Multifunctional Hybrid Colloids: Polymers and Inorganics Meet at the Nanoscale

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Max Planck Partner Group on Colloidal Methods for Multifunctional Materials

Motivation and Overview

Colloidal particles (both polymeric and inorganic) can act as a support for crystallization processes on their surface.

The **colloidal structures** generated by micelles and surfactant-stabilized droplets serve as soft templates or **nanoreactors** for the controlled precipitation of inorganic materials. In this poster, we will provide four topics under current investigation by our team. In all four cases, the confinement of chemical processes at the nanoscale of systems stays in the foreground.

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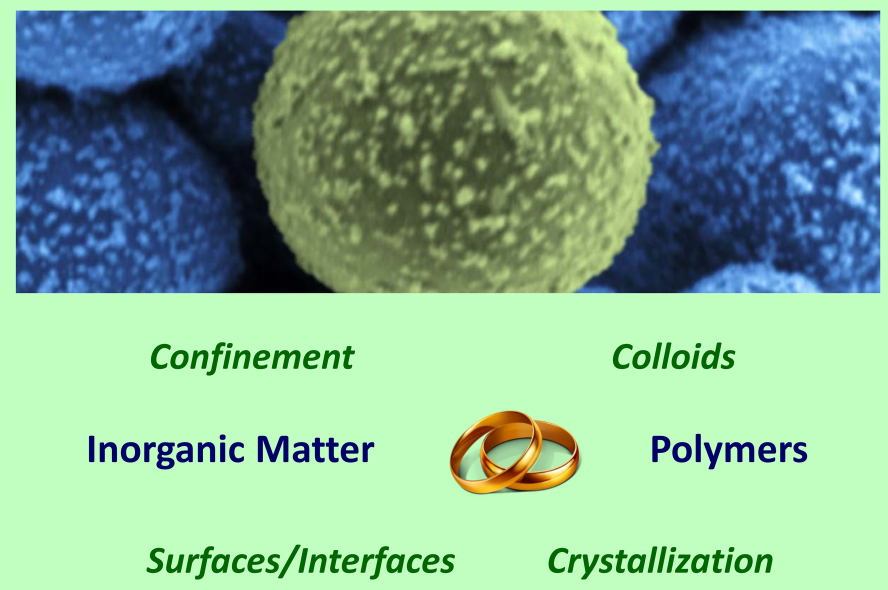


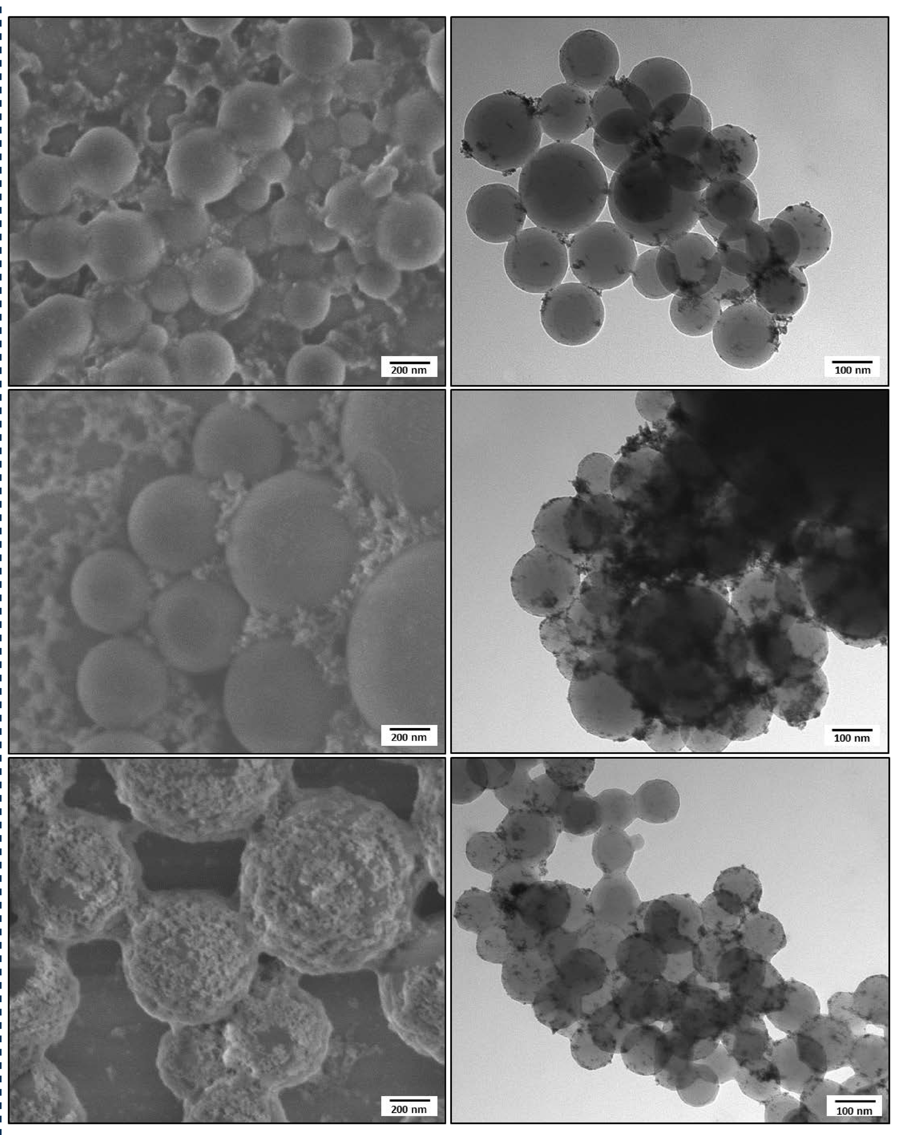
Colloidal methods, especially those involving liquid–liquid heterophase systems, are very versatile for the preparation of polymer/inorganic hybrid nanoparticles and nanocapsules

Herein, we present an overview of the applicability of miniemulsion systems for the synthesis of hybrid nanomaterials:

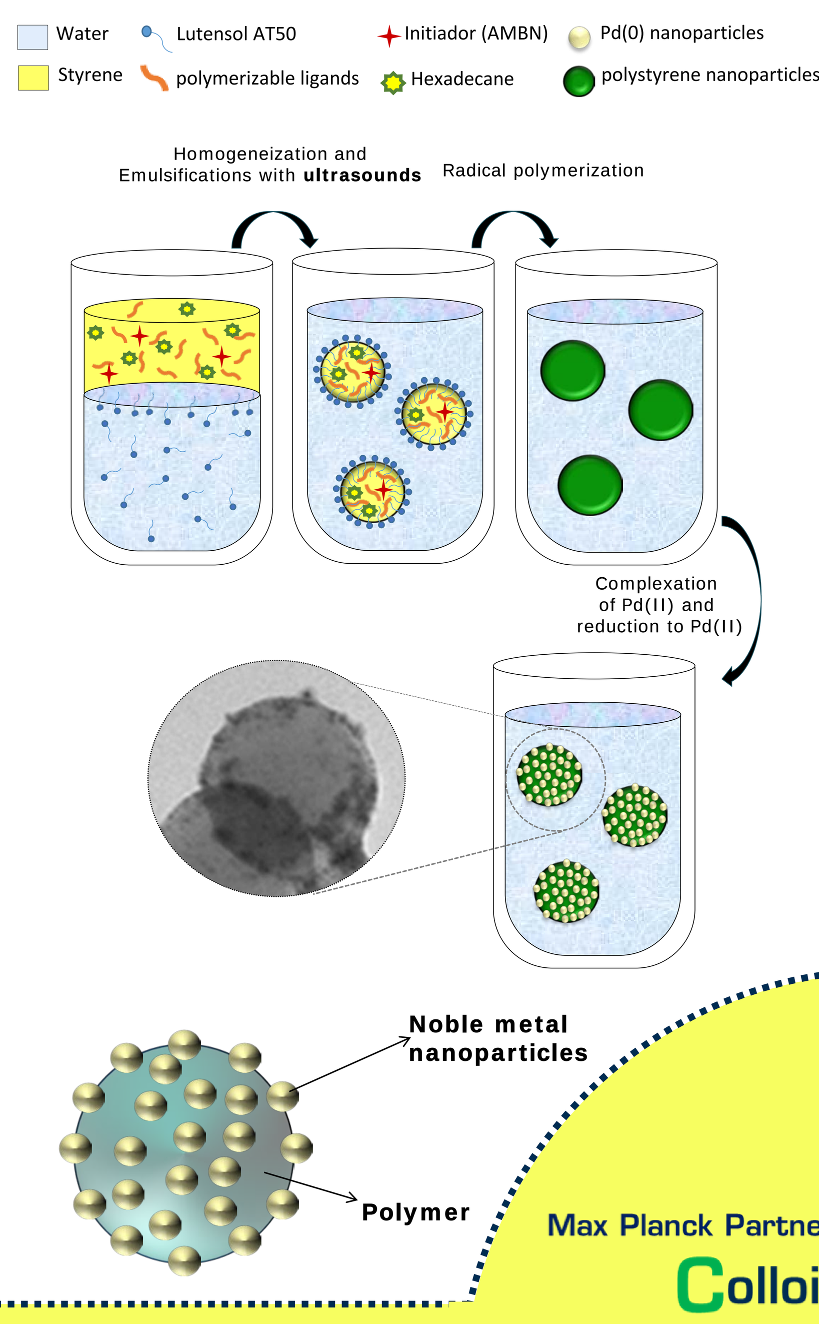
1. **Chiral polymer-based nanoparticles**, prepared by surface functionalization of particles prepared by miniemulsion copolymerization.
2. **Encapsulation of phase change materials (PCMs)** for **storage of thermal energy** in the form of latent heat.
3. **Conducting** hybrid nanoparticles of **polyaniline** or **polypyrrole**.
4. **Magnetoresponsive catalytic nanoparticles** prepared by so-called Pickering stabilization.

Chiral Polymer-Based Nanoparticles

Chiral polymer nanoparticles were prepared by miniemulsion copolymerization of styrene and **polymerizable ligands based on Schiff bases**, previously synthesized in our lab. Afterward, palladium(II) was complexed on the polymer particles and reduced to Pd(0) to deposit metal nanoparticles. These particles are potentially useful for asymetric catalysis.



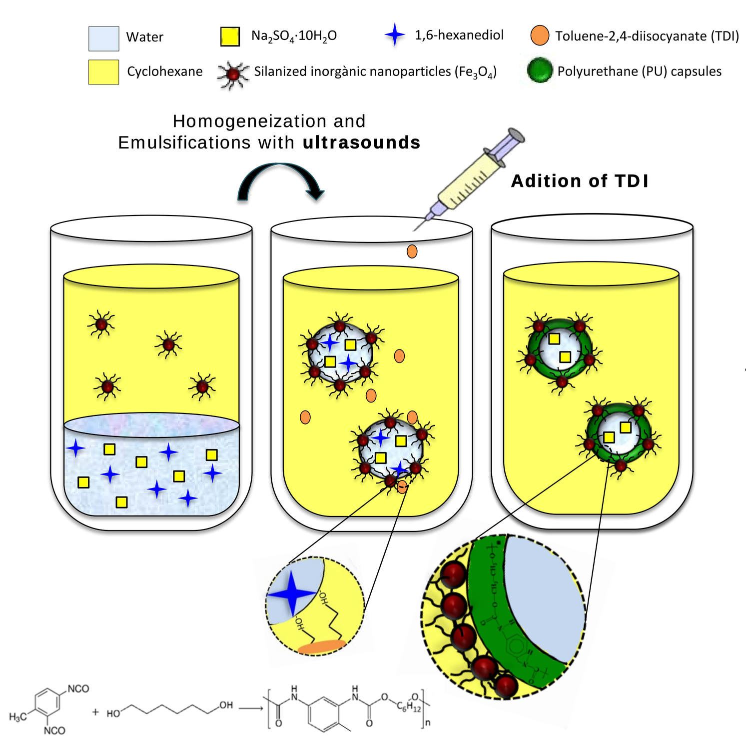
SEM/TEM micrograph of hybrid polystyrene-salen nanoparticles



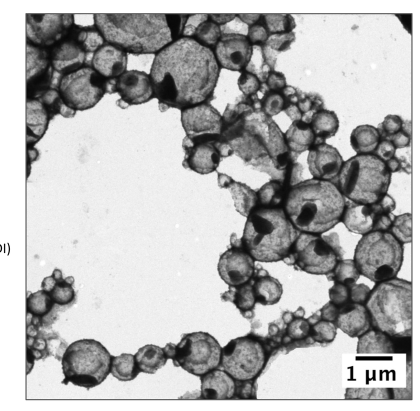
Encapsulation of Phase Change Materials (PCMs)

Hybrid capsules are prepared by **inverse Pickering miniemulsion,** used as a synthetic platform to **encapsulate phase change materials (PCMs)** to achieve **thermal energy storage** for low temperature applications.

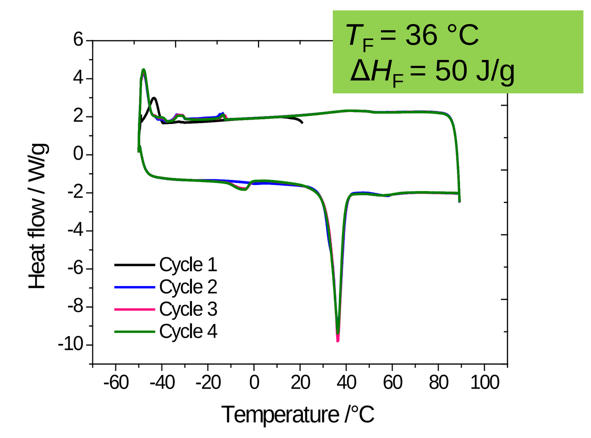
$Na_2SO_4{\cdot}10H_2O$, taken as a model inorganic hydrated salt, was successfully encapsulated within **magnetoresponsive** polyurethane hybrid capsules synthesized by inverse (oil-in-water) Pickering emulsion stabilized with functionalized Fe_3O_4 nanoparticles.



Formation of polyurethane shell via interfacial polymerization (hexanediol + TDI)

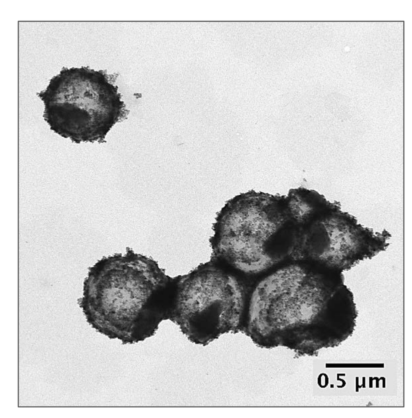


TEM micrograph of PU-Fe_3O_4 capsules with 20 wt% $Na_2SO_4{\cdot}10H_2O$

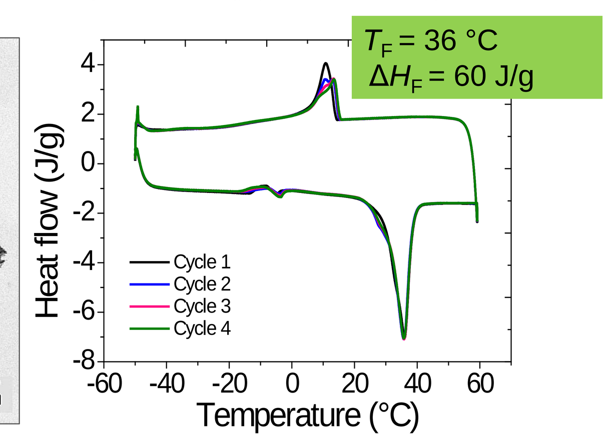


Corresponding differential scanning calorimetry (DSC) trace

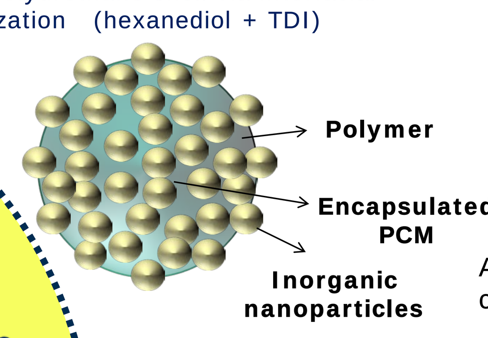
The hybrid structure showed high efficiency for **energy storage** applications with **thermal** and **chemical stability** after several cycles of thermal treatment. Although the **supercooling** problem still presents.



TEM micrograph of PU–Fe_3O_4 capsules with $Na_2(SO_4)_2{\cdot}10H_2O$ + $Na_2HPO_4{\cdot}2H_2O$ (20/0.4 wt%)



Corresponding differential scanning calorimetry (DSC) trace



A **nucleating agent ($Na_2HPO_4{\cdot}2H_2O$)** was used to promote the crystallization of the PCM to **overcome the supercooling**.

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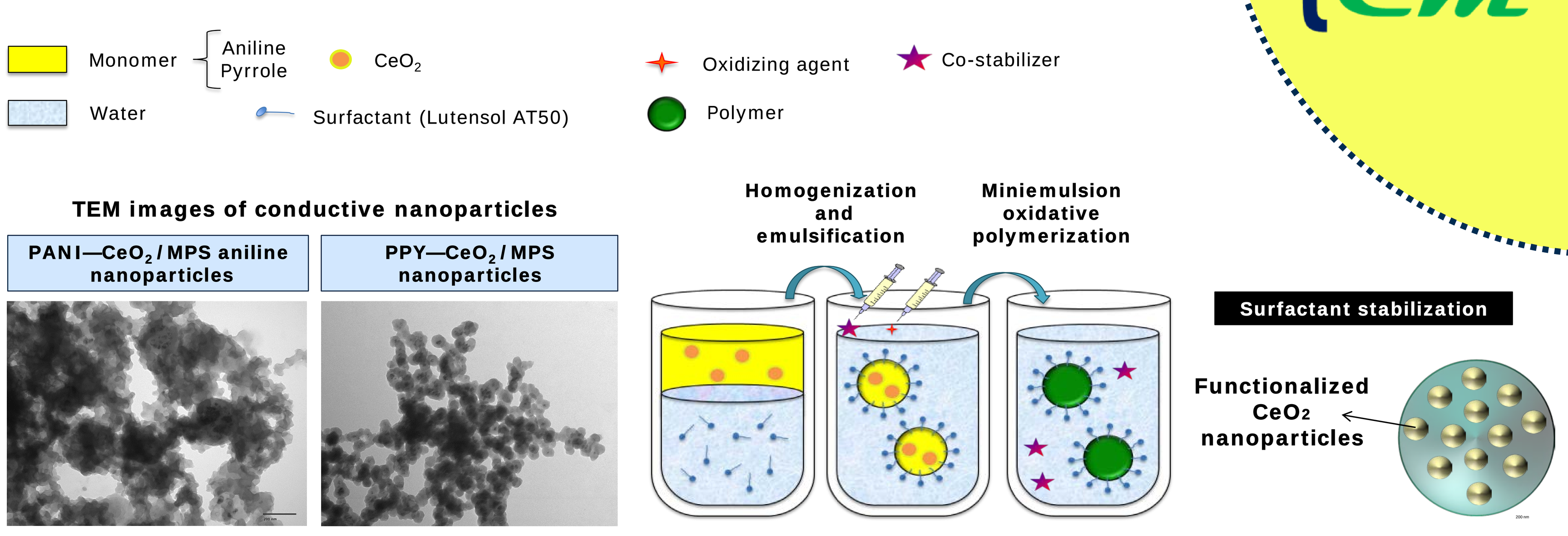
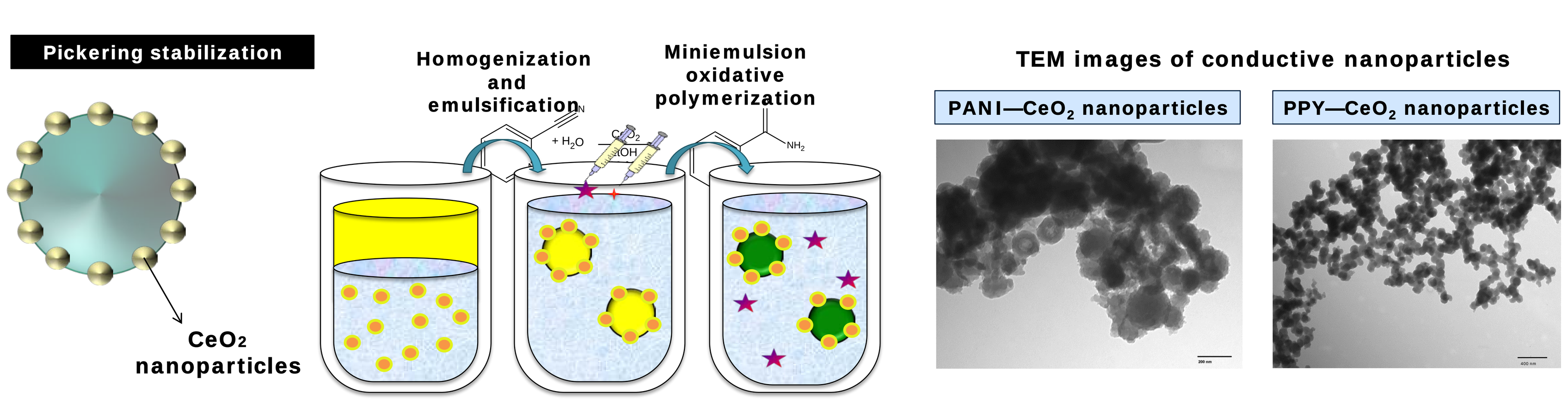
Hybrid Conducting Nanoparticles

Hybrid nanoparticles of polyaniline (PANI) or **polypyrrole (PPY)** are synthetized by **miniemulsion oxidative polymerization**.



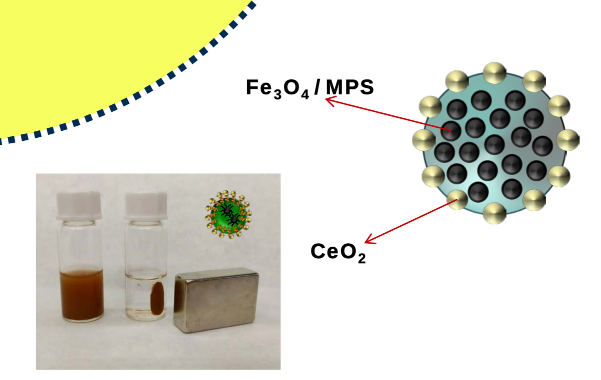
Conductive properties are obtained as a result of the incorporation of CeO_2 nanoparticles. Those may be functionalized to increase the and the hydrophobicity of the cerium oxide(IV) using 3–(methacryloyloxy)propyl trimethoxysilane (MPS) as a functionalizing agent.

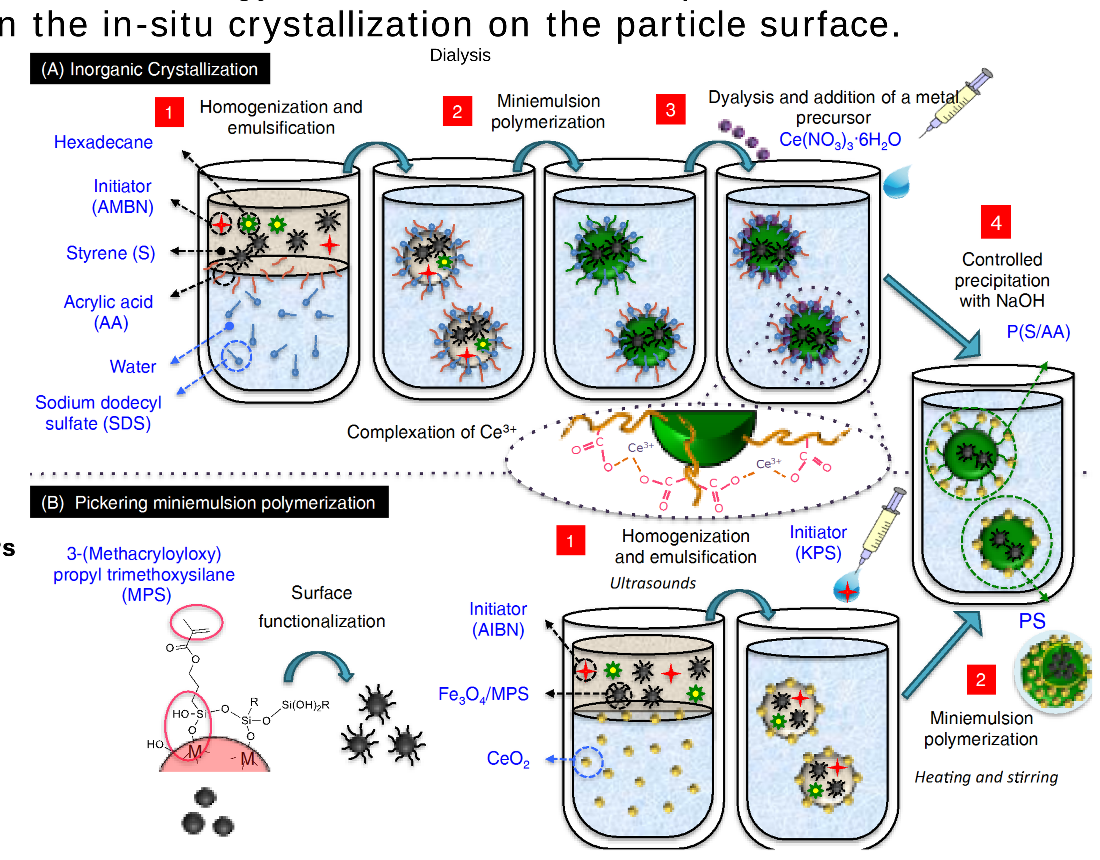


Once synthesized, the nanoparticles are used to produce films, which is a way to increase the applicability of the hybrid system.

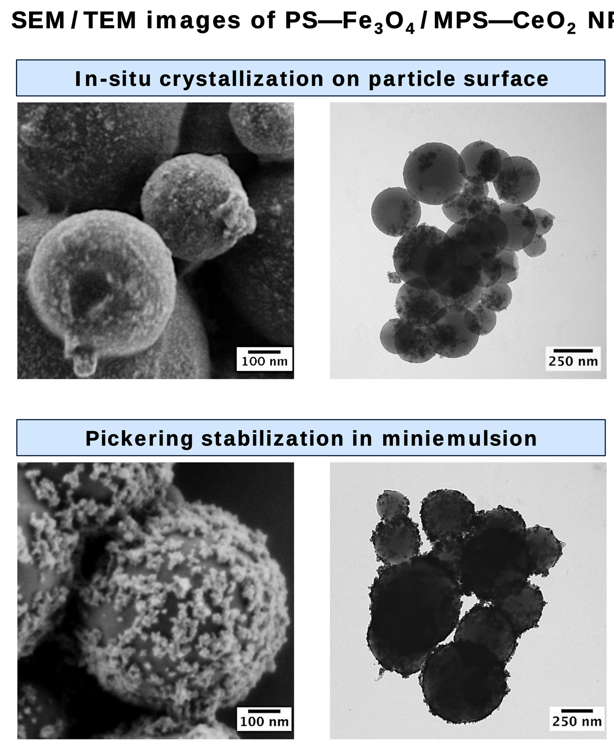
Magnetic Catalytic Nanoparticles

Magnetoresponsive catalytic nanoparticles comprised of polystyrene and metal oxides (CeO_2 and Fe_3O_4) are prepared by **Pickering stabilization** (i.e., the use of inorganic nanoparticles for the stabilization of emulsions). This strategy is an alternative to previous routes of our team based on the in-situ crystallization on the particle surface.

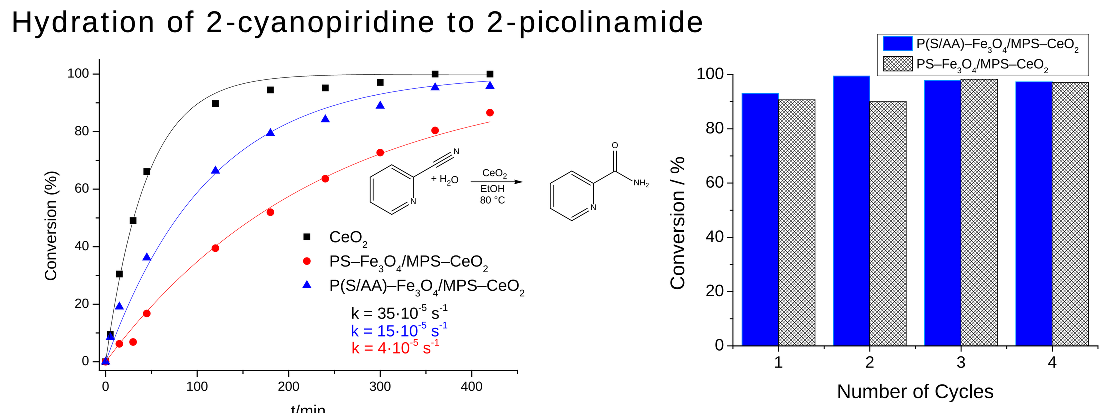




SEM/TEM images of PS—Fe_3O_4/MPS—CeO_2 NPs



Hydration of 2-cyanopiridine to 2-picolinamide



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