PROGRESS IN PHOTOELECTROCHEMICAL RESEARCH 2014

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SELFUEL
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Contents

Foreword

Solar Hydrogen group focuses on research and development to ehnance the performance of heterogeneous photocatalyst and photoreactor to directly split water to give hydrogen and oxygen gas using solar energy. The research projects involve designing and synthesizing sensitizer molecules; development of photoelectrode; development of photoreactor incorporating the photoelectrode for water splitting and testing of the integrated system under simulated or real conditions.

This book consists of a collection of short papers from Solar Hydrogen researches at the Fuel Cell Institute and Faculty of Science and Technology, UKM. The information reported in these papers is new and supports the master plan and the research direction of Solar Hydrogen research group. In addition, the research programme is also working along the direction of the Fuel Cell and Hydrogen Technology programme for the Renewable Energy Niche.

An appreciation goes to Dr. Siti Fairus Binti Mohd Yusoff, Dr. Lorna Jeffery Minggu and Dr. Khuzaimah Arifin for reviewing the manuscripts for this book.

Mohammad B. Kassim

December 2014

SECTION I

PHOTOCURRENT GENERATION WITH ADDITION OF METHANOL, FORMALDEHYDE AND FORMIC ACID

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INTRODUCTION

Hydrogen (H_2) has the potential to be a mobile energy carrier in the future. It contains high energy density and produces only water at end use [1]. However, in the current stage, most of the H_2 gas was produced from methane-steam reforming process which produces greenhouse gas (mainly carbon dioxide) [2].

In contrast, photoelectrochemical H_2 production from water splitting reaction is a zero emission of greenhouse gas process. It uses naturally available solar energy and water resources. However, this process remains in low efficiency due to the limitations of the materials used as photocatalysts [3]. In these recent years, H_2 production using photoelectrochemical cells to produce H_2 gas from biomass-derived oxygenates was proposed [4]. This method has several advantages against the conventional H_2 gas production from biomass. This PEC system can operate at a lower temperature in a smaller scale, and the separation of product gas is much easier [5]. Besides, the thermodynamic voltage requirement of oxygenate species is much smaller than the electrolysis of water [6]. These oxygenates can also improve the photocurrent generation (or hydrogen production rate) by suppressing electron-hole pair recombination at the photoelectrode [7].

Tungsten trioxide (WO_3) is one of the suitable materials for photoelectrochemical water splitting reaction. It has received much attention because of its smaller band gap (2.8 eV), high stability in acidic conditions, no photo-corrosion and its valence band position is sufficiently low to oxidize water molecules [8]. It is also a mild oxidation agents that can oxidize oxygenates species.

The performance of WO_3 in H_2 production was evaluated in this paper based on the photocurrent density generated during the photoelectrochemical reactions.

RESULTS AND DISCUSSION

The photocurrent was measured in different concentration of additives under 1000 W/m^2 xenon lamp irradiation with 0.5 M Na_2SO_4 as supporting electrolyte. All samples were purged with argon gas for 30 minutes before the photocurrent measurement.

As seen in Figure 1, the photocurrent generation was improved with the addition of methanol. The photocurrent density increased as the concentration of methanol increased. The photocurrent production was improved from 0.65 mA/cm^2 to 2.0 mA/cm^2 by the addition of 4 M methanol.

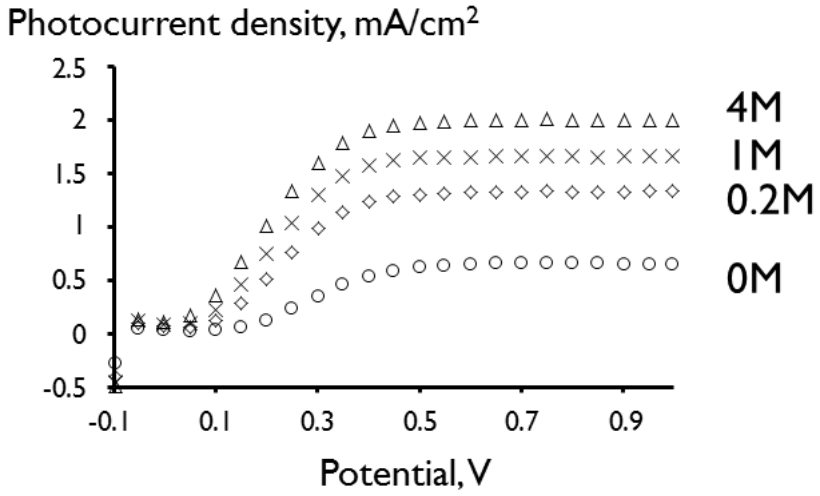

Fig. 1. Photocurrent density of WO_3 in different concentrations of methanol.

The photocurrent generation was further improved to 2.1 mA/cm^2 with an additional amount of formaldehyde (shown in Figure 2). In a PEC that contained lower concentration of additives (0.2 M and 1.0 M), the photocurrent produced by WO_3 was higher in the electrolyte contained formaldehyde compared to methanol.

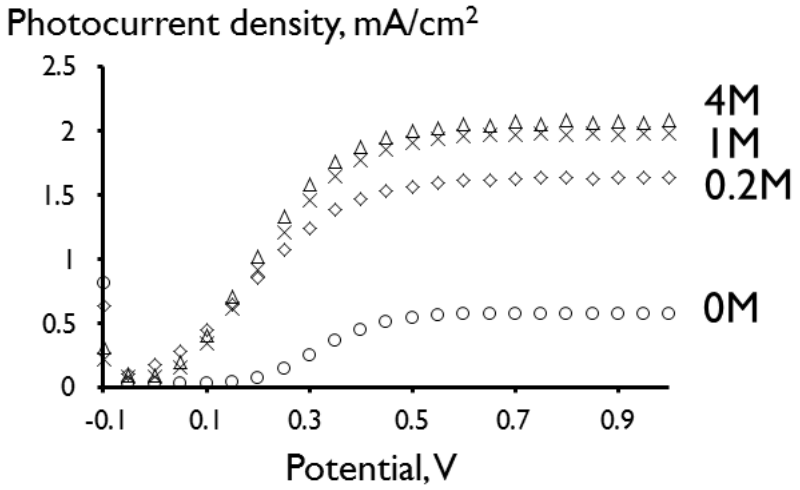

Fig. 2. Photocurrent density of WO_3 in different concentrations of formaldehyde.

Photocurrent generation with an electrolyte containing 4 M formic acid was similar to formaldehyde. However, the saturation of photocurrent shifted to a higher potential compared to a PEC containing methanol and formaldehyde electrolytes. This might be due to the pH changed after the addition of formic acid.

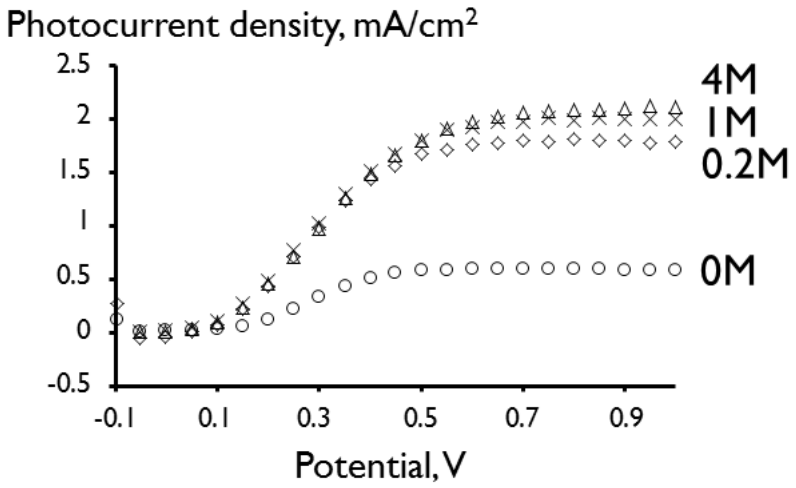

Fig. 3. Photocurrent density of WO_3 in different concentrations of formic acid.

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