Value Added Conversion of CO_2

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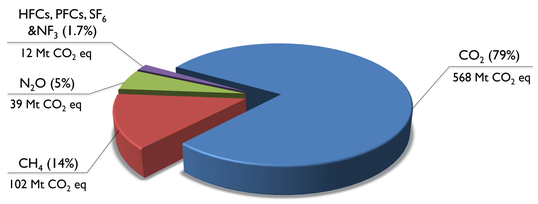
BACKGROUND

Greenhouse Gas (GHS) Emissions

It is commonly accepted that the emission of carbon dioxide (CO_2), a major component of greenhouse gas, has a significant effect on climate changes and global warming. Recent data shows that the Canadian CO_2 emission in 2015 was approximately 568 Mt.

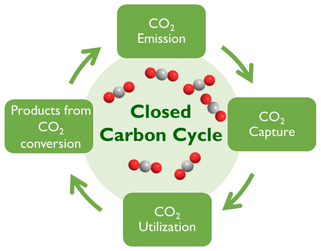


Canada's Emission Breakdown by GHG (2015).
(Ref: http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=662F9C56-1)

In response, the Canadian government has implemented many mitigation measures, such as carbon tax, carbon capture and storage (CCS), phasing out coal pollution, etc. All of these have attracted increasing interest towards developing and implementing more and better CO_2 reducing technologies.

Closing the Carbon Cycle

Closing the carbon cycle is the key for environmental sustainability.



SHORT-TERM OBJECTIVES

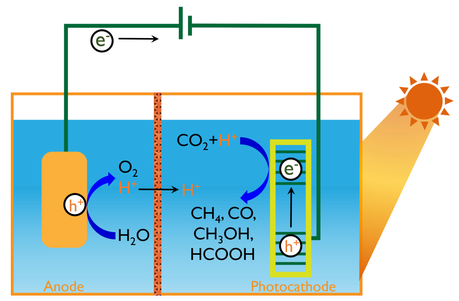
The short-term objectives of this project are:

- To screen and select a suitable material (catalyst);
- To fabricate heterogeneous catalysts with controlled structures for PEC reduction of CO_2;
- To design and fabricate PEC reaction cell.

PROJECT OVERVIEW

Photoelectrocatalytic (PEC) Reduction of CO_2

The PEC reduction of CO_2 is a chemical process where carbon dioxide is reduced to carbon monoxide or hydrocarbons by the energy of applied bias voltage and incident light with aid of a catalyst. It integrates photocatalysis and electrocatalysis and shows some distinct advantages of reduction of CO_2 with H_2O.

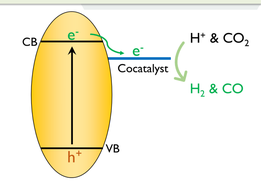


Schematic illustration of a two-compartment PEC cell separated by proton-exchange membranes for the reduction of CO_2.

Advantages of PEC reduction of CO_2 compared with electro- and photocatalytic reduction processes:

1. Reduced Electricity Consumption
   Electrolysis requires a large amount of electricity to overcome the high energy barrier of CO_2 reduction. PEC reduction of CO_2 can minimize electricity consumption by introducing solar energy.
2. Higher Efficiency
   The recombination of photo-excited electrons and holes is a crucial step in limiting the photocatalytic efficiency. PEC process may achieve higher efficiency because it allows better separation of photo-generated charges.
3. Employment of Separated Half Cells
   Avoid re-oxidation of the reactive products by photo-generated holes in conventional single-compartment photocatalytic system.

Catalysts for PEC Reduction of CO_2

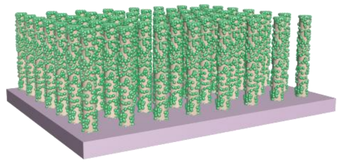


Common Issues

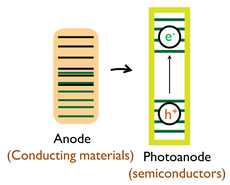
- Balance between stability vs activity of the cocatalyst;
- Competing side reactions that reduce efficiency and selectivity;
- A large bias voltage required to drive the H_2O oxidation reaction.

Strategies

- Develop heterogeneous catalysts with controlled structures like hierarchical structures and 1D nanowire arrays;



- Develop more efficient materials for the oxygen evolution reaction (OER);
- Combine the photocathode and photoanode.



THEME OVERVIEW

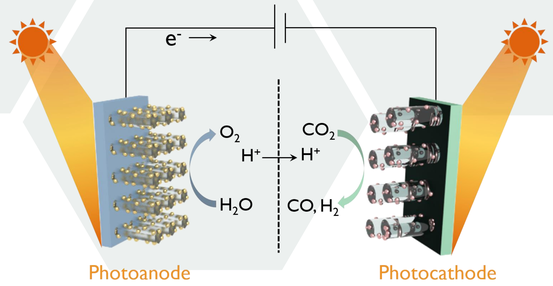
Carbon Capture, Utilization & Storage

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 CO_2 in the atmosphere? Existing technologies can capture carbon, but these methods can be costly and energy-intensive. Extracting energy without burning fuels, improving CO_2 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

PEC Reduction of CO_2 and OER Combined

Combination of PEC CO_2 reduction and OER in one cell



Schematic illustration of combination of PEC CO_2 reduction and OER in one cell. Semiconductors are used as components of both photocathode and photoanode.

Performance of Catalysts

Efficient catalysts for PEC CO_2 reduction:

- High Faradaic efficiency;
- Tunable syngas (H_2 + CO) production;
- Durability with limited degradation under continuous operation.

Efficient catalysts for PEC OER:

- Low overpotential;
- Stable performance output.

Structure control:

- Heterogeneous catalysts with controlled structures.

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