Carbon Dioxide Dissolution in Saline Pore Fluids

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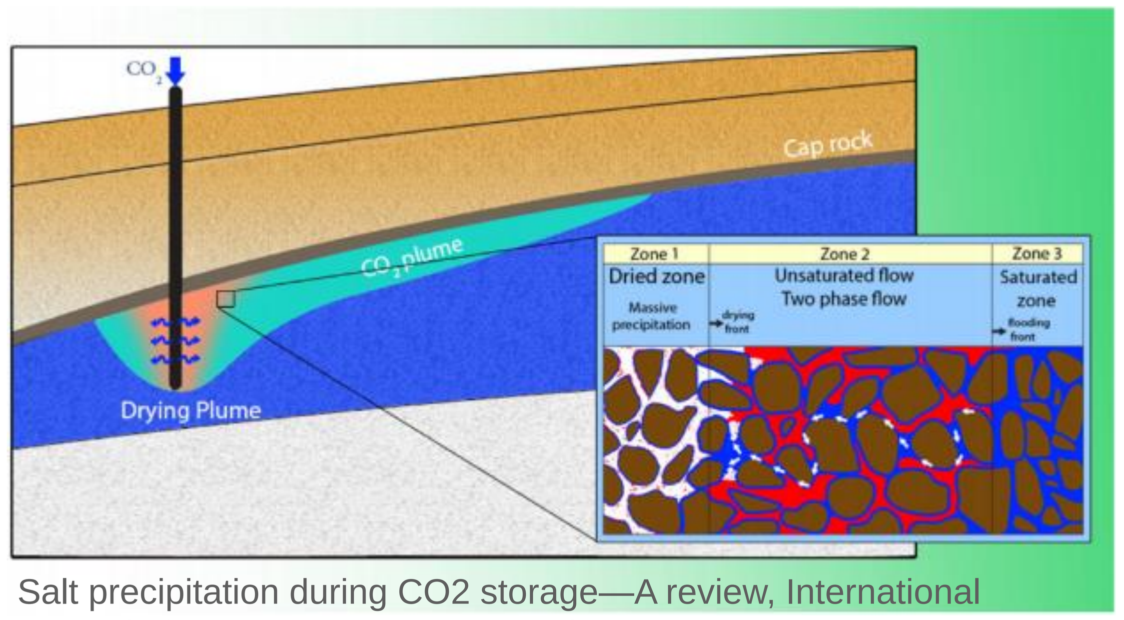
BACKGROUND

Carbon dioxide (CO2) sequestration and storage (CCS) in saline aquifers and CO2-enhanced oil recovery (EOR) are promising technologies to mitigate CO2 in the atmosphere while potentially generating economic benefit. In CCS process, several essential fluid dynamic problems affect the long-time safety of carbon storage, including CO2 gravity current, dissolution, convective transport, and chemical reactions interacting with pore-fluid and porous rocks. Recently, CCS and CO2-EOR have attracted much research effort, primarily using numerical simulations. To fill important gaps in the literature, this project focuses on pore-scale measurements and observations of supercritical CO2 dissolution, transport, and interactions with pore-fluid at high pressure (P > 50MPa), temperature (T > 70℃), and salinity.

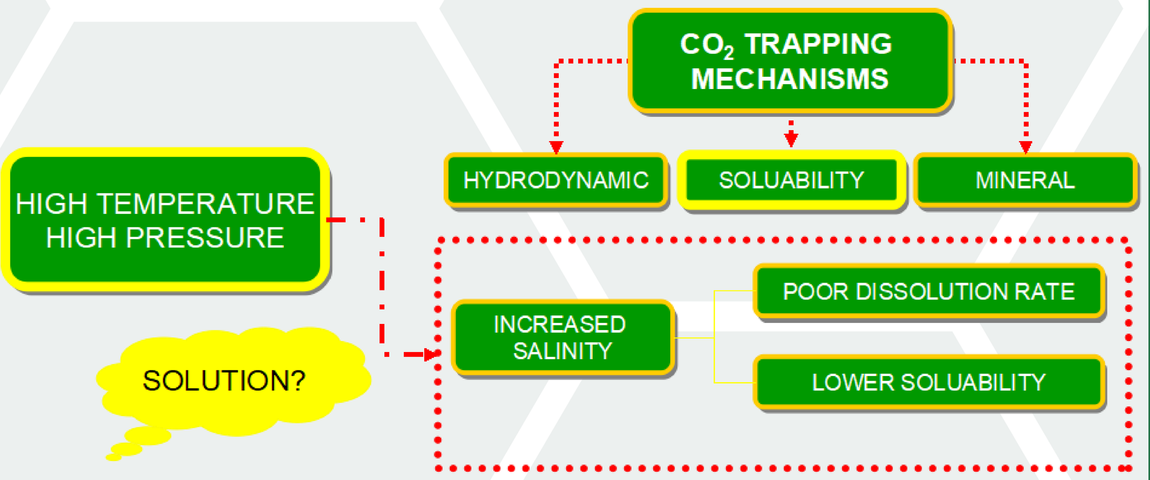
To this end, this project exploits robust microfluidics, as "Geological/Physical/Chemical/Mechanical Lab on a Chip", which enables clear and high-resolution measurements of CO2 transport and interactions with pore-fluid and rocks to provide a better understanding and crucial data for accurate numerical modeling.



Salt precipitation during CO2 storage—A review, International Journal of Greenhouse Gas Control, 2016, R. MIri and H. Hellevang

SHORT-TERM OBJECTIVES

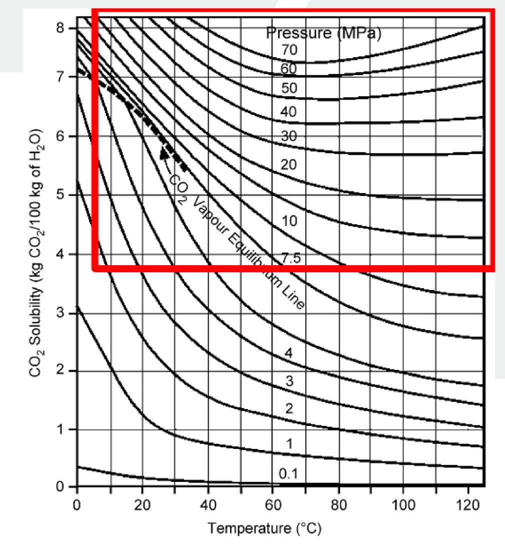
- Micro-fabrication of chips integrated with the flow visualization of carbon dioxide in porous media.
- Designing and manufacturing chips sustaining high temperature, pressure, and salinity concentration.
- Capability to generate specific size of super-critical carbon dioxide droplet into the system.
- Measurements of carbon dioxide dissolution rate in brine (and oil) under conventional and reservoir operating conditions.



PROJECT OVERVIEW

Scientific/Technological Challenges

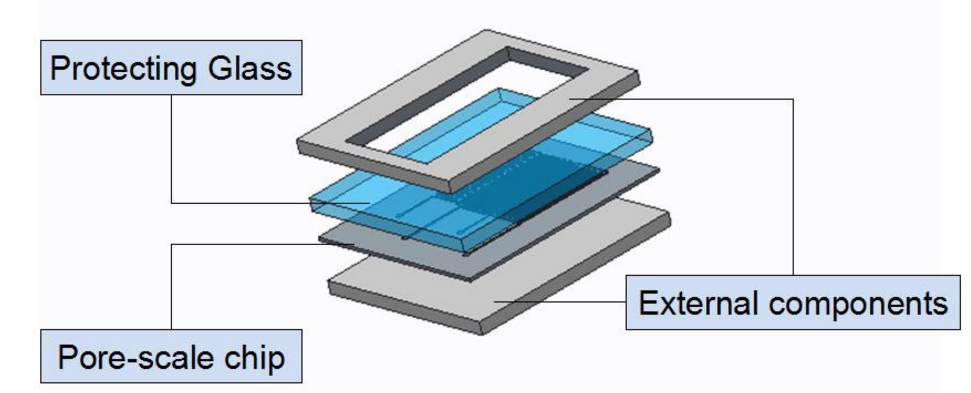
- Supercritical CO2 in deep saline aquifers (~2000 m subsurface, at high T, P, and salinity)
- CO2 Dissolution rate as a function of high T, P, and salinity
- Pore-scale observations of real-time CO2 dissolution, transport, and chemical reactions
- Better understanding of CO2 dissolution transport and trapping mechanism in brine

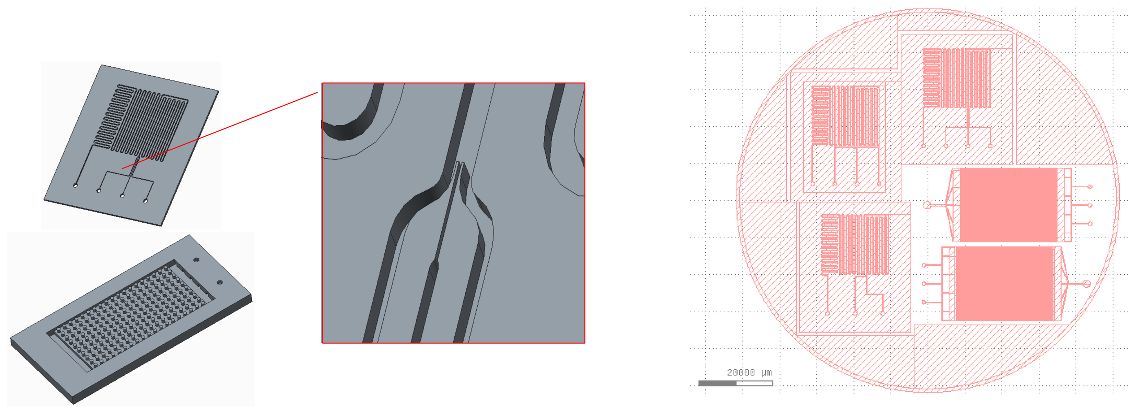


Methodology

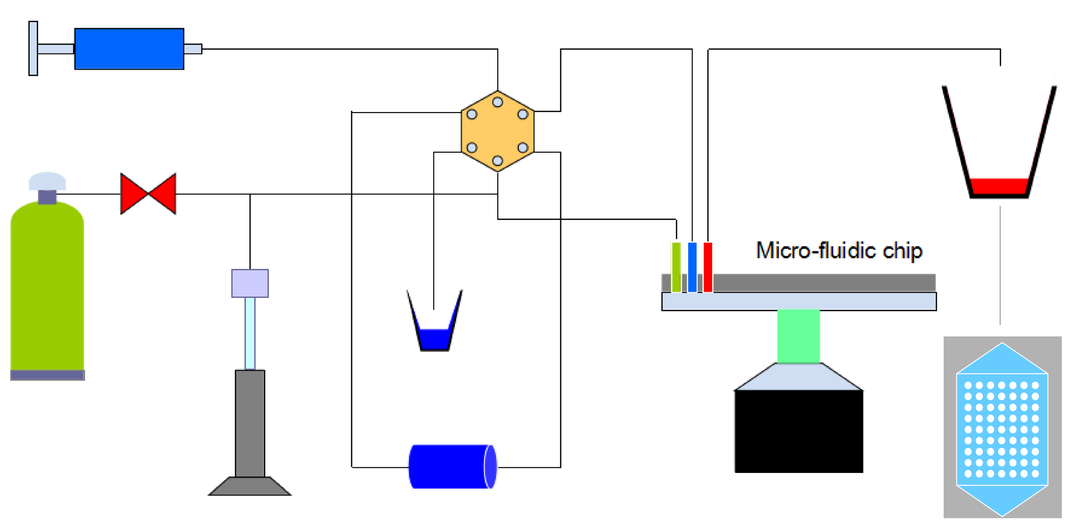
- Utilizing microfluidics
- Generating supercritical (SC) CO2 droplets using microfluidic generation techniques.
- High-speed imaging integrated with microscope observations.
- Observing SC-CO2 droplets chasing size with time as a function of salinity concentration.
- Microfluidic chips integrated temperature (T) control unit to actively control T.
- By raising the pressure and temperature up to above 50MPa and 70℃ to see if it will improve the solubility in higher salinity brine.
- Pump the SC-CO2 and CO2 dissolved brine into micro-fluidic with pore-structures to obtain a comprehensive understanding of salt precipitation.

Micro-fluidics





Experiment Set-up



References:

1. Robert M. Enick and Scott M. Klara, "CO2 Solubility in Water and Brine under Reservoir Conditions," Journal of Chemical Engineering Communications (1990)
2. S. Marre et al., Design and Packaging of Microreactors for High Pressure and High Temperature_American Chemical Society (2010)

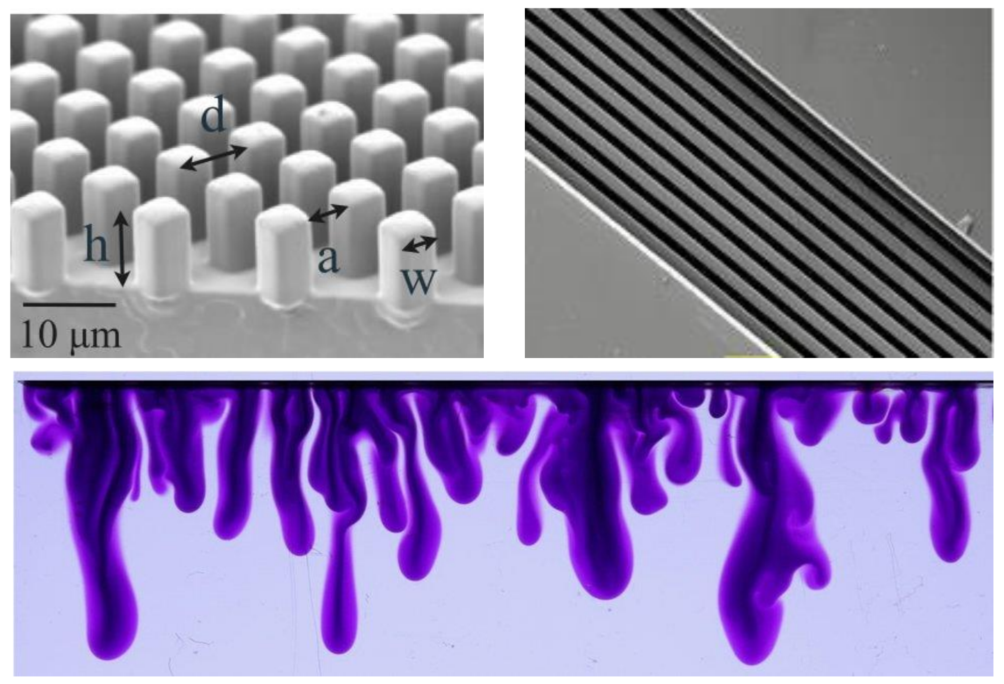
THEME OVERVIEW

Carbon Capture, Utilization & Storage

Hydrocarbons will continue to serve as an essential energy source while the world transitions to a lower-carbon energy economy, but can we prevent the use of those fuels from contributing to the accumulation of CO2 in the atmosphere? Existing technologies can capture carbon, but these methods can be costly and energy-intensive. Extracting energy without burning fuels, improving CO2 capture efficiencies if they are burned, and finding effective ways to store or reuse captured carbon may be essential to ensuring it does not enter the atmosphere.

EXPECTED OUTCOMES

- Microfabrication of micro-droplet generator of mono-disperse droplets.
- Microfabrication of high pressure and high temperature resistant microfluidics and external enforcement components.
- Microfluidics that closely simulates the environmental condition around 2000 meter deep underground.
- Comprehensive understanding of carbon dioxide solubility in brine under high temperature and high pressure conditions.
- Supercritical CO2 dissolution rates as a function of salinity.
- Real-time monitoring the dynamic behaviour of carbon dioxide with oil using micro-fluidics with different pore-structures.
- Observations and understanding of salt precipitation of SC-CO2 in saline at pore-scales.



References: P. A. Tsai et al., Physical Review Letts. (2010); PNAS (2014); Phys. Rev. Fluids. (2017)

EXTERNAL PARTNERS

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CANADA FIRST RESEARCH EXCELLENCE FUND

NSERC CRSNG — People. Discovery. Innovation.

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