



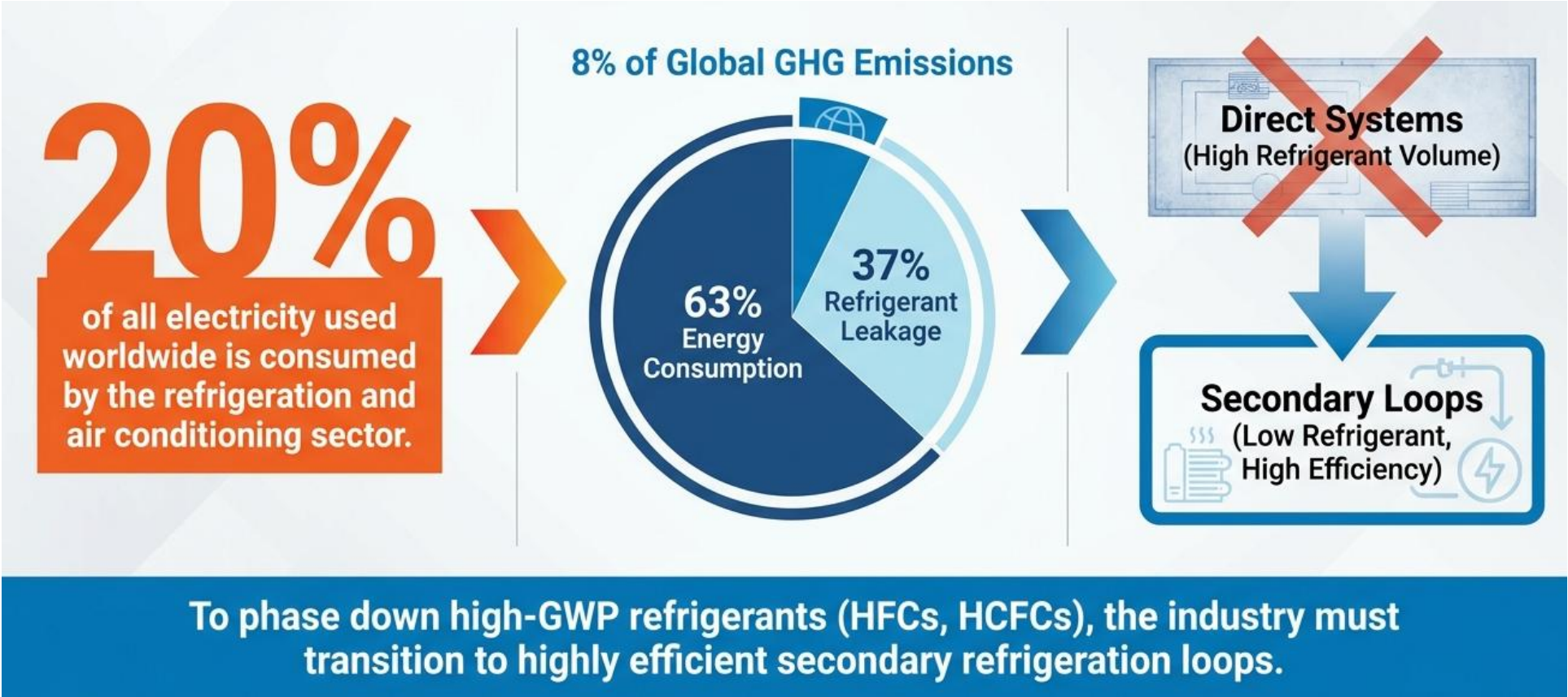
RHEOLOGICAL CHARACTERIZATION OF HEXADECANE-IN-WATER PICKERING EMULSIONS STABILIZED BY CELLULOSE NANOCRYSTALS AND AOT



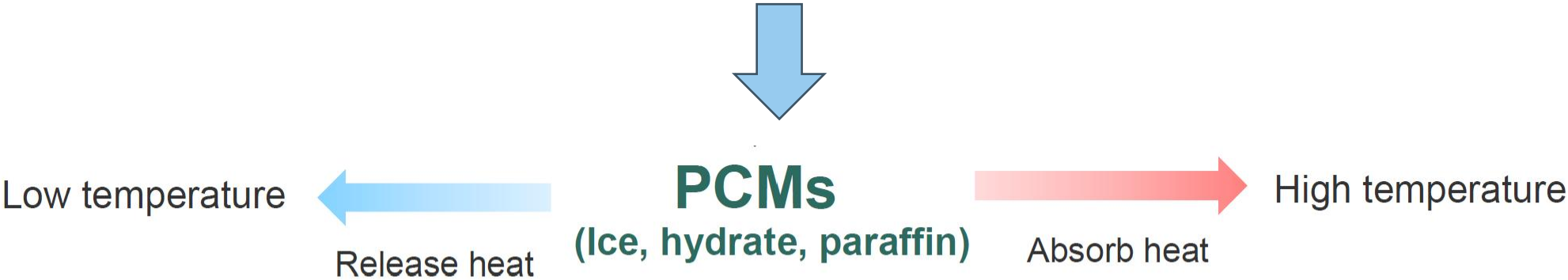
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Paper 15

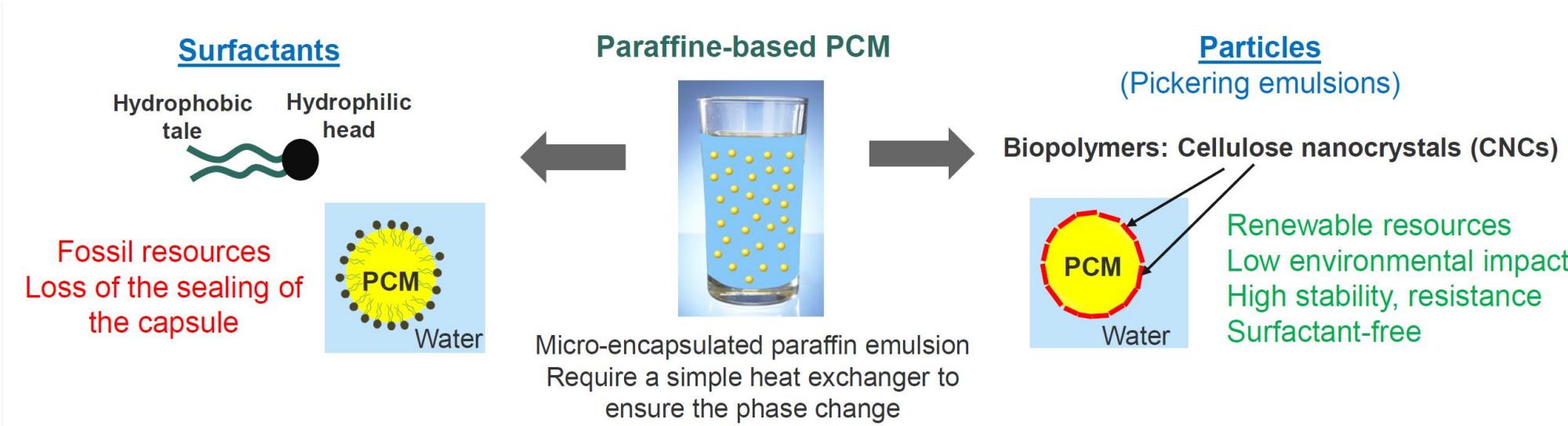
General context



General contextPhase Change Slurry (PCS)



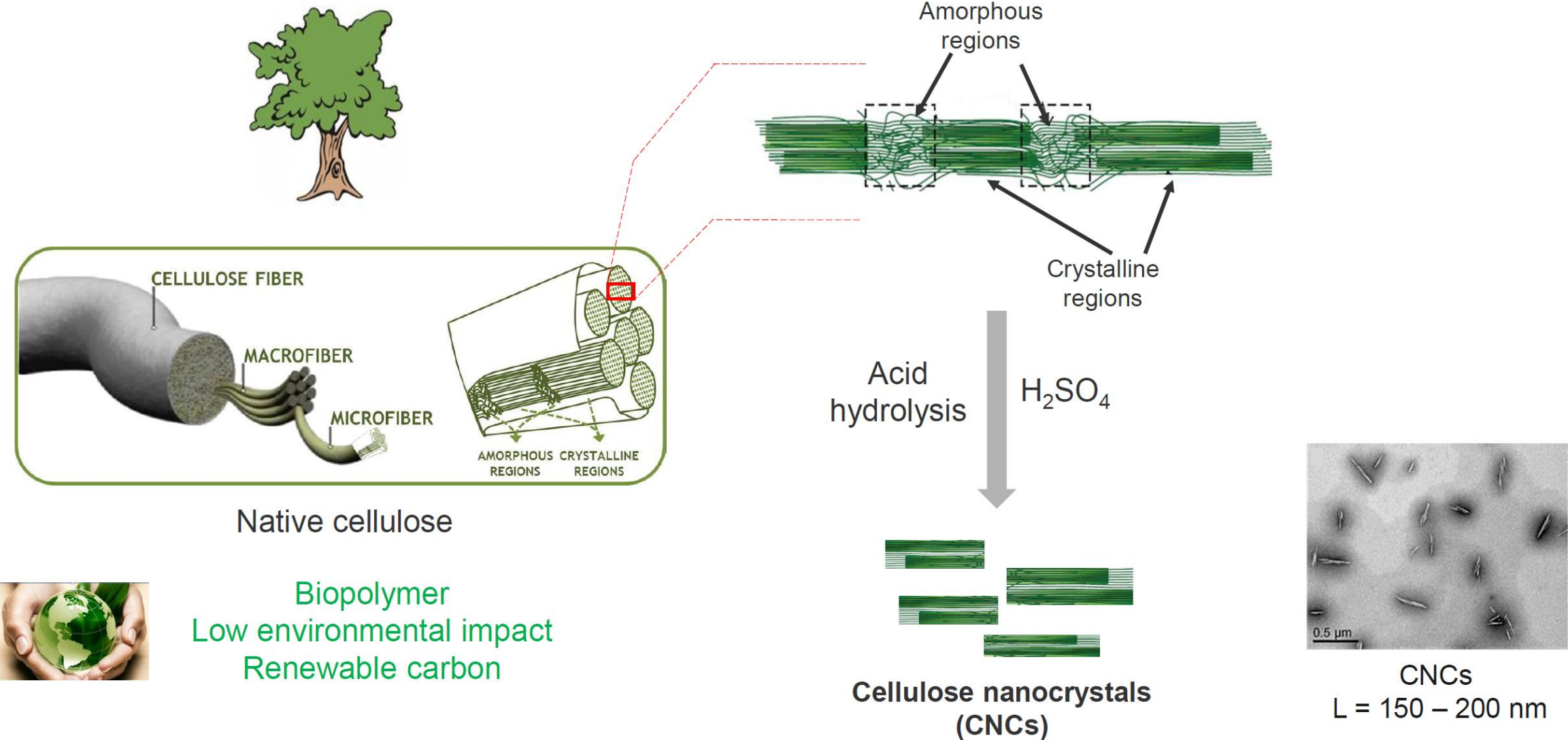
Store and release large amounts of energy as latent heat through a phase change



Work plan

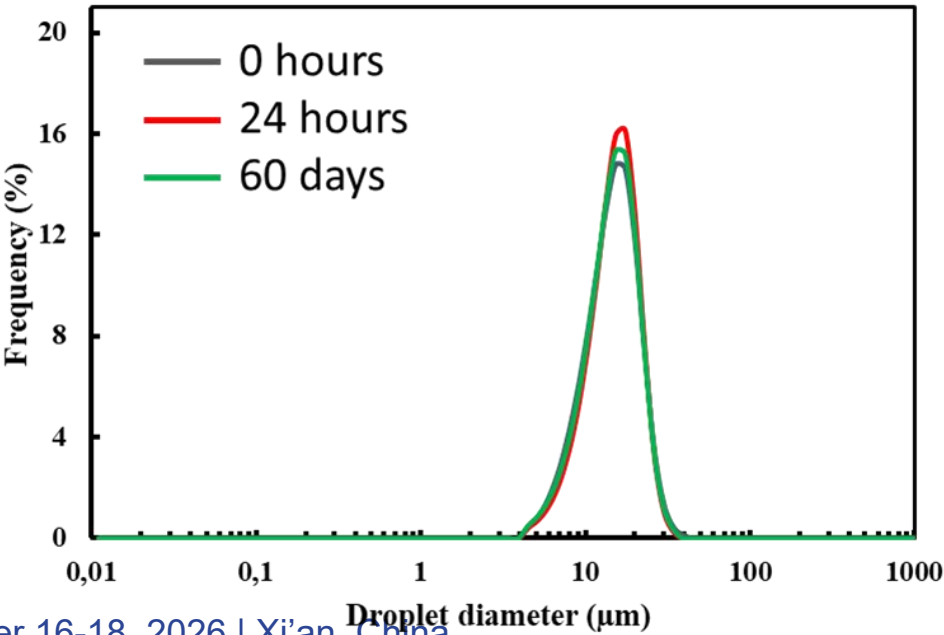
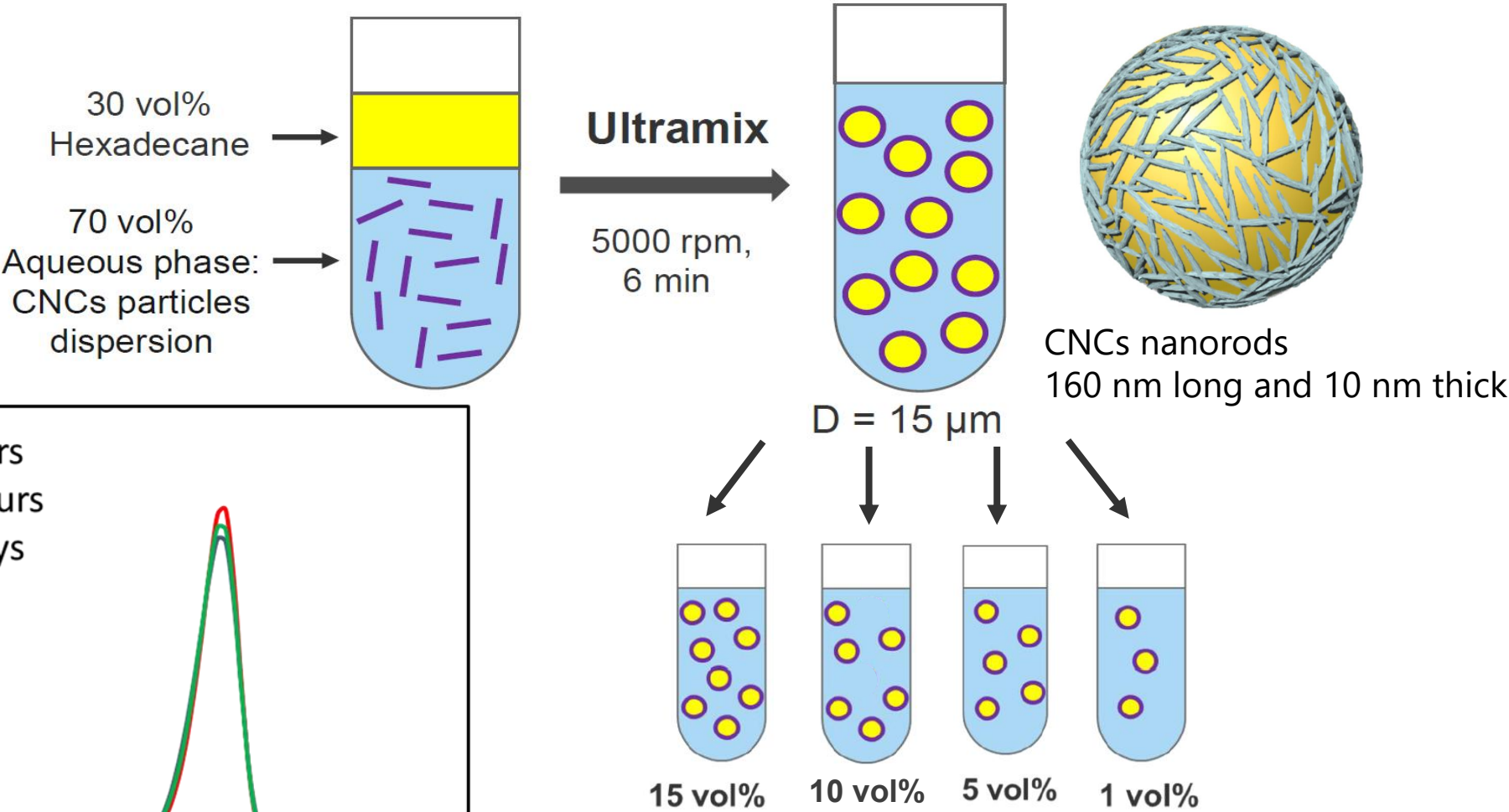
1. Preparation of CNCs stabilized hexadecane-in-water (h/w) emulsion
2. Rheological behavior of h/w emulsion
3. Rheological behavior of h/w emulsion with AOT
 - a. Effect of solid hexadecane emulsion
 - b. Effect of AOT concentration
4. Influence of the cycling on the apparent viscosity

CNCs preparation

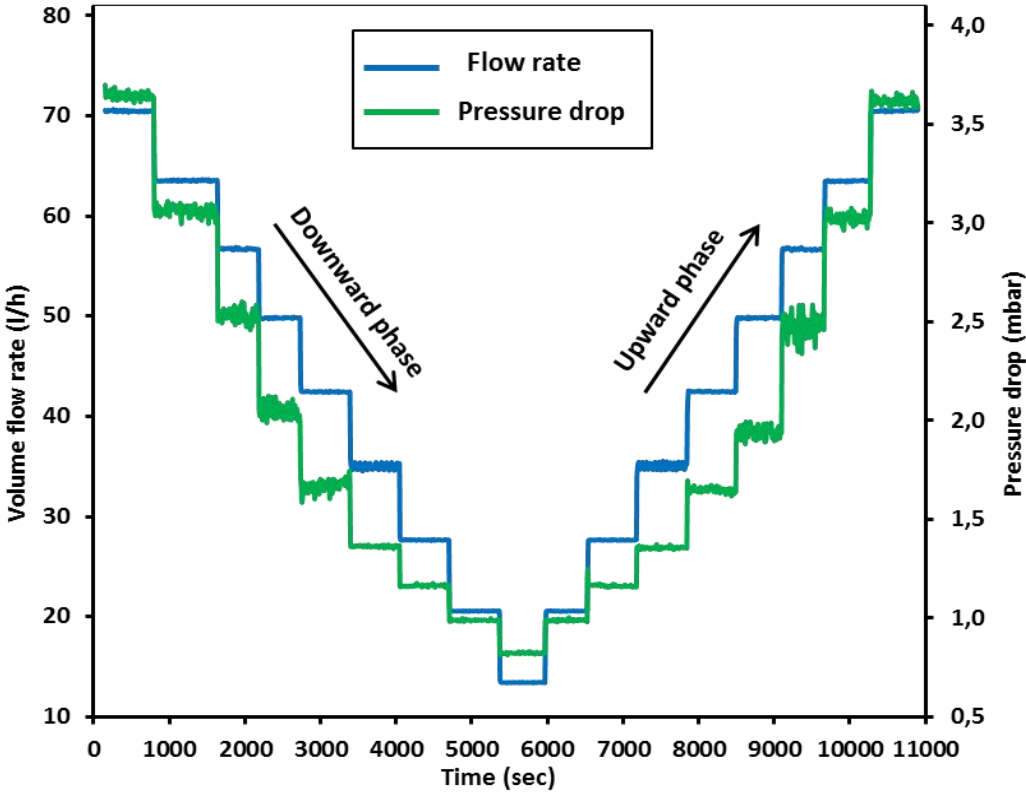
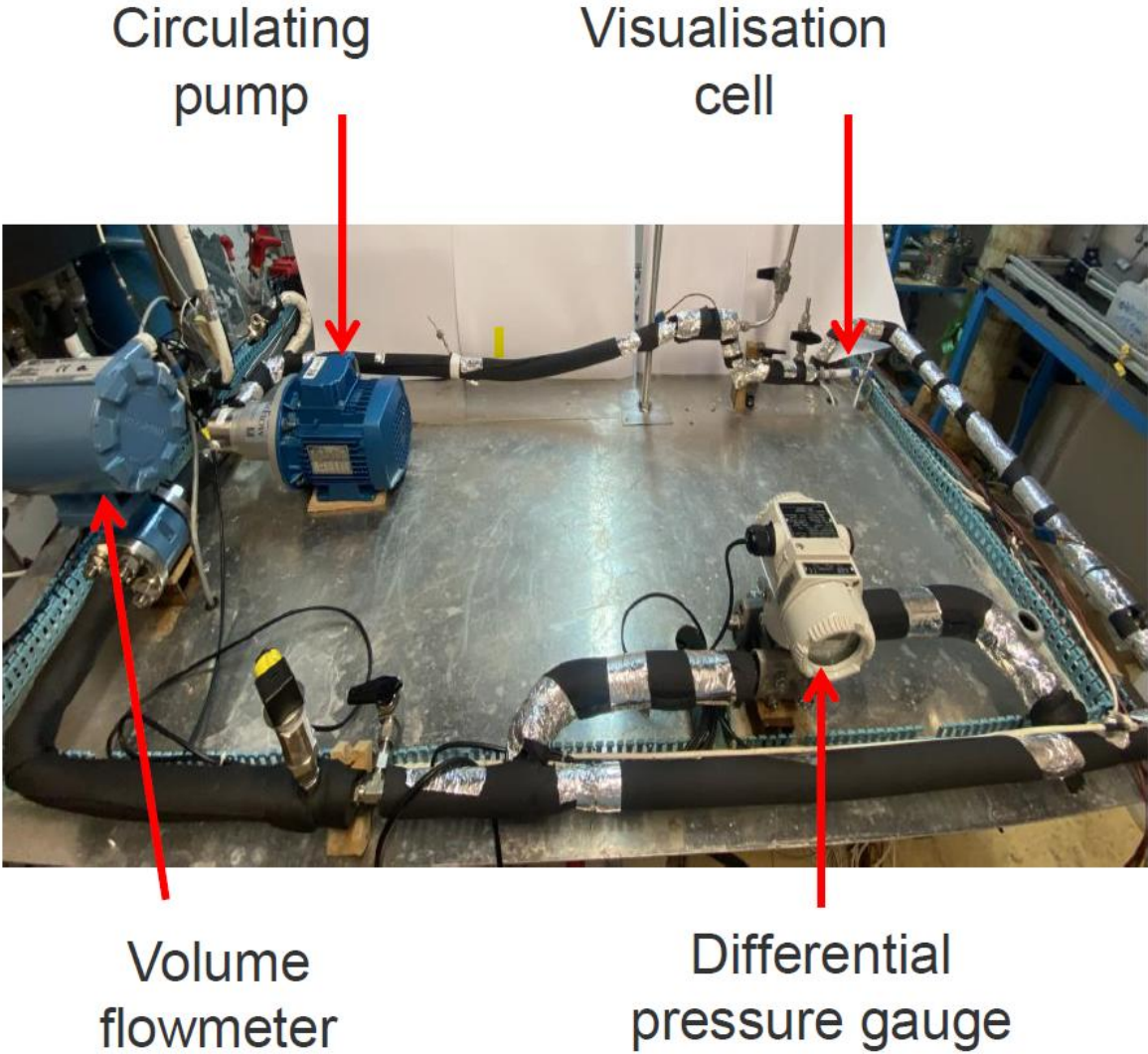


CNCs stabilized hexadecane-in-water emulsion

Hexadecane
Melting enthalpy = 235 kJ/kg
Melting temperature = 18 °C



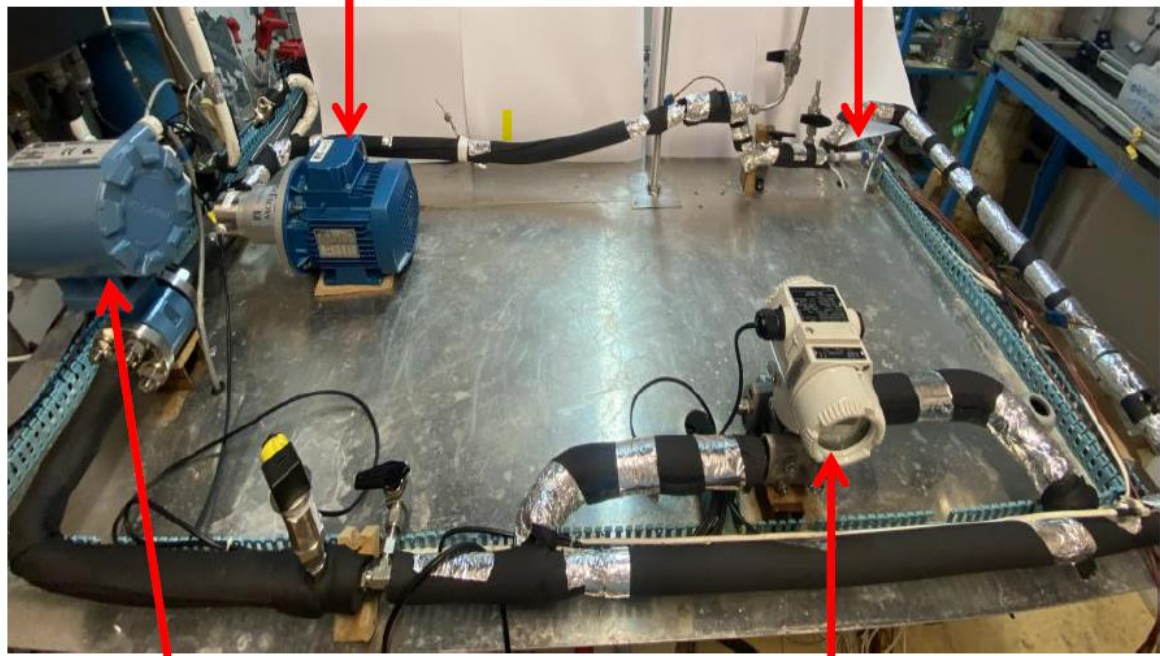
Experimental set-up for rheology



Experimental set-up for rheology

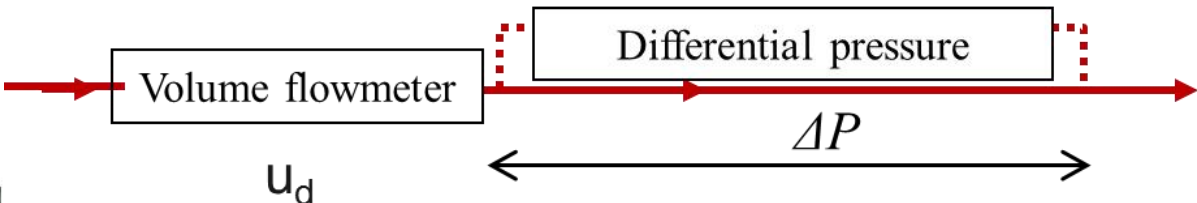
Circulating
pump

Visualisation
cell



Volume
flowmeter

Differential
pressure gauge



From measurements ΔP and u_d : **(Rabinowitsch and Mooney)**

$$\tau_w = \frac{D\Delta P}{4L}$$

Shear stress

$$\dot{\gamma}_w = \left(\frac{8u}{D}\right) \left(\frac{3n+1}{4n}\right)$$

Shear rate

$$n = \frac{d(\ln \tau_w)}{d\left(\ln \frac{8u_d}{D}\right)}$$

Behaviour index

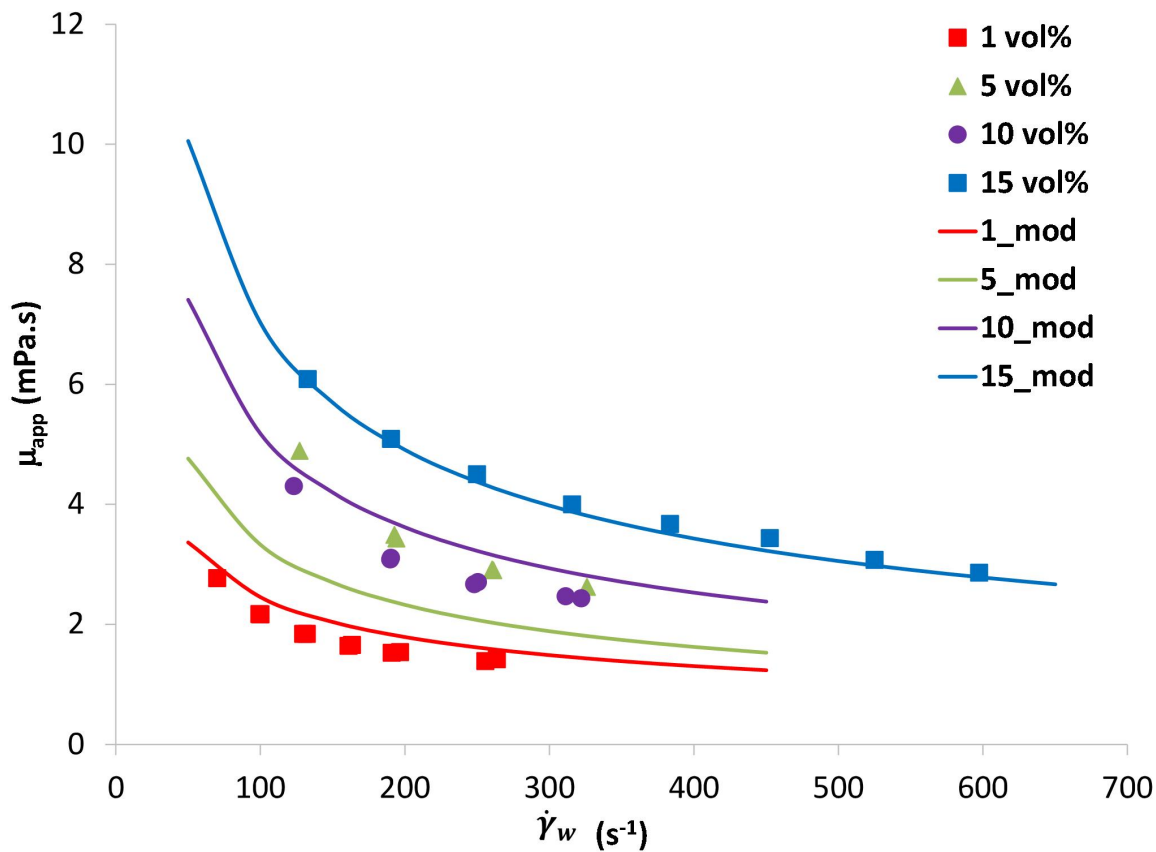
Ostwald- de Waele model:

$$\tau = k\dot{\gamma}_w^n$$

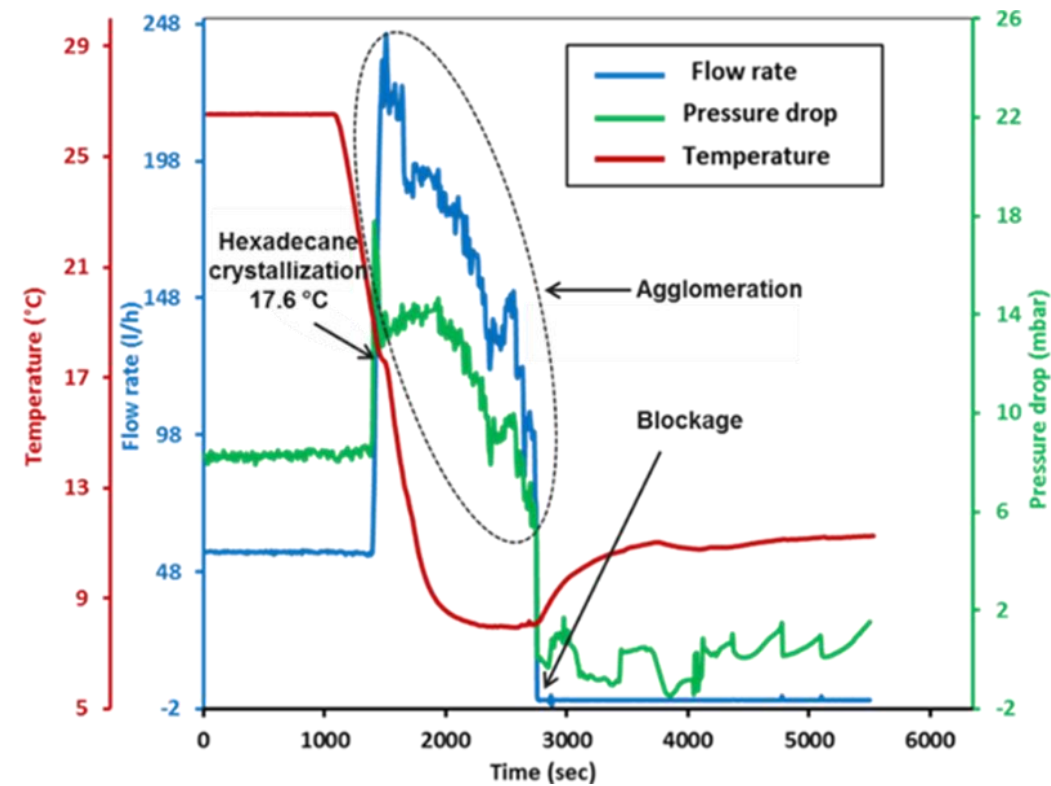
k: consistency index

$$\text{Apparent viscosity: } \mu_{app} = \frac{\tau_w}{\dot{\gamma}_w} = k\dot{\gamma}^{n-1}$$

Rheological behaviour of liquid and solid H/W



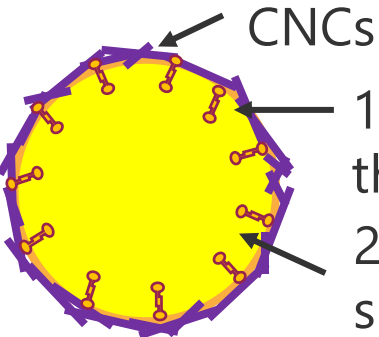
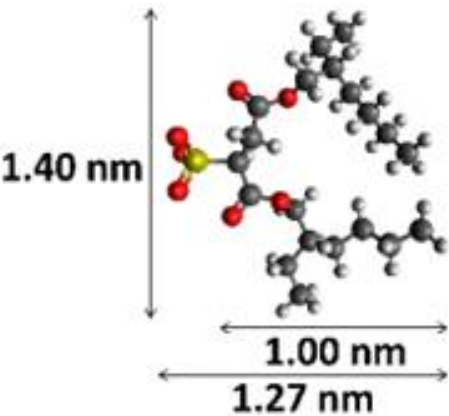
$$\mu_{app} = (0.004 * \phi_{HD} + 0.016) * \dot{\gamma}_w^{(0.483+0.564* 0.109\phi_{HD})-1}$$



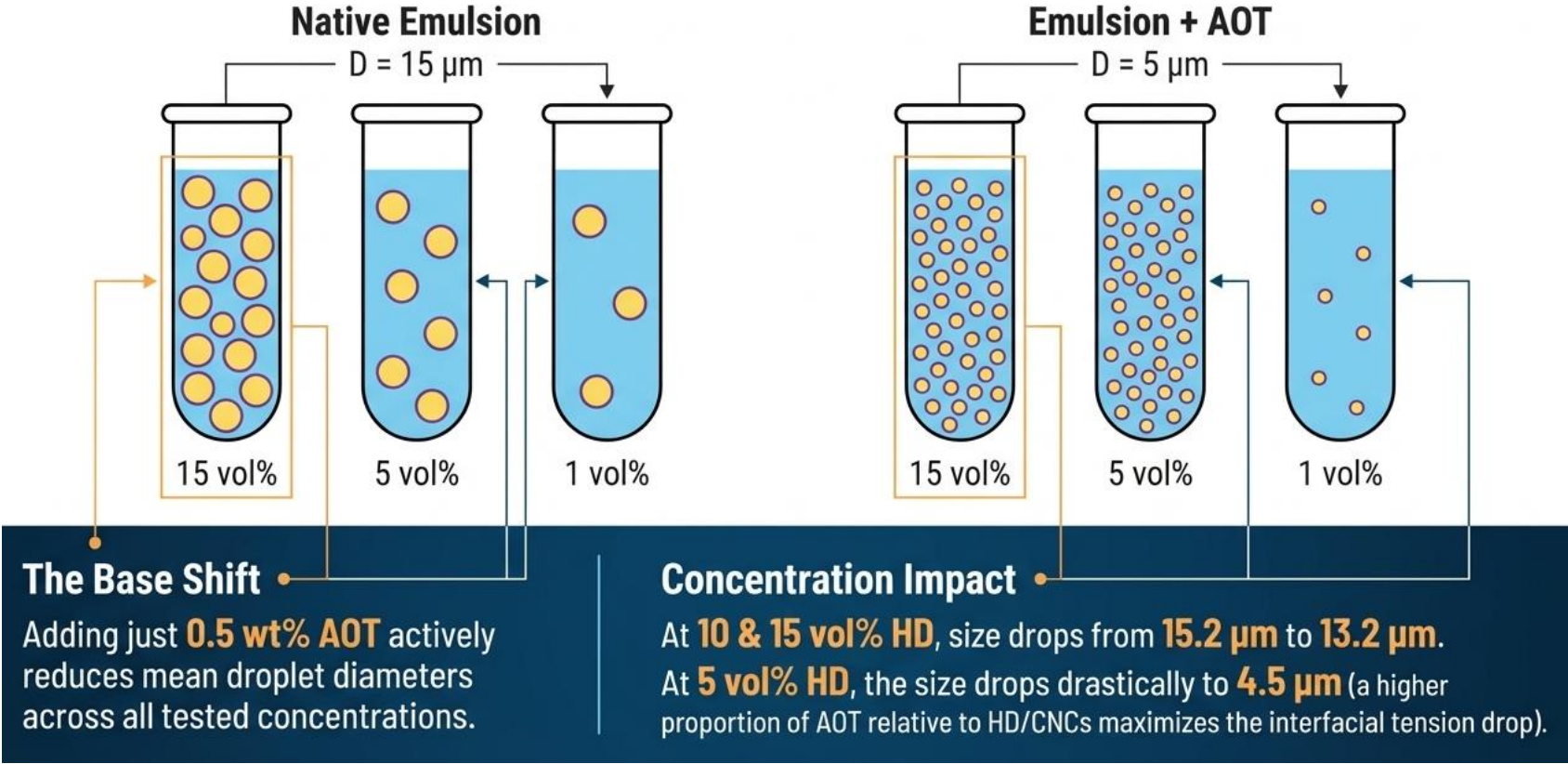
Plugging in the loop !

Adding of AOT – Effect on droplet size

AOT (Dioctyl Sodium Sulfosuccinate): Anionic surfactant, highly miscible in apolar solvents.

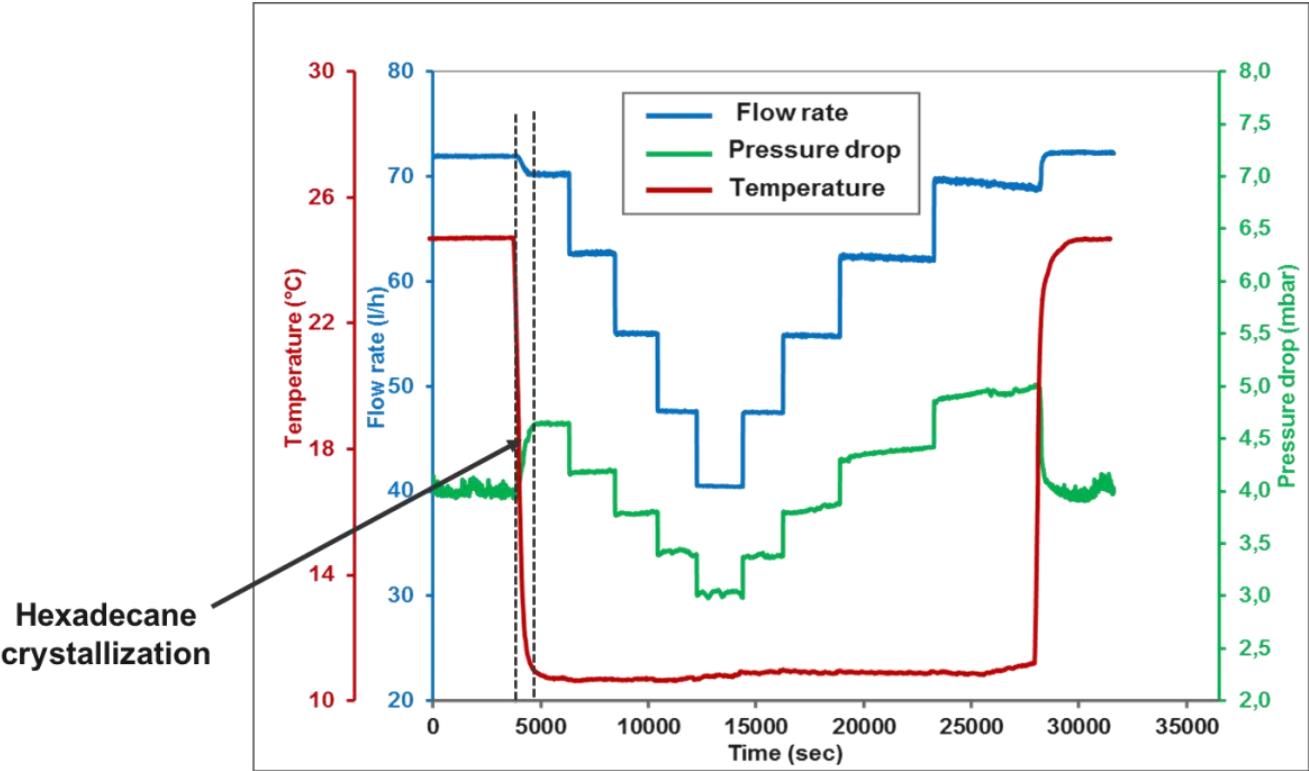
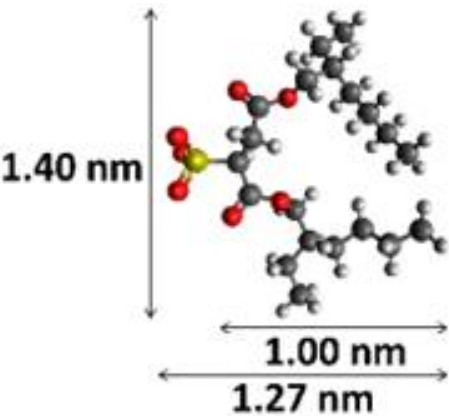


- 1. AOT adsorbs onto the CNCs surface
- 2. Synergistic interaction sharply decrease interfacial tension at h/w boundary



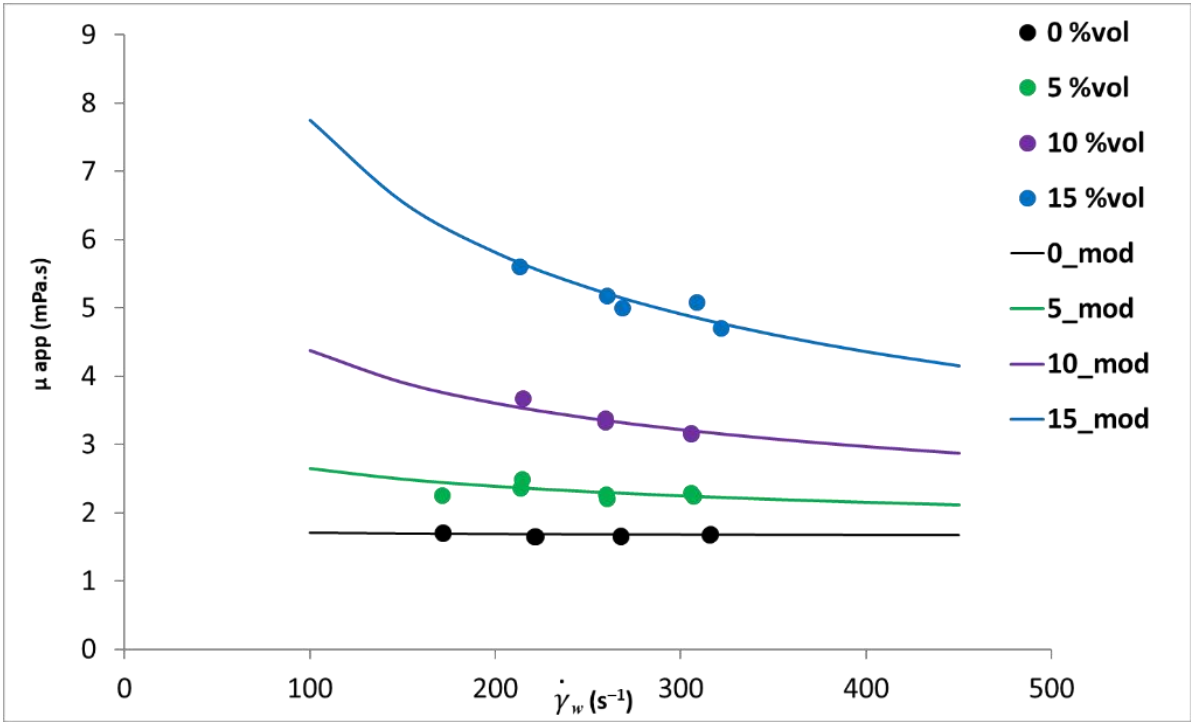
Adding of AOT – Effect on agglomeration

AOT (Dioctyl Sodium Sulfosuccinate): Anionic surfactant, highly miscible in apolar solvents.



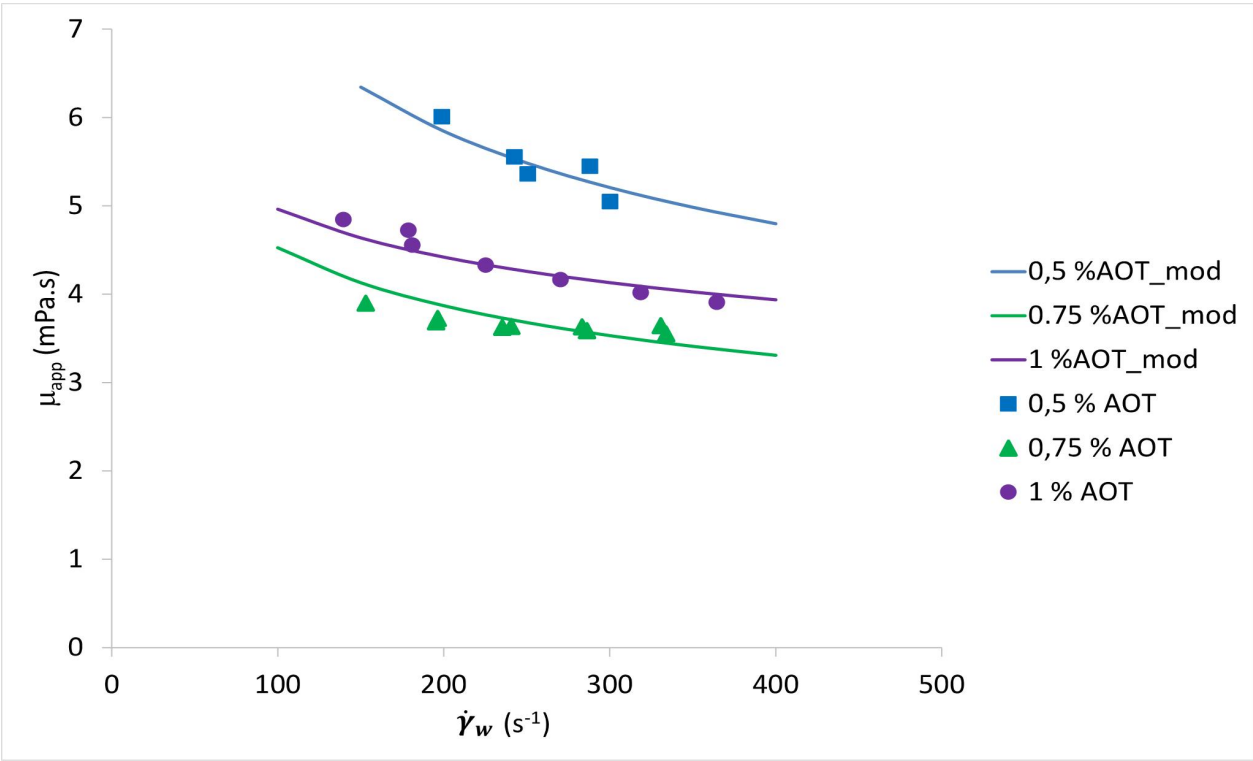
Introduction of AOT completely prevents the agglomeration of solid HD particles.

Rheological behaviour of H/W emulsion with AOT



At 0.5 wt% AOT

✓ Apparent viscosity of the PCS increases as a function of the HD solid fraction.



At 15 vol% HD

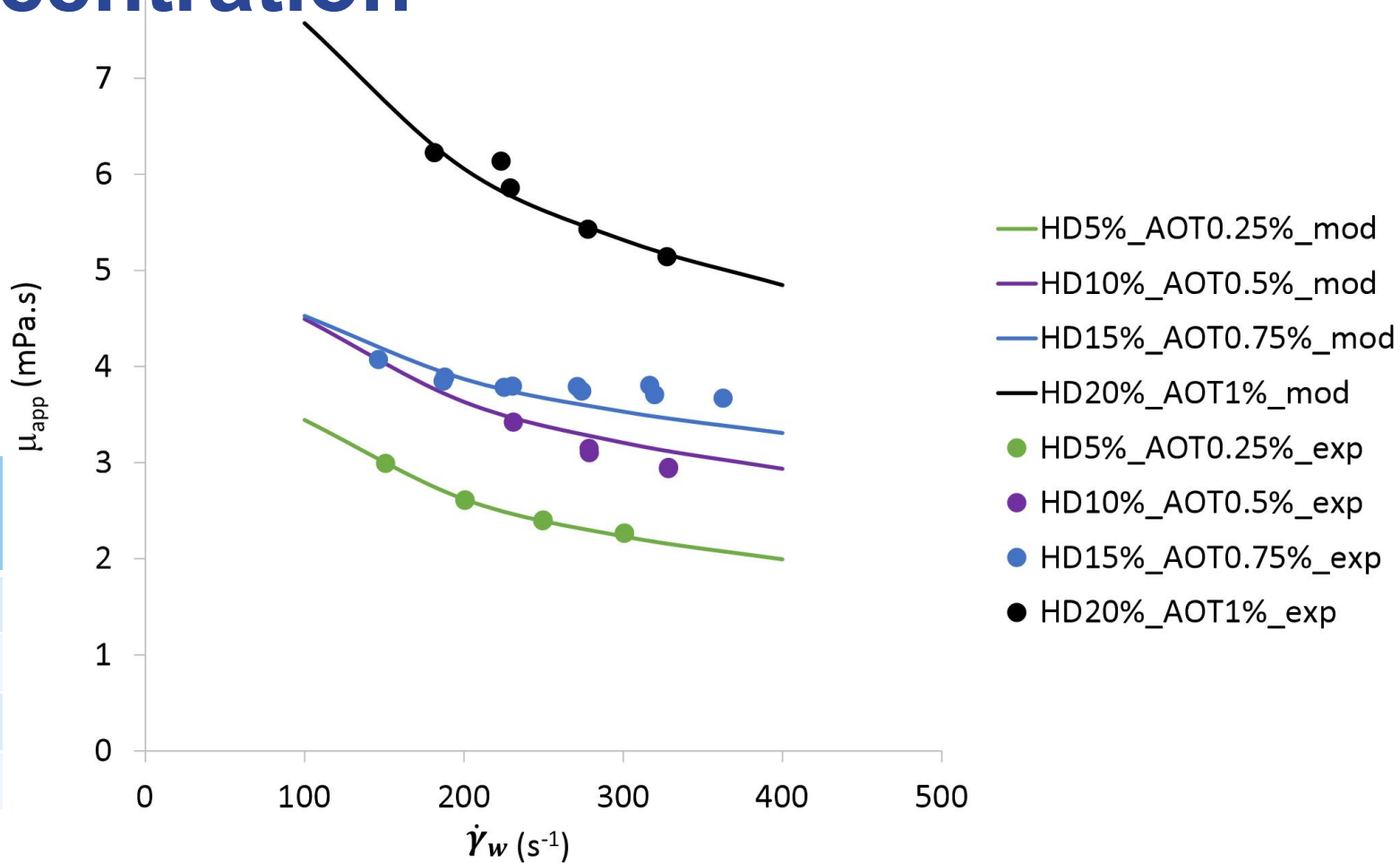
✓ Apparent viscosity of HD slurries decrease as a function of AOT concentration but needs to be adjusted.

Rheological behaviour of H/W emulsion with optimal AOT concentration

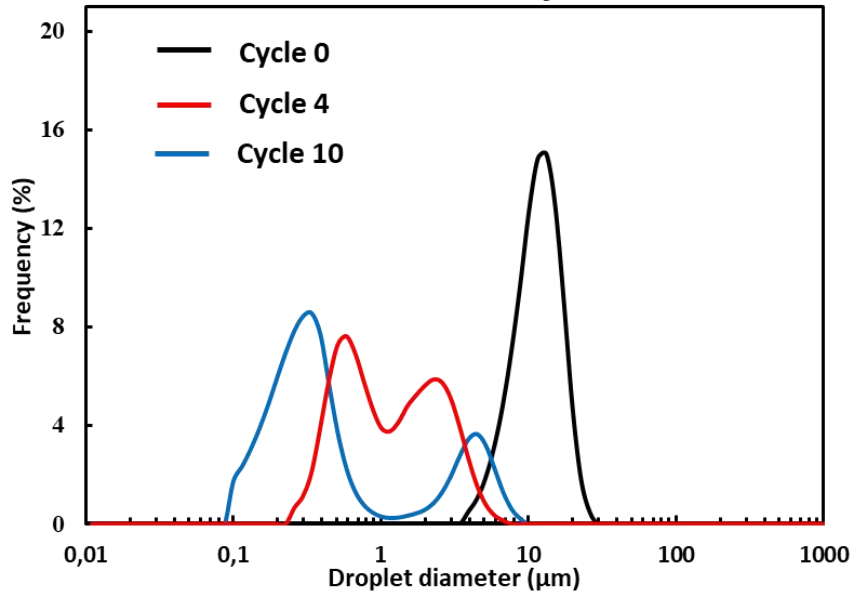
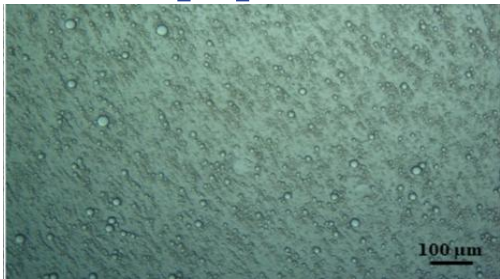
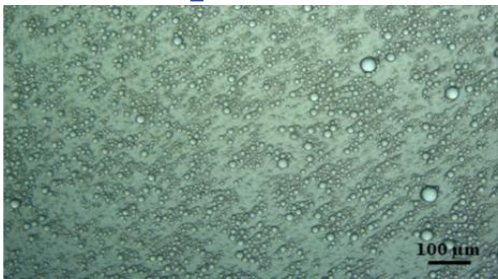
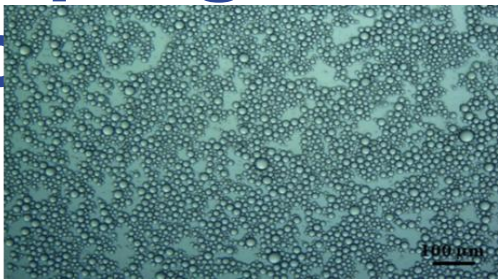
Amount of AOT added was calculated in relation to the total surface displayed by the HD droplets (S_d) in the emulsion.

$$S_d = \frac{3V_{HD}}{R}$$

HD (vol%)	S_d (m ²)	AOT (wt%)
5	150	0.25
10	300	0.5
15	450	0.75
20	600	1

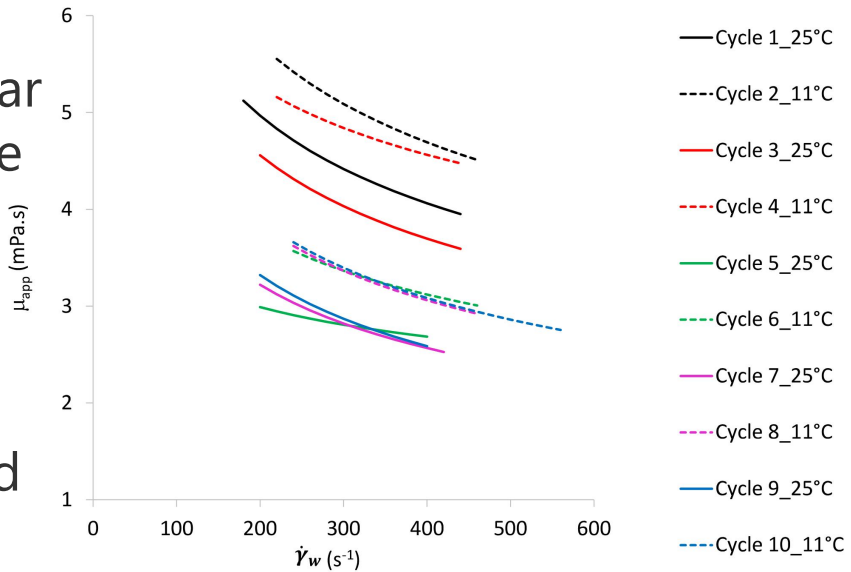


Pumping effect on droplet size and apparent visco



Gear pump effect: Mechanical shear from the pump actively fractures the droplets during cycling.

After 3 cycles, apparent viscosity drops by 10-25% and stabilizes as droplets reach a minimum threshold size.



Conclusions

- ✓ First successful validation of biostabilized PCM slurries under continuous loop flow.
- ✓ Shear-thinning behaviour ensures high-energy transport with minimal pumping penalty.
- ✓ CNCs + AOT create a robust, pump ready secondary fluid that actively resists agglomeration.

Further work

- ❖ Ensure the long-term stability of these emulsions under continuous operating conditions and the potential formation of AOT aggregates at higher concentrations.
- ❖ Understand impact of shear rate on droplet size control.



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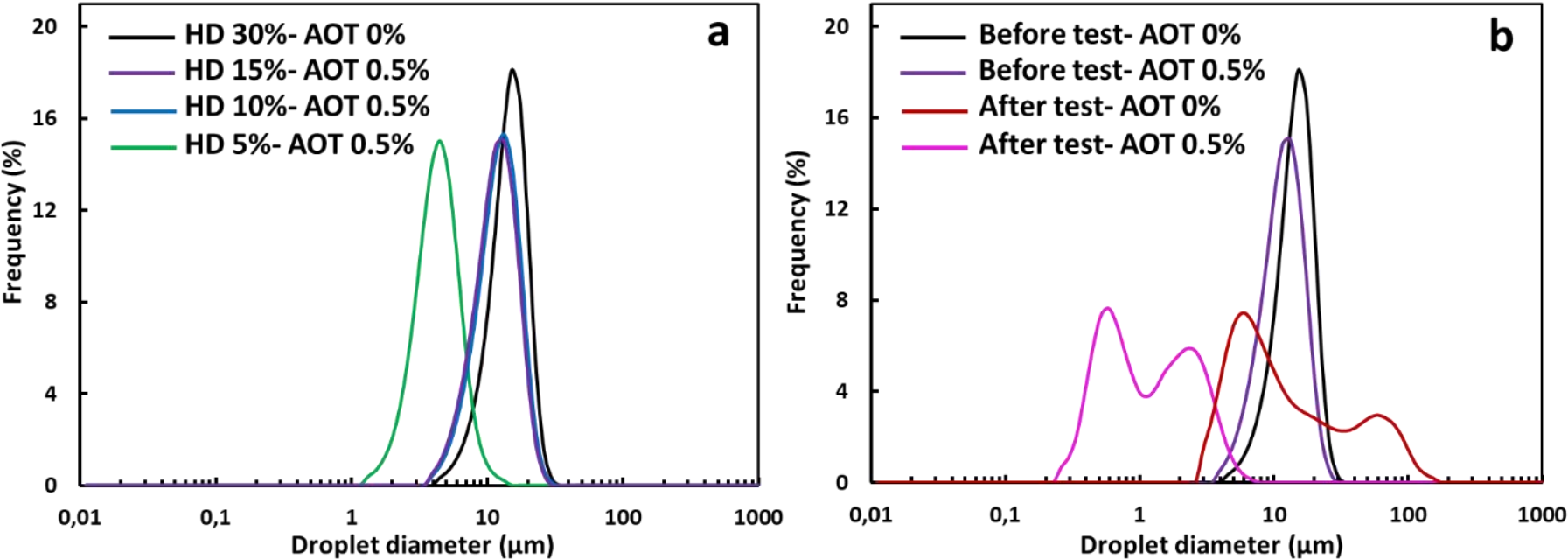
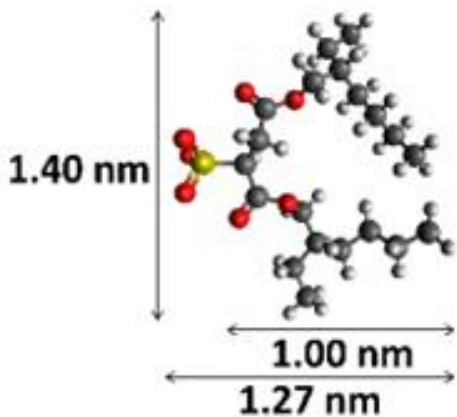
Laurence Fournaison



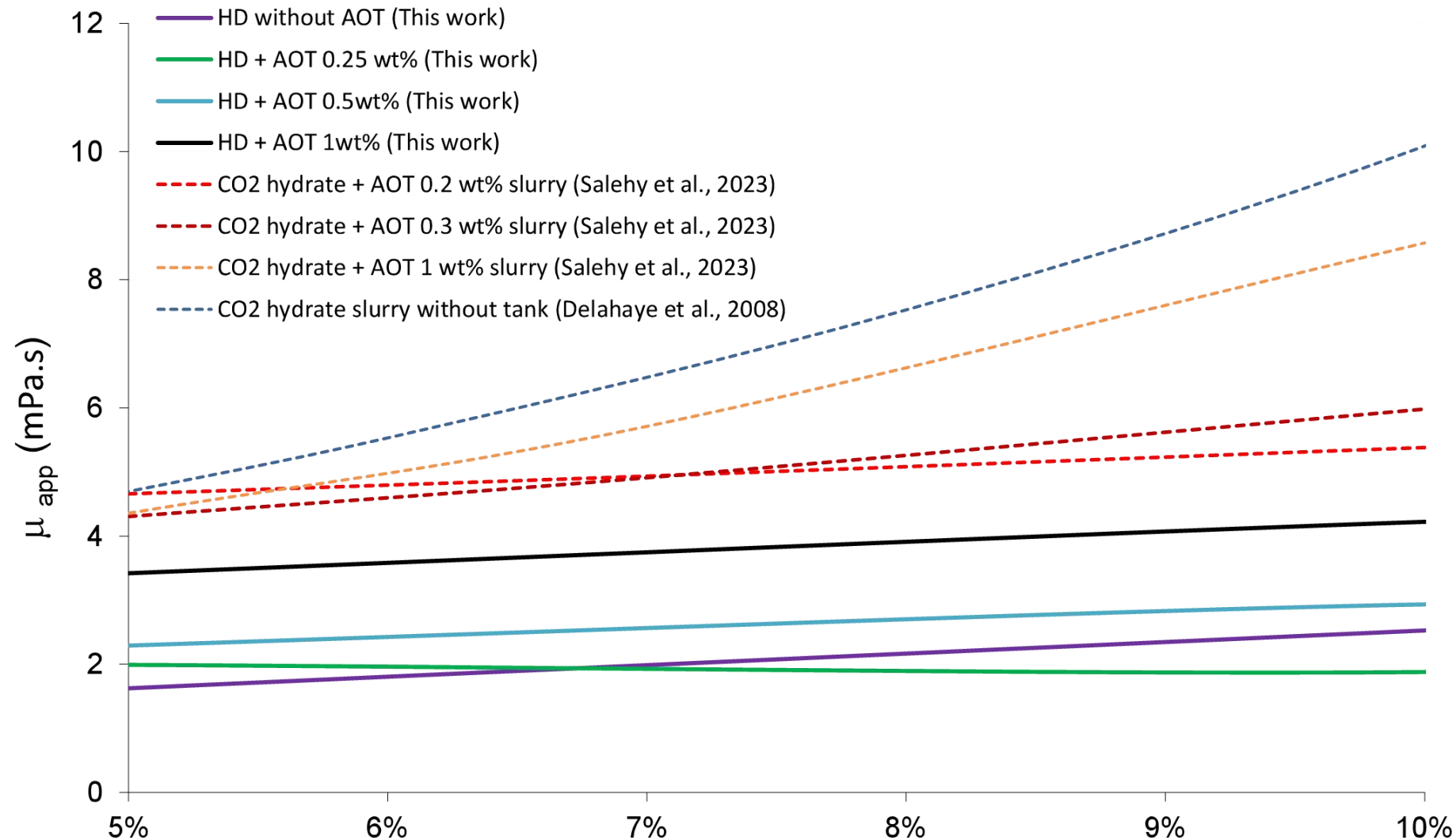
Thank you

Adding of AOT – Effect on droplet size

AOT (Dioctyl Sodium Sulfosuccinate): Anionic surfactant, highly miscible in apolar solvents.



Comparison with literature results



- ✓ Significant impact of flow behaviour of PCS with AOT.
- ✓ CO₂ hydrate slurries, the viscosity values are nearly twice as high as those found in H/W dispersions at the same AOT concentration and solid fraction.