Efficient Photoelectrochemical Production of Hydrogen from Water by a Carbon Modified (CM)- n-TiO_2 Thin Film Electrode

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INTRODUCTION

Much studies (1-9) were made on n-TiO_2, semiconductor after it was found by Fujishima and Honda (1) to photosplit water to hydrogen and oxygen gas. Other applications of n-TiO_2 were found in wet solar cells for the generation of electricity and in photocatalytic decomposition of organic compounds. In most applications n-TiO_2 samples were prepared by sol-gel method except few by thermal flame oxidation of Ti metal (2) and spray pyrolytic deposition (SPD) methods (5, 8, 9). The advantage of thermal flame oxidation method is that it can generate lower bandgap carbon-modified (CM)-n-TiO_2 thin film electrodes for efficient photoelectrochemical water splitting to hydrogen and oxygen gases (2). In this study we focused on fabricating the thin films of n-TiO_2 by thermal flame oxidation of Ti Metal sheet by a using a custom designed burner (C.M. Knight Co.) and characterized the thin films by photocurrent, UV-Vis, X-ray diffraction (XRD) and EDAX measurements.

EXPERIMENTAL

Thin films of n-TiO_2 were fabricated by thermal flame oxidation of Ti-metal sheets of 0.2 mm thick and 3.0 cm^2 area Ti metal sheet (Strem Co.). Different flame oxidation temperatures of 800 to 880°C and oxidation times of 5 to 20 min were used to optimize the synthesis. The electrolyte solution used for water splitting was 5.0 M KOH in a 18 ohm^{-1} triple ionized water.

RESULTS AND DISCUSSION

The Figure 1 and 2 show the photocurrent density and the photoconversion efficiency for the hydrogen and the oxygen production from water at CM-n-TiO2 thin film electrodes respectively. The photocurrent density of 5.55 mA cm^{-2} (**Fig. 1**) at light intensity of 40 mW cm^{-2} from a 150 watt xenon-arc lamp generated a maximum photoconversion efficiency of 12.0 % (**Fig. 2**) at an applied potential of 0.3 volt vs E_{aoc} (=- 1.0 volt/SCE)where E_{aoc} is the electrode potential at the open circuit condition. The results of X-ray diffraction indicated mainly rutile structure for CM-n-TiO_2 thin films prepared at flame temperature of 825 ^oC and oxidation time of 15 minutes. EDAX data showa a 7.4 atom % carbon doping and monochromatic photocurrent data and UV-Vis data showed two bandgaps of 2.6 eV and 1.65 eV depending the degree of carbon doping on different depths of the thin films of CM-n-TiO_2. These bandgap lowering helped to enhance the photoresponse and the photoconversion efficiency to a considerable extend.

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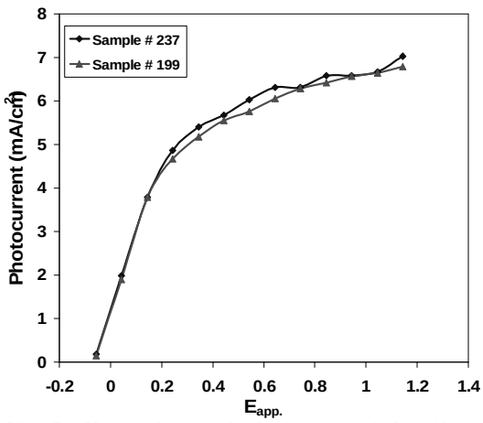

Fig. 1. Dependence of photocurrent density on applied potential vs SCE in 5.0 M KOH solution at light intensity of 40 mW cm^{-2} from a 150 watt xenon lamp.

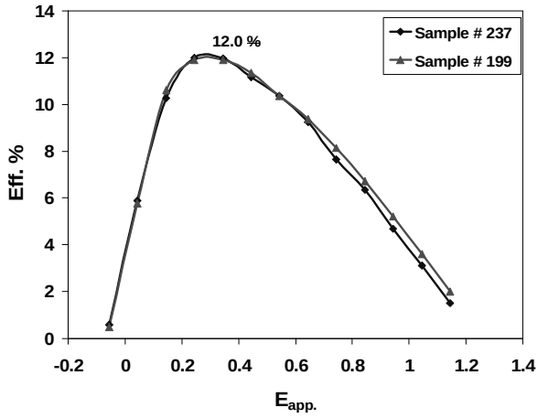

Fig.2. The % photoconversion efficiency E_{eff} %) as a function of applied potential.