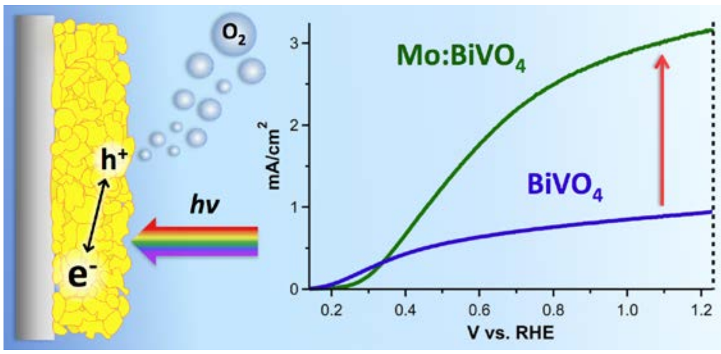
NREL Demonstrates Efficient Solar Water Splitting by Metal Oxide Photoabsorber

Highlights in Science

New development demonstrates that inexpensive and robust metal oxide photoabsorbers hold great promise as photoanodes for water oxidation.



Doping nanoporous bismuth vanadate with molybdenum (Mo:$BiVO_4$) improves the rate of majority carrier transport, dramatically increasing the water oxidation performance.

The production of solar fuels (e.g., H_2 from H_2O, hydrocarbons from CO_2) via direct photoelectrochemical reactions is a promising approach in the pursuit of renewable energy sources. Production of O_2 is the only scalable and renewable oxidation that can balance these fuel-forming reduction reactions. However, few materials have the necessary properties (e.g., strong visible light absorption, stability to corrosion, n-type conductivity) to evolve O_2 as photoanodes, and the few that meet these general requirements often have significant limitations (e.g., high charge recombination, sluggish charge transport, poor charge transfer to catalysts) that result in low O_2 production efficiencies. Researchers at the National Renewable Energy Laboratory (NREL) have now demonstrated a nanostructured molybdenum (Mo)-doped bismuth vanadate ($BiVO_4$) photoanode that solves many of these challenges.

Several characterization techniques were used to provide the first quantitative measurements of the effect of Mo doping on the electron transport rate in nanoporous $BiVO_4$ films, with an electron diffusion length of 300 nanometers found for the optimal 1.8% Mo doping level. Importantly, the charge separation efficiency was determined to be 90%, meaning that the energy from every 10 photons absorbed by Mo:$BiVO_4$ produces 9 equivalents of charges (electrons and holes) that can be used to perform fuel-forming chemistry. This level is close to that achieved by the best photovoltaic materials and demonstrates that inexpensive and robust metal oxide photoabsorbers hold great promise as photoanodes for water oxidation.

This study paves a pathway to low-cost solar fuel systems—and, more generally, this unique understanding and control of charge separation and electron transport provides a road map to understand the charge transport properties of other metal oxide photoanodes for solar photoelectrolysis.

This work was funded by the Solar Photochemistry Program of the Division of Chemical Sciences, Biosciences, and Geosciences, Office of Basic Energy Sciences of the U.S. Department of Energy.

Technical Contact: Nathan Neale, *nathan.neale@nrel.gov*

Reference: Seabold, J.A.; Zhu, K.; Neale. N.R. (2014). "Efficient Solar Photoelectrolysis by Mo:BiVO4 Through Controlled Electron Transport." *Phys. Chem. Chem. Phys*. 16; pp. 1121-1131. DOI: 10.1039/c3cp54356k.

Key Research Results

Achievement

NREL researchers have characterized the electron diffusion length in a nanoporous Mo-doped $BiVO_4$ photoanode; this understanding led to water splitting efficiencies that are among the highest ever reported by a metal oxide photoabsorber.

Key Result

Researchers studied the Mo doping level and the Mo:$BiVO_4$/catalyst interface. Mo doping was shown to improve the electron diffusion coefficient four-fold and the electron diffusion length by over an order of magnitude.

Potential Impact

This study provides a pathway to low-cost solar fuel systems—and, more generally, this unique understanding and control of charge separation and electron transport provides a road map to develop other metal oxide photoanodes for solar photoelectrolysis.

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.

15013 Denver West Parkway
Golden, CO 80401
303-275-3000 | www.nrel.gov

NREL/FS-5900-61070 | January 2014

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.