

Electrochemical characterisation of Pt/C suspensions for the reduction of oxygen

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Accepted 4 February 2005

Available online 28 April 2005

Abstract

Electrodes based on carbon-supported platinum electrocatalysts (Pt/C) have been studied in aqueous electrolyte electrochemical cells. The electrodes are prepared from suspensions of commercial Pt/C catalyst, deposited onto a carbon-covered Pt disk. Three deposition methods have been used, impregnation, spray and electrospray. The utilisation of Pt, i.e. the amount of Pt that really participates in the electrochemical reaction, was determined for each preparation method from measurements of the mass of Pt deposited on the electrode, and of the electroactive area of Pt. Higher utilisation rates are found on electrodes prepared by the impregnation method. The activity towards oxygen reduction in aqueous electrolyte was studied with the rotating electrode at different temperatures.

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Keywords: Polymer electrolyte membrane fuel cell (PEMFC); Electrospray; Oxygen reduction; Pt; Rotating ring disk electrode (rrde)

1. Introduction

So far, electrodes based on platinum nanoparticles are used for proton exchange membrane fuel cell (PEMFC), but their cost may hinder the future generalisation of the technology. The cost problem, and even the supply of Pt, will be increasingly acute in the next years considering that even the installation of state-of-the-art PEMFC of the highest efficiency, with the lowest platinum content ($0.4 \text{ mg Pt cm}^{-2}$) [1], in 10% of annually matriculated cars worldwide (75×10^6 U in 2001), would require more than the annual production of Pt (170 tonnes) [2]. To deal with this problem research effort must concentrate on the reduction of the amount of Pt in the electrodes, as well as the search for alternative electrocatalysts, notwithstanding other solutions like increasing Pt production, the search for new reserves and recycling technologies.

In principle, the platinum load in the electrodes can be reduced to a limit when attaining maximum utilisation, i.e. the maximum amount of Pt atoms participates in the electrochemical reactions with the highest turnover frequency. High turnover rates, as well as low overvoltages, are electrocatalyst-dependent properties necessary for high power fuel cells. If assuming that Pt atoms are able to support turnovers rates until $10,000 \text{ atom}^{-1} \text{ s}^{-1}$, which is a maximum number typical for enzymatic sites, then a monolayer of Pt should be able to support the electrocatalysis for a current density of almost 700 mA cm^{-2} . This value is in the range of currents demanded to present electrodes at 0.7 V. Such estimation may conclude that an ultimate limit for the amount of Pt in the electrode is the amount of a monolayer, $0.54 \text{ } \mu\text{g cm}^{-2}$. However, this number must be increased if considering that Pt is in the form of spherical particles of 5 nm diameter, where about 10% of atoms are in disposition to be catalytic sites (i.e. disregarding bulk and ‘buried’ atoms), to give a more realistic limit of $50\text{--}5 \text{ } \mu\text{g cm}^{-2}$. This load is still one to two orders of magnitude below actual loads and may be considered an objective for future Pt based

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