Resin Wafer-Electrodeionization for Flue Gas Carbon Dioxide Capture

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Lead Recipient:	Nalco Company
Project Title:	Energy Efficient Capture of CO_2 from Coal Flue Gas
Nalco Principal Investigator:	Jitendra T. Shah
Argonne Principal Investigator:	Yupo J. Lin

Presented by Jitendra T. Shah and Wayne M. Carlson

A new strategy for CO_2 capture: CO_2_RW-EDI

Strategy:

- Addresses CO_2 absorption & release
  - Resin Wafer-Electrodeionization designed and developed to capture and release CO_2 (CO_2_RW-EDI)
  - Kinetics enhanced with carbonic anhydrase enzyme
- Employs electrochemical pH control
  - pH shifts capture and release CO_2 in separate cells
  - Water splitting enables in-situ pH control for optimum activity
  - Eliminates the need for acids and bases
- Decreases parasitic energy load
  - Avoids temperature and/or pressure swings for regeneration
  - Avoids the use of steam and vacuum

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Project goals will significantly advance CO_2 capture technology

Project Goals

- Develop Resin Wafer-Electrodeionization technology for CO_2 capture
- Target 90% CO_2 capture and released CO_2 with 90% purity
- Establish a prototype demonstration of a pilot system that captures CO_2 at an effective rate of 1 tonne/day, Technology Readiness Level 6 (TRL-6)

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Project benefits for the environment & consumers

- Energy-efficient CO_2 capture to mitigate climate change
- Minimize the impact on cost of electricity (by as much as 50% to keep coal-fired power production affordable)
- Easily retrofitted to existing industrial facilities and compatible with carbon storage technologies
- Make clean CO_2 available for beneficial uses such as algal biofuels, renewable plastics, etc.
- Develop advanced manufacturing capabilities in the U.S.

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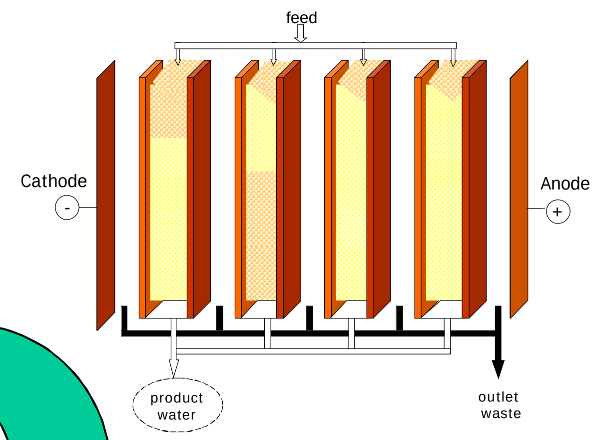
What is RW-EDI?

RW-EDI is based on a progression of water purification technologies



- Ion Exchange (IX)
- Electrodialysis (ED)
- Electrodeionization (EDI)

Resin-Wafer Electrodeionization (RW-EDI)

- Liquid Systems
- Gas/Liquid Systems

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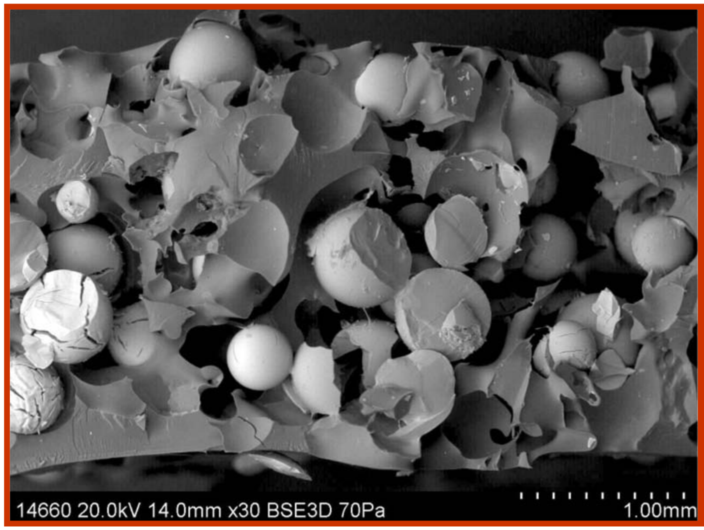
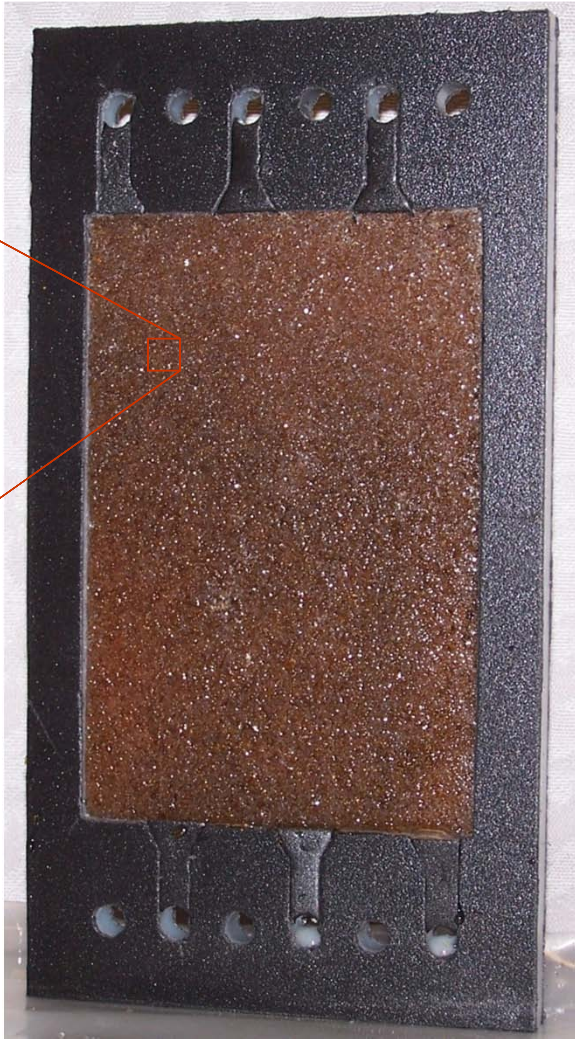
Single RW-EDI cell



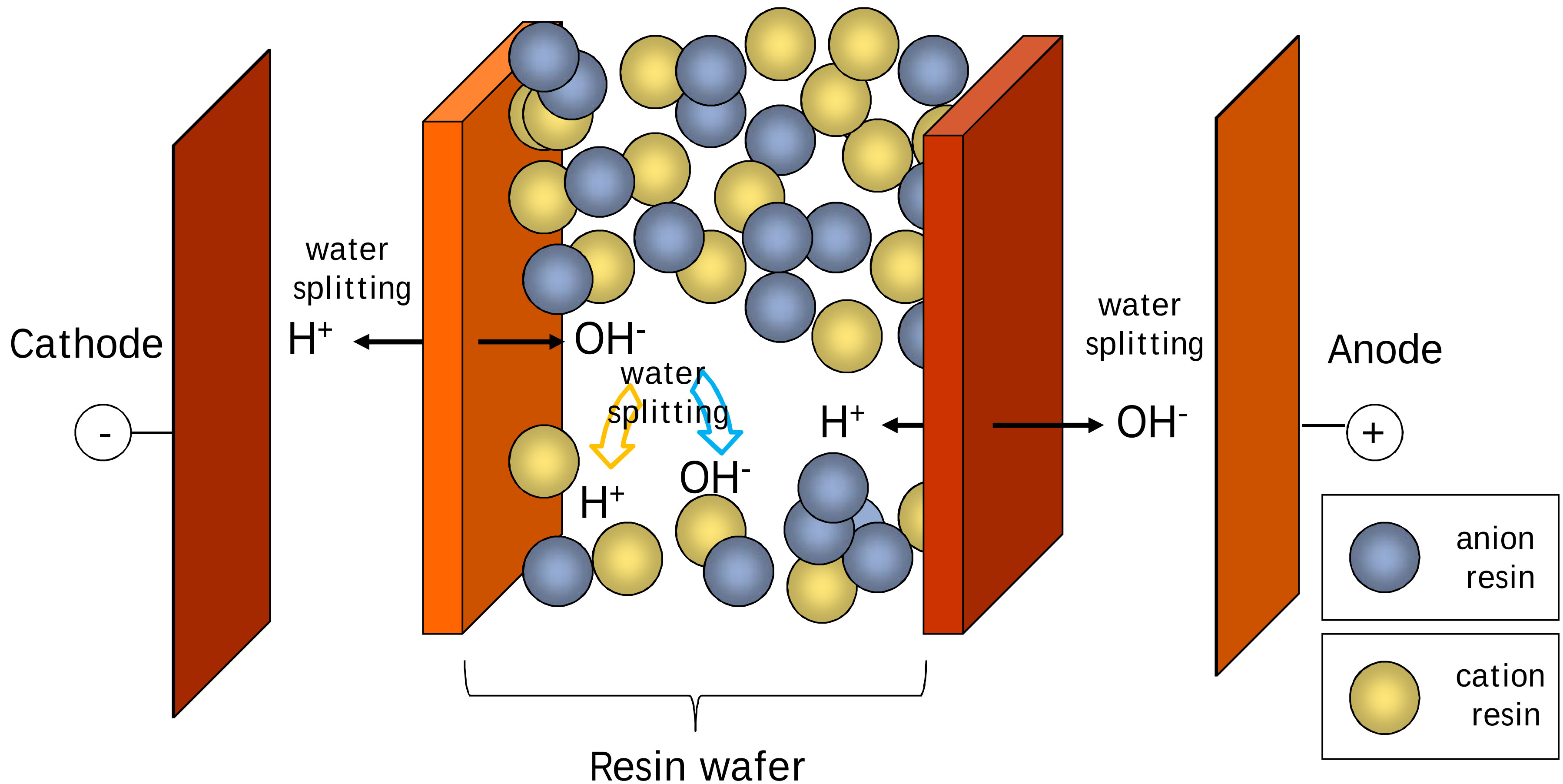
Scanning electron microscope image of an ion-exchange resin wafer



Resin wafer held within a gasket

Close-up view of a single RW-EDI cell

Water splitting provides ions that continuously regenerate the ion-exchange resin and enables electrochemical solution pH control

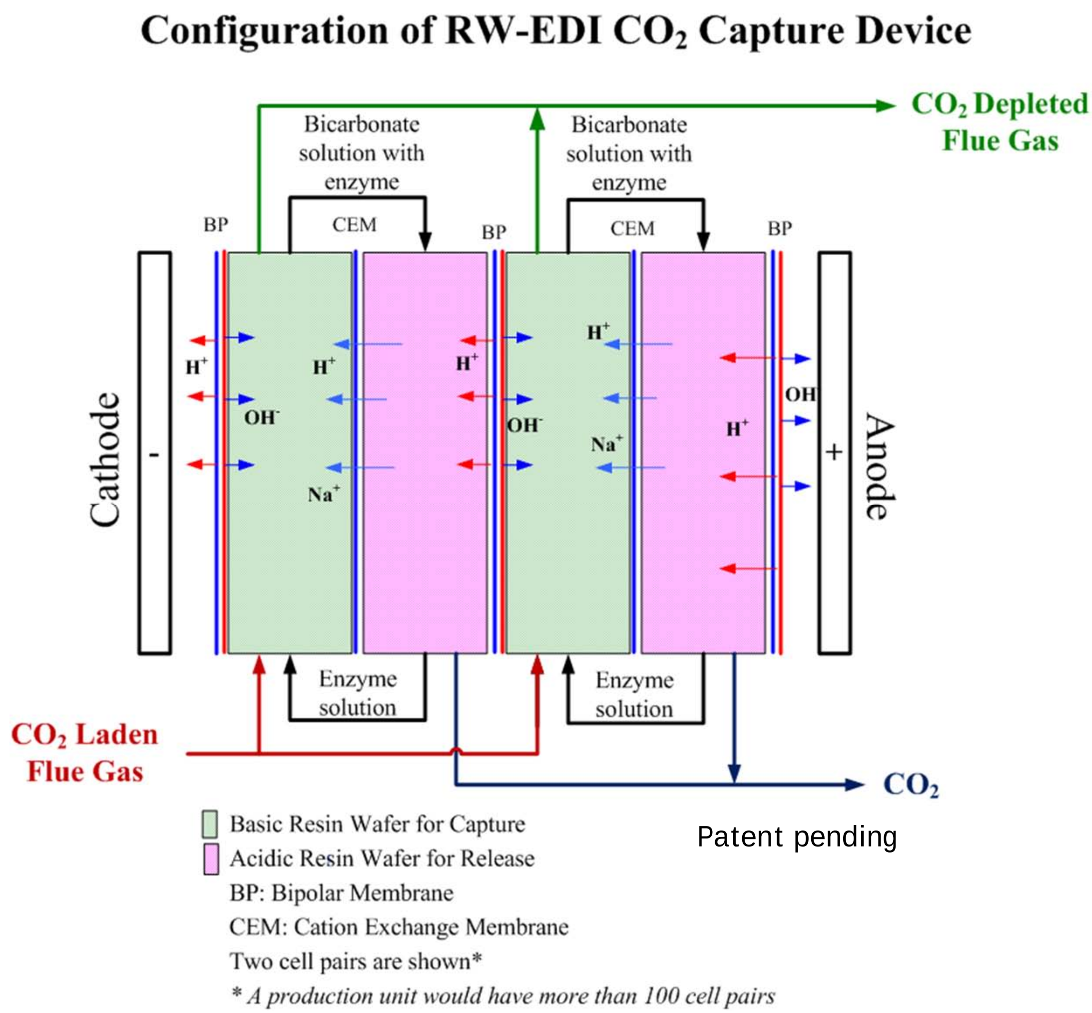


The platform is a unique adaptation of deionization technology

The RW-EDI uses the electrochemical pH shifts to capture CO_2 from the flue gas and to release the CO_2.

Advantages:

- Ø Electrochemical pH control
- Ø Carbonic anhydrase enzyme drives kinetics for faster capture and release of CO_2
- Ø Energy efficient CO_2 capture
- Ø Minimizes impact on cost of electricity



Patent pending

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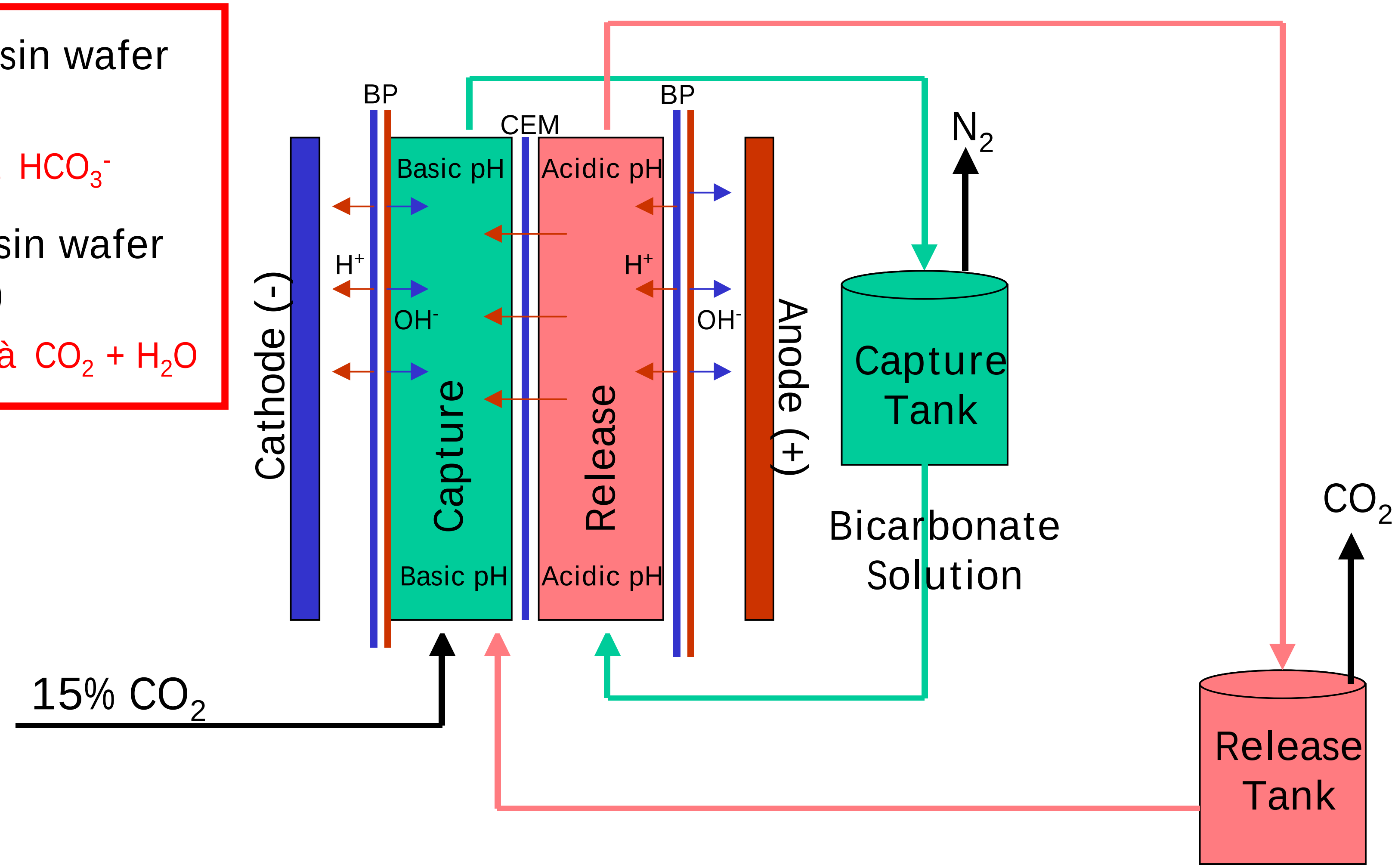
Schematic of experimental set-up

Capture resin wafer (basic pH)

$CO_2 + OH^-$ à HCO_3^-

Release resin wafer (acidic pH)

$HCO_3^- + H^+$ à $CO_2 + H_2O$



BP: Bipolar Membrane
CEM: Cation Exchange Membrane

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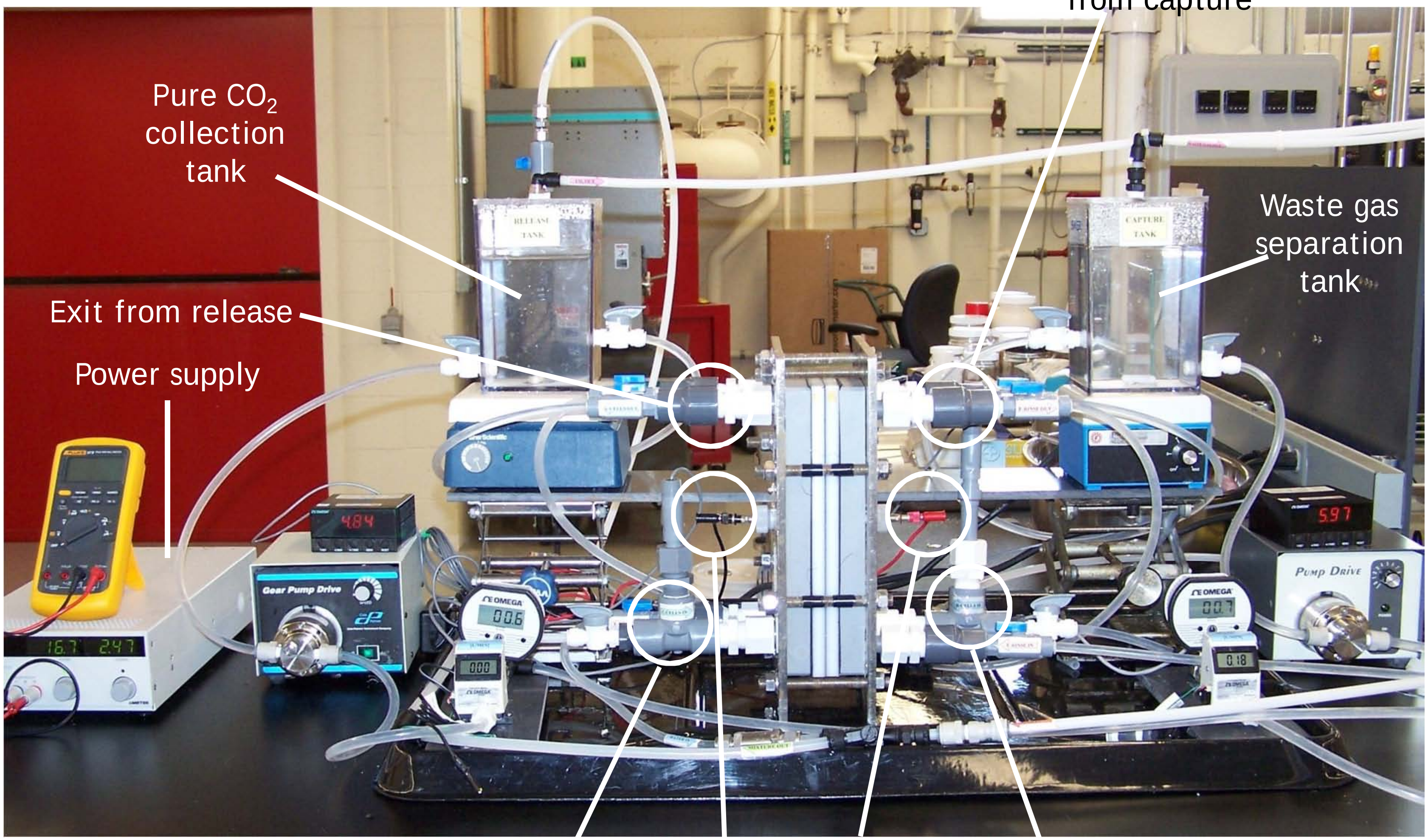
Lab-scale system with one cell pair

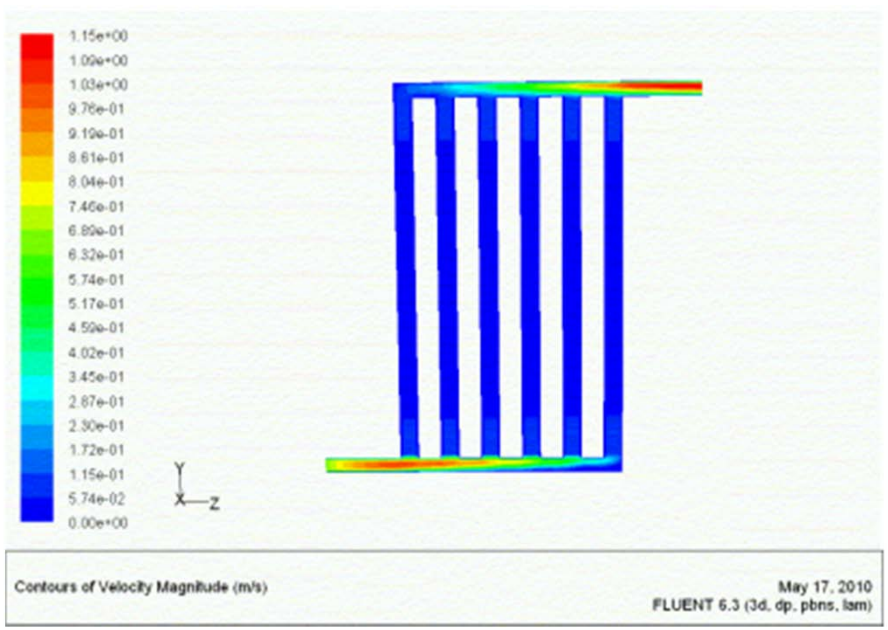
‘Head-on’ view



Critical performance attributes in the research plan

- Gas-Liquid Delivery System
  - Introduction of gas-liquid to the RW-EDI
  - Distribution of gas and liquid among multiple cell pairs
  - Mixing
  - Gas-liquid separation

- Power Consumption Optimization
  - pH control
  - Effective catalyst loading
  - Pressure drop
- Effects of Flue Gas Characteristics on Performance
  - Fine particles, NO_X, SO_X
  - Temperature



Computational fluid dynamics modeling of flow distribution in 6 parallel wafers in an RW-EDI stack.

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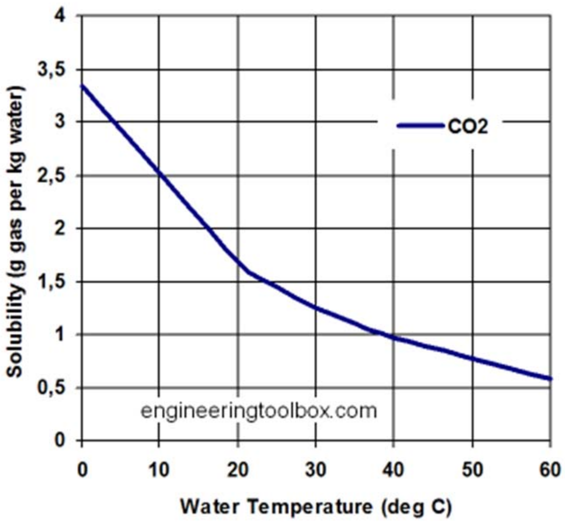
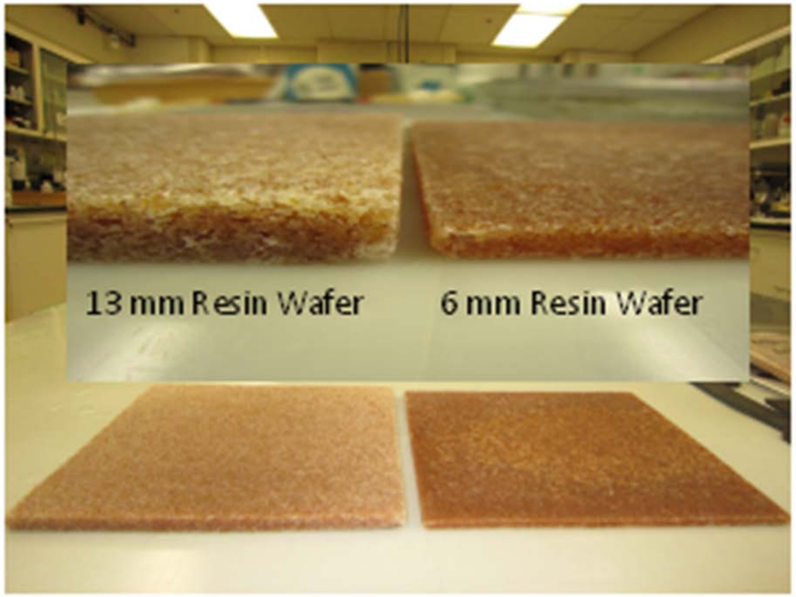
Proof of concept results

Capture Cell pH	Release Cell pH	% CO_2 Captured	% CO_2 Released	Comment
8.22	5.91	49	78	No Catalyst @ 25ºC
7.87	5.94	44	82	No Catalyst @ 25ºC



Resin wafer fabrication



Ion-exchange resin wafers (RW) are used as the reaction chambers for CO_2 capture from flue gas and release as pure CO_2 gas. Engineering scale-up of RW fabrication was achieved and the RW properties shown below have reached the development targets.

- RW thickness and size: 6 & 13 mm in 11"x11" and 17"x20" sizes
- RW void space: 20% to 40% of volume
- RW ionic conductivities: 1.5 mS/cm to 4.0 mS/cm with 500 ppm NaCl
- Types of IX in RW: macroreticular resin & gel resin
- Resin particle sizes used in RW: range from 50 um to 400 um

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Efficiency improvements & macroeconomic benefits

- COE
  - Targeted in the range of 25 to 35%
- CO_2 purity
  - System has potential to produce >97% purity
  - Further upgrading to pipeline or utilization requirements possible
- Potential costs
  - Initially targeted at \$20 - \$40/tonne pure CO_2
  - Costs likely to decrease with commercial deployment
- Potential integration with end use
  - Bicarbonate production
  - Atmospheric CO_2
  - Pipeline CO_2

Acknowledgements

Project Team

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