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Electrochemical Deposition (ECD) of ZnO as the Photoanode in Dual-Chamber Photocatalytic Fuel Cell (PFC) for Methyl Red Degradation

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Photocatalytic fuel cell (PFC) is known to treat the organic-based wastewater efficiently. The coating method of zinc(II) oxide (ZnO) as the photocatalyst on the zinc (Zn) plate of photoanode plays important role in maintaining the efficiency and power generation from PFC. In the present study, a new coating method of ZnO on the zinc plate is developed by using electrochemical deposition (ECD) and the removal efficiency as well as power generation are compared with typical ultrasonicate method. A dual-chamber PFC is constructed with ZnO/Zn photoanode and graphite plate as the cathode to treat methyl red dye synthetic wastewater. The surface morphology of both coating methods of ZnO/Zn photoanode is observed using scanning electron microscope (SEM) before and after the treatments. The dual chamber PFC with ECD coating shows a faster complete degradation rate with higher power generation than ultrasonicate method. Although, both coating methods can reach to 100% degradation efficiency of methyl red dye, the maximum power output for ultrasonicate method is 134.67 mW cm^{-2} while for ECD is 285.30 mW cm^{-2} under optimum conditions.

1. Introduction

Along with rapid development of industrialization and urbanization, the amount of wastewater discharged into water bodies from various sources such as textile and manufacturing industries has been increased which brought irreversible impacts to the environments.[1,2] Currently, climate change, environmental pollution, and energy crisis are the most formidable foes which are driven by rapid economic growth around the world. Hence, it is a need to develop an efficient, but with energy conservation function, wastewater treatment system.[3]

The capability of wastewater degradation fuel cell has gained attention as it is considered green and eco-friendly technology toward the environment by using photocatalyst such as zinc oxide (ZnO), and titanium dioxide (TiO_2). Photocatalyst plays vital role in organic pollutant degradation in wastewater due to the production of electron (e^-) and hole (h^+) pair from the photoexcitation ($h\nu$) where highly reactive oxidation species (ROS) such as hydroxyl radical (OH•), superoxide anion radical (O_2•$^-$), hydroperoxyl radical (•HO_2), and alkoxyl radical (RO•) are generated (Equations (1–4)).[3–5] By incorporating photocatalyst in fuel cell, the organic-based wastewater can be further utilized as fuel supply, and during the degradation process, the mass transfer of electron can be harvested as electrical energy.

$$\text{Photocatalyst} + h\nu \rightarrow \text{Photocatalyst}\left(e^- + h^+\right) \quad (1)$$

$$\text{Photocatalyst}\left(h_{VB}^+\right) + H_2O \rightarrow \text{Photocatalyst} + H^+ + \bullet OH \quad (2)$$

$$\text{Photocatalyst}\left(h_{VB}^+\right) + OH^-(\text{adsorption}) \rightarrow \text{Photocatalyst} + \bullet OH \quad (3)$$

$$e^- + O_2 + H^+ \rightarrow \bullet HO_2 \quad (4)$$

In the previous researches,[2,6–10] the photocatalytic system has been proven successfully treated organic-based wastewater using single chamber photocatalytic fuel cell (PFC). However, the method of preparation for ZnO/zinc (Zn) photoanode affects the overall degradation efficiency and power generation in several aspects such as surface area to volume (SA/V) ratio, and surface morphology. So far, the improvement of ZnO/Zn photoanode coating method has not been done to further enhance the degradation efficiency and power generation. Hence, the alteration of preparation of ZnO/Zn photoanode was carried out in our research to increase the efficiency of organic-based wastewater degradation and power generation. In the present paper, we demonstrate an alternative electrochemical deposition method (ECD) to coat ZnO on a zinc plate. The ECD method was compared to typical ultrasonicate method in terms of the degradation efficiency of synthetic azo dye wastewater (methyl red) as well as the electricity generation in a dual chamber PFC (**Figure 1**) under different pH and hypochlorite (ClO^-) concentrations.

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