Active, Stable, and Abundant Photocatalytic Materials for Hydrogen Fuels: Solar fuels by tandem photocatalysis

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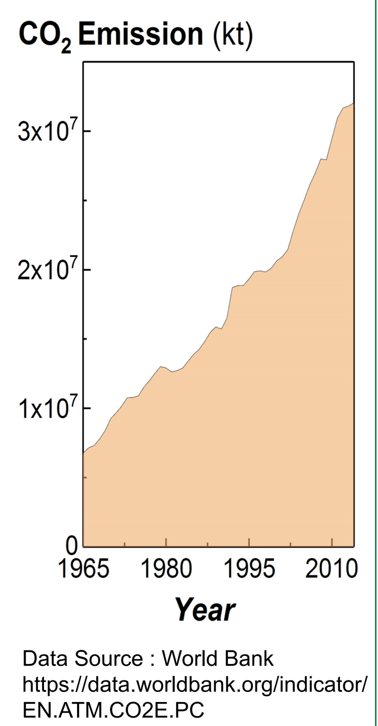
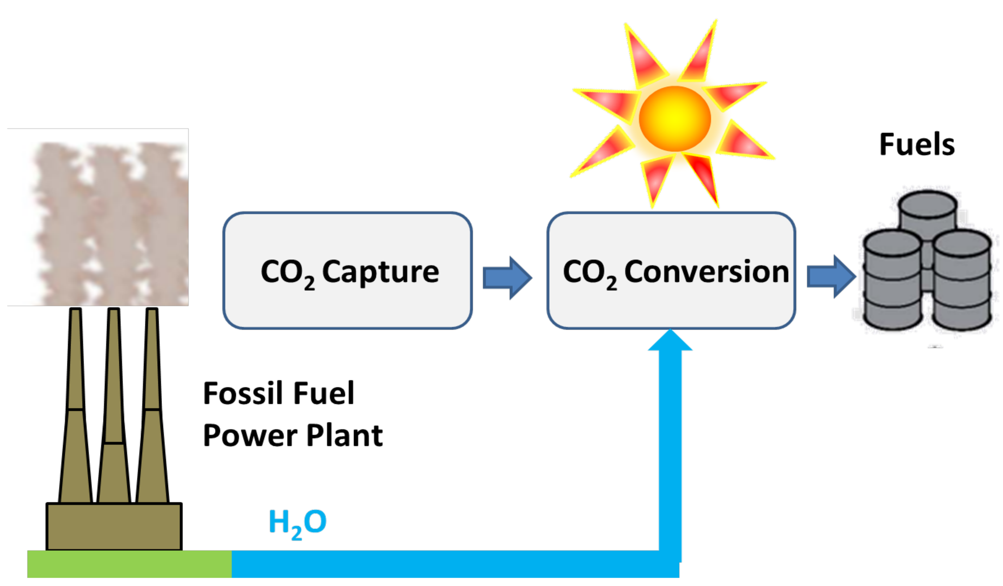
BACKGROUND

Solar Conversion: Future Energy Systems

Solar harvesting, conversion, and utilization are vital to the economy, environment, and society. It is essential to minimize the negative impact of fossil fuels, and to expand the development of renewables. Solar voltaics are key to achieving these goals.

We are developing hybrid photocatalytic cells that convert sunlight, water, and CO_2 into high-energy fuels, or hydrogen. These fuels will help power a sustainable and carbon-neutral society.





SHORT-TERM OBJECTIVES

I. Screen to develop active, efficient CO_2 to fuel, and water to hydrogen conversion catalysts.

II. Develop novel robust bonds between sunlight harvesting centres and CO_2/water conversion catalysts.

III. Develop active and stable photoelectrodes containing the sunlight harvesting/conversion catalysts.

IV. Assemble tandem photocatalytic cells with the electrodes that convert CO_2 or produce hydrogen.

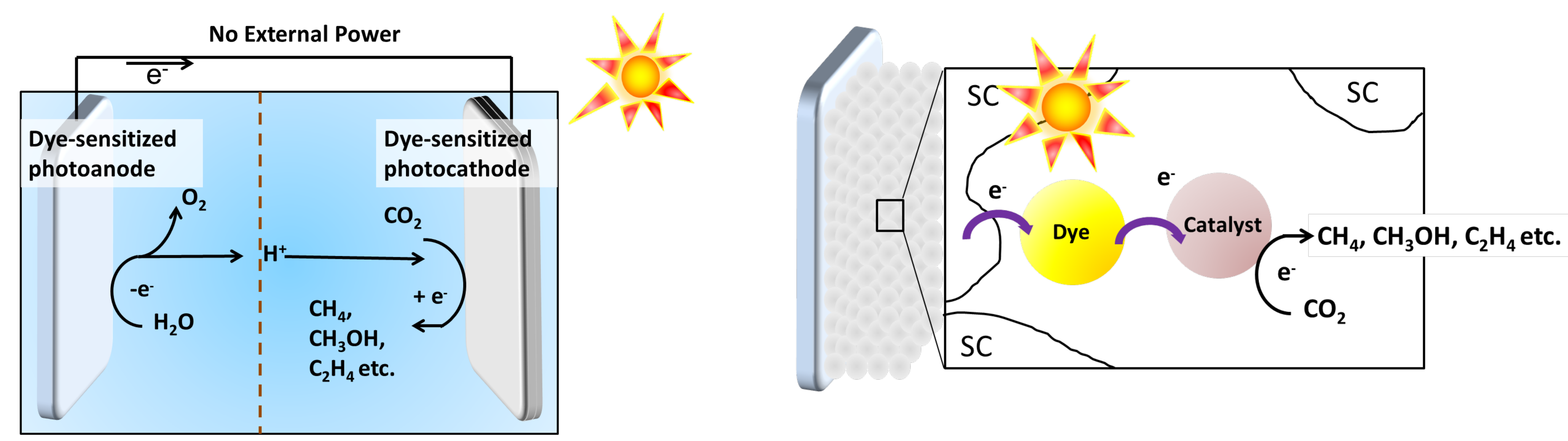
PROJECT OVERVIEW

Tandem photocatalytic CO_2 and water conversion

Dye (sunlight harvesting molecule)-sensitized tandem photocatalytic cell converts CO_2 to fuels (eg. CO, CH_4, CH_3OH, C_2H_4 etc) or H_2O to H_2 at the cathode using only the energy of sunlight while oxidizing water to produce oxygen at the anode.

Challenges:

Low performance of sunlight driven devices.
Activity and stability of the catalysts and dyes need improvement.



Schematic illustration of a tandem photocatalytic cell and an example of a dye-sensitized photocathode for CO_2 conversion. (SC: Semiconductor)

Advantages of photocatalytic tandem cells:

1. Operate without external power (voltage). Simpler system, lower costs, no loss in efficiency to external power source.

2. Operate with visible light driven solar to fuel conversion.

3. Easy control and optimization of CO_2 reduction and water oxidation process separately.

4. Fuels and O_2 generated in separate compartments.

5. Membrane systems in principle avoid liquid phase.

Strategies:

Develop new linkage between dyes, catalyst, and semiconductor electrode to increase activity and stability

Develop active heterogeneous CO_2 and water conversion catalysts

Develop high efficiency sunlight harvesting-catalyst dyads

Combine photoanode and photocathode in the same cell to maximize solar-to-fuel conversion efficiency

Take knowledge from molecular system studies, combine with machine learning to construct active, robust, earth abundant systems

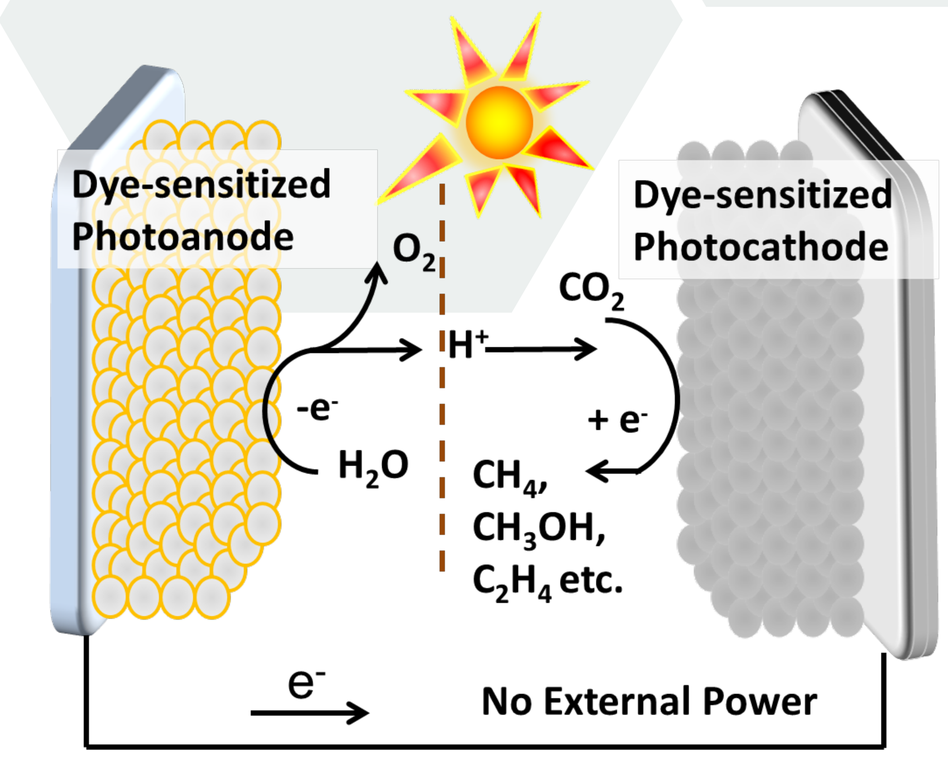
THEME OVERVIEW

Solar

The sun powers the entire world, providing warmth, light, and sustenance for countless forms of life. Technologies have made it possible to use some of the sun's energy to produce electricity and fuels, but new refinements may allow us to diversify the ways in which solar energy can be generated, stored, and utilized. By identifying lower-cost materials for use in the construction of solar cells, finding new catalysts to enable different types of production, identifying more efficient methods for market integration, and considering the possibility of solar-derived hydrogen fuels, it may be possible to develop vast energy resources from the most abundant source in our lives.

EXPECTED OUTCOMES

Tandem photocatalytic cell for CO_2 reduction and water oxidation.



Tandem photocatalytic cell without applied voltage for water oxidation and CO_2 conversion.

Novel sunlight harvesters based on earth abundant metal complex or organic dyes with strong visible light absorption and high quantum efficiencies.

Low cost CO_2 conversion heterogeneous catalyst with high efficiency, stability and good product selectivity.

High efficiency and stable dye sensitized photoelectrodes for dye-sensitized hybrid photocatalytic tandem cell applications.

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