PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Sequestration

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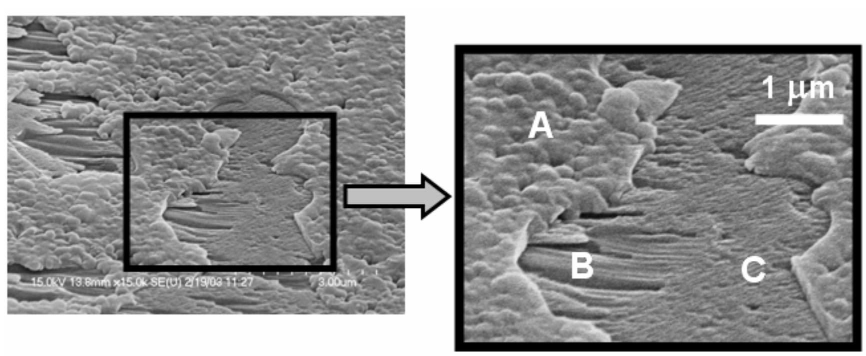
A NOVEL APPROACH TO MINERAL CARBONATION: ENHANCING CARBONATION WHILE AVOIDING MINERAL PRETREATMENT PROCESS COST

Background

If the environmental problems associated with CO_2 emissions can be overcome, known fossil fuel reserves, especially coal, can support global energy demands for many years. One option is to sequester CO_2 emissions. However, many CO_2 sequestration candidate technologies that propose long-term storage need to be carefully monitored to ensure that the sequestered CO_2 does not leak into the atmosphere. Unlike these processes, mineral sequestration provides permanent disposal by forming geologically stable mineral carbonates. Carbonation of the widely occurring minerals of the olivine group, such as forsterite (Mg_2SiO_4), is a potential large-scale sequestration process that converts CO_2 into the environmentally benign mineral magnesite ($MgCO_3$). Because the process is exothermic, it inherently offers low cost potential. Enhancing carbonation reactivity is the key to economic viability.

Recent studies at the U.S. DOE Albany Research Center (ARC) have established that aqueous-solution carbonation using supercritical CO_2 is a promising process; even without olivine activation, 30-50% carbonation has been achieved in an hour. Mechanical activation by attrition accelerated the carbonation process to an industrial timescale (near completion in less than an hour) at reduced pressure and temperature. However, the activation cost is too high to be economical and lower cost pretreatment options are needed. The Arizona State University Center for Solid State Science proposes a novel approach that offers the potential to dramatically enhance carbonation reactivity while bypassing any pretreatment/activation.



Scanning electron micrograph showing silica-rich passivating layer exfoliation. A) the passivating layer; B) a recently fractured and exfoliated region exposing part of the olivine particle core; C) a new passivating layer beginning to grow in the exfoliated region.

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COST

Total Project Value
$558,663

DOE/Non-DOE Share
$430,482/$128,181

Recent mechanistic investigations have shown that robust silica-rich layers form on an olivine surface during carbonation. As carbonation proceeds, these passivating layers thicken, fracture, and eventually exfoliate, exposing fresh olivine surfaces. Particle-particle and particle-wall collisions within the slurry stream can dramatically impact both the exfoliation rate and the extent of carbonation. Order of magnitude increases in the extent of carbonation have been observed for different flow systems. In order to identify key parameters that can enhance carbonation, it is proposed to explore exfoliation mechanisms and their relationship to enhanced carbonation using three innovative approaches:

- Multiphase fluid modeling and experimental investigations to elucidate key fluid-flow parameters that facilitate the slurry interactions that enhance exfoliation.
- Chemical studies to establish the potential for controlling passivating layer effectiveness and exfoliation rate by adjusting aqueous cation size (e.g., Li^+, Na^+, K^+).
- Sonic investigations to elucidate the potential that controlled sonication offers to enhance exfoliation and particle cracking.

Once the key parameters for each approach are identified, they will be integrated to evaluate their combined potential to synergistically enhance exfoliation and carbonation. The above studies will be complemented by detailed morphological, structural, and compositional investigations of their intermediate and final reaction products down to the nanoscale. These studies will be further integrated with advanced computational modeling of key phenomena to develop an atomic-level understanding of the mechanisms that govern carbonation reactivity and exfoliation.

Primary Project Goal

The primary goal is to develop the understanding needed to engineer a new low-cost mineral carbonation process that avoids the cost of pretreatment/activation.

Objectives

The objectives of this project are to:

- Explore novel low-cost approaches with the potential to facilitate olivine passivating layer exfoliation to enhance olivine carbonation.
- Investigate the impact these approaches have on exfoliation and carbonation mechanisms.

Benefits

Mineral sequestration processes have the potential to permanently dispose of CO_2 in geologically stable mineral carbonate rocks that will not require continuous monitoring, which is required with many other CO_2 sequestration technologies. The technology to be developed under this proposal will hasten the natural mechanism of turning CO_2 into a solid. The solidification process could be accomplished in less than an hour rather than in hundreds of thousands of years via natural mineral weathering. Having an effective, economic method for permanently sequestering CO_2 would allow continued use of our abundant coal reserves.