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Boosting light-driven hydrogen evolution through cerium vanadate/cerium sulphide type–II heterostructure

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ABSTRACT

Fabrication of heterostructures to boost the light-driven hydrogen evolution is one of the efficient way to address the energy crisis across the globe. Cerium vanadate (CeV)/Cerium sulphide (CeS) heterostructure has been synthesized using a simple hydrothermal method. Structural, spectroscopic, morphological, optical and photoelectrochemical characterizations confirm the formation of heterostructure between CeV and CeS. Photochemical hydrogen evolution was observed in all the three catalysts (CeV, CeS and CeV/CeS) both under visible and ultraviolet light sources. CeS, CeV and CeV/CeS found to evolve 3897, 6453 and 12,456 µmol of hydrogen in 4 h, respectively under visible light. In addition photoelectrochemical hydrogen evolution experiment was conducted in which, CeV/CeS heterostructure showed high photocurrent density at 0.25 V vs. RHE, which is almost 1.47 folds greater than that of CeV and 2.1 times that of CeS. The optical and electrochemical characteristics shows that photocatalytic hydrogen evolution follows type-II heterostructure. A good stability of the CeV/CeS heterostructure finds its suitability for practical applications for various photocatalytic experiments.

1. Introduction

The evolution of hydrogen is critical in many fields due to its ability to address serious global concerns and support sustainable development [1,2]. Hydrogen is a clean energy carrier that, when used in fuel cells, combustion engines, or as a feedstock for chemical processes, emits only water vapour as a byproduct, making it critical for decreasing greenhouse gas emissions and fighting climate change [3–5]. When energy demand is high or renewable energy generation is low, we can convert this stored hydrogen back into electricity or use it as a fuel, thereby improving grid stability and reliability. Hydrogen fuel cells are a possible solution for zero-emission transportation in cars, buses, trucks, and even trains [6,7]. The evolution of hydrogen permits the generation of clean energy for transportation, lowering air pollution and reliance on fossil fuels. Research and development in hydrogen evolution mainly involve electrocatalytic, photochemical, and photoelectrochemical techniques [8,9]. Hydrogen evolution is widely achieved using costly metals like Pt, Pd, and Ru through electrochemical techniques. Light-driven H_2 evolution is a viable avenue for sustainable hydrogen synthesis, with various advantages over electrochemical approaches, particularly in terms of using renewable energy sources and reducing environmental effects [10–12].

Photochemical/electrochemical hydrogen evolution reactions depend mainly on the bandgap, structure, defects, light assimilation, and flat band potentials of the catalyst [13–15]. Rare earth metal vanadates have been used for various photocatalytic and other catalytic applications [16–18]. $CeVO_4$ (CeV) is one such bimetallic oxide projecting its semiconductor characteristics with a bandgap of 2 to 2.6 eV. CeV's remarkable redox and optical capabilities as a catalyst are due to the multiple electronic transitions of its constituent lanthanides and its

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