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Development of carbon nanotube/platinum electrocatalytic electrodes for proton exchange membrane fuel cell

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Abstract

The electrodes of a fuel cell are the sites where the electrical energy conversion takes place and they are considered as the heart of the proton exchange membrane (PEM) fuel cell. This work is aimed at preparation of these electrodes using locally available materials which are carbon nanotubes and platinum. Carbon nanotubes were synthesized using Swirled Floating Chemical Catalyst Vapour Deposition (SFCCVD) and conventional chemical vapour deposition (CVD) methods developed by Iyuke and Coville respectively. The SFCCVD method was used to produce various carbon nanomaterials such as nanoballs, nanofibres, diamond particles, and carbon nanotubes using acetylene gas carbon source and ferrocene as an iron catalyst precursor. The horizontal CVD reactor was used mainly to produce carbon nanotubes using acetylene gas as carbon source and a bi–metallic catalyst of iron and cobalt on a calcium carbonate support. The SFCCVD reactor was optimized and various carbon nanomaterials were produced at different experimental conditions of pyrolysis temperature, flow rate of acetylene, hydrogen and argon gases. A maximum production rate of 0.35 g/min was obtained at 1000°C, acetylene flow rate of 370 ml/min, hydrogen flow rate of 180 ml/min and a flow ratio of acetylene to hydrogen equal to five. This production rate allows for the future scale up of this equipment. These carbon nanotube samples were purified and functionalized with a mixture of concentrated H_2SO_4 and HNO_3, and used as support for a platinum catalyst using K_2PtCl_4 as platinum source and ethyl glycol as a reducing agent. The resultant catalyst samples are thermally stable up to 400°C and have platinum particles uniformly distributed on the CNTs with average size range between 1 and 8 nm. The various loadings of platinum on this carbon support were determined using UV

spectroscopic analysis of the filtrate before and after impregnation on the carbon material. A parametric study of the adsorption of platinum particles on CNTs indicates that an increase in stirring time and temperature increases the amount of platinum loaded on the CNTs. The cyclic voltammetric analysis of the resultant catalyst revealed that these catalyst samples showed electrocatalytic activity for both hydrogenation and oxygen reduction reactions. These catalyst samples were evenly cast on the carbon paper to make electrocatalytic electrodes which were subsequently bonded to a sulphonated membrane using a hot press method using constant conditions of temperature, pressure and time, to produce the membrane electrode assembly (MEA). The performance of the fabricated MEA was tested in a single PEM fuel cell using hydrogen as the fuel gas and oxygen as oxidant. Analysis of the results obtained shows that the cell performance increases with increase in platinum loading on the electrodes. A maximum voltage of 718 mV at 11.8 mA/cm^2 was recorded for the highest platinum loading. A Hitchenhofer's equation was used to model the performance of the electrode in the cell.