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Hydrogen Production Using Alkali-Metal-Doped BiVO4 for Near-Perfect Suppression of Bulk Recombination by Photo-Electrochemical Water Oxidation

Background

Hydrogen has been considered one of the most promising alternative fuel due to its high gravimetric energy density, low greenhouse gas emission, and ease of storage. Solar hydrogen production by water splitting in a photo-electrochemical cell (PEC) enables direct conversion of solar to fuel energy. To realize economical solar hydrogen production, photo-electrodes should be fabricated using inexpensive, abundant materials and simple processing techniques. Several wide-bandgap oxides have been studied as potential photoanode materials which can oxidize and reduce water to generate O2 and H2. BiVO4 (n-type monoclinic) has received considerable attention due to its direct bandgap (~2.4 eV), favorable band edge positions, and stability against chemical and photo-electrochemical corrosion. However, solar energy conversion in BiVO4 is challenged by poor light absorption efficiency, charge separation, and surface charge transfer efficiency.

Invention Description

Researchers at Arizona State University have developed a method for complete suppression of electron hole-pair recombination along with light absorption enhancement in bulk BiVO4 by alkali metal doping. The spray-coated electrodes have achieved photocurrent densities of 8.0±0.35 mA·cm-2 at 1.23 V vs. a reversible hydrogen electrode (RHE)—this is the maximum ever reported in the literature under 1 sun illumination. The corresponding solar-to-hydrogen conversion efficiency is ~10.2% with a hydrogen production rate of 0.6 L/min/m2. This record performance meets the targets for water splitting and solar-to-fuel energy conversion set forth by the U.S. Department of Energy (DOE). Additionally, the scalable fabrication process for doped BiVO4 electrodes and stability under 1 sun emphasize this method’s potential for commercial energy production.

Potential Applications

- Solar-hydrogen production
- Solar-powered electrolysis (splitting) of water
- Alternative fuels

Benefits and Advantages

- Reaches maximum theoretical efficiency for charge carrier generation and separation efficiency
- Performance meets Department of Energy (DoE) targets for commercial water splitting
- Enhanced light absorption from novel nanoparticle-based catalysts
- Near complete suppression of electron hole-pair recombination