Synthesis of the Polymer Encapsulated Porous Proppant for Bacteria Delivery

Kyu-Bum Han[1], Alexandre Stella[3], John Fuertez[2], John McLennan[2], and Taylor D. Sparks[1]

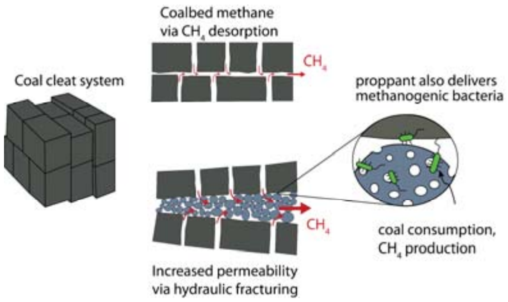
[1]Materials Science and Engineering, University of Utah, Salt Lake City, UT 84112 USA
[2]Chemical Engineering, University of Utah, Salt Lake City, UT 84112, USA
[3]Materials Engineering, Universidade Federal do ABC, Av. Dox Estados, 5001-Bangu, Santo Andre-SP, 09210-580, Brazil

Abstract

Many coal reservoirs are too deep to safely, economically, and environmentally extract. It has been proposed to convert these coal reservoirs into methane *in-situ* using methanogenic bacteria.

Electric power plants fueled by natural gas have many benefits. They emit 54% less greenhouse gas emissions, have very low levels of NO_x and SO_2 pollutants, have virtually no mercury, soot, or other solid particulates, and use 60% less water than coal fired plants

Our approach to this biogasification challenge has been to redesign proppant already critical for enhancing coal seam permeability. Methanogenic microbial consortia can be loaded into this specialized porous proppant and delivered directly to the coal seam.



Hypothesis

- Is it possible to redesign proppant to house methanogenic bacteria and thereby deliver it to unminable coal seams for biogasification?
- Can a polymer time-release coating be developed to protect microbes during delivery?
- Can specific microbial consortia be grown for targeted methane yield rates?

Research Objective

- Introduce bi-modal porosity into proppant to reduce the density while also providing housing for bacteria.
- Encapsulate the proppant with a two-part polymerization process that retains a dye molecule prior to testing with bacteria.
- Evaluate methane and carbon dioxide production for different microbial consortia, coal sources, growth conditions, and nutrients.

Materials and methods

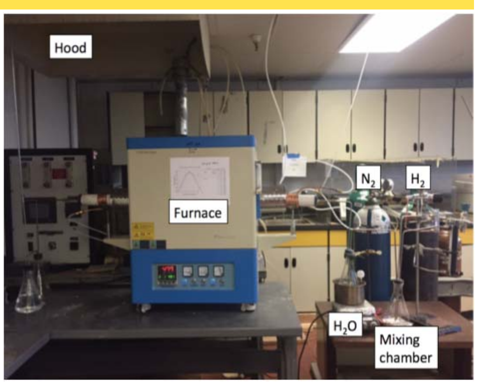


Figure 1. The high temperature furnace with reducing atmosphere to decrease partial pressure oxygen and selectively reduce species to generate porous microstructure.

Results and discussion

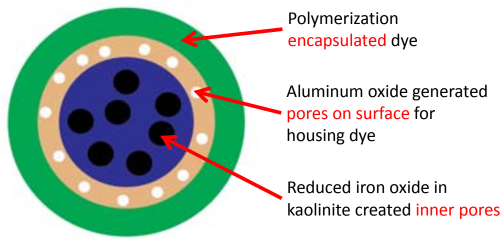


Figure 2. Diagram of the proposed redesigned and encapsulated porous proppant. The dark green (core) was consisted of kaolinite and Fe_2O_3 with the inner pores (black). The coating composed of Al_2O_3 (blue) creates surface pores (white), which house dye molecules. The light green is the polymer encapsulation, a mixture of sodium alginate and calcium lactate.

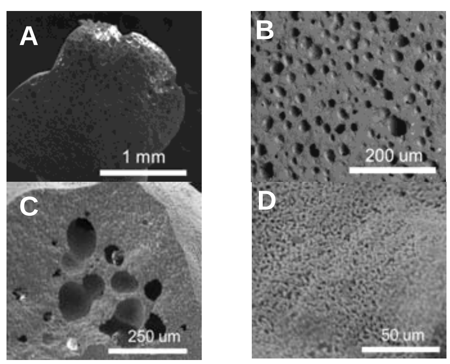


Figure 3. The scanning electron microscope images of porous proppant. The proppant without aluminum oxide coating (A 40x and B 150x) had the inner pores (24 μm +/- 12). The proppant with Al_2O_3 coating (C 180x and D 600x) had both pores inside of the particle and on surface (8 μm +/- 3).

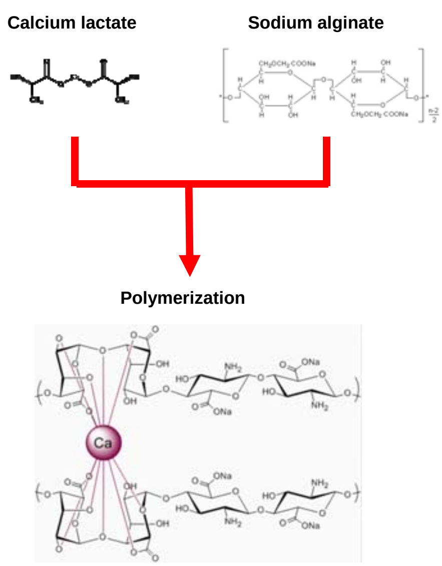


Figure 4. Diagram of lactate alginate polymerization reaction. Sodium alginate (0.5 wt.%) solution was added to calcium lactate (2.0 wt.%) solution by titration method. The polymer encapsulates proppant with a thin elastic exterior.

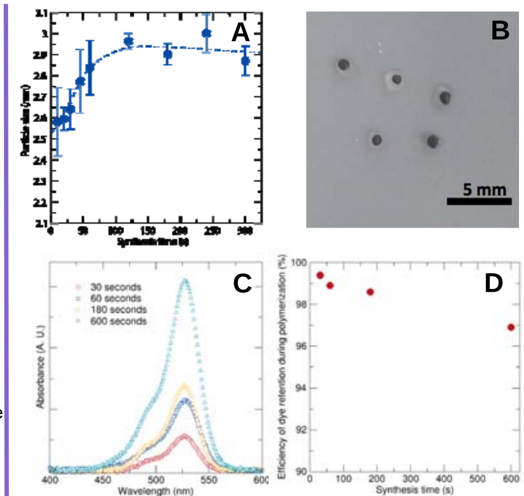


Figure 5. A) The particle size versus polymerization time. Particles increased from 2.6 mm to 2.9 mm and plateaued after 60 s synthesis time. B) The optical image of the encapsulated proppant generated via manual extrusion. Polymer thickness was 0.4 mm (+/- 0.1). C) The light absorption of dye molecule in the left over polymerization solution. The dye concentration steadily increased with synthesis time. D) The calculated dye retention efficiency during polymerization.

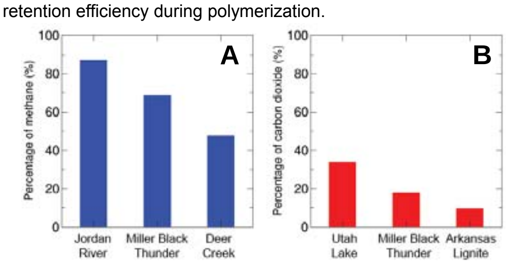


Figure 6. The measured A) methane and B) carbon dioxide produced at week 2 from the selected bacteria sources. The bacteria were collected from 9 places in the United States. A full design of experiment (not shown) has been performed to identify what microbial consortia, nutrient solution, and growth conditions provide highest methane yield of different coal sources.

Conclusion

- Proppant synthesized with bimodal pore distribution ideal for reducing density while also housing bacteria.
  - Inner pore size was 25 μm while surface pore size was 10 μm.
- Proppant was encapsulated with a polymer.
  - Over 96% retention of the dye during even the longest polymerization times.
- Different microbial consortia identified that can produce high methane yields for different coals, nutrients, growth conditions etc.

Future work

- Measure the strength and conductivity of the proppant
- Load/encapsulate the selected bacteria to the proppant
- Measure the release time of bacteria from the encapsulation

Acknowledgment

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