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Membrane Optimization for Electrochemical CO_2 Storage

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Rock weathering is a process that stores CO_2

Natural rock weathering has the potential to store 10^6 gigatons of CO_2,[1–3] but the slow reaction kinetics lead to only 0.13 gigatons of CO_2 stored by natural weathering per year.[1]

Electrochemical “Rock Reactors” can accelerate CO_2 storage

An electrochemical “Rock Reactor” is capable of CO_2 mineralization at rates 2-3 orders of magnitude faster than natural rock weathering.[4] An example 3-chamber Rock Reactor configuration is shown in Fig. 1, where a chemical chamber is sandwiched between the anode and cathode. A bipolar membrane (BPM) is used to supply H^+ into the chemical chamber containing silicate minerals, reacting to form metal cations and SiO_2. The liberated cations then migrate through a cation exchange membrane (CEM) into the cathode chamber, where they react with OH^-, produced by hydrogen evolution reaction, and an external supply of CO_2 to form metal carbonates.

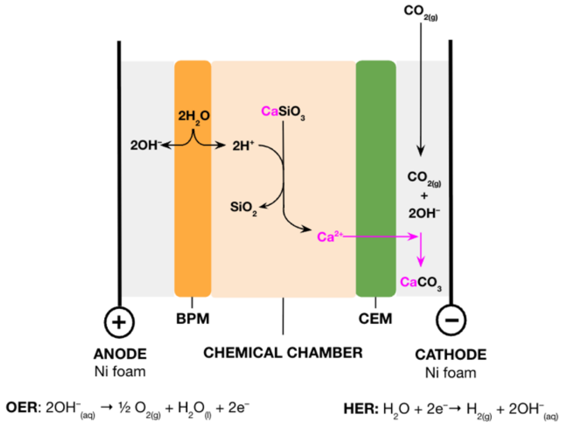

Fig. 1: Example Rock Reactor schematic.

The cation exchange membrane (CEM) limits CO_2 storage rates

Commercial CEMs are designed to efficiently transport monovalent cations with low ohmic resistance. CEM modifications are required to target divalent cation selective transport and increase membrane conductivity. We propose using automation and machine learning to accelerate membrane optimization.

Semi-automated Bayesian optimization of Rock Reactor CEMs

We propose using multi-objective Bayesian optimization and a semi-automated workflow to identify Pareto-optimal membranes with high conductivity and permselectivity (Fig. 2). Explored parameters could include membrane curing time and temperature, ratio of backbone polymer to size chain polymer, and fixed charge identity (i.e., $-SO_3^-$, $-COO^-$, or PO_3^{2-}).

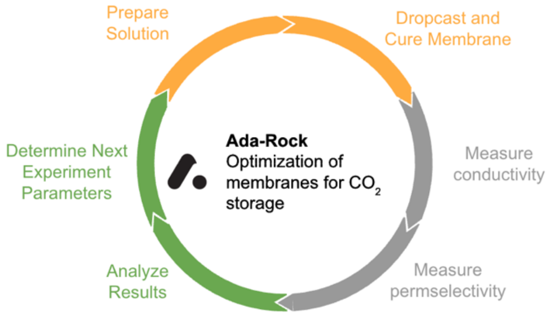

Fig 2: Workflow outline for membrane fabrication and characterization.

We intend to leverage flexible automation and our self-driving lab “Ada” to accelerate fabrication. For example, previously developed modules could be leveraged to automate precursor mixing[5], membrane deposition[5,7], and membrane curing[6,7].

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