NATIONAL RENEWABLE ENERGY LABORATORY

A New Method to Stabilize Solar Water-Splitting Electrodes

Highlights in Science

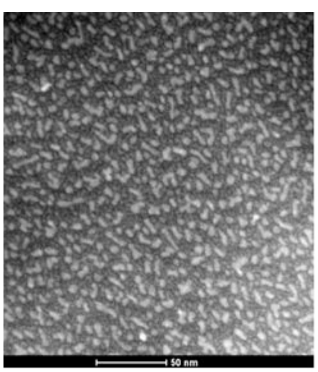
A two-step surface modification of high-efficiency III-V photoelectrolysis materials provides corrosion protection for hundreds of hours without sacrificing conversion efficiency.

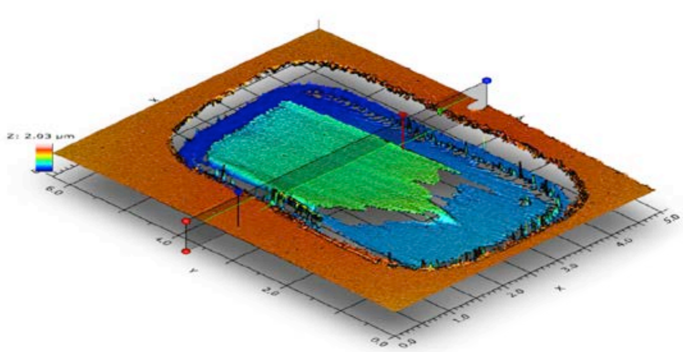
Scientists from the National Renewable Energy Laboratory (NREL) have developed a method of treating semiconductor surfaces that can stabilize the material under hydrogen evolution conditions in an electrolyte.

This method can specifically benefit photoelectrochemical (PEC) devices, which use sunlight to directly split water into hydrogen and oxygen. In a PEC device, a light-harvesting system is combined with a water-splitting system, which comprises a semiconductor immersed in an aqueous electroyte solution. A problem with semiconductor materials currently used in the light-harvesting system is that they can corrode because of prolonged operation under illumination in harsh aqueous electrolytes.

NREL's approach mitigates the corrosion problem by using a two-step method: 1) an ion implantation step, bombarding the semiconductor surface with nitrogen (N_2^+) ions, and 2) a deposition step, placing small amounts of a platinum-ruthenium alloy (PtRu) on the semiconductor surface (see left image below). The N_2^+ implantation and flash sputtering of a PtRu alloy results in covering about 30% of the semiconductor surface with ~5-nm particles.

This treatment has enabled over 300 hours of stability for a *p*-$GaInP_2$ photocathode at 10 mA/cm^2. In another test, NREL scientists optimized the N_2^+ implantation surface passivation treatment for *p*-InP semiconductors with a 1.33-eV bandgap. The promising results demonstrated durability of up to 24 hours of continuous hydrogen evolution, operating at ~25 mA/cm^2 under 1-sun illumination.





Scanning transmission electron microscope image (left) of platinum/ruthenium nanoparticles covering $GaInP_2$ electrode. This coating helps to prevent corrosion that occurs in an untreated electrode (right), where the blue and green areas in this optical profilometry plot indicate locations of detrimental etching compared to the orange area, which was covered by epoxy during operation. Left image by Andrew Norman, NREL; right image by Heli Wang, NREL.

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References: Deutsch, T., et al. "Stable Electrode Surface and Methods." Non-provisional patent (filed May 14, 2014). *http://www.faqs.org/patents/app/20140332374*

Key Research Results

Achievement

NREL scientists have developed a method of treating semiconductor surfaces that can stabilize the material under hydrogen evolution conditions in an electrolyte.

Key Result

In one test, NREL scientists performed an optimized N_2^+ implantation surface passivation treatment to *p*-InP semiconductors with a 1.33-eV bandgap. The promising results demonstrated durability up to 24 hours of continuous hydrogen evolution, operating at ~25 mA/cm^2 under 1-sun illumination.

Potential Impact

Successful development of high-performance PEC devices with good durability can support economical hydrogen production as a way to store intermittent solar radiation in chemical bonds.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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