

King Saud University

### Journal of Saudi Chemical Society

www.ksu.edu.sa www.sciencedirect.com



### **ORIGINAL ARTICLE**



# Activated carbon from orange peels as supercapacitor electrode and catalyst support for oxygen reduction reaction in proton exchange membrane fuel cell

M. Dhelipan<sup>a</sup>, A. Arunchander<sup>b</sup>, A.K. Sahu<sup>b</sup>, D. Kalpana<sup>b,\*</sup>

<sup>a</sup> Ingsman Energy and Fuel Cell Research Organization Pvt. Ltd, Chennai, India <sup>b</sup> CSIR – Central Electrochemical Research Institute – Madras Unit, CSIR Campus, Taramani, Chennai 600 113, India

Received 26 August 2016; revised 16 December 2016; accepted 20 December 2016 Available online 28 December 2016

### KEYWORDS

Orange peels; Activated carbon; Surface area; Supercapacitors; PEM fuel cell; Catalyst support **Abstract** Activated carbon is synthesized using orange peel as precursor through chemical activation using  $H_3PO_4$  and its ability as electrocatalyst support for ORR reaction is examined. The prepared material was subjected to various structural, compositional, morphological and electrochemical studies. For ORR activity, the platinum loaded on activated carbon (Pt/OP-AC) was investigated by cyclic voltammograms (CVs) recorded in  $N_2$  and  $O_2$  saturated 0.1 M aqueous HClO<sub>4</sub>. For supercapacitor performance, three electrode systems was tested in aqueous  $H_2SO_4$  for feasibility determination and showed electrochemical Scleetorchemical surface area (ECSA) of the activated carbon from orange peel is measured using CV. The physical properties of the prepared carbon are studied using SEM (scanning electron microscope), XRD (X-ray diffraction), Fourier transform infrared (FT-IR) spectroscopy and Raman spectroscopy. The AC derived from orange peels delivered a high specific capacitance of 275 F g<sup>-1</sup> at 10 mV s<sup>-1</sup> scan rate. Hence, this study suggested that orange peels may be considered not only as a potential alternative source for synthesizing carbon supported catalyst for fuel cell application but also highlight the production of low-cost carbon for further applications like supercapacitors.

© 2017 King Saud University. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

\* Corresponding author. Fax: +91 044 22544526. E-mail address: drkalpanaa@gmail.com (D. Kalpana). Peer review under responsibility of King Saud University.



#### 1. Introduction

Polymer Electrolyte Membrane Fuel Cell (PEMFC) has viable potential as next generation power source, especially for portable applications due to its high power density and zero or low emission of pollutant [1–4]. However, commercialization of fuel cell is hindered by high cost and limited resource of platinum catalyst. Prodigious research efforts have been made

http://dx.doi.org/10.1016/j.jscs.2016.12.003

1319-6103 © 2017 King Saud University. Production and hosting by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

to overcome the cost of fuel cell by using non-noble catalyst and ultra-low platinum catalyst with high surface area catalyst support. Carbon has more advantage than metal oxides as electrocatalyst support in terms of high specific surface area, high stability in acidic and basic media and easy recovery of metal catalyst by burning off the carbon support. The widely used material as electrocatalyst support is carbon black but it still suffers from setbacks like corrosion and deep micro porous, where the catalyst nanoparticles are trapped and failed to achieve three phase interface. However in the past decades, many efforts have been done for fabricating high surface area activated carbon (AC) from agricultural waste such as grass, nut shells etc. [5], which would drastically reduce the cost of production of activated carbon. Conversion of waste into AC reduces the cost of waste disposal and provides an economic alternative to the conventional method of fabricating AC [6]. Many literatures are available for synthesizing low cost AC from agriculture waste such as groundnut shell [7], coconut shell [8], palm oil shells [9], mango nuts [10], olive stone [11], waste cherry stones [12], Neem husk [13], Peanut hulls [14], paper mill sludge [15], banana fibres [16], sunflower seed oil [17] and sugarcane bagasse [18] etc. But very few literatures are available on using AC derived from orange peels as electrocatalyst support for fuel cell application.

Activated carbons are mostly used in commercial supercapacitors as electrode material because of their good electrochemical stability, high surface area, electrochemical properties etc. As the application of AC is increasing day by day, the large scale production of AC is hindered by increasing raw material cost and less availability of precursors. However fossil fuels do not meet this demand as they are not renewable in nature. Hence, utilization of bio-waste as precursor for production of AC can fulfil the demand because of their low-cost accessibility.

In this work, orange peels (Citrus Sinensis) are utilized as a precursor for production of activated carbon and the same will be used as a support material for platinum catalyst. The orange peels are chemical activated using H<sub>3</sub>PO<sub>4</sub> acid. Fernandeza et al. synthesized activated carbon from orange peels using H<sub>3</sub>PO<sub>4</sub> acid as a activator for removing basic dyes (methylene blue and rhodamine B) from single and binary dyes solutions in continuous and batch modes. This type of activated carbon from orange peels has high surface area of 1090 m<sup>2</sup> g<sup>-1</sup> [19] which is higher than commercially used Vulcan XC-72 (250 m<sup>2</sup> g<sup>-1</sup>) [20]. Arie et al. used AC from orange peels as an electrode material for lithium ion capacitors [21]. The physical morphology of the prepared AC will be analyzed using SEM, XRD and Raman shift. Furthermore the electrocatalytic properties of the electrode coated with platinum reduced carbon support will be studied using CV and LSV. Fuel cell performance of the MEA fabricated using the prepared electrode for ORR will be studied using fuel cell workstation. This type of AC using orange peels as precursor for fuel cell catalyst support is first of kind ever reported.

### 2. Experimental

## 2.1. Preparation of orange peels derived activated carbon (OP-AC)

The orange peel was dried at 100 °C for 8 h. In a typical synthesis experiment, 60 g of orange peel was mixed with 15 g of

phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) in 100 mL of distilled water. The mixture was stirred at room temperature for 24 h and then dried in a furnace at 100 °C. Carbonization was performed in a tube furnace under argon gas flow and at a heating rate of 600 °C. The maximum temperature was held for 24 h. The carbonized samples were rinsed with distilled water followed by acetone, filtered and then dried at 100 °C for 24 h.

## 2.2. Preparation of Pt/OP-AC electrode for electrochemical studies

Pt was successfully deposited on OP-AC by chemical reduction method. Typically, 0.3 g OP-AC was dispersed in 50 mL DI water and sonicated for 30 min. Then, 200 mg H<sub>2</sub>PtCl<sub>4</sub> was dissolved in 50 mL of DI water and added to the carbon dispersion. The mixture was stirred for 1 h and 3 M NaBH<sub>4</sub> in 0.3 M NaOH solution was added to it. Further the mixture was stirred for 1 h for the reduction of Pt<sup>2+</sup> to Pt. The above mixture was filtered and washed thoroughly with copious amount of DI water. Then the product was dried at 80 °C overnight.

### 2.3. Physical characterization of OP-AC

Surface morphology of OP-AC is analysed using SEM image which is performed in Vega3Tescan. X-ray diffraction patterns were recorded between 10° and 90° on PW3040/60 X'pert PRO diffractometer with Copper radiation sources. Surface functionalities of the prepared OP-AC were identified using FT-IR (BrukerOptik GmbH), Raman spectroscopy was conducted to evaluate the graphitic character of the sample and the surface area of the sample is measured by BET method.

### 2.4. Electrochemical characterization of Pt/OP-AC

Electrochemical properties of the catalyst were measured by cyclic voltammetry (CV) and Linear Sweep Voltammetry (LSV) studies using BioLogic potentiostatat room temperature (25 °C). The glassy carbon (GC) disk electrode with the area of  $0.071 \text{ cm}^2$  was considered as the working electrode. Prior to use, the GC was polished with  $0.3 \mu$  alumina powder till to get mirror finish. To prepare the working electrode, Pt/OP-AC slurry was made by ultrasonically dispersing 2.13 mg Pt/ OP-AC in 0.9 mL DI water and 0.1 mL iso-propyl alcohol mixture with 5 wt% Nafion solution for 30 min. Then, 5 µL of the catalyst ink was dropped on to the top of the GC electrode and dried at room temperature to obtain Pt loading of  $30 \,\mu g \, \text{cm}^{-2}$ . A Pt wire and a saturated calomel electrode (SCE) were used as counter and reference electrodes, respectively in a standard three-electrode electrochemical cell. All potentials are reported in terms of the reversible hydrogen electrode (RHE) scale for convenience. Hydrogen adsorption-desorption voltammograms were recorded in 0.1 M HClO<sub>4</sub> aq. solution at a scan rate of 50 mV s<sup>-1</sup> purging with  $N_2$  gas to remove dissolved O2. The region for hydrogen adsorption between 0.05 V and 0.4 V vs. RHE on the backward potential scan was used to estimate the electrochemical surface area (ESA). Linear Sweep Voltammetry (LSV) for oxygen reduction reaction (ORR) measurements was performed in aqueous 0.1 M HClO<sub>4</sub> saturated with O<sub>2</sub> at a scan rate of 5 mV s<sup>-1</sup>. For supercapacitor performance, the electrode was prepared as

Download English Version:

# https://daneshyari.com/en/article/4909329

Download Persian Version:

https://daneshyari.com/article/4909329

Daneshyari.com