Electrical Swing Adsorption for CO$_2$ Capture

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Advanced Materials and Electric Swing Adsorption Process for CO$_2$ Capture

EU-Australian Cooperation, 7$^{th}$ Framework Project, ENERGY
The consortium is formed by: 5 universities (2 Australian), 2 R&D institutes, 3 SMEs and 2 large industries.

web-page:
www.sintef.no/projectweb/MATESA
The main idea

- Create a honeycomb material able to conduct electricity.
- Embed within this a material able to selectively adsorb CO\textsubscript{2}.
- Use this material in an innovative Electric Swing Adsorption (ESA) process.
- Evaluate the integration of the ESA process into the power plant.
- Make a full life cycle assessment of the entire capture process.
**ESA Concept**

**Electrical Swing Adsorption**

- A controlled (efficient), rapid, low cost regeneration process for conductive monolithic adsorbents

**Desorption is the key to an efficient adsorption process**
Objectives of Australian Study

Develop active carbon monoliths from brown coal
Embed this with a highly CO$_2$ selective adsorbent material
Evaluate performance at bench scale
Process modeling
Life cycle analysis

Victorian brown coal is a good carbon precursor
- it is very cheap
- it has very low inorganic content
Latrobe Valley Coal Fields

Flue gas composition:
- 60% N₂, 12% CO₂, 24% H₂O

Coal moisture content: ~ 60% (wb)

Loy Yang Mine and Power Stations
Heterogeneity of Victorian Brown Coal (VBC)
Active carbon monoliths from brown coal

Known features from work to date:

• Brown coal monoliths can be made.

• Active carbon from powdered brown coal has good reversible CO₂ capacity.

• Functionalised carbon monoliths improve CO₂ capacity.

• Active carbon monoliths prepared from polymers work for ESA.
Strength Development on Drying

Fig. 3. Drying behaviour of densified brown coals in still (●—●) and in forced draught (——) conditions. A, B and C = Morwell coal (Narracan bore) containing 5% magnesite. D = Maddingley coal. (5 h kneading in each case, 55% relative humidity, 20°C; forced draught of 0.5 m/s). D — = 10 mm pellets; ●—● = 3 mm pellets, both under forced draught conditions.

Coldry® Process*

* Environmental Coal Technologies Ltd

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Activated Carbons (ACs)

- High Surface Area & Porosity (wide PSD)
- Water tolerant (usually)
- Precursors inexpensive & readily available
- Surface chemistry easy to tailor
- Adsorption of gases on ACs is non-selective

AC Production

- Prepared by one of two activation methods:
  - **Physical Activation**: Pyrolysis, followed by partial gasification.
    1. **Pyrolysis** – Volatile Matter Removal
    2. **Partial Gasification** – Pore Development
  - **Chemical Activation**: Uses catalysts in addition to pyrolysis & partial gasification.
CO₂ adsorption of brown coal derived carbon

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CO$_2$ adsorption on functionalised VBC carbons

Polyethyleneimine (PEI)

CO$_2$ adsorption on synthetic mesoporous carbons

Mesoporous Carbon Synthesis

Amination procedure

Pellet products

PPSA on mesoporous carbon pellets
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Electrically heated reactor units

- Monoliths acquired from Mast Carbon Pty Ltd, UK
- Thermocouple reading on external surface of monolith
- Sealed in glass vessel or with heat shrink wrap
**ESA Investigation**

**Protocol**
- **Adsorption**
  - Feed gas (15% CO\textsubscript{2} in N\textsubscript{2}) at 80ml/min, ‘breakthrough’ at 35-40ml of CO\textsubscript{2} adsorbed
- **Electrical Stimulation**
  - Power requirements (10W)
  - ~65 sec to heat to 105\textdegree C (~5V, 2A)
- **Desorption**
  - Thermal evolution
  - Purge flow (4 – 8 ml/min), varied durations
- **Cooling**
  - High purge (cool) flow rates

S Delaney, PhD Thesis, 2009, Electrically Regenerable Carbon Adsorbents for CO\textsubscript{2} Capture
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**Amination procedure**

ESA Investigation

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**Functionalisation**
- Improved CO₂ adsorption capacity
- Slower breakthrough time
- Working capacity slightly increased for functionalised sample
ESA test unit - Effect of functionalisation

Purity and Recovery of Desorbed CO₂

- Increased rate of recovery for functionalised sample.
- Electrical stimulation higher (~30%) to effect same temp increase
  - ~30% increase in resistivity for functionalised sample
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ESA Equipment – Mk 2 and 3

Bench scale testing

Under construction

4-bed testing
Computational Fluid Dynamics

Dimension of Monolith

- Diameter: 20mm
- Length: 200mm
- Wall: 0.525mm
- Channel: 1.05mm
- CPSI: 286
- Open area: 42%

Due to symmetry, need to study the velocity of just 1/8 of monolith
ESA Concept

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Desorption is the key to an efficient adsorption process

Thank you!
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