Electric Field Swing Adsorption for Carbon Capture Applications

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Concept Summary

- Electric field swing adsorption (EFSA) involves using DC electric bias to modify adsorption of CO_2 on electrically conducting high-surface area carbon (HSAC)
- Sorbent can be switched "in-place" between adsorption and desorption modes by switching electric bias on and off

Specific Approach: Electric Field Driven Ion Sweeping (EFDIS)

- EFDIS uses mobile ions to reversibly change interaction of CO_2 molecules with sorbent
- HSAC material combined with liquid or solid electrolyte to form electric double layer capacitor with 5-25 F/g capacitance
- In discharged (field off) state, HSAC nanopores yield high adsorptivity for CO_2 (~40 std. cm^3/g at room temp.)
- In charged (field on) state, ions move from electrolyte into nanopores to form electric double layer
- Two effects possible in principle:
  - ions displace CO_2 from pores (sweeping)
  - electrostatic ion-molecule interaction with surface ions increases adsorption (enhancement)
- Direction of effect may depend on electrode character (anode vs. cathode)
- Both effects observed experimentally in preliminary results (see below)

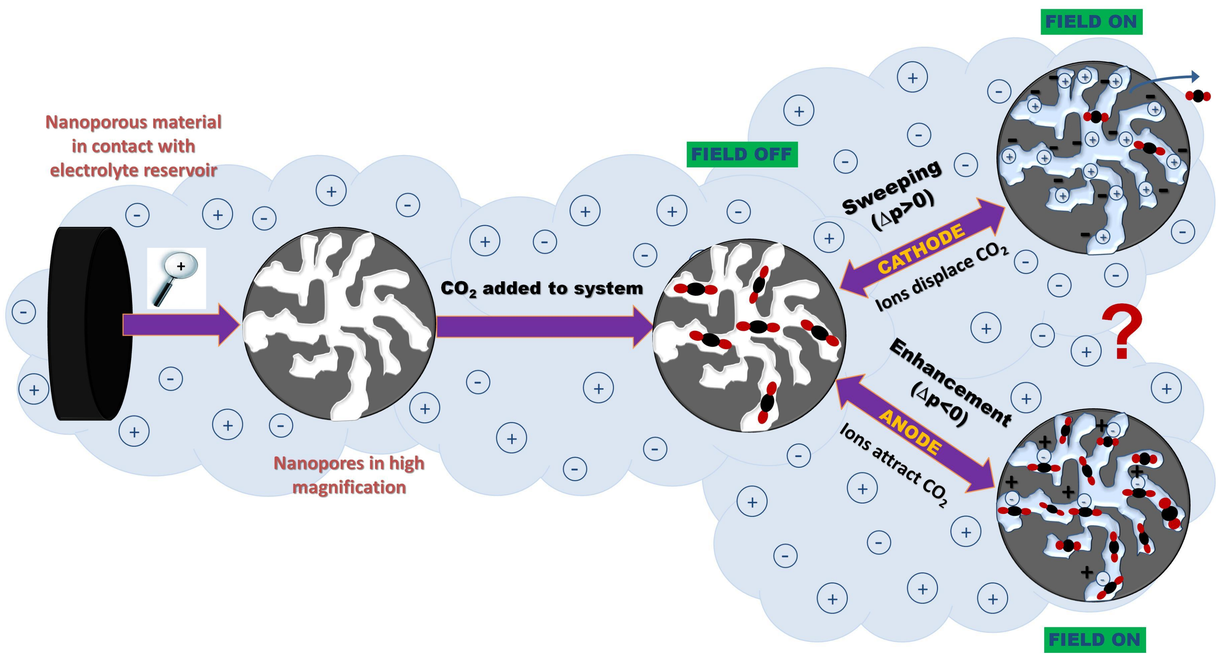
Experimental Characterization: Static pressure method

- Electrodes w/electrolyte sealed in pressure cell filled w/~1 atm. gas for several hours
- Electrical potential (1.0 V) switched on/off with 20-60 min duty cycle
- Changes in amount of adsorbed gas reflected as pressure changes(per ideal gas equation)
- Comparison between pressure data with CO_2 vs. non-adsorbing gas (helium) isolate effects due specifically to adsorption changes

$$\Delta P = \Delta n\,(RT/V)$$

Key Transformational Advantages

- **Simple:** EFSA enables gas separation and capture using electric fields to change thermodynamics of adsorption
- **Reversible:** Switching between ad-/desorption achieved by reversing field →removes need to transport or heat sorbent materials
- **Efficient:** Electrical current used during charging is partially regenerated in discharging → well-suited for low-parasitic load CO_2 capture technology



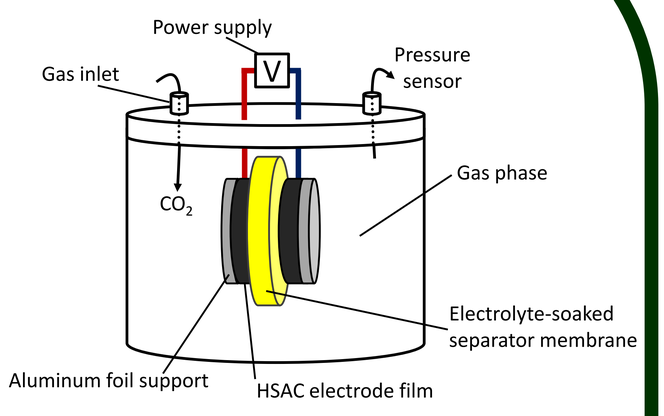
Principal Technical Targets

- **Magnitude:** Generate sufficient change in adsorbed CO_2 between charged and uncharged states for utility in carbon capture (> 20%)
- **Selectivity:** Field-induced effect for CO_2 must dominate of that for N_2/H_2O
- **Scalability:** Technology must be suitable for large-scale application

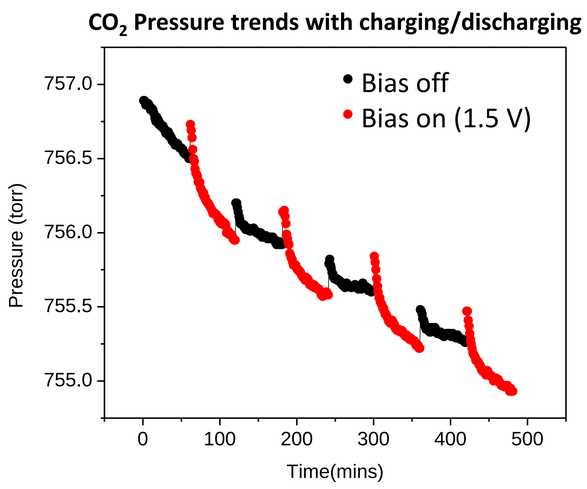
Ionic Liquid Electrolyte Implementation

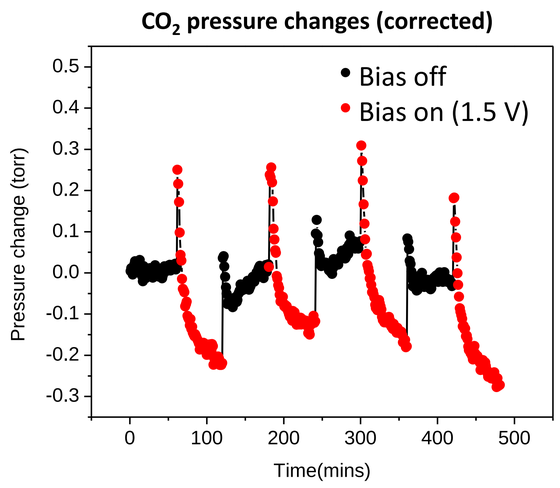
Experimental Details

- 0.106g HSAC film electrode w/separator in coil configuration
- Electrodes & separator soaked w/non-volatile ionic liquid (EMIM FAP)
- Gas volume 118mL
- Capacitance ~25 F/g
- Electrical bias 1.5 V

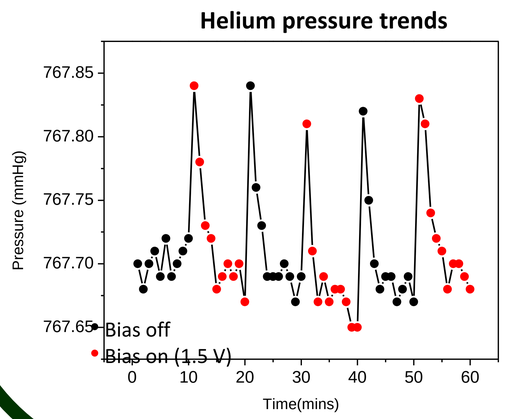


Results





- clear, repeatable changes in CO_2 pressure between charged and discharged states
- spikes immediately following bias changes attributed to temperature jumps due to resistive heating
- control experiment w/helium shows only thermal features



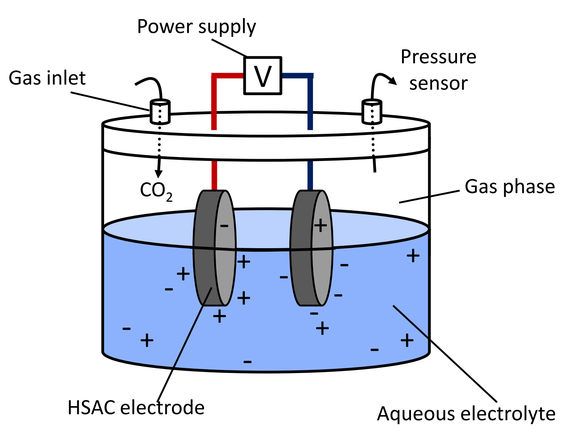
Conclusions & Future directions

- Field-induced enhancement of CO_2 adsorption by 1.0-1.2% vs. uncharged state
- Calculation does not account for pores blocked by electrolyte → true value may be significantly larger
- Future efforts include:
  - Improving gas access to micropores
  - Optimizing electrolyte (different ionic liquids, small ion dopants)

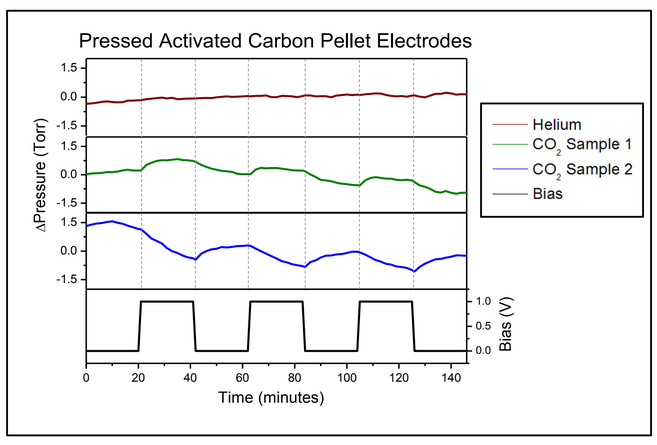
Aqueous Electrolyte Implementation

Experimental Details

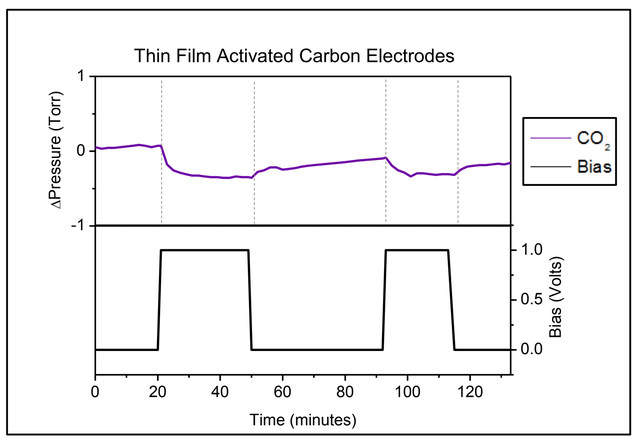
- Water-compatible electrode material (BPL carbon w/13% pVDF binder)
- Thin film (50-100 mg) & pressed pellet (120-200 mg) electrodes investigated
- Electrodes immersed half-way in salt-water electrolyte (1 M NaCl)
- Gas volume 60 mL
- Capacitance ~6-9 F/g
- Electrical bias 1.0V



Results



- CO_2 pressure responds to changes in voltage, while helium does not
- Experiments with different pairs of pellets show opposite trends (sweeping vs. enhancement)
- Experiment with thin film shows only enhancement
- Possible competitive effects between anode & cathode (?)



Conclusions & Future directions

- Field-induced changes in CO_2 adsorption of =/- 0.9-1.1%
- Calculation does not account for pores blocked by electrolyte
- Future efforts include:
  - Improving gas access to micropores
  - Varying salt concentration and immersion depth
  - Using electrolyte-soaked separator as in ionic liquid case
  - Test anode/cathode separately to assess possible competitive effects