Development of Robust Particle Gels for CO_2 Flooding

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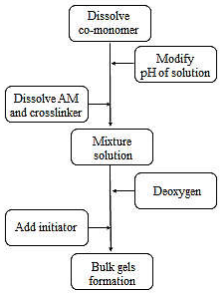
Objectives

1. Develop CO_2 resistant preformed particle gels.
2. Maintain excellent mechanical integrity under CO_2 conditions.

Introduction and background

As a significant carbon capture and storage (CCS) technology, carbon dioxide-enhanced oil recovery (CO_2-EOR) contributed to reducing 10-20 billion tons of Greenhouse Gas (GHG) emission in U.S. The rapid increase of CO_2-EOR projects indicated its enormous industrial value wherein 127 projects have been established across the country. However, the sweep efficiency of CO_2 is still limited owing to its unfavorable mobility and heterogeneity of oil reservoir. Gel treatment is a low-cost, high-efficiency, and widely applicable technology to remedy such conformance problems. In spite of the versatility, conventional gel system based on copolymers of polyacrylate (PAA) and polyacrylamide (PAM) turned out to be a deficient plugging agent for CO_2 flooding due to its syneresis in acidic conditions.

Experimental



Scheme 1. PPG preparation.

The preparation is similar to traditional PPG synthesis. However, special *monomers* and *additives* were employed to prepare CO_2 resistant PPGs

Results and discussion

1. Swelling behavior under CO_2 conditions

pH	CRG Swelling ratio	Commercial PPG Swelling ratio
pH-2	28	87.5
pH-3	20.5	158
pH-4	13. 5	220
pH-5	12.5	242.5
pH-6	11.5	248.5
pH-7	11	278

Table 1. Swelling ratio comparison under acidic conditions.

The swelling ratio of our lab-made PPG increased 2 times PPG under acidic conditions compared to the size in neutral conditions while the size of commercial 40K dramatically reduced to ~ 6% its original volume. Thus, our PPG showed CO_2 resistant behavior, which would benefit CO_2 flooding.

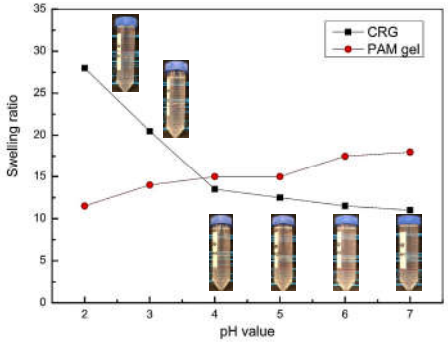


Figure 1. Swelling ratio at different pHs.

As indicated in **Figure 1**, our PPG had higher swelling ratio under acidic conditions while having lower particle size at pH of 7. The lower swelling ratio would facilitate the particle gel injectivity. The increase of the particle gel is due to electrostatic repulsion between cationic moieties after protonation of tertiary amines within the hydrogels.

2. Temperature effect on swelling ratio

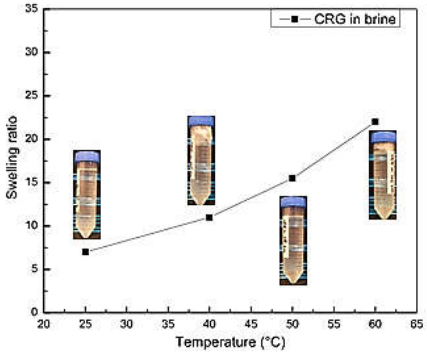


Figure 2. Swelling ratio as a function of temperature.

The swelling ratio increased with temperature as shown in **Figure 2**. This temperature responsive behavior would increase the plugging efficiency of the gels under reservoirs.

3. Mechanical strength under CO_2 conditions

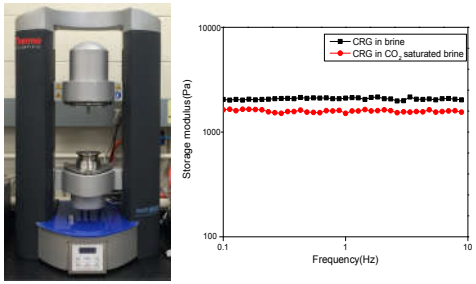


Figure 3. Mechanical strength of our PPG.

Mechanical strength was evaluated via HAAKE MARSIII Rheometer. As shown in **Figure 3**, our PPG had excellent mechanical strength under CO_2 saturated brine, similar to the gel in brine. In comparison with commercial 40K of 440 Pa, our PPG had approximately 3 times of elastic modulus of 1200 Pa.

4. PPG swelling ratio in brine

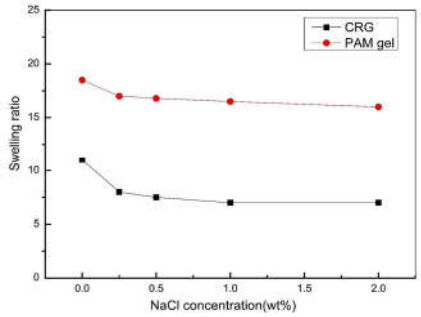


Figure 4. Swelling behavior in brine.

Our PPGs have better salt resistance compared to poly(acrylamide) gels. The size of our PPG remained constant in aqueous NaCl solution with different concentration.

5. Morphology study using SEM

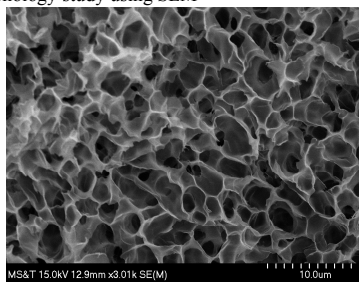


Figure 5. PPG microstructure as imaged by SEM.

The PPG showed well-defined porous microstructures as observed from SEM in the range of micrometer size.

Conclusions

1. We have prepared CO_2 resistant PPG. The particle size would increase under acidic condition.
2. The gel has better mechanical strength compared to commercial gel 40K.

Acknowledgement

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