Renewable and Sustainable Energy Reviews 69 (2017) 862–870

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Graphene in electrocatalyst and proton conductiong membrane in fuel cell applications: An overview

N. Shaari[a], S.K. Kamarudin[a,b,*]

[a] Fuel Cell Institute, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[b] Department of Chemical and Process Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

ARTICLE INFO

Keywords:
Graphene
Electrocatalyst
Polymer electrolyte membrane
Fuel cell

ABSTRACT

This study elaborates the development and great attraction of graphene in fuel cell application. The main focus is to highlight the contribution of graphene based material in fuel cell application particularly used in two important part of fuel cell system that are electrocatalyst and polymer electrolyte membrane. This paper also introduces the graphene and its derivative such as graphene oxide (GO), reduced graphene oxide (rGO) and sulfonated graphene oxide (SGO) in terms of their special properties, advantages, disadvantages as well as the modification method. It also discusses the application and capability of graphene based material and CNT used in electrocatalyst material. Later it also highlights the application of graphene and its derivative as well as their achievement in fuel cell as proton conductor and efficient fuel blocker. Thus, it is bright future to see more development of graphene based material in fuel cell application. However, there are several challenges that can be big inhibitor of graphene and its derivative to be applied in various applications such as production volume limitation, cost, electrical properties, other material competition as well as health and safety issues. Finally, this study explains all the challenges and opportunity in commercialization.

1. Introduction

Currently, researchers are focusing on efforts to produce nano-size materials for optimal function. Among the advantages of nano-sized materials are their very high surface area to volume ratio and high absorption rate. Among the applications that take advantage of the material is nano-sized photovoltaic cells, where the rate of the absorption of solar energy is very high in the structure, which consists of nanoparticles. This shows that the smaller the particle size is, the higher the rate of absorption of solar energy. There are nanoscale materials of various types, including nanoparticles, nano-powders, nano-rods, nanotubes, and nanowires. Nanomaterials have multiple dimensionalities, including zero dimensional, 1-D, 2-D and 3-D. 1-Dimensional materials are widely used in various applications because of their high surface area and porosity [1]. Carbon-type material is one substance known to have good features, such as abundance, stability, environmental safety and high durability. They exhibit high chemical stability over a wide temperature range in both acidic and alkaline conditions, making them the most suitable candidates as electrodes in electrochemical energy devices. There are many available carbon allotropes, such as buckminsterfullerene, carbon nanotubes, graphene and nano-diamonds [2]. Graphene is considered an important asset in energy conversion and storage applications, with unique characteristics such as a high specific surface area (2630 $m^2\ g^{-1}$) [3], good chemical stability and excellent electrical conductivity. As Kotov [4] wrote in his review "When carbon fibers just won't do but nanotubes are too expensive, where can a cost-conscious materials scientist go to find a practical conductive composite? The answer could lie in graphene sheets".

This present review paper chose to focus on graphene applications as materials in fuel cells. A brief overview of graphene will be discussed first. Then, the application of graphene as electrocatalysts and membranes is discussed. Previous studies on the applications of graphene have been briefly listed in the tables. The challenges of graphene are also described in the review. Finally, a conclusion to the whole study is presented.

2. Graphene

Graphene, also known as the mother of all types of graphite, consists of a single layer of carbon atoms that forms a two-dimensional hexagonal lattice sheet, where it can form a fullerene, be rolled to form

* Corresponding author at: Fuel Cell Institute, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
E-mail address: ctie@ukm.edu.my (S.K. Kamarudin).

http://dx.doi.org/10.1016/j.rser.2016.07.044
Received 30 March 2015; Received in revised form 9 May 2016; Accepted 8 July 2016
1364-0321/ © 2016 Published by Elsevier Ltd.

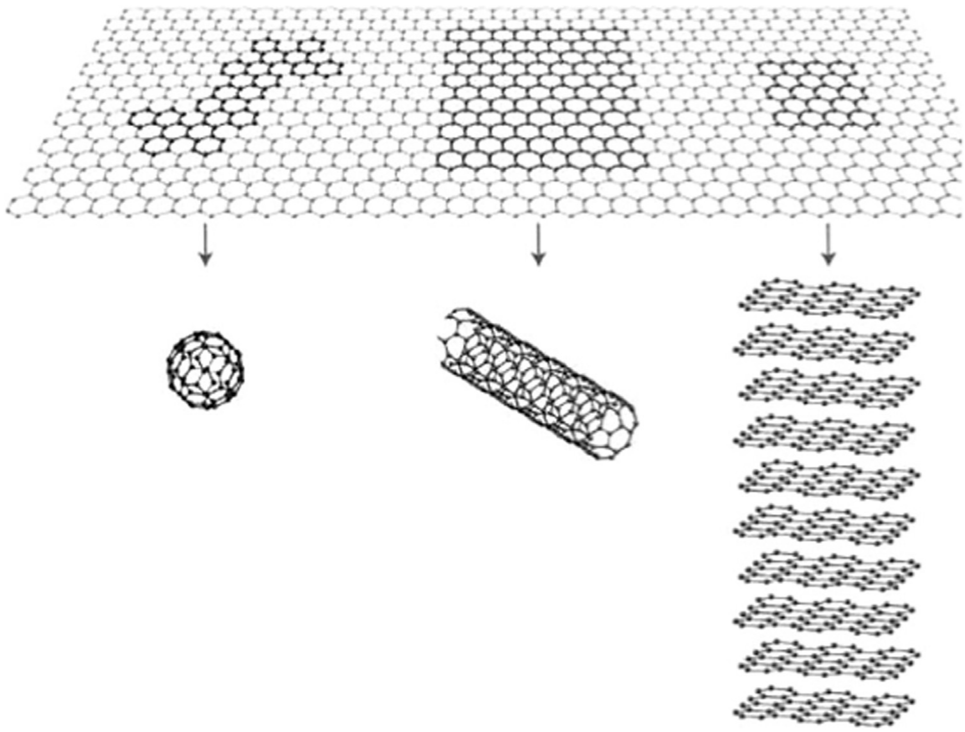

Fig. 1. Schematic representation of graphene, which is the fundamental starting material for a variety of fullerene materials; buckyballs, carbon nanotubes, and graphite. Re-modelled from Ref. [17].

a carbon nano tube (CNT), and arranged into graphite, as shown in Fig. 1. Graphene has been recognized as the strongest material based on mechanical experiments [5]. In essence, graphene is the same as carbon nano tube (CNT) in that it consists of only carbon atoms, but graphene is 2D flat sheet, and carbon nano tube (CNT) is in tubular form. Graphene consists of a network whose sp^2 hybridization is an important factor in determining its basic characteristics, such as mechanical properties and thermal and electrical conduction [6]. Methods for fabricating graphene include physical or chemical exfoliation, epitaxial growth via chemical vapor deposition (CVD), the unzipping of carbon nano tube (CNT) (via electrochemical, chemical, or physical methods), and the reduction of sugars (such as glucose or sucrose). Thus far, there is no single method of fabricating graphene that can produce graphene with optimal properties for all potential applications [7]. Graphene is widely known for its exclusive physical, chemical and thermal properties, and it is very appropriate for electrochemical applications in this field [8,9]. Surface area is an important factor in its application as an electrode for the production and storage of energy. Reports indicate that graphene has a surface area (~2630 $m^2\ g^{-1}$) greater than those of single wall carbon nano tube (SWCNT) and graphite, 1315 min^{-1} and 2–10 $m^2\ g^{-1}$, respectively [10]. Furthermore, graphene shows advantages in electrical conductivity, which is reported as high as ~ 64 $mScm^{-1}$, 60 times higher than single wall carbon nano tube (SWCNT), and can be maintained over a wide temperature range. It is particularly important in applications that involve energy [11,12].

There are more properties of graphene that make it suitable for energy applications. Graphene shows a half-integer quantum Hall effect even at room temperature, with the effective speed of light as its Fermi velocity F~106 ms^{-1} and graphene is also distinguished from its counterparts by its uncommon band configuration, in which its quasiparticles are equivalent to massless Dirac fermions [13–15]. A gate electrode can be used to control the charge density of graphene [14]. Charge carriers can be tuned constantly between electrons and holes, in which the movement of electrons is still high, although at high concentrations, in both electrically and chemically doped tools, which converts to ballistic passage on the submicrometer scale [8]. A single graphene nanosheet (GNS) suspended in a Si/SiO_2 electrode has shown that the movement of electrons in graphene is ultra-high, as high as 200,000 cm, 2 $V^{-1}\ s^{-1}$, at electron densities of ~$2\times10^{11}\ cm^{-2}$, compared with the movement of electrons in silicon, which is approximately ~ 1000 $cm^2\ V^{-1}$; this means that the movement of electrons in graphene is 200 times greater [16]. The special properties of graphene as a fast carrier have been continuously reported, and graphene is believed to show properties comparable to high-quality crystals, in which the charge carriers can move until thousands of interatomic distances without scattering though the existence of metallic impurities [17]. This statement proposes that if graphene is employed as a coupling agent, a transistor can permit an enormously high-speed process with low electric power utilization [17]. The graphene nanosheet (GNS) has the advantage of flexibility compared with graphite, enabling it to be used in electronics and energy storage devices that are flexible, instead of graphite, which is more fragile [10]. Another advantage of graphene that has a significant impact on its electrochemical performance is the existence of oxygen-containing groups on the edge or surface, which increases the rate of heterogeneous electron transfer [8]. In applications such as fuel cells and electrochemical batteries, functional groups such as oxygen species are very important in an 'anchoring' role for the attachment of glucose oxidase (Ei) Forus in a variety of power generation applications [18]. Graphene can be functionalized with groups such as oxygen that can facilitate the attachment of other elements. It is clear that the electrochemical properties of graphene-based electrodes can be improved by chemical modifications to increase their performance and suitability in particular applications [19]. Many topics are still being studied by researchers, such as whether the presence of oxide on the surface or defects in graphene will positively or negatively affect its electronic and chemical properties [8]. Graphene oxide (GO) is the most recognizable graphene derivative in the production of polymer-graphene nanocomposites due to its excellent mechanical and chemical properties that provide broad capabilities and widespread utilization. It is also suitable for various applications due to its high dispersibility and process ability in aqueous

Download English Version:

https://daneshyari.com/en/article/5483379

Download Persian Version:

https://daneshyari.com/article/5483379

Daneshyari.com