Modified Carbon Black Nanoparticles for Carbon Sequestration

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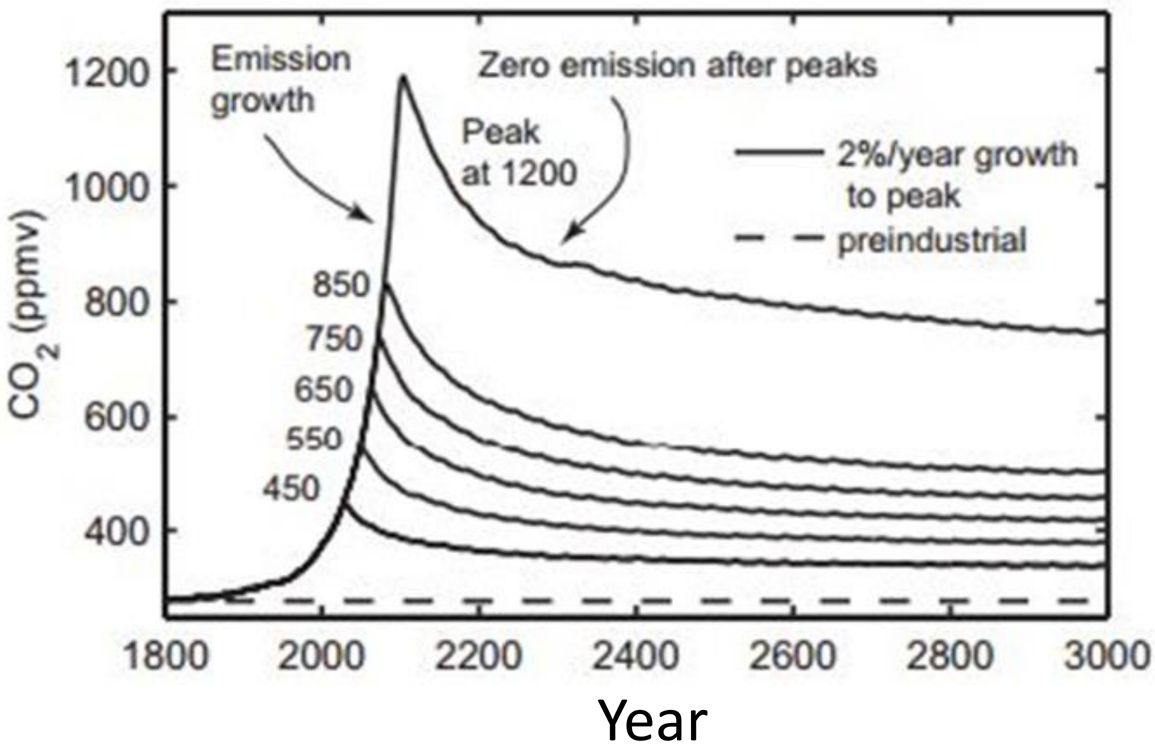
Outline

- Carbon Capture and Storage - General Concept
- Carbon black as a material and its potential usefulness for CCS applications
- Coating nanoparticles
- Future work
- Summary

Research Motivation

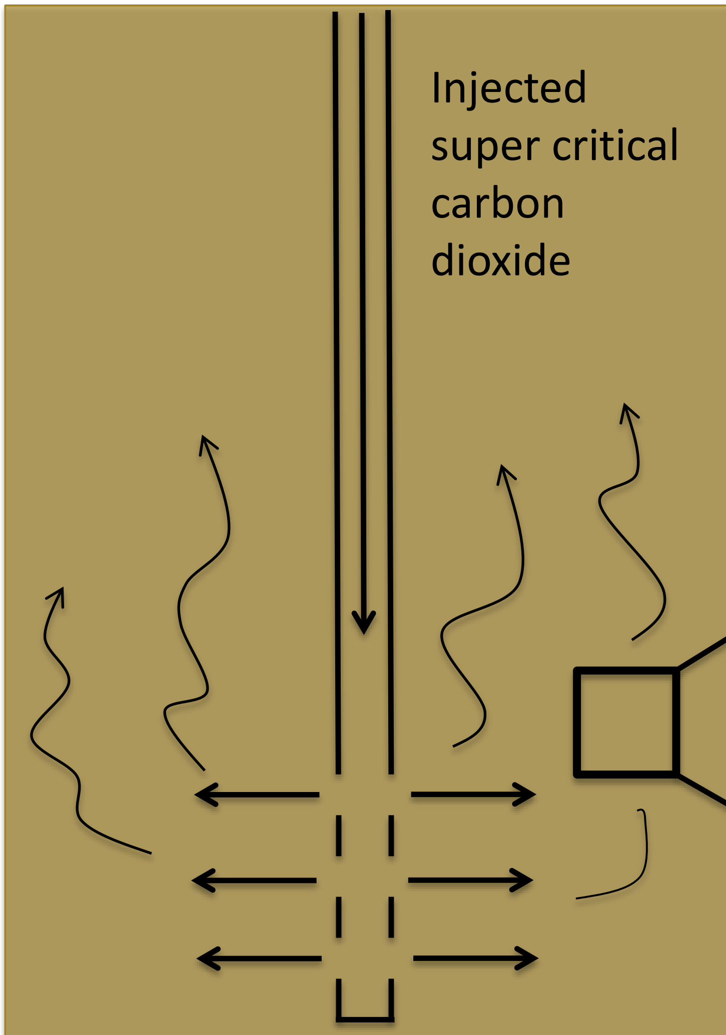
The Center for Frontiers of Subsurface Energy Security(CFSES) estimates:

1. ~35 gigatonnes CO_2/yr
2. 2 major commercial projects injection 0.001 Gt CO_2/yr
3. Storage of current CO_2 emissions would require thousands of wells
4. Currently there is enough reservoir capacity to handle CO_2 demand – but more research needed



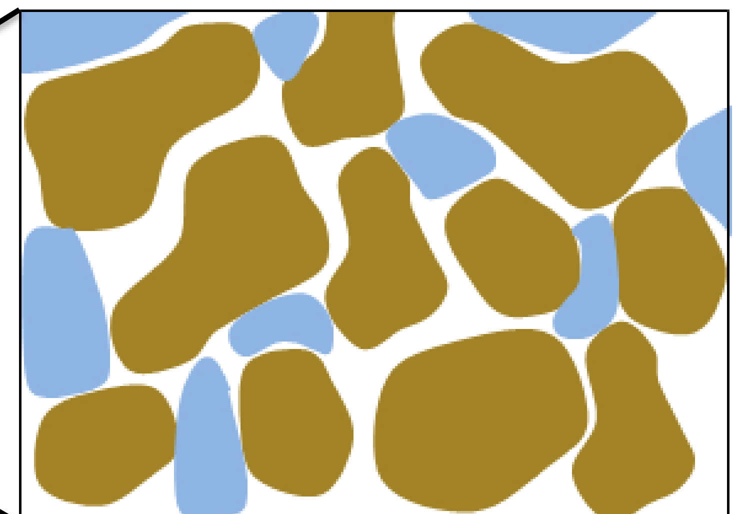
From Solomon et al., 2008

CCS Storage Mechanism



$$P_C = P_{CO_2} - P_{brine} = \frac{2\,\gamma_{bc}\cos\theta}{R}$$

The residually trapped carbon dioxide ranges considerably, and is estimated to be 10-90% of the total injected volume (Chaudhary et al., 2013)



Brown represents rock grains
Blue represents carbon dioxide

Carbon Black

- Compared to nanoparticles derived from other materials (e.g., silica, iron oxide, titanium dioxide, etc):
  - Carbon black contains a very high specific surface area (>1500 m^2/g)
  - High adsorption capacity
  - Exhibits adsorption/desorption hysteresis
  - Cheap, readily available, and easy to make

From goodyear.com

Nano-milling

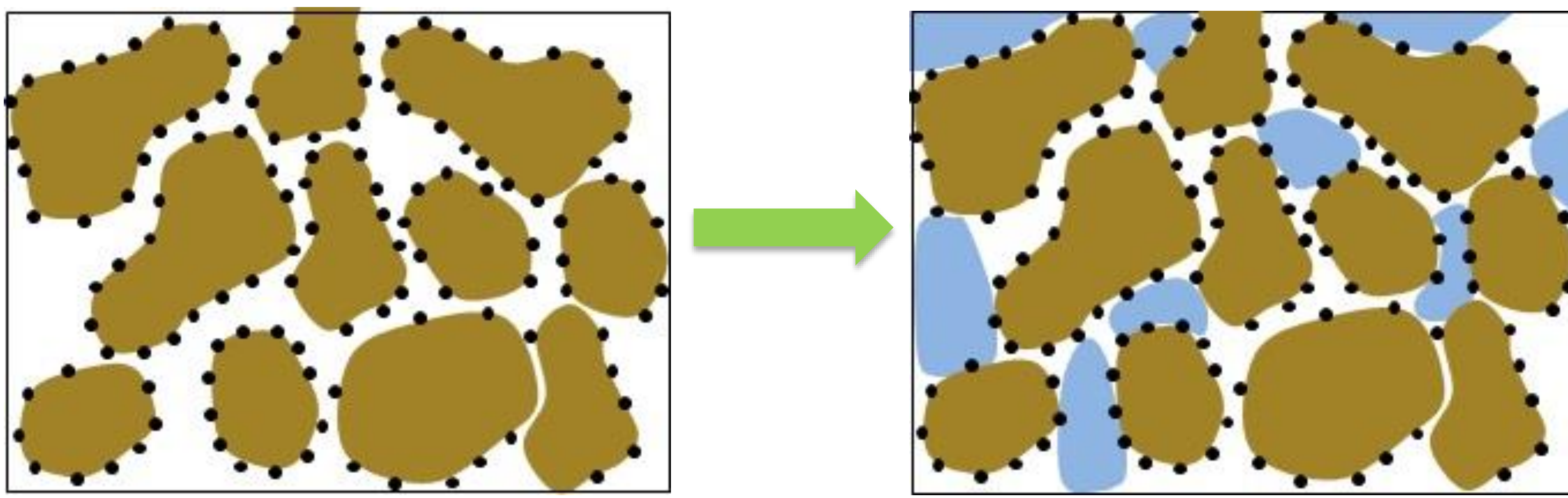
From: http://www.clarcorindustrialair.com/

From HP.com

Conceptual Idea for Improved CO_2 Storage

Step 1: Inject nanoparticle dispersion of CB loaded with known volume (V1) of CO_2 and allow for NPs to electrostatically bind to the grains of reservoir rock

Step 2: Inject pure carbon dioxide, similar to normal operations, and allow for free CO_2 to become residually trapped (V2)



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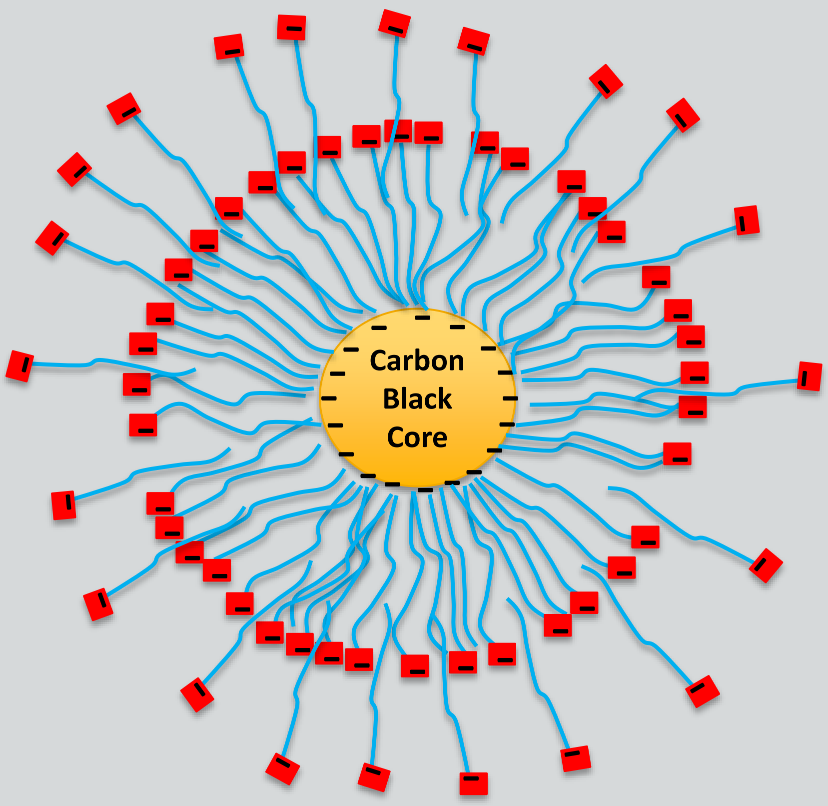
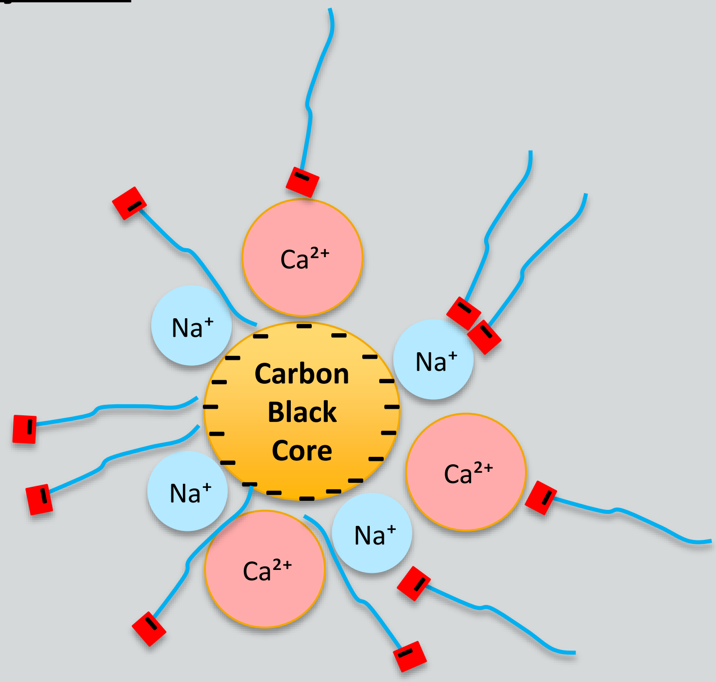
Nanoparticle Dispersion Stability

DI Water System with SDS Surfactant



DLS measurements recorded hydrodynamic diameter of ~200 - 350 nm w/ 100 ppm – 10,000 ppm SDS surfactant and from pH 6-9

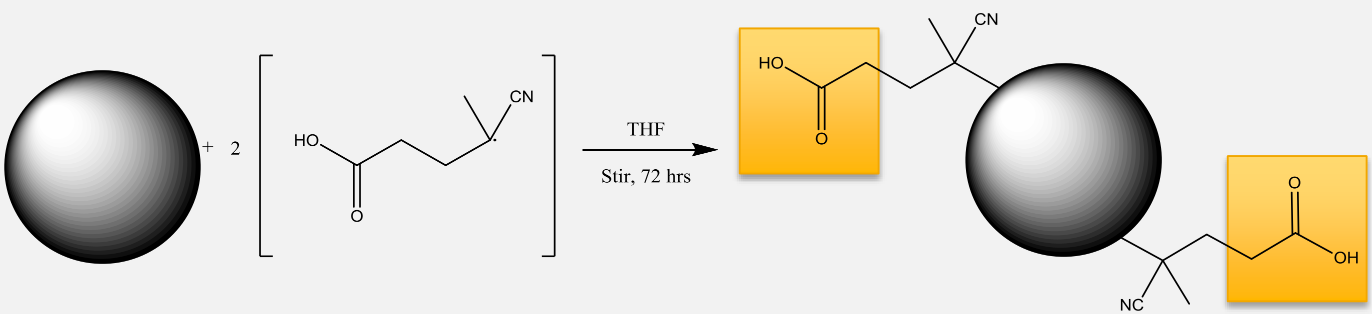
Brine System



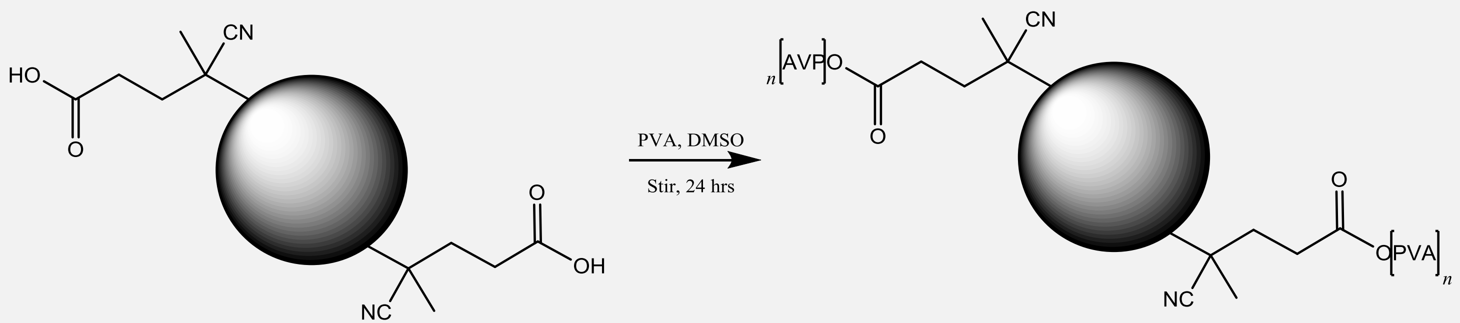
Ions, in particular Ca^{2+} and Na^{+} limit the desired properties of surfactants and allow for particle aggregation. Hydrodynamic diameter 1.5-2.5 um in 3.5 wt % brine

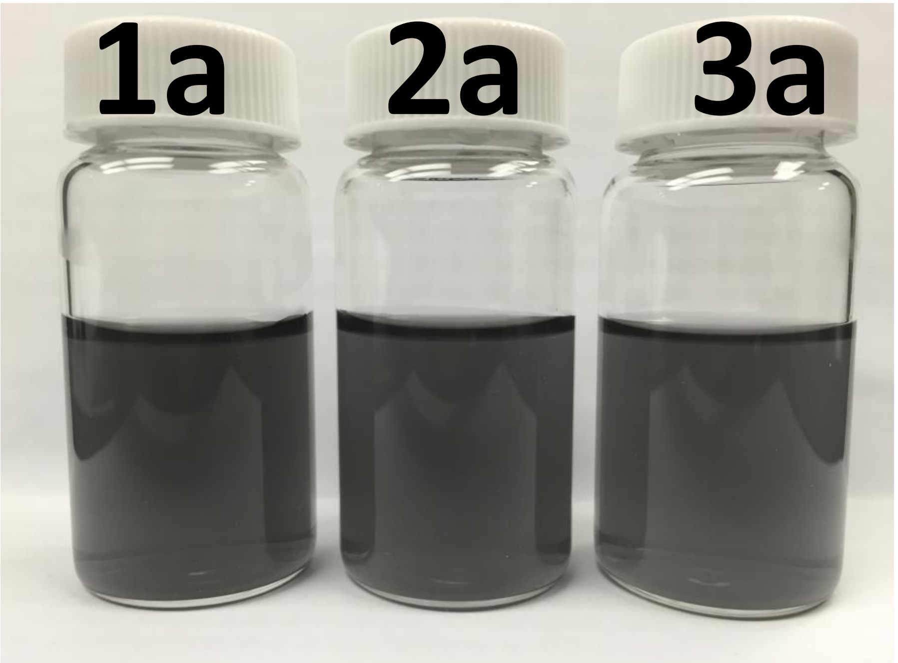
Coating of Carbon Black Nanoparticles

Step 1: Carboxylic Acid Functionalization



Step 2: PVA grafting





<u>Initial Condition</u> – dispersed NPs at t=0:

-Vial 1a: CB NPs in DI H_2O

-Vial 2a: (50k)PVA CB NPs in brine

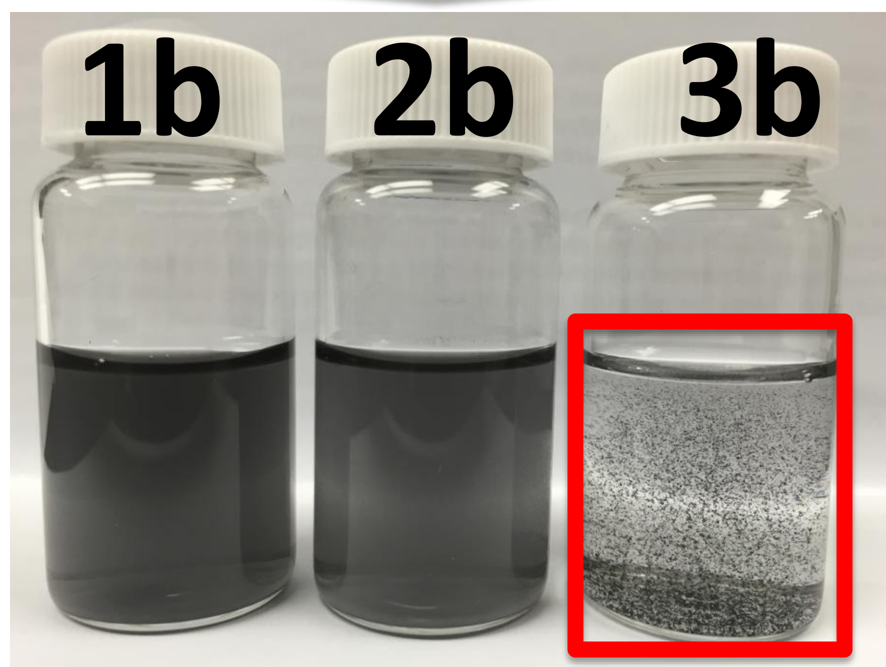
-Vial 3a: CB NPs in brine

<u>Final Condition</u> – NP dispersions after t = 24hrs:

-Vial 1b: CB NPs in DI H_2O

-Vial 2b: (50k)PVA CB NPs in brine

-Vial 3b: CB NPs in brine



Future Work

- Perform additional chemical reactions to induce slight ionic charge onto PVA chains in order to:
  - Improve dispersion stability, and
  - Enhance interaction and retention with silica rock grains
- Core flood experiments in Berea sandstone cores to investigate the transport properties of functionalized CB nanoparticles in porous media
- Contact angle and interfacial tension measurements in brine/supercritical carbon dioxide/silica systems

Summary

- Increase the total volume of sequestered carbon dioxide using a two step approach
- Increase the interfacial tension between brine/carbon dioxide
- Decrease the contact angle such that we maintain the original critical capillary pressure

Thank you, Questions?

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