Journal of Power Sources 196 (2011) 4388–4395

Contents lists available at ScienceDirect

Journal of Power Sources

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

Optimized hydrogen generation in a semicontinuous sodium borohydride hydrolysis reactor for a 60 W-scale fuel cell stack

G.M. Arzac [a,*], A. Fernández [a], A. Justo [a], B. Sarmiento [b], M.A. Jiménez [b], M.M. Jiménez [b]

[a] Instituto de Ciencia de Materiales de Sevilla, CSIC-Univ. Sevilla, Américo Vespucio 49, Isla de la Cartuja, Seville, Spain
[b] Hynergreen Technologies, S.A., Campus Palmas Altas, Seville, Spain

ARTICLE INFO

Article history:
Received 5 August 2010
Received in revised form
24 September 2010
Accepted 25 October 2010
Available online 3 November 2010

Keywords:
Hydrogen storage
Portable applications
Borohydride hydrolysis
Semicontinuous reactor

ABSTRACT

Catalyzed hydrolysis of sodium borohydride (SBH) is a promising method for the hydrogen supply of fuel cells. In this study a system for controlled production of hydrogen from aqueous sodium borohydride (SBH) solutions has been designed and built. This simple and low cost system operates under controlled addition of stabilized SBH solutions (fuel solutions) to a supported CoB catalyst. The system works at constant temperature delivering hydrogen at 1 L min^{-1} constant rate to match a 60-W polymer electrolyte membrane fuel cell (PEMFC). For optimization of the system, several experimental conditions were changed and their effect was investigated. A simple model based only on thermodynamic considerations was proposed to optimize system parameters at constant temperature and hydrogen evolution rate. It was found that, for a given SBH concentration, the use of the adequate fuel addition rate can maximize the total conversion and therefore the gravimetric storage capacity. The hydrogen storage capacity was as high as 3.5 wt% for 19 wt% SBH solution at 90% fuel conversion and an operation temperature of 60 °C. It has been demonstrated that these optimized values can also be achieved for a wide range of hydrogen generation rates. Studies on the durability of the catalyst showed that a regeneration step is needed to restore the catalytic activity before reusing.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

Proton-exchange membrane fuel cells (PEMFC) are promising and attractive candidates for meeting the power demands of portable applications [1]. In PEMFCs hydrogen and oxygen are converted by an electrochemical reaction and produce electric energy with water vapour as its sole by-product [2]. For a power generation system based on PEMFC, hydrogen must be supplied at a constant rate and free from carbon monoxide to prevent catalyst poisoning [3]. Among hydrogen storage compounds, sodium borohydride (SBH) has attracted attention due to its high theoretical hydrogen content and the excellent stability of its solution at a high pH value at ambient temperature. Recent review articles on this topic can be found in Refs. [4] and [5]. Furthermore, carbon monoxide free hydrogen can be released from the hydrolysis of SBH alkaline solution in the presence of certain catalysts [6,7]. The maximum storage capacity of sodium borohydride solutions is limited by the formation of hydrated borates during the reaction Eq. (1). In certain conditions these compounds may precipitate from the solution and damage the catalyst [8].

$$NaBH_4 + (2+X)H_2O = NaBO_2{\cdot}XH_2O + 4H_2 + Q \qquad X = 2\text{–}4 \qquad (1)$$

Cobalt boride is a well known and often selected catalyst as it is easy to synthesise and is not as expensive as precious metals [9]. For certain applications, it is preferred to support the catalyst on proper substrates such as Ni foam [10].

Many systems based on SBH hydrolysis have been designed [11–15]. Any design must take into account the exothermic character of the reaction and the fact that constant hydrogen rates only occur at constant temperatures [16]. That control over temperature can be achieved through proper design: immersing a batch reactor in a water bath, operating the reactor under constant flow of reactants and products [11], or just adding stabilized SBH solutions at a certain rate. To the best of our knowledge, there have not been many studies in which control over temperature is achieved by simply controlling the SBH solution supply rate [11–14]. In any case in these papers no simultaneous optimization of storage parameters was found. That is the main reason why we consider of high interest to undertake a research for optimizing both conversion and hydrogen storage capacity in a semicontinuous reactor at constant hydrogen evolution rate. The here presented simple and low-cost design is adapted for portable applications.

These SBH hydrolysis based systems do not store hydrogen in a reversible way but they work at temperatures below 80 °C and

* Corresponding author. Tel.: +34 954489531; fax: +34 954460665.
E-mail address: gisela@icmse.csic.es (G.M. Arzac).

0378-7753/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.jpowsour.2010.10.073