Solar Generation of Hydrogen using Titanium Oxide Nanoparticles: Impact of Size on Stability and Efficiency

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Objective

The aim of the current work is to study:

- The hydrogen generation efficiency of photoelectrodes with different particle sizes in 2 and 3 electrode systems
- The stability of the photoelectrode in the alkaline aqueous electrolyte by running a long term test under solar irradiation
- The kinetic aspects of photoelectrochemical cells based on different TiO2 nanoparticle sizes

Introduction

Converting solar energy into fuels due to the great economic and environmental interests has received much attention lately. One of the capable technologies that would be able to produce a clean and cost-effective energy is solar photoelectrochemical (PEC) hydrogen production [1]. In a PEC when a photoelectrode illuminated with sunlight was immersed in an aqueous electrolyte, the photon energy was converted to electrochemical energy, which can directly split water into hydrogen and oxygen as seen in Figure 1 [2, 3]. TiO2 can utilize UV light due to its wide band gap.

Figure 1. UV absorption by TiO2

Anatase TiO2 particles of 5, 18, and 30 nm in diameter and Rutile of 30, 50, and 100 nm (Purity ≥99.9%) were used for making TiO2 thin films using doctor-blading method [4]. Microstructural and phase characterization of TiO2 powders were studied using XRD as seen in Figure 3. A commercial PEC cell device “PEC22- Zahner Germany” with a volume of 7.2 cm3 was used to study the photoelectrochemical behavior of TiO2 electrode (Figure 4).

Methodology

- Photocurrent–Voltage(J–V) and Current–Time(t–t)
- Solar to Hydrogen Efficiency (STH)
- Intrinsic Solar to Chemical Efficiency (ISTC)
- Electrochemical impedance spectroscopy (EIS)

Results and Discussions

The behavior of the 5 nm TiO2 thin film on generating photocurrent was different compared to the other electrodes (Figure 5).

Current–Time(t–t)

The behavior of charge carriers dynamics of each electrode was evaluated by running t–t test under backside illumination (Figure 6).

The majority carries (electrons) need small diffusion to reach the interface than the minority carrier (holes) when the cell illuminated from the backside as shown in Figure 7. Therefore, having larger particle size make charge transport much easier as reported by Docampo et al. [5].

The ISTC efficiency of photoelectrodes shown in Figure 8. The 5 nm particle size has the highest ISTC efficiency near the zero-bias potential vs. Ag/AgCl (1.42 mW/cm² at the potential of 1.03 V vs. RHE).

Conclusion/Further work

In term of cell efficiency for hydrogen production without any external bias, the particle size of 30 nm exhibited the highest solar to hydrogen (STH) efficiency. The EIS values show that the 30 nm particle size had a better charge transportation efficiency. Further investigations is needed to characterize the effect of particle sizes on the charge recombination rate which directly affect the cell efficiency.

REFERENCES


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