Photoelectrochemical Reduction of CO_2

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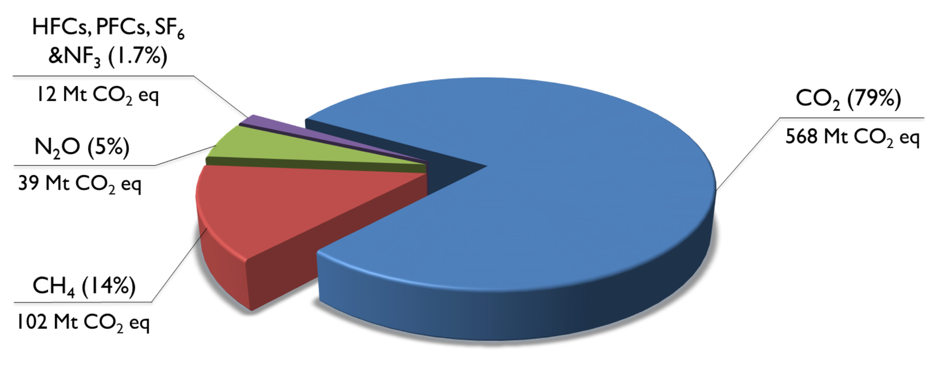
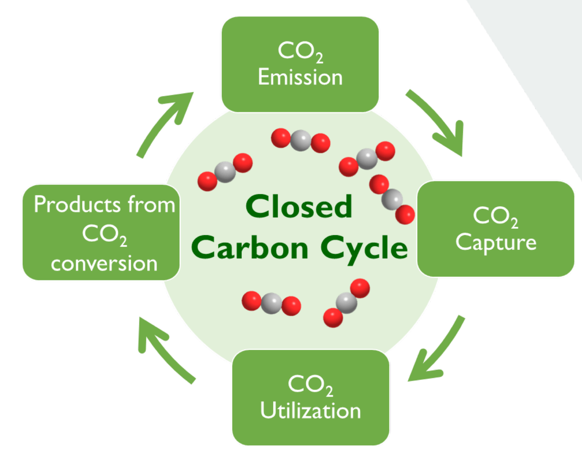
BACKGROUND

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)



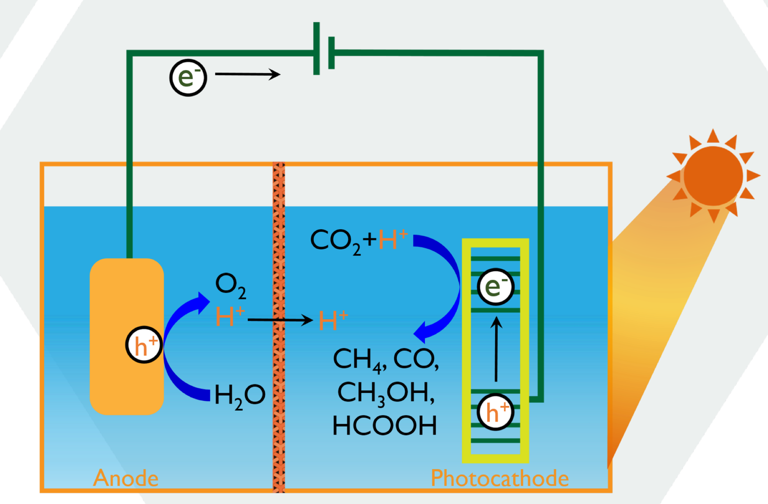
Closed Carbon Cycle

Closing the carbon cycle is the key for environmental sustainability.

AIMS AND OBJECTIVES

Develop efficient catalysts for Photoelectrochemical (PEC) CO_2 reduction with:

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

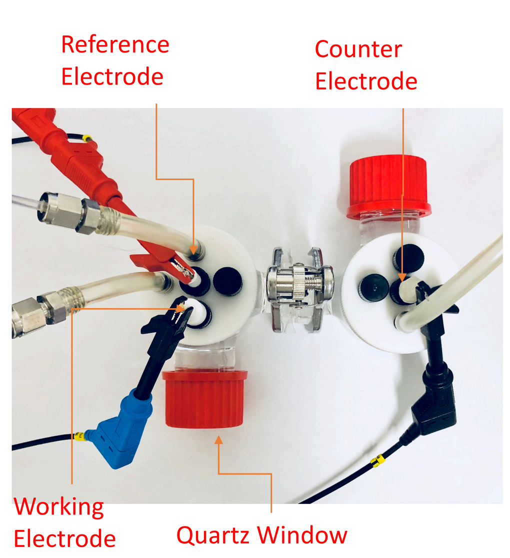


Schematic illustration of a two-compartment PEC cell separated by proton-exchange membranes for the reduction of CO_2.

RESULTS

Experimental Setup

Solar Simulator



Photoelectrochemical Cell

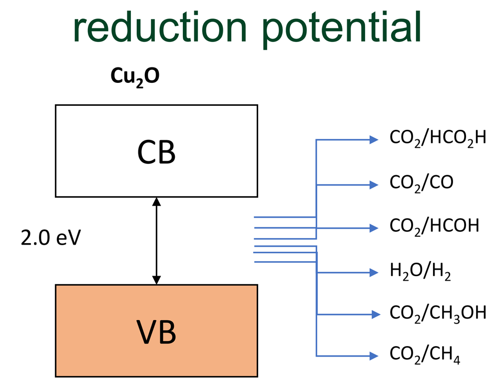
Model	ScienceTech, SF300A
Simulated Light	AM1.5G (1 Sun)
Light Intensity	100 mW/cm²
Spot Size	25 mm diameter
Working Distance	110 mm

Working Electrode	Fluorine-doped Tin Oxide Glass (FTO)
Reference Electrode	Ag/AgCl (sat)
Counter Electrode	Platinum Wire
Electrolyte	0.1M $NaHCO_3$
pH	6.75

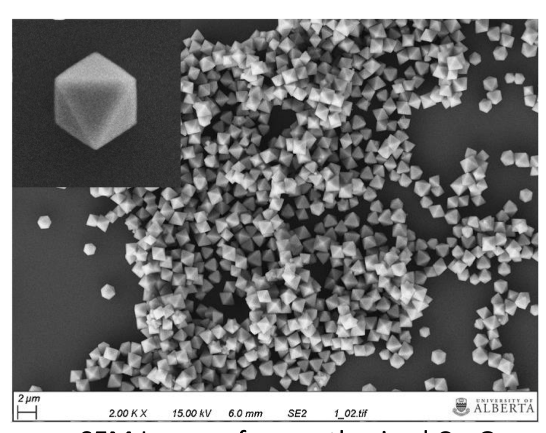
Catalyst Selections and Results

Cu_2O (Cuprous Oxide)

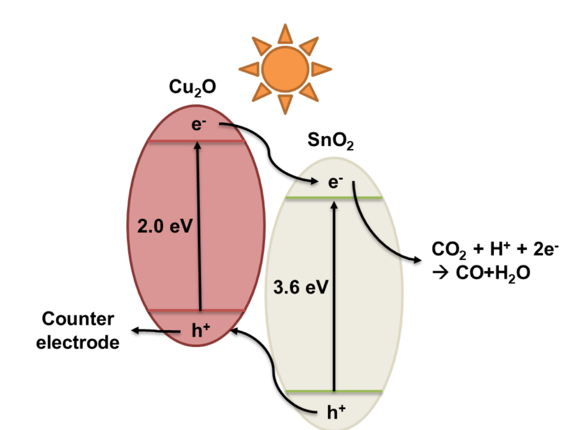
- Visible-light active: bandgap of 2.0~2.4 eV
- Bandgap matching: conduction band above CO_2 reduction potential



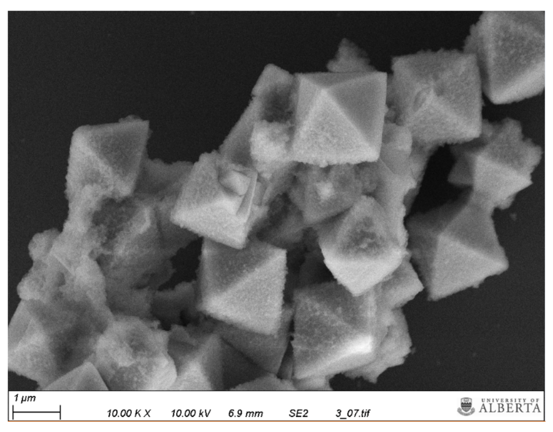
Several CO_2 redox couples that lie within the bandgap of Cu_2O



SEM Image of as-synthesized Cu_2O octahedral crystals



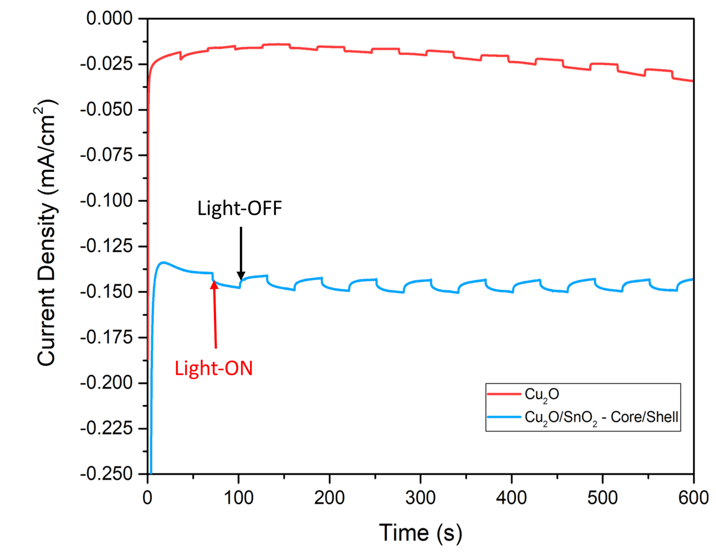
Band structure of the Cu_2O/SnO_2 heterojunction



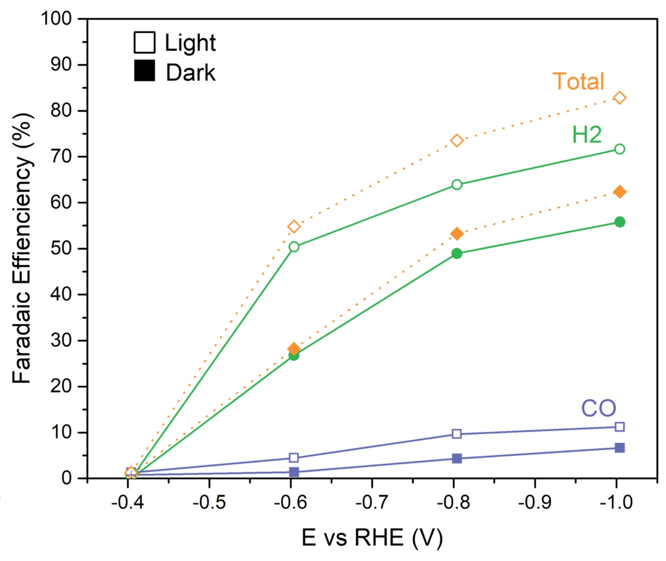
SEM Image of as-synthesized Cu_2O/Sn_2O core-shell crystals

Cu_2O/SnO_2 Heterojunction

- SnO_2 is known to selectively reduce CO_2 to CO with high faradaic efficiency
- Promote charge separation and enhance photo-response of material



Chronoamperometric measurement at -0.5V vs. Ag/AgCl (sat) of Cu_2O and Cu_2O/SnO_2 photocatalysts under illumination, with ON/OFF interval of 30s/30s.



Measured faradaic efficiency of Cu_2O/SnO_2 under dark and under illumination at applied potential from -0.4V to -1.0V vs RHE

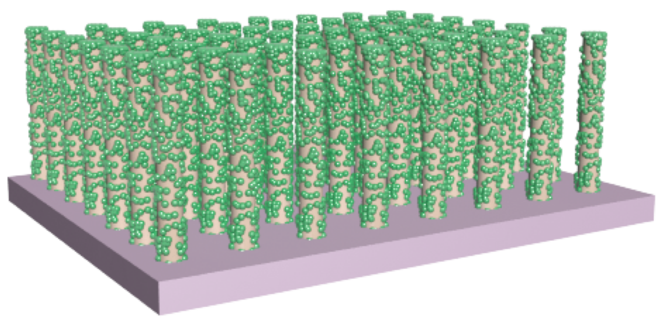
FUTURE DIRECTIONS

Improving Performance of Current Catalyst

- Enhance faradaic efficiency towards syngas
- Improve the photo-current output of the material
- Improve stability of the catalyst

Controlling Structures of Catalyst

- Increase surface area of active catalyst through fabricating 1D material
- Increase light absorption capability of the photocathode



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FES PROJECT OVERVIEW

An intense, world-wide effort is underway in industrial, government, and academic labs to develop efficient and selective earth-abundant electrochemical CO_2 conversion (ECC) catalysts. ECC is distinct from the photocatalytic conversion of CO_2 into light hydrocarbons, which does not involve an external bias to drive the reaction. We propose to use light in addition to electrical bias (photoelectrochemical CO_2 conversion) to increase the electrical and photochemical efficiencies for CO_2 reduction. The ultimate goals are to develop highly efficient photoelectrochemical catalysts and a cell that converts CO_2 into liquid fuels and valuable products.

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FUTURE ENERGY SYSTEMS

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