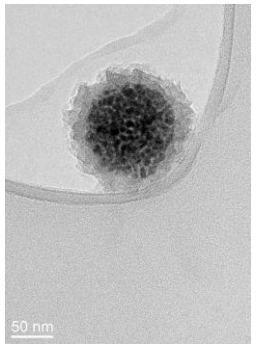


"TRIS"



Triethylamine;
38 nm; 19 nm

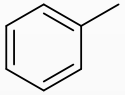


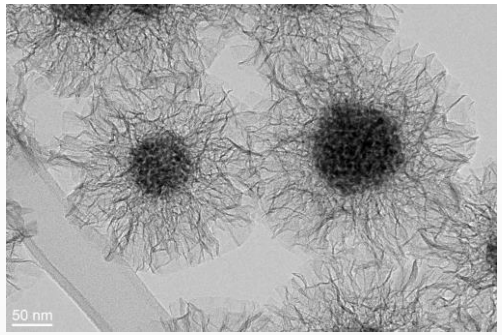


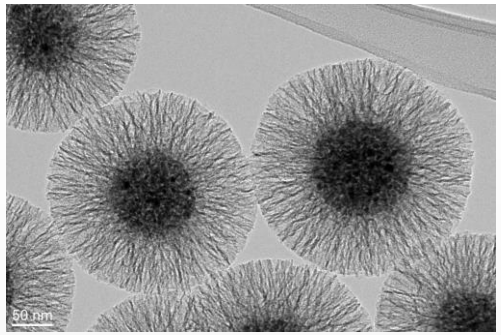
NaOH;
19.7 nm; compact

- Organic solvent (PORE EXPANDER)

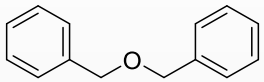
Toluene;
90 nm;
41 nm
Largest pore size.

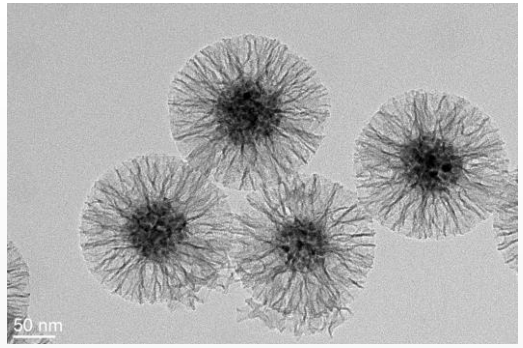


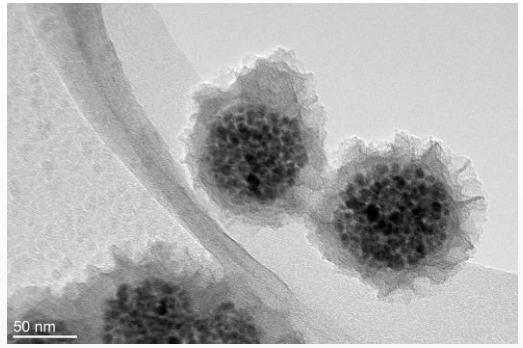




Dibenzyl ether;
83 nm; 7 nm

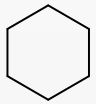


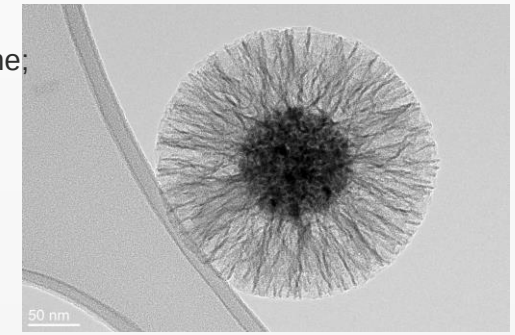


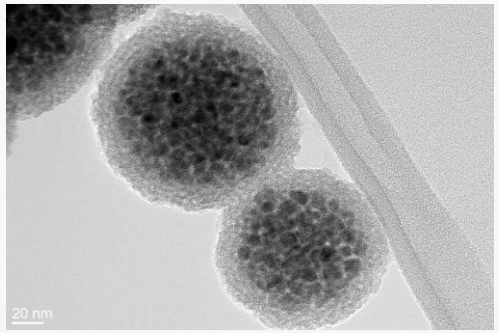


Triethanolamine

Cyclohexane;
83 nm;
14 nm

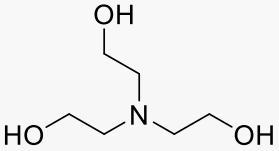






No organic solvent added
25 nm;
compact

58 nm; 17 nm

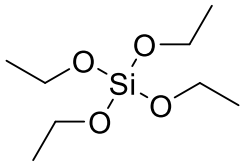


6-fold amount;
29 nm; ~31 nm

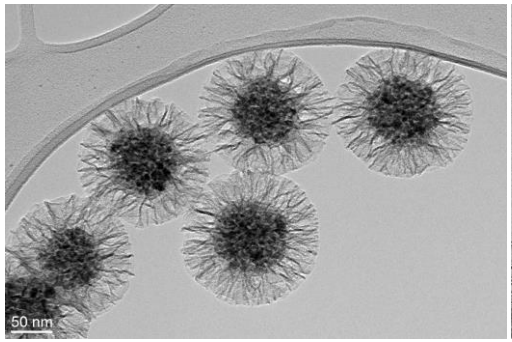
Shell tunability (continued)

- **Shell thickness and pore size**

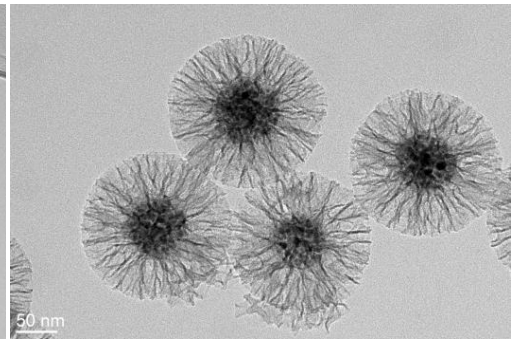
- Silica precursor



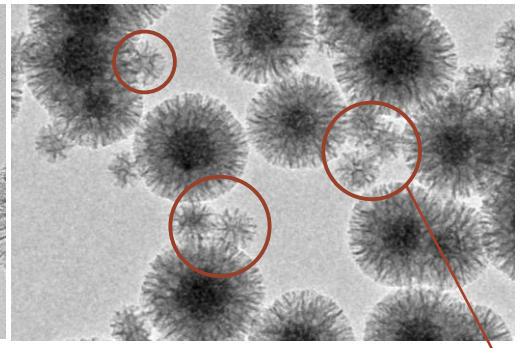
Tetraethoxysilane (**TEOS**)



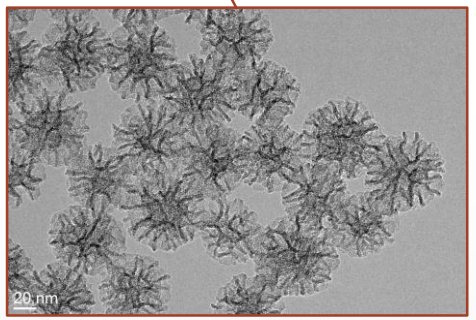
One-third amount
45 nm; 18 nm



Three-fold amount
90 nm; 16 nm

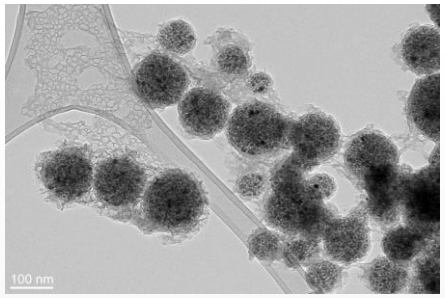


Nine-fold amount
80 nm; 12 nm

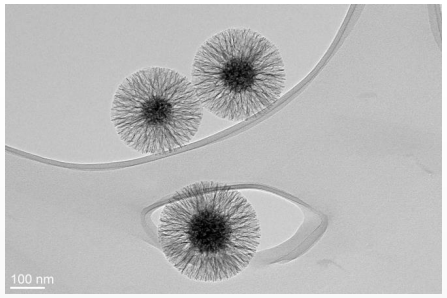


By-formed homogenous mesoporous silica nanoparticles.

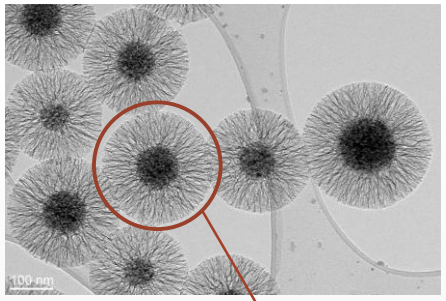
- Reaction conditions (temperature)



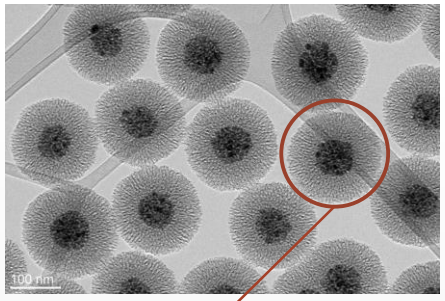
RT or 40 ˚C
No coating



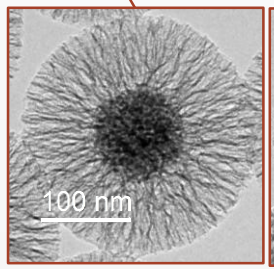
65 ˚C
80 nm; 17 nm

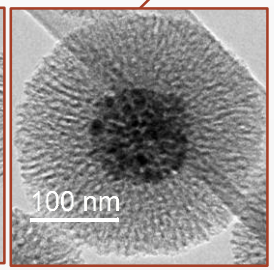


75 ˚C
82 nm; 10 nm



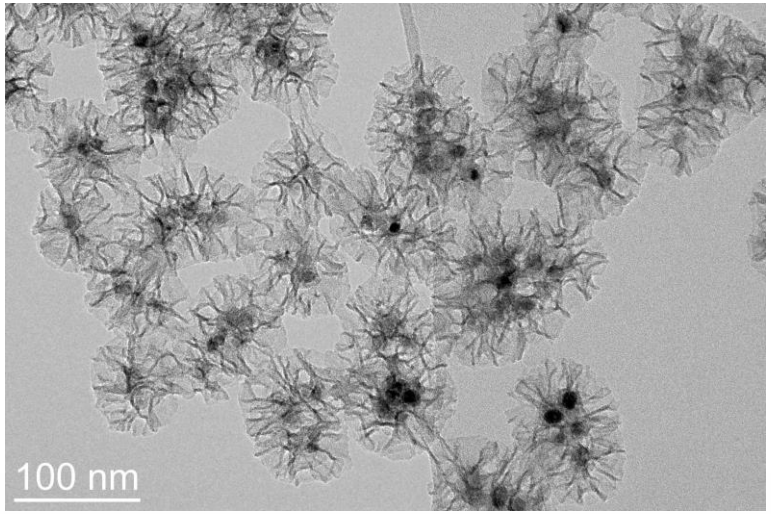
90 ˚C
54 nm; raspberry

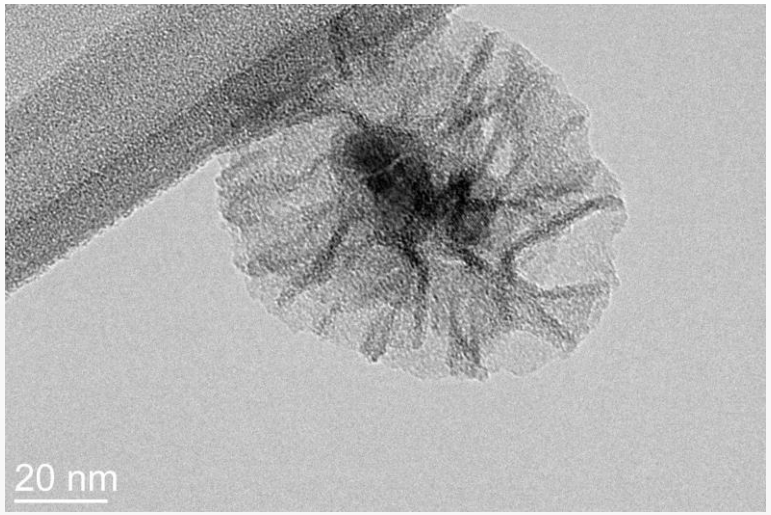




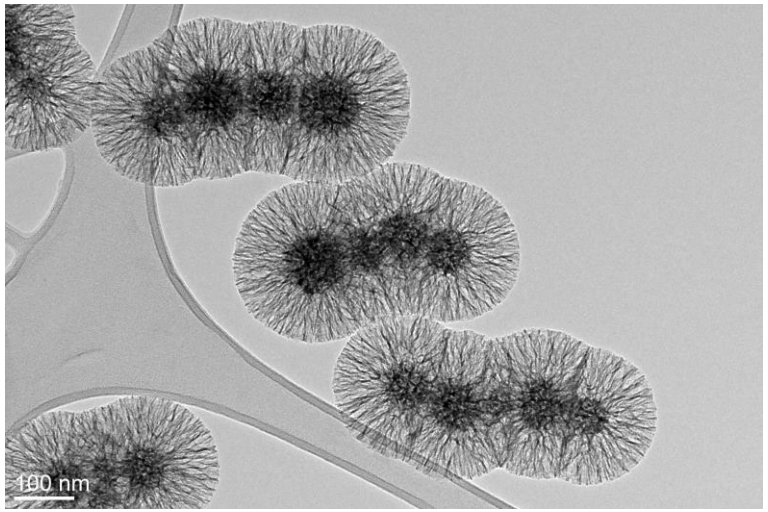
Procedure versatility

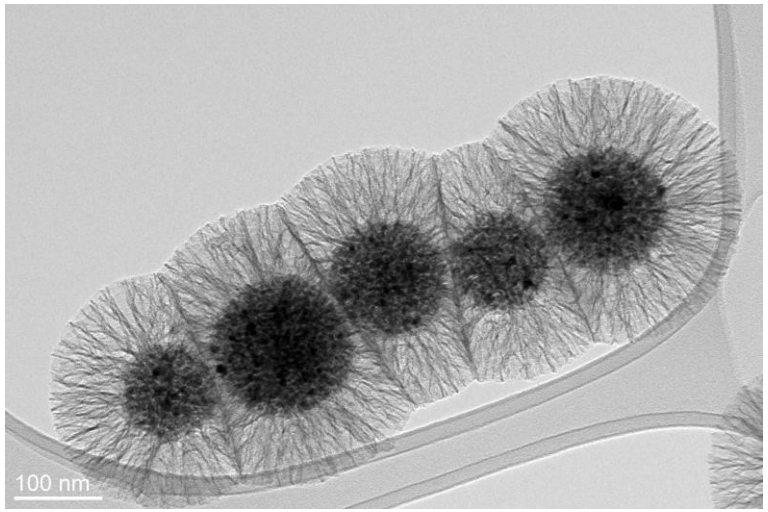
- **Superparamagnetic iron oxide nanoparticles**



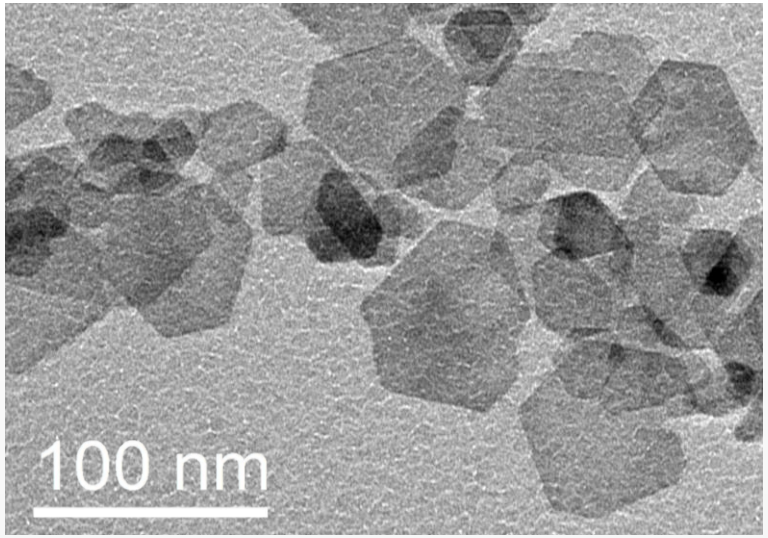


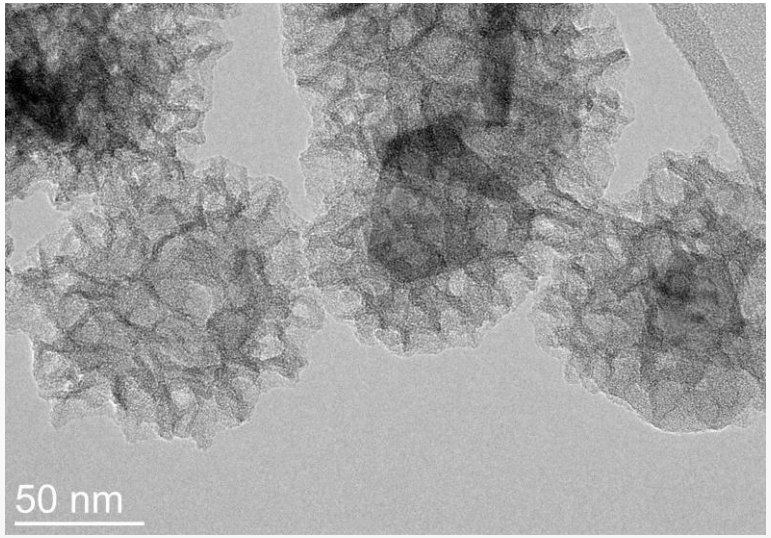
- **Superparamagnetic iron oxide nanochains**





- **Ferromagnetic barium-scandium hexaferrite nanoplatelets**





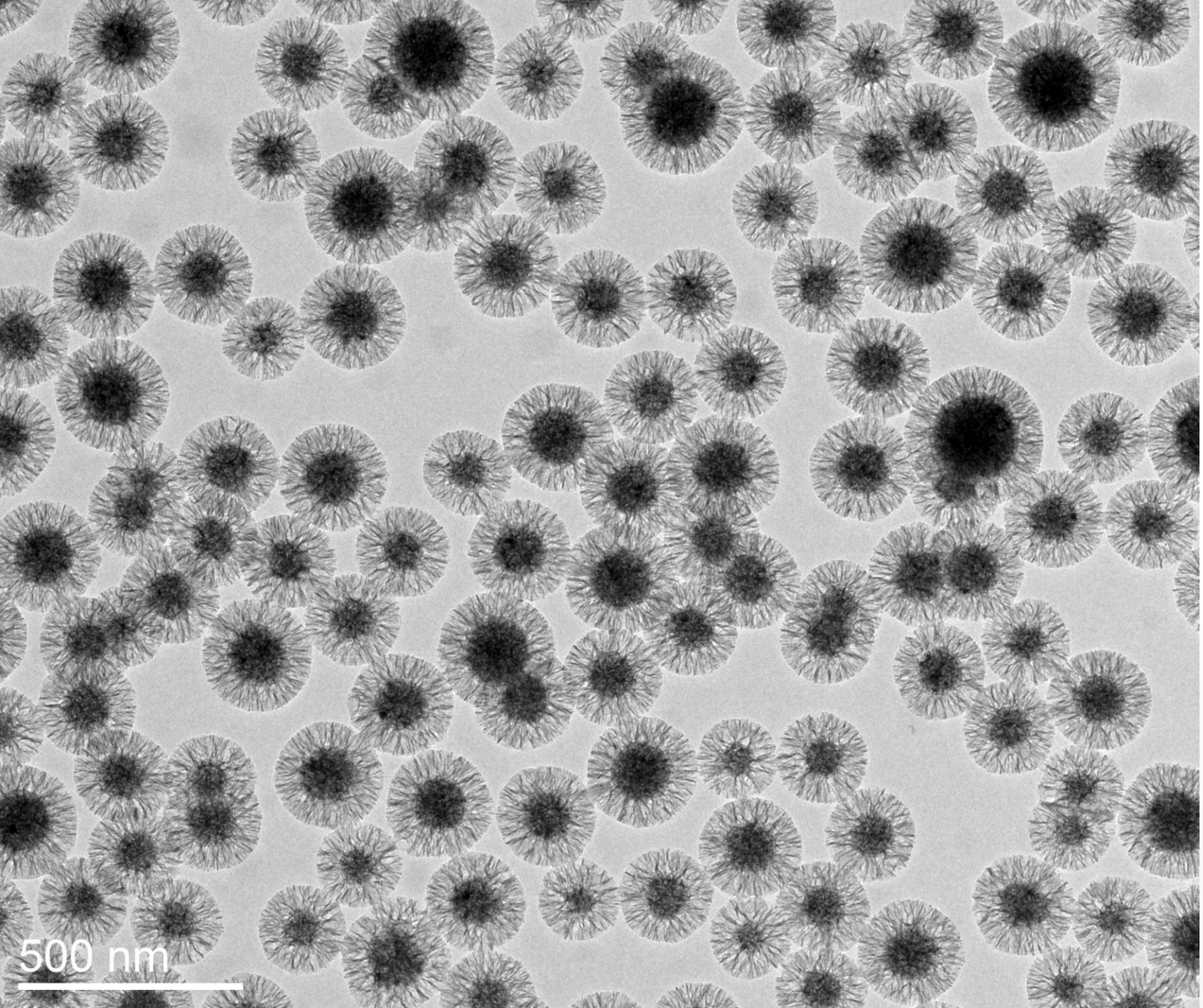
(Uncoated)

Conclusions and further work

- Tunable procedure for desired application
- Thick shell
- Large pores

- Importance of slow silica deposition on core nanoparticles (weak base)
- Pore expanding with organic solvents

- Future work: apply the synthesized nanomaterials for specific applications (drug loading, catalysis, plasmid loading along with cell transfection), functionalization

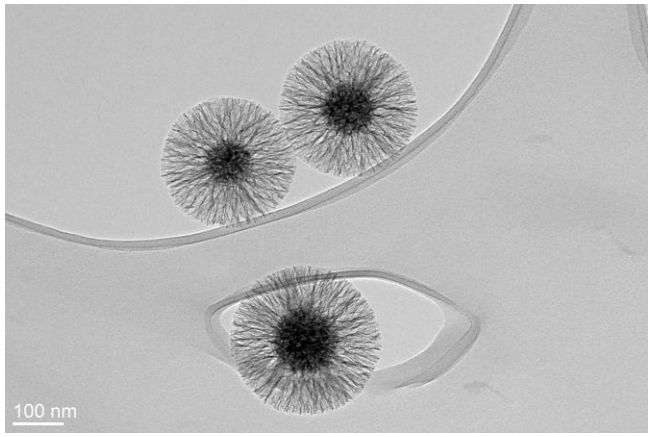
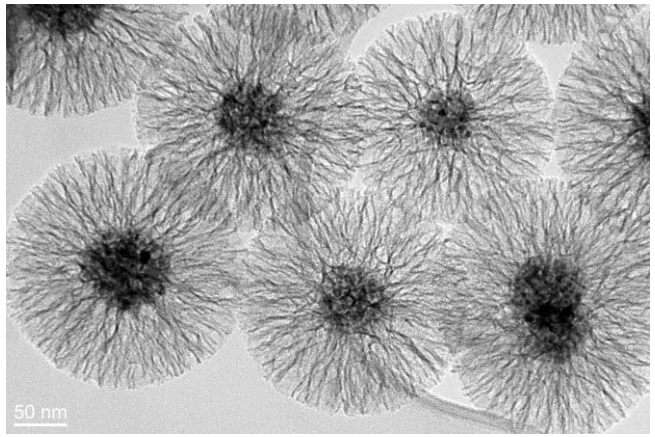
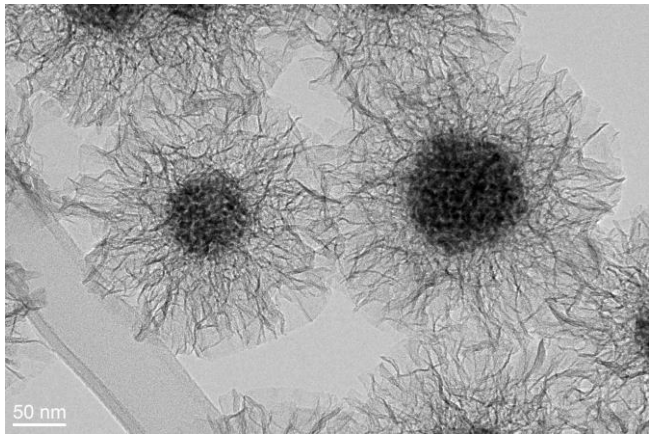


Thank you!

Any questions?

Funding:
ARRS research program P2-0089
ARRS research project J1-7302

Nitrogen adsorption/desorption analysis

	 CTAB	 2-amino-2-(hydroxy methyl)propane-1,3-diol	 Toluene
Specific surface (multi-BET)	577 m^2/g	441 m^2/g	529 m^2/g
Pore volume (BJH analysis)	1.8 ml/g	2.2 ml/g	1.0 ml/g
Pore size	17 nm	17 nm	41 nm
Shell thickness	80 nm	86 nm	90 nm