



## High-Efficiency Artificial Photosynthesis Using a Novel Alkaline Membrane Cell

Successful artificial photosynthesis is significant for future human/robotic exploration and terrestrial carbon emissions control.

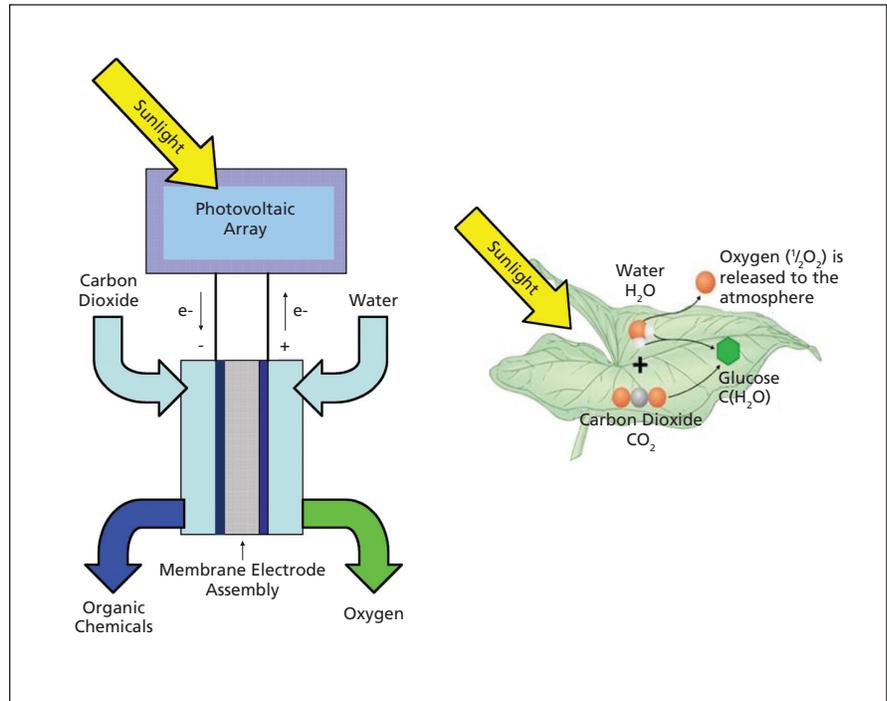
NASA's Jet Propulsion Laboratory, Pasadena, California

A new cell designed to mimic the photosynthetic processes of plants to convert carbon dioxide into carbonaceous products and oxygen at high efficiency, has an improved configuration using a polymer membrane electrolyte and an alkaline medium. This increases efficiency of the artificial photosynthetic process, achieves high conversion rates, permits the use of inexpensive catalysts, and widens the range of products generated by this type of process.

The alkaline membrane electrolyte allows for the continuous generation of sodium formate without the need for any additional separation system. The electrolyte type, pH, electrocatalyst type, and cell voltage were found to have a strong effect on the efficiency of conversion of carbon dioxide to formate. Indium electrodes were found to have higher conversion efficiency compared to lead. Bicarbonate electrolyte offers higher conversion efficiency and higher rates than water solutions saturated with carbon dioxide. pH values between 8 and 9 lead to the maximum values of efficiency. The operating cell voltage of 2.5 V, or higher, ensures conversion of the carbon dioxide to formate, although the hydrogen evolution reaction begins to compete strongly with the formate production reaction at higher cell voltages.

Formate is produced at indium and lead electrodes at a conversion efficiency of 48 mg of CO<sub>2</sub>/kilojoule of energy input. This efficiency is about eight times that of natural photosynthesis in green plants. The electrochemical method of artificial photosynthesis is a promising approach for the conversion, separation and sequestration of carbon dioxide for confined environments as in space habitats, and also for carbon dioxide management in the terrestrial context.

The heart of the reactor is a membrane cell fabricated from an alkaline polymer electrolyte membrane and cat-



The **Artificial Photosynthesis Process** and its similarity to natural photosynthesis. The reduction of carbon dioxide to organic chemicals in an electrochemical cell is a viable approach to achieving artificial photosynthesis.

alyst-coated electrodes. This cell is assembled and held in compression in gold-plated hardware. The cathode side of the cell is supplied with carbon dioxide-saturated water or bicarbonate solution. The anode side of the cell is supplied with sodium hydroxide solution. The solutions are circulated past the electrodes in the electrochemical cell using pumps. A regulated power supply provides the electrical energy required for the reactions. Photovoltaic cells can be used to better mimic the photosynthetic reaction. The current flowing through the electrochemical cell, and the cell voltage, are monitored during experimentation. The products of the electrochemical reduction of carbon dioxide are allowed to accumulate in the cathode reservoir. Samples of the cathode solution are withdrawn for

product analysis. Oxygen is generated on the anode side and is allowed to vent out of the reservoir.

*This work was done by Sri Narayan, Brennan Haines, Julian Blosiu, and Neville Marzwell of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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*Innovative Technology Assets Management  
JPL*

*Mail Stop 202-233  
4800 Oak Grove Drive  
Pasadena, CA 91109-8099*

*E-mail: iaoffice@jpl.nasa.gov*

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