Nanofluids for IOR and Tracer Technology

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Institute for Energy Technology
NORCE
PUC RIO
Universidade de São Paulo
ESPCI ParisTech
UNIVERSITÉ DE RENNES 1

Nanofluids for IOR and Tracer Technology
Research Council of Norway, Petromaks2 project 2018-22

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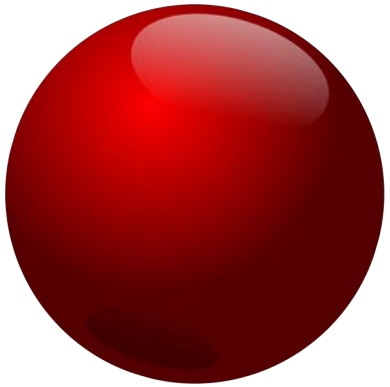
Objectives

- Develop microcapsules for controlled gelation in oil reservoirs
- Develop encapsulated tracer particles

Microcapsule controlled gelation



Motivation

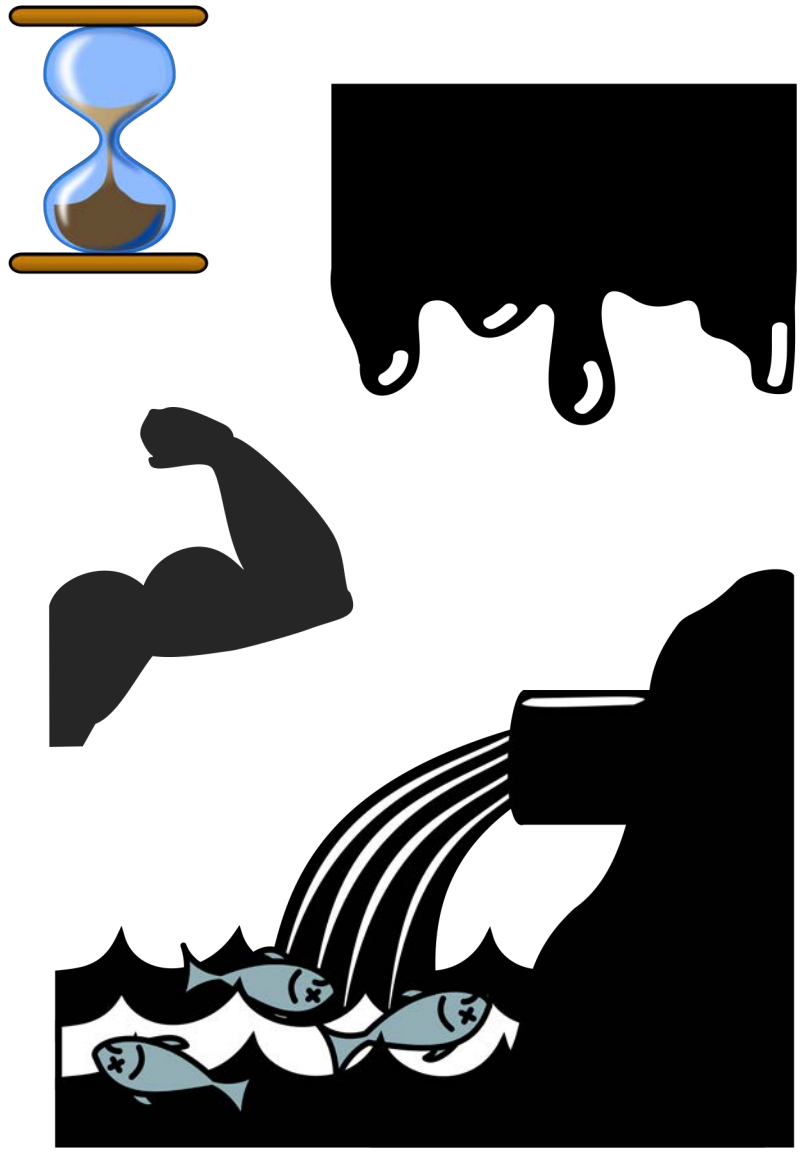
- High water production in mature oil reservoirs, especially if fractures and high permeability zones
  - Water-oil separation
  - Water disposal/environmental footprint
  - Corrosion of equipment
  - Abandonment of well due too high water-cut

Water shut-off gel treatment

- Inject gelant or pre-formed gel in reservoir
  - E.g. silica gel with Na^+ as activator
- Follow preferable paths of water
- Block paths and redirect injected water

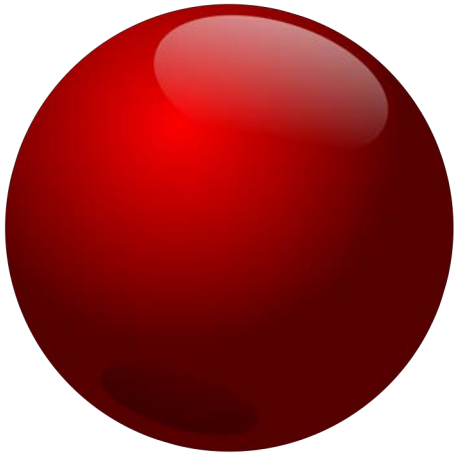
Challenges

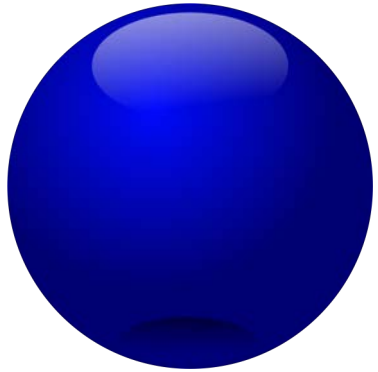
- Controlled gelation time
  - Placement of gel in reservoir
- Rheology
- Strength
- Long-term stability
- Environmental concerns



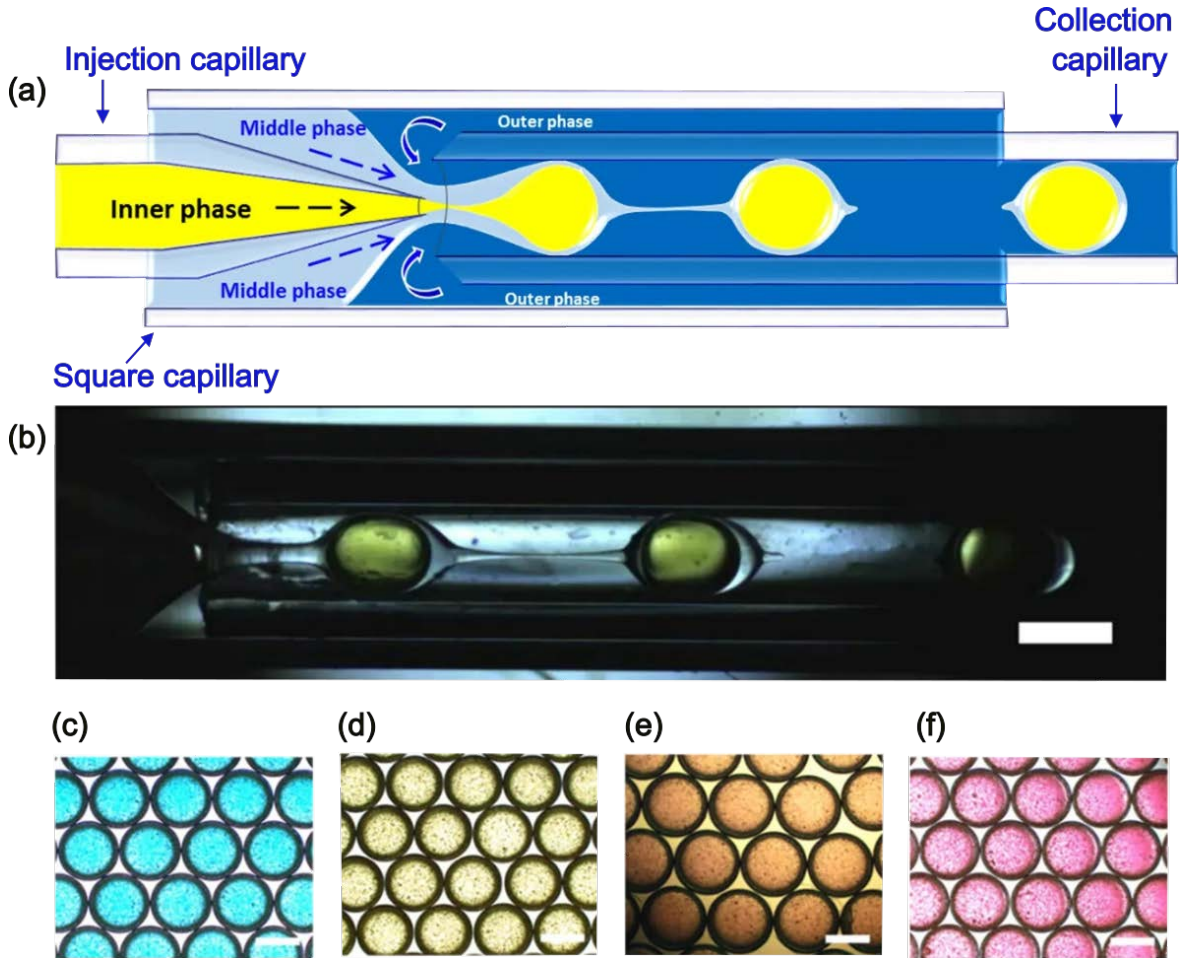
Microcapsules

- Encapsulating activators
- Triggered release, e.g.
  - pH, salt, temperature, reaction with oil
- Easy fabrication in laboratory using microfluidic devices
- Tunable properties
  - Size
  - Material





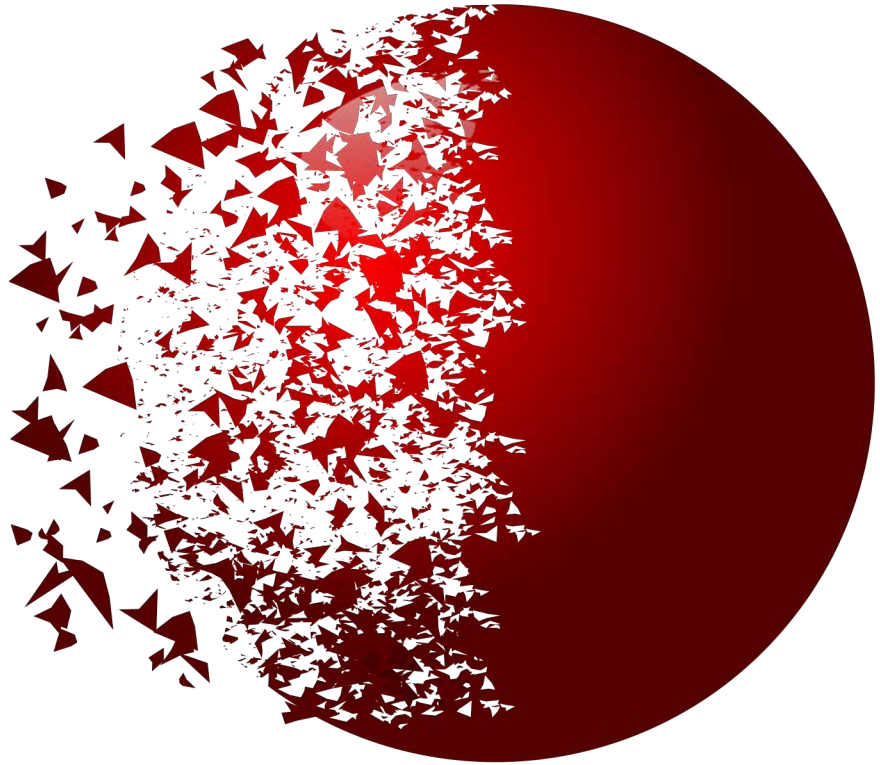
Microcapsules



Adapted from: Do Nascimento DF *et.al*. Flow of Tunable Elastic Microcapsules through Constrictions. Sci Rep. 2017;7(1):1–7.

Microcapsule material

- Controlled rupture or leakage triggered by e.g:
  - pH
  - Temperature
  - Osmotic swelling
  - Reaction with oil
  - Other mechanisms

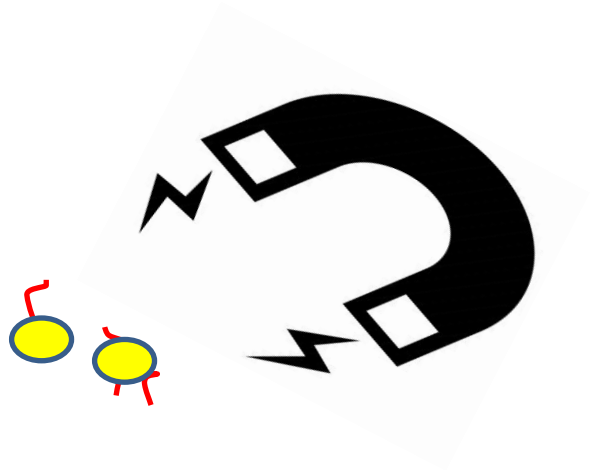


Plan

- Selection of gel type, capsule material and activator type
- Characterize gel
  - Rheometry
  - Small Angle X-ray Scattering (SAXS)
    - Sirius or similar facility in Europe or USA
  - Small Angle Neutron Scattering (SANS)
  - Gel strength test
- Produce and characterize capsules
- Investigate release properties of capsules
- Core-flood experiments with gel and capsules

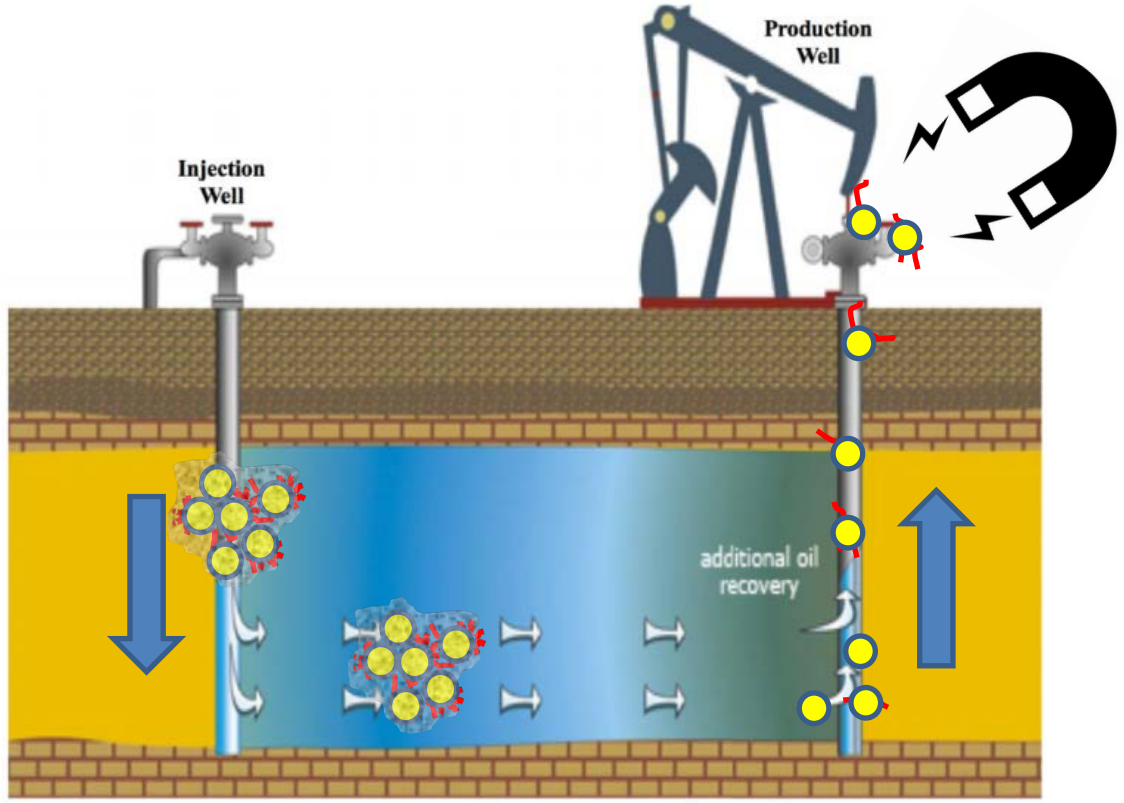
Sirius at UNICAMP

Encapsulated tracer particles



Motivation

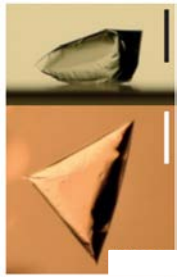
- Transport of Tracer Particles for EOR
- Easy capture of magnetic nanoparticles



Goal

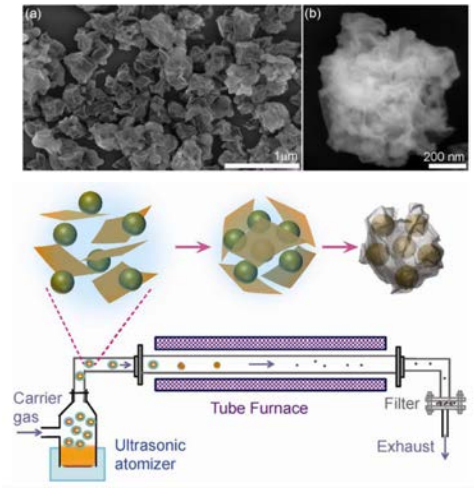
- Wrapping (e.g. of magnetic nanoparticles) using nanosheets of clay
- Understand and control process
- Functionalizing magnetic nanoparticles to control packages

Single Sheet

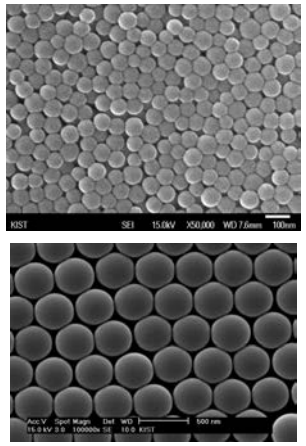


Polystyrene sheets wrapping water drops inside silicone oil, 1mm Scale bar [1].

Multi Sheet



Crumpled GO thin sheets wrapping Si particles. [2].



Self-assembled GO capsules of (top) 80nm and (bottom) 400nm size [3].

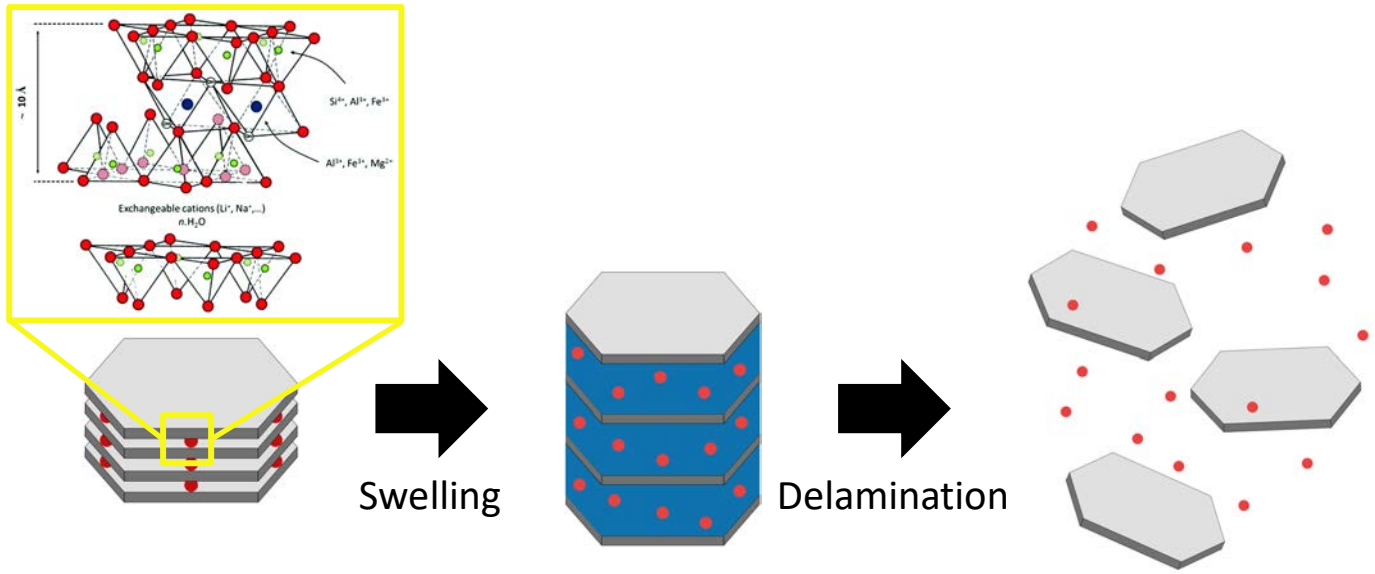
[1] Paulsen, J. D. *et al.* (2015). Optimal wrapping of liquid droplets with ultrathin sheets. *Nature materials*, *14*(12), 1206

[2] Luo, J. *et al*. (2012). Crumpled graphene-encapsulated Si nanoparticles for lithium ion battery anodes. *The journal of physical chemistry letters*, *3*(13), 1824-1829.

[3] Ju, S. A. *et al.* (2011). Graphene-wrapped hybrid spheres of electrical conductivity. *ACS applied materials & interfaces*, *3*(8), 2904-2911.

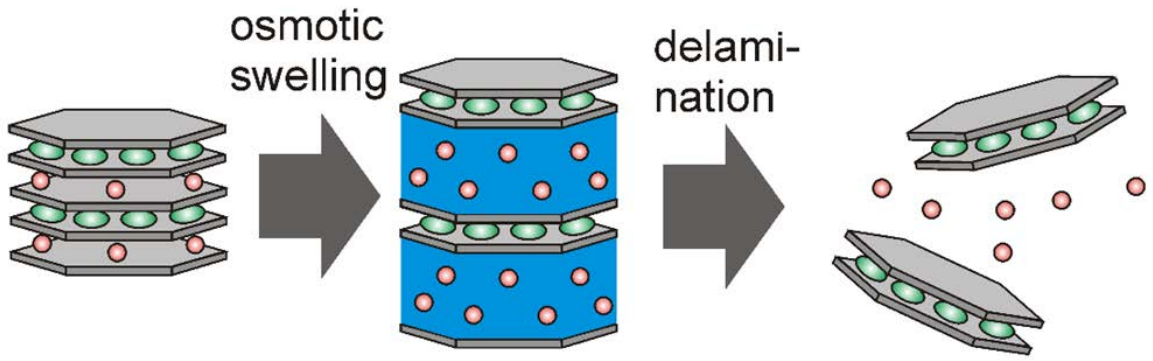
Clay

- In nature & synthetically made
- Clays from University of Bayreuth, with very well-defined charge and homogeneous charge distribution
- Layered material
- Swells in water and delaminates



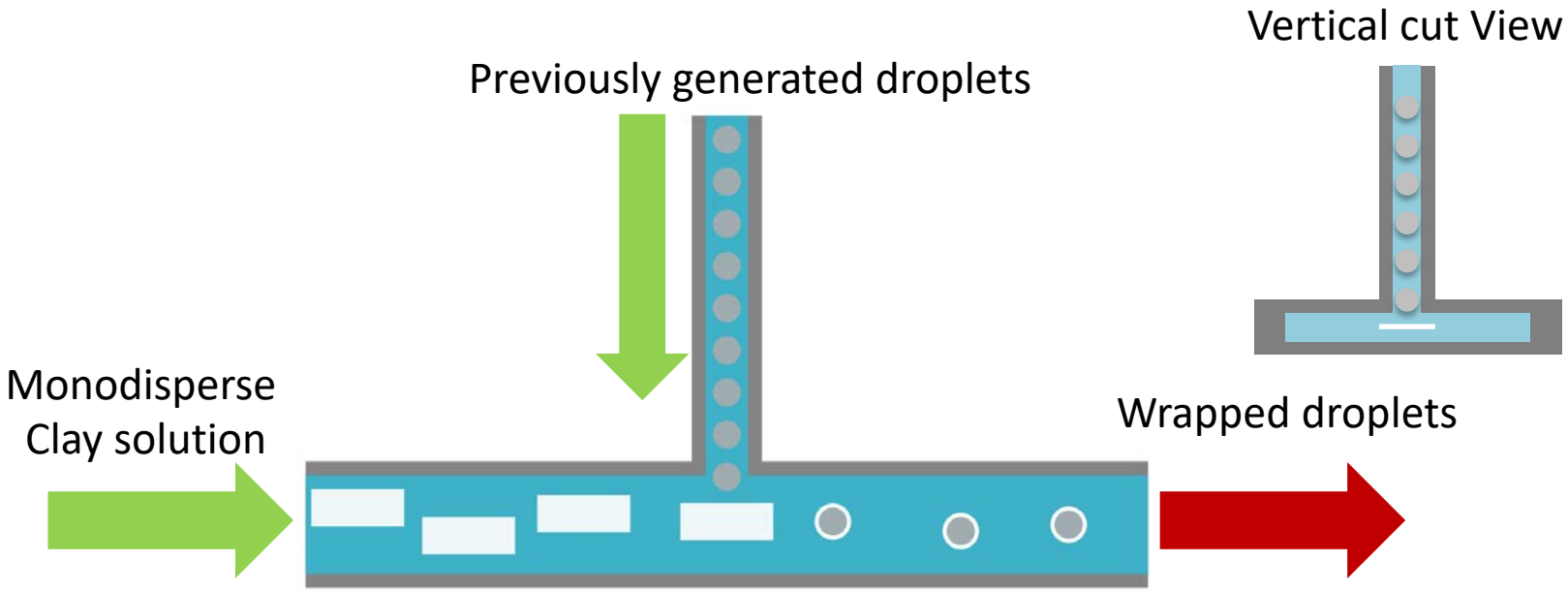
Activity associated with the Project

- Double Layered Clay
- Provided by University of Bayreuth (Prof. Josef Breu)
- Swells in water and delaminates



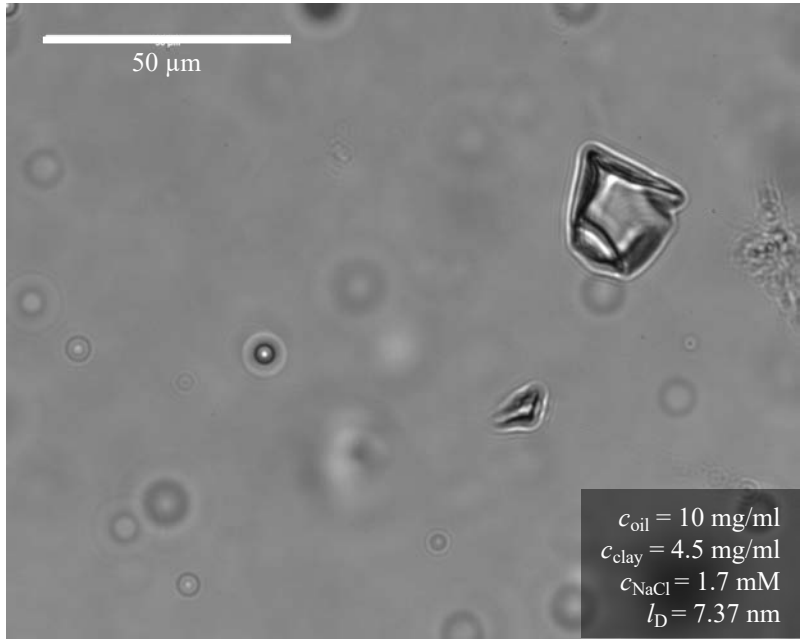
Microfluidic device for wrapping

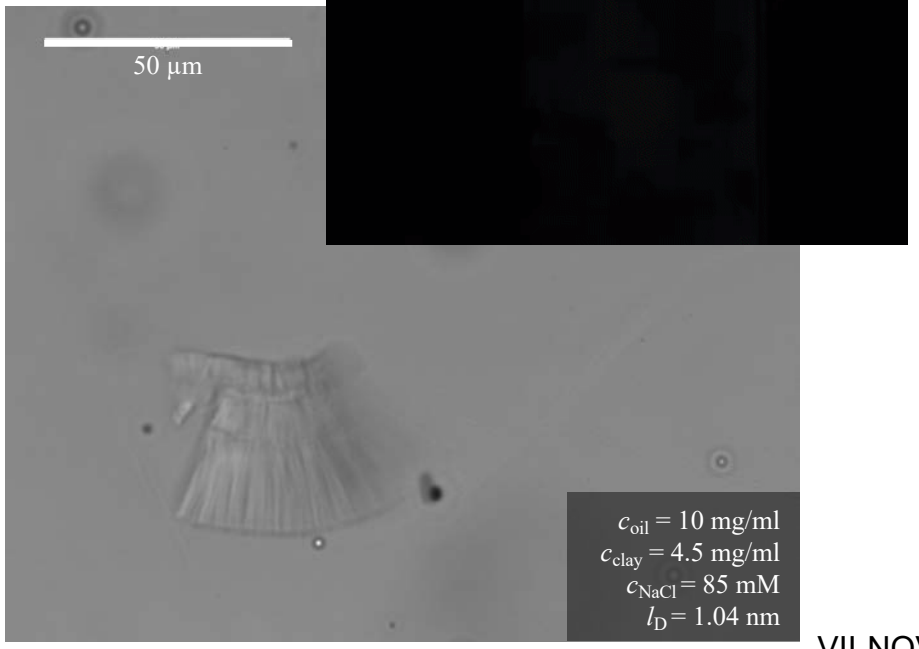
- Uses previously made monodisperse clay solution to wrap droplets
- Droplets in a T junction going into the nanosheets
- Work to be done in Paris, under Patrick Tabeling's supervision



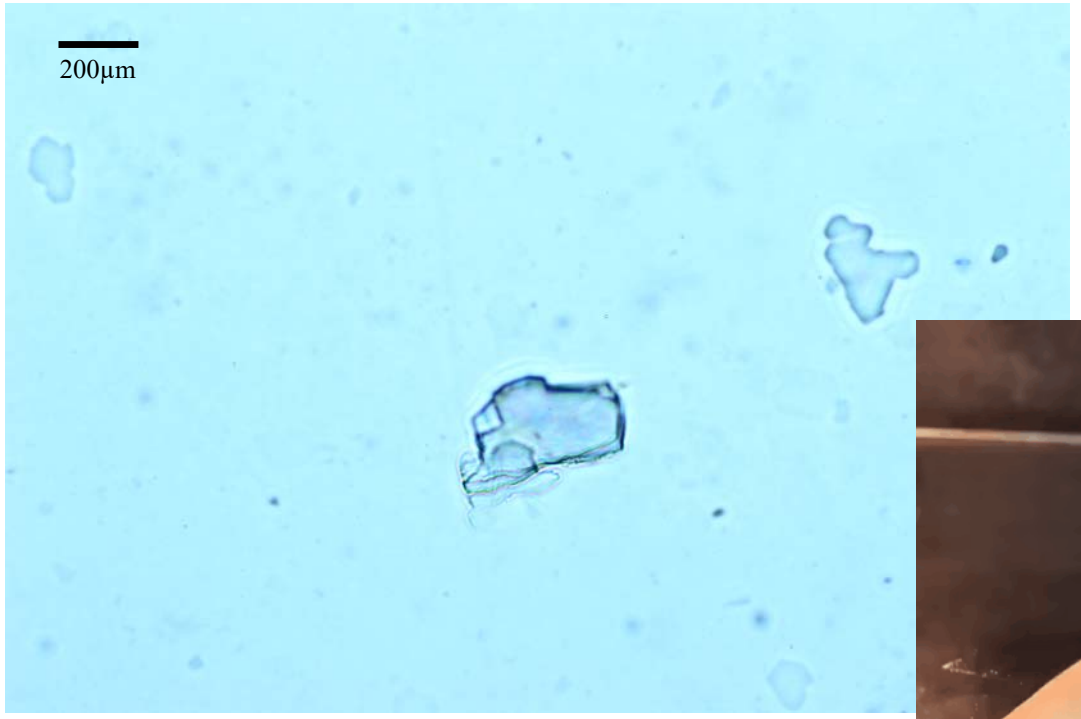
Possible Solution

- Castor Oil + Clay + Saline water
  - Wrapping Occurred





Swelling to Rupture



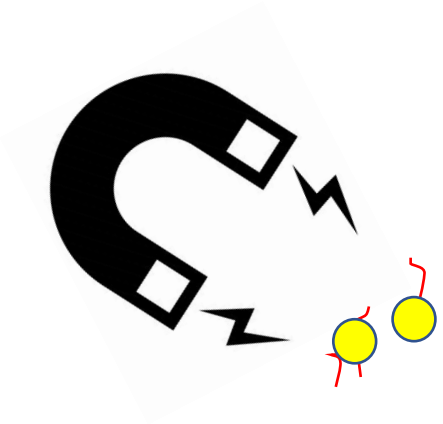
Plan

- Clay functionalization and selection of functionalized tracer particles
- Optical microscopic characterization
- Nanocapsules
  - Small Angle X-ray Scattering (SAXS): Sirius or similar facility in Europe or USA
  - Small Angle Neutron Scattering (SANS)
- Mechanical strength and stability of capsules (Atomic Force Microscopy)
- Investigate control of release properties of capsules
- Core-flood experiments with extraction by magnetic field

Sirius at UNICAMP

Summary

- Development started
  - Microcapsules for controlled gelation in oil reservoirs
  - Encapsulated magnetic tracer particles



Thanks for your attention

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