Approaches to Light-Driven CO2 Reduction

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Abstract:

Two approaches to light driven conversion of carbon dioxide to C2+ products are shown.

- In a process analogous to natural photosynthesis, solar-driven reduction of carbon dioxide to hydrocarbon and oxygenate products is demonstrated with an overall efficiency exceeding 5%.
- Solar-driven photocathode converts carbon dioxide to C 2 and C 3 products and has 20 day stability.

Introduction

Solar to chemical energy conversion could provide an alternative to mankind's unsustainable use of fossil fuels. One promising approach is the electrochemical reduction of CO2 into chemical products, in particular hydrocarbons and oxygenates which are formed by multi-electron transfer reactions. Widespread adoption of such a technology could slow the rate of carbon dioxide emissions into the atmosphere by replacing chemicals obtained from oil with sustainably generated alternatives.

Team

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Outlook

These studies provide a clear framework for the future advancement of efficient solar-driven CO2 reduction devices. Future work will concentrate on improving selectivity and longevity and in making performing CO2 conversion directly with light.

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Results, Highlights, and Accomplishments

Efficient Solar-Driven Electrochemical CO_2 Reduction to Fuels and Chemical Building Blocks

Scientific Achievement

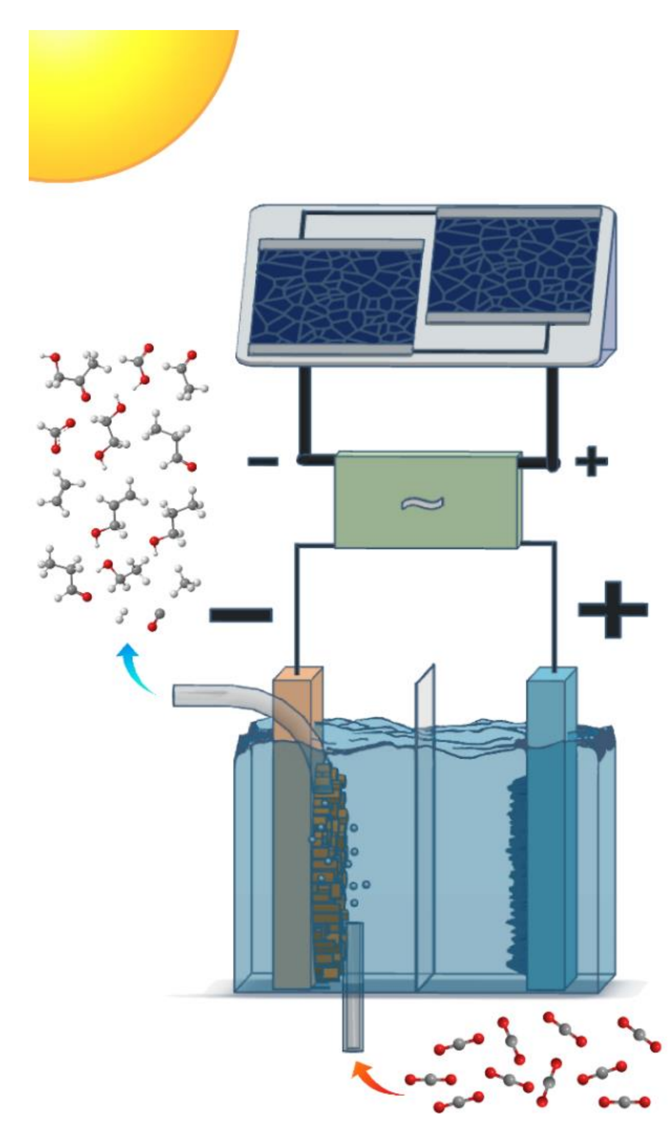
Solar-driven CO_2 reduction system generates hydrocarbon and oxygenate products with an efficiency far higher than natural photosynthesis.

Significance and Impact

Practical demonstration of direct, solar-driven conversion of CO_2 to valuable products is a major step towards providing an alternative to mankind's unsustainable use of fossil fuels.

Research Details

- Bimetallic "nanocoral" CO_2 reduction cathode produces ethanol and ethylene with high energetic efficiency
- 3-4% overall efficiency for the production of C_2 hydrocarbons and oxygenates over the course of a solar day using commercial silicon solar cells
- Over 5% efficiency with tandem solar cell



Schematic of a solar-powered system which converts CO_2 into hydrocarbon and oxygenate products with 10x the efficiency of natural photosynthesis. Power-matching electronics coupling the photovoltaic and electrochemical elements allow the system to operate over a range of sun conditions.

Photocathode converts carbon dioxide to C2+ products

Scientific Achievement

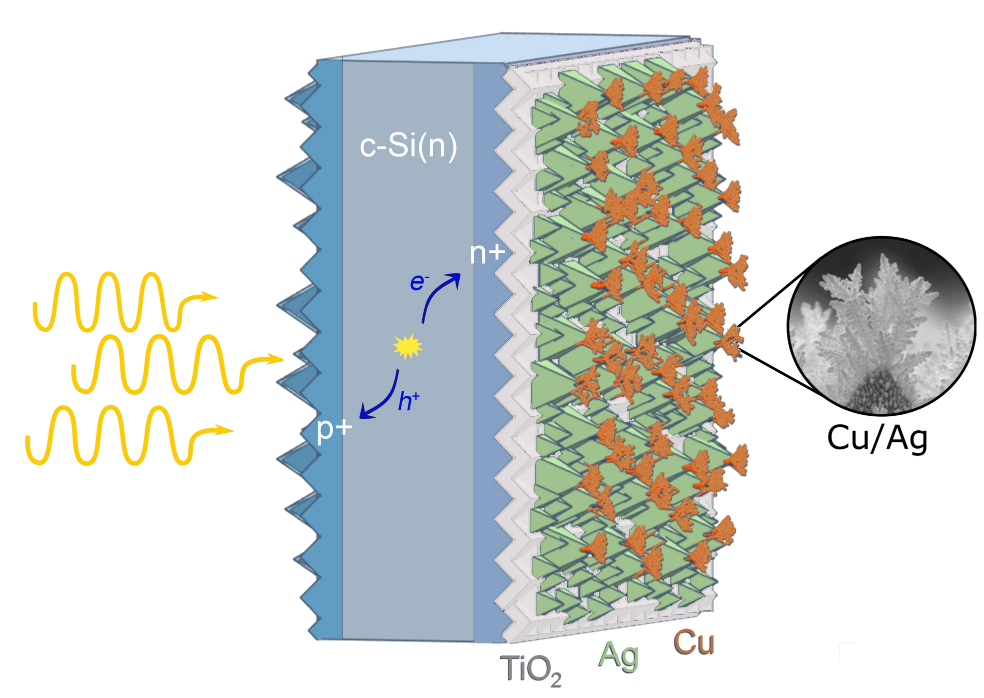
Coupling photocathode to halide perovskite solar cells produces C_{2+} products with an efficiency greater than that of photosynthesis.

Significance and Impact

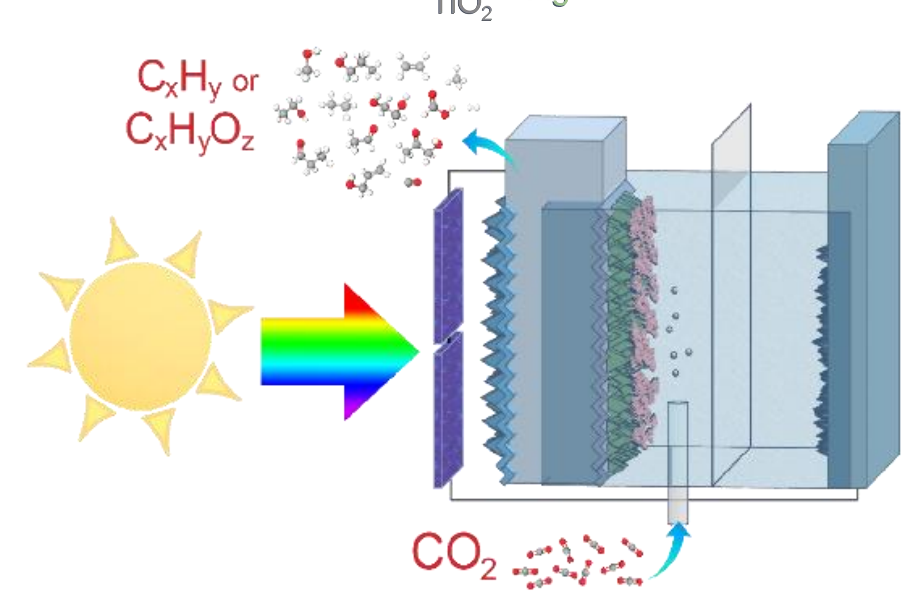
Integration of light absorbers with selective catalysts will enable modular design of solar-driven CO_2 reduction systems.

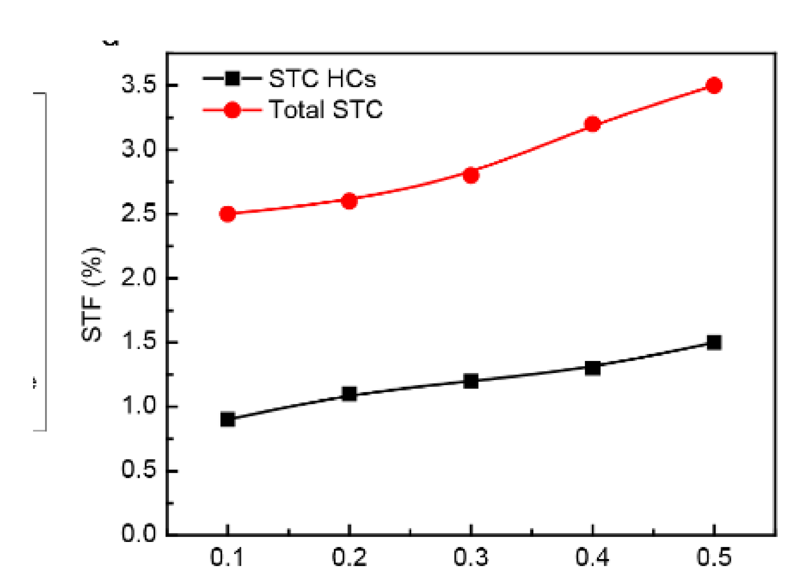
Research Details

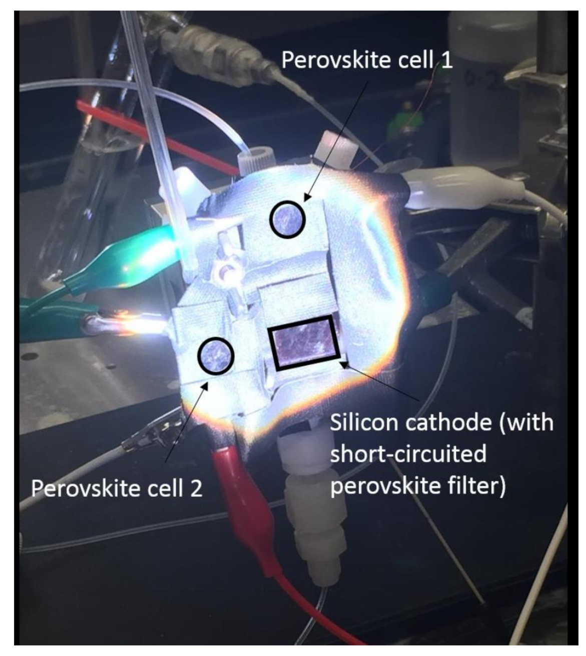
- JCAP-developed selective CO_2 reduction catalyst integrated with Si light absorber
- Engineered interface layers collect charge selectively and suppress recombination
- 20 day operation demonstrated with regeneration of catalyst



Si photocathode. Surface texturing improves light capture and maximizes catalyst surface area, interface layers passivate surfaces and selectively collect carriers, and integrated Ag-supported dendritic Cu catalyst drives CO_2 reduction to C_2/C_3 products.







Solar CO_2 reduction system. Two halide perovskite solar cells wired in series with photocathode allow for solar CO_2 reduction with no additional electrical bias. Increasing electrolyte concentration reduces series resistance in the cell and boosts the conversion efficiency for producing C_{2+} products (ethylene, ethanol) to over 1.5%.

References

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2. Gurudayal; Beeman, J. W.; Bullock, J.; Wang, H.; Eichhorn, J.; Towle, C.; Javey, A.; Toma, F. M.; Mathews, N.; Ager, J. W. Si Photocathode with Ag-Supported Dendritic Cu Catalyst for CO 2 Reduction. *Energy Environ. Sci.* **2019**, *12*, 1068–1077.