Stabilization of CO_2/Water Foams and Nanoparticles in Subsurface Reservoirs

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Sustaining Injectivity

Development of CO2 soluble surfactants to aid injectivity of CO2/water foams that form upon contacting water to control flow pathways and increase CO_2 storage capacity.

Storage Efficiency

Design nanoparticles surfaces to change mineral surfaces from oil wet to water wet to increase residual trapping of CO2 and raise structural trapping capacity

Controlling Emergence

Design reactive foams that sense and arrest CO_2 leakage. The trigger could be presence of water, pH, or interaction of amphiphiles with minerals.

Objectives and Methods

Nanoparticle stabilization in high salinity brine and mobility in porous media: low MW ligands and polymers

- modify nanoparticle surfaces with covalent grafting and characterize with dynamic light scattering, zeta potential and nmr
- examine nanoparticle stability in various brines versus temperature
- study nanoparticle mobility and influence on permeability for sandstone

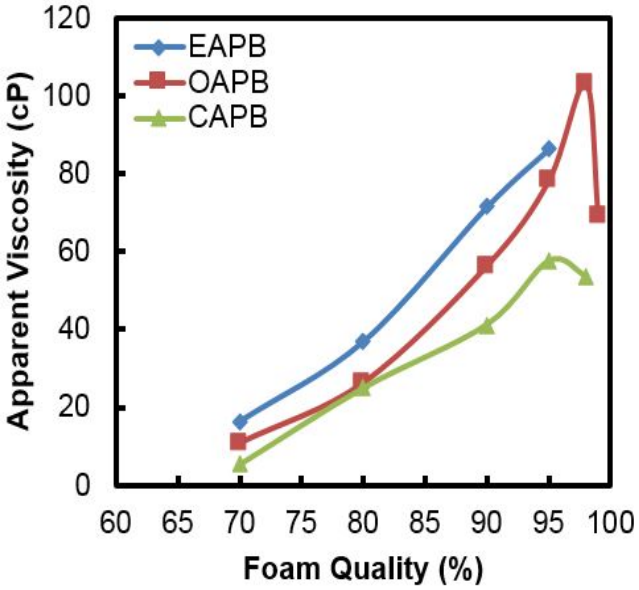
Stabilization of CO_2/water foams with surfactants, wormlike micelles and nanoparticles: phase behavior, interfacial properties, texture and rheology

- sandpacks for screening
- flow through porous consolidated rock and CT scan

Wettability alteration with nanoparticles with designed surfaces from contact angle measurements at high pressure and temperature

Magnetic nanoparticles for subsurface imaging: design ligands to enable high mobility in porous rock

Results

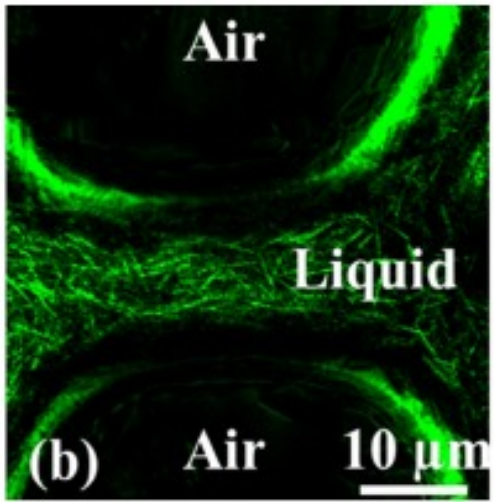


- 208 trillion m^3 of CH_4 in shale (world)
- 2~5 million gallons of water/well for disposal
- Xue, KJ et al. (16) Alzobaidi, KJ et al. (17)

$$V = -\frac{dh_f}{dt} = \frac{2h_f^2}{3\mu_e R^2}(P_c - \Pi(h))$$

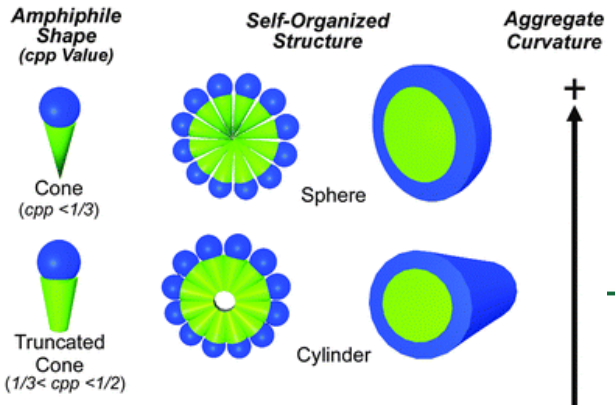
Very dry foams, high ϕ gives high P_c
Rapid lamellae drainage

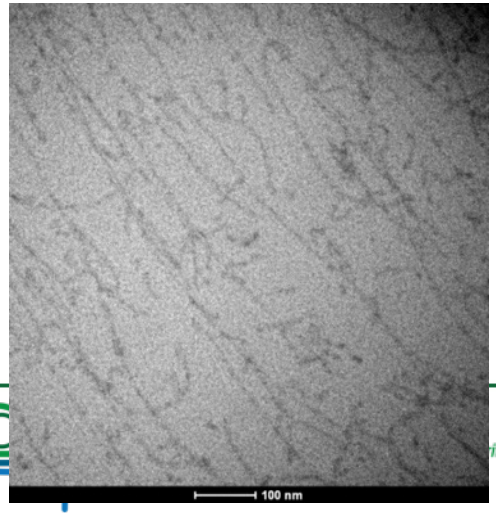
$P_c = \gamma / R(1-\phi)^{0.5}$

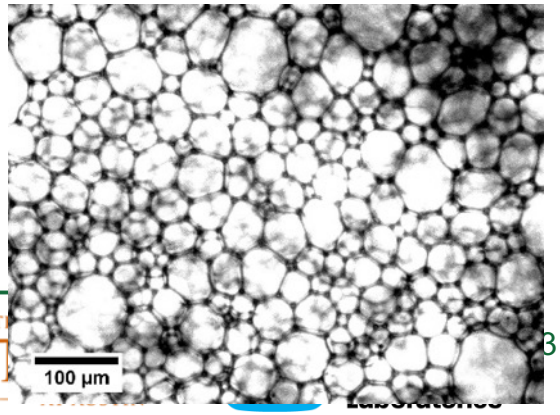


Stable foams at only 2% water: (E: C22, O: C18, C: C12-14)
low drainage of viscoelastic lamellae
thicker lamellae resist Ostwald ripening and coalescence

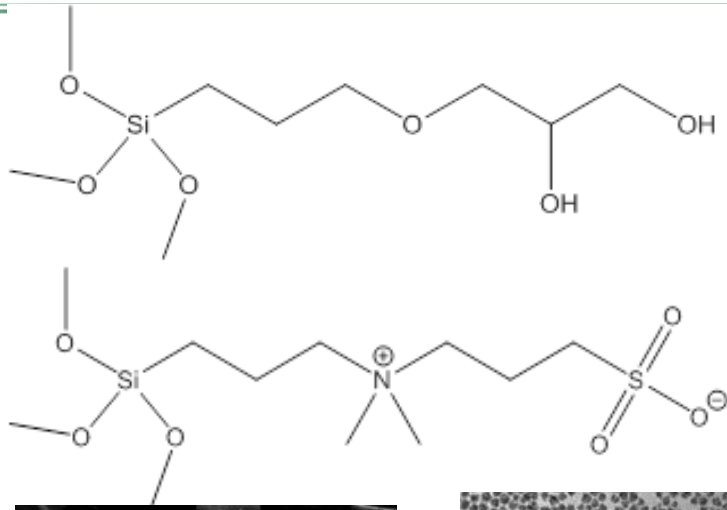
Catanionic micelles:
Jamming: slow drainage maintains thick lamellae
Fameau et al., Ang. Chem. (11)

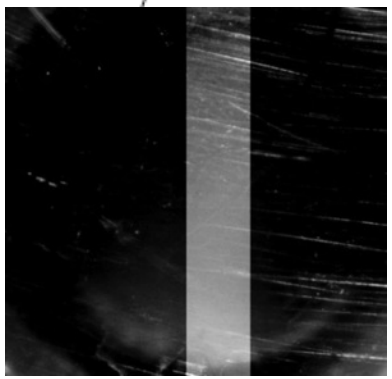


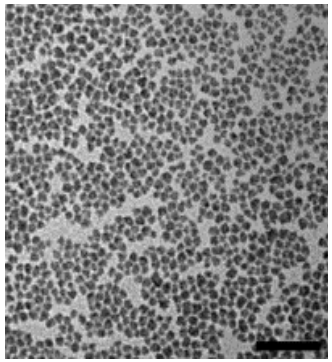




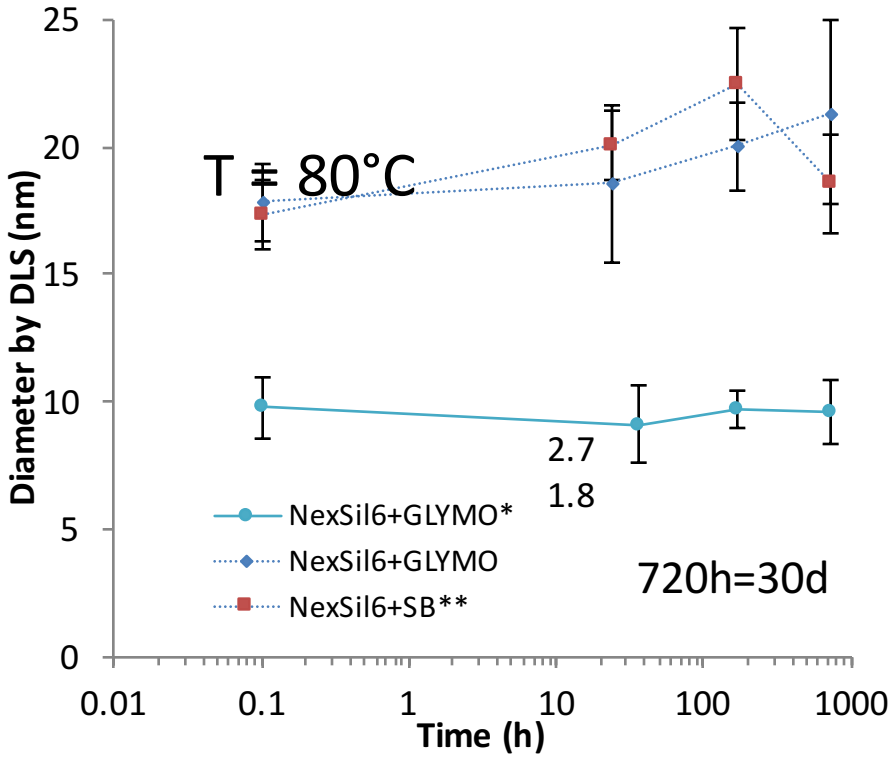
Results







Scale bar 100 nm



- **Stability in API brine with low MW ligands (8% NaCl and 2% $CaCl_2$)**
- **Ether diol has some CO2 philicity and lower hydrophilicity of SiO^-**
  - At 1 wt%, lower surface tension of API brine from 75.2 to 65.6 mN/m
  - particles stabilize C/W foams in API brine tested up to 50°C (1.8 µmol/m^2)

Planned Manuscripts

- Design of ligands on silica nanoparticles for high mobility in sandstone at high salinities, Johnston, DiCarlo, Prodanovic
- Synergism of nanoparticles and surfactants for stabilization of CO2/water foams in porous media: Johnston, DiCarlo, Prodanovic
- Conformation of Polyelectrolytes on Nanoparticle Surfaces and influence on Colloidal Stability, Johnston, DiCarlo, Prodanovic
- Influence of nanoparticles on the interfacial tension at the CO_2/water interface and wettability alteration of mineral surfaces, Johnston, DiCarlo, Prodanovic