INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 38 (2013) 10364–10372

Available online at www.sciencedirect.com

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

Activated carbon from grass – A green alternative catalyst support for water electrolysis

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ARTICLE INFO

Article history:
Received 21 January 2013
Received in revised form
1 June 2013
Accepted 7 June 2013
Available online 8 July 2013

Keywords:
Grass
Activated carbon
Catalyst support
Electrochemical studies
Hydrogen
Water electrolysis

ABSTRACT

Grass blades (turf grass) have been selected as a cheap biomass source of producing activated carbon for supporting Pt particles for utilizing as electrocatalyst for H_2 generation through electrolysis of water. Activation is done using $ZnCl_2$ followed by thermal processing at 250 °C. 1% Pt was supported over the grass derived activated biomass carbon (G-ABC) powder to result in Pt@G-ABC. After physical characterization, Pt@G-ABC sample has been tested for its catalytic activity in 1 M sulfuric acid solution for H_2 gas generation through Linear Sweep & Cyclic Voltammetry. Cost factor involved in the production of G-ABC has also been compared with the traditional commercially available carbon support. The studies suggest that grass may be considered not only as a potential alternative source for producing carbon supported catalyst for H_2 generation but also highlight the production of low-cost carbon for further applications like electrode materials, adsorbent for color, odor and hazardous pollutants.

1. Introduction

Hydrogen is a promising energy source and hence significant research is currently being focused to test its feasibility to meet the world energy demand [1,2]. It is also ideal from an environmental standpoint—it burns cleanly producing water as the only product. Invariably it is stored in nature as water and hydrocarbons and one has to expend energy to generate H_2 from either water or hydrocarbons. A number of production methods including water electrolysis, steam reformation of natural gas, and coal gasification are the foci of widespread production research; but water electrolysis is one of the renowned technologies which provide domestically viable, CO_2 neutral and non-polluting H_2. Noble metal like Pt or Ru based electrocatalysts are being employed for producing H_2 by electrolyzing water. Generally electrocatalysts are prepared by loading or supporting fine Pt or Ru particles on quality carbon powders – the so called catalyst support, such that more number of active sites will be available for efficient and complete electrolysis. In fact carbon black suits well for catalyst support applications [3,4]. Vulcan XC-72 is the most utilized conducting carbon for fabricating electrocatalysts for water electrolysis for hydrogen gas generation [5,6]. But electrocatalysts are costly, hampering widespread commercialization of water electrolysers. Consequently, there are two directions in which the cost factor can be addressed. Firstly, usage of less noble metal as catalysts and secondly, to use low-cost carbonaceous materials on which the metal particles

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0360-3199/$ – see front matter
http://dx.doi.org/10.1016/j.ijhydene.2013.06.022

can be supported. In fact our work aims at achieving the second factor by producing carbon support powders from a cheap and abundantly existing resource namely the biomass of grass blades. Obviously, the significance of adopting different types of biomass materials as starting materials in producing carbon electrodes lies in its abundance, low cost, simple and green methodologies in obtaining the carbon and the ability to become highly porous carbon or to get desired physical features after carbonization procedure.

Carbon materials function as a unique material and are characterized by high specific surface area and tunable porosity just to find utility in many vital technologies namely, energy conversion (fuel cells and solar cells), energy storage (super capacitors, batteries and H_2 sorption), sensors, environmental production of fine and bulk chemicals and catalysis [7,8]. The choice of carbon as the electrode material is because of its unique properties of electrical conductivity and structural diversity. In addition to being good catalyst and catalyst support, carbon materials are effective in removing pollutants (both gaseous and liquid). Further carbon materials being insensitive to toxic substances and corrosive (acidic and basic) environments, its regeneration is possible and easy, rendering the industrial use of carbon materials an economically viable option [9,10]. A fact observed by researchers that the specific physico-chemical properties that make carbon materials a potential adsorbent for pollutants are high specific surface area, porous architecture, high adsorption capacity and surface functionality [11]. Carbon consists of a highly porous structure with hydrophobic graphene layer as well as hydrophilic surface functional groups making them beneficial for sorption and catalytic applications.

It is now realized that wastes are unutilized resources. Hence chemical recycling of wastes has been recognized as one of the suitable methods of waste management and also to recover valuable products, the net result is zero-waste world. There have been many attempts to obtain low-cost carbon (activated) from agricultural wastes such as sunflower shell [10], pinecone [12], cotton residues [12], olive residues [12], wheat [13], corn straw [13], olive stones [14,15], bagasse [14,15], birch wood [14,15], miscanthus [14,15], rapeseed [16], pine rayed [17], eucalyptus maculata [17], sugarcane bagasse [17,18], rice hulls [18], pecan shells [18], grape seeds [19], cherry stones [19], hazelnut shells [20], apricot stones [19,20], almond shells [19,21], peach stones [22], straw [14,15,23], oat hulls [24,25], corn stover [24,25], peanut hull [26], nut shells [19,27–30], corn cob [22,31–33], corn hulls [25], rice husks [34,35], rice straw [18,36] and used tea refuse [37]. An exhaustive report on the various classes of biomass used for supercapacitor, batteries and fuel cells has been made by the authors of the present paper [38]. Although the above biomasses have been utilized as resources for obtaining carbon powders for fabricating electrodes for the aforesaid energy devices, there has been no report on the usefulness of these biomass carbons as a catalyst supporting material. As for the knowledge of the authors of this communication goes, Kang et al. [39] describe a method of using grass for obtaining carbon nanotubes. Thus the reports on the utilization of grasses are only limited and so the current work may likely to get attention from researchers working on non-conventional energy sources and environmentalists as well.

Carbons have many advantageous features over metal oxide catalyst supports such as (i) a high specific surface area up to 3000 $m^2 g^{-1}$, (ii) high stability in acidic and basic media, and (iii) easy recovery of supported metals by burning off the carbon. However, only specific carbon materials belonging to the class of carbon blacks namely Vulcan XC-72 [5,6] and black pearls 2000[1] (both from Cabot Corp.) and activated carbon material viz Nuchar carbon (from MWV corp.) with surface area 1400–1800 $m^2 g^{-1}$ have been used as catalyst support.[2] Recently, Andersen et al. [40] have employed carbon nanofiber and carbon nanotube as catalyst support for PEM fuel cells. So finding conductive carbon support for electrocatalyst is an entirely new concept of research, which has not been reviewed that much elsewhere. Thus for our work we have planned to use hitherto unutilized and novel biomass waste namely *grass* to convert into active carbons for possible application as conductive support for electrocatalyst for water electrolysis for H_2 gas evolution. Our work therefore represents an essential, easy and innovative strategy to produce carbon powders from grass that may have electronic, scientific and industrial applications as conductive support for electrocatalysts for H_2 gas generation through electrolysis of water and the results have been presented in a simplified and systematic way. The work also stresses Green Energy from Waste concept, which is the want of the hour.

It is to be stated that though there are hundreds of varieties of grasses exist comparison of properties of them serves another important and interesting theme of research, but right now it is not our intention.

It may be interesting to the readers of this article for the fact that a database called *Phyllis* containing information on the composition of biomass and wastes is now available at http://www.ecn.nl/phyllis/ constructed at Energy Research Centre of The Netherlands. Phyllis enables making analysis data of individual biomass or waste materials available and offers the possibility to obtain the average composition of any combination of groups and/or subgroups.

2. Experimental

2.1. *Preparation of grass derived activated biomass carbon (G-ABC)*

A view of the freshly plucked turf grass bunch can be had from Fig. 1. Mature blades of turf grass bunches were collected from our Institute lawn, washed several times with hot distilled water to remove soil, dust and dirt and were dried under sun shade. The dried grass blades were shredded into small pieces and added to a solution of $ZnCl_2$ taken in the ratio of 1:1 w/w of biomass:$ZnCl_2$. The contents were maintained at 60 °C for 48 h and finally heat treated at 250 °C for 2 h for charring.

The char was washed several times with doubly distilled water until all the $ZnCl_2$ is completely removed. Absence of Zn^{2+}, Cl^-, neutrality in pH and low conductivity of the washings ensures thorough washing of the sample. The powder

[1] www.cabot.com.

[2] http://www.meadwestvaco.com/mwv/groups/content/documents/document/mwv039306.pdf.