Experimental Thermal and Fluid Science 35 (2011) 180–189

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

An on sun parametric study of solar hydrogen production using WO_3 photoanodes

Christopher K. Halford [a,*], Robert F. Boehm [b,1]

[a] UNLV Center for Energy Research, 4505 S. Maryland Parkway, Las Vegas, NV 89154, United States
[b] UNLV Center for Energy Research, 4505 S. Maryland Parkway, UNLV Box 454027, Las Vegas, NV 89154-4027, United States

ARTICLE INFO

Article history:
Received 22 March 2010
Received in revised form 13 June 2010
Accepted 31 August 2010

Keywords:
Solar
Hydrogen
WO_3
Tungsten trioxide
Water splitting

ABSTRACT

The solar production of hydrogen using photoactive electrodes is a topic receiving much attention in recent years. The use of thin metal oxide films as photoanodes allows the water splitting reaction to occur at a much lower applied voltage than would be necessary with a straight electrolysis process. The University of Nevada Las Vegas in collaboration with the UK based firm Hydrogen Solar and funded by the United States Department of Energy, has developed a prototype of this type of cell using a WO_3 photoanode. An on-sun test facility has been constructed by the UNLV Center for Energy Research (CER) where a study is being conducted with regard to the effects various design parameters on the rate of hydrogen evolution. Parameters being studied include electrolyte temperature, electrolyte flow rate, electrolyte resistivity, applied voltage, and membrane to electrode spacing. The data collected is used in a parametric study of the cell performance. The results of this study are then used to establish general trends as to the effects of these parameters on the performance of the cells outside of a laboratory environment.

1. Introduction

The splitting of water into its elemental components can be achieved at a theoretical minimum potential difference of 1.23 V under standard conditions. In conventional electrolysis, this energy is supplied from an external source such as a battery or solar panel. The use of thin film photoactive materials as electrodes allows for the reduction and possible eventual elimination of any external voltage source. In addition to eliminating the need for a separate power source, the photoactive material used in these types of cells is quite inexpensive when compared to photovoltaic panels. With the development of the right semiconductor material, cells could be produced to output hydrogen and oxygen with water and sun as the only inputs. Much of the current literature is devoted to altering the bandgap of these types of materials (mainly TiO_2 and WO_3) to maximize absorption of the solar spectrum and eliminate the need for an external bias [1–21]. These cells are typically tested under simulated solar illumination. Artificial light sources are convenient because they are stationary and their intensity is relatively constant over time. Testing on-sun, while more difficult, has the advantage of more accurately representing the standard AM 1.5 spectrum [22]. In [23] it is shown that use of a xenon lamp can lead to a large overestimation of photoconversion efficiencies compared to efficiencies under the standard AM 1.5 spectrum. This is mainly due to the fact that the xenon lamp emits a significant photon flux below 250 nm whereas the there is essentially no emission below 300 nm for the AM 1.5 standard. This deviation of artificial light sources from the actual solar spectrum is also noted in [24–26].

This writing serves to document the joint research project involving UNLV and the UK based firm "Hydrogen Solar" created for the purpose of studying these types of PEC devices under realistic operating conditions. CER was tasked with the design and construction of an outdoor test facility as well as the development of a suitable outdoor test procedure which would explore the effects of various input parameters on cell performance. The photoactive WO_3 anodes for the devices were to be developed at Hydrogen Solar's Henderson, NV laboratory. It is worthwhile to note here that this aspect of the project is not the focus of this report and UNLV had no input into the development of the photoanodes except to specify the size of the units. Instead, the purpose of this article is the documentation of the work performed by the CER for this study. This includes the development of the test facility, test procedures, and cells, as well as the results and analysis of one of the initial parametric studies.

2. Experimental setup

2.1. Design and construction of test facility

Before the testing could commence, it was first necessary to construct a test platform which would allow for the control of the following key system parameters:

* Corresponding author. Address: 7202 East Cactus Road, Apt #7312, Phoenix, AZ 85032, United States. Tel.: +1 702 727 7958.

E-mail addresses: ckhalford@gmail.com (C.K. Halford), boehm@me.unlv.edu (R.F. Boehm).

[1] Tel.: +1 702 895 4160.

0894-1777/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2010.08.019