"Proton Exchange Membrane Fuel Cells: Materials Properties and Performance"

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Introduction

This book is part of the series "Green Chemistry and Chemical Engineering" published by CRC Press. The series aims to meet the challenges of the 21st century in chemistry and chemical engineering by detailing the development of alternative sustainable technologies. The present volume focuses on providing updated, detailed background information on key developments in material properties and performance for proton exchange membrane fuel cells (PEMFCs). Although PEMFCs are currently at an early commercialisation stage, and moving into volume commercialisation, significant technical challenges still remain. These include reliability, durability, cost, operational flexibility, technology simplification and integration.

The book's chapters are divided between the major components of the unit fuel cell, including: platinum group metal (pgm) catalysts, catalyst layers (CLs), membranes, diffusion layers, bipolar plates and materials modelling. This selective review covers the chapters on pgm electrocatalysts, CLs and diffusion layers.

Chapter 1: 'Recent Developments in Electrocatalyst Activity and Stability'

This chapter, by David Thompsett (Johnson Matthey Technology Centre, Sonning Common, UK), is successful in providing an overview of the wide range of electrocatalyst topics associated with hydrogen, reformate and direct methanol fuelled-PEMFCs. The chapter highlights the key aspects by means of examples, rather than attempting a comprehensive study of all areas. The chapter is subdivided into sections on pgm electrocatalyst discovery (combinatorial and computational approaches), preparation (conventional and more novel approaches) and testing (**Figure 1**), followed by

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detailed sections on the activity and stability of cathode oxygen reduction catalysts based on pgms. Finally there is a section on anode catalysts for hydrogen oxidation, reformate and direct methanol applications. Different types of non-carbon and carbon supports and the modification of carbon supports are also described, along with an overview of the mechanisms of support degradation and materials-based mitigation strategies.

There is a strong focus on materials composition and preparation aspects and how these are linked to performance and stability. Although less detail is provided on mechanistic aspects in some sections, clear references are made to recent reviews elsewhere. A wide range of catalyst preparation strategies are described, defined as conventional, colloidal, molecular precursor and surface modification.

Chapter 2: 'Catalyst Layers and Fabrication'

This chapter by Zhong Xie *et al*. (National Research Council of Canada Institute for Fuel Cell Innovation, Vancouver, British Columbia, Canada) provides an overview of the main types of CL used in PEMFCs. It is mainly directed at hydrogen-fuelled systems, rather than direct methanol fuel cell (DMFC) or other variants. After a general introduction, the chapter is organised into a description of the components of the CL and their functions; a description of the main types of CL; fabrication methods for the CLs and finally a section on their optimisation. Only platinum-based catalysts are considered, but several forms are covered, for example, unsupported (Pt black), carbon-supported and various directly deposited types (sputtered, electrodeposited, etc.) (**Figure 2**). In

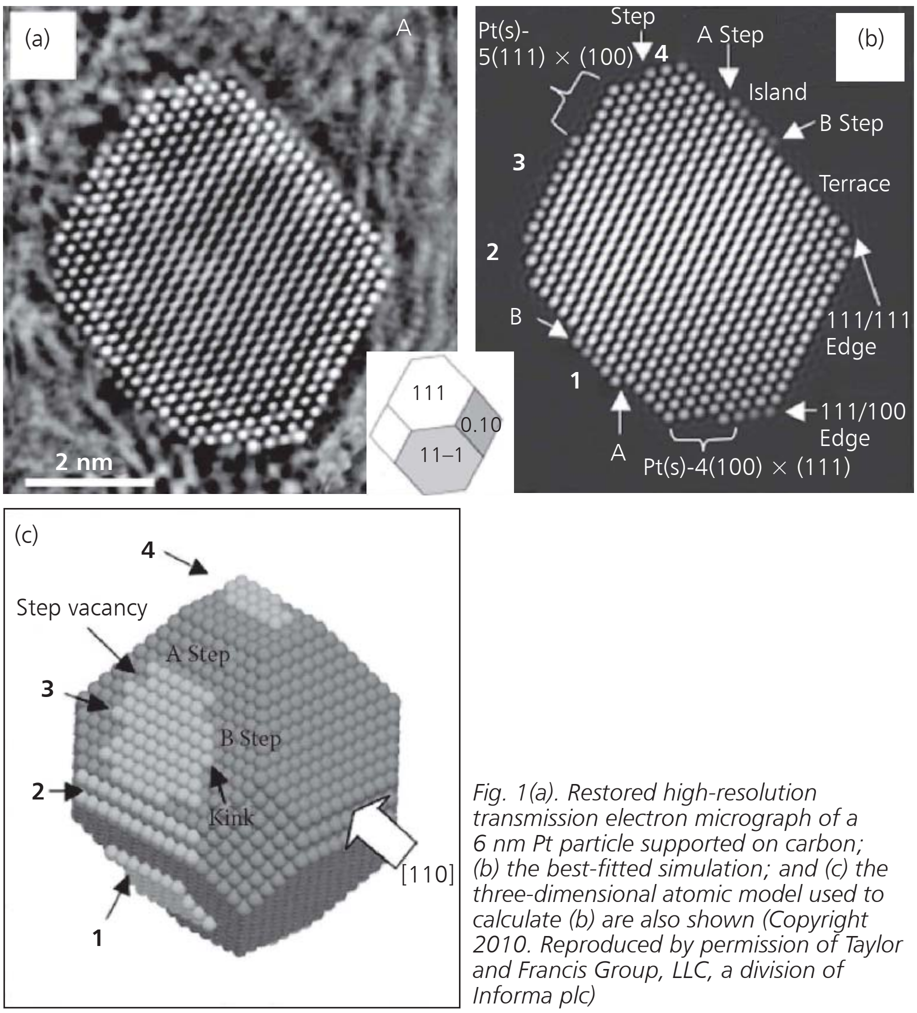

Fig. 1(a). Restored high-resolution transmission electron micrograph of a 6 nm Pt particle supported on carbon; (b) the best-fitted simulation; and (c) the three-dimensional atomic model used to calculate (b) are also shown (Copyright 2010. Reproduced by permission of Taylor and Francis Group, LLC, a division of Informa plc)

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terms of ionomers, Nafion is dominant, with a short section on non-perfluorosulfonic acid (non-PFSA) ionomers, but there is little reference to other fluoropolymer ionomers.

The writing is mostly clear, although there are several typographic errors, and sufficient references are included for those wanting more information. The chapter is not intended to be comprehensive and will suit those looking for a short introduction to this technology area. It is very similar in scope to Litster and McLean's chapter 'PEM Fuel Cell Electrodes' in "Fuel Cells Compendium" (1), and contains a number of the same examples. Quite a wide range of different fabrication techniques are covered from well established ink-based methods to more recent vacuum and laser deposition techniques.

Little analysis is provided on how the CLs function in practice or what the mechanistic effects are of changes in structure and composition. For a detailed analysis of PEM CLs, the chapter 'Principles of MEA Preparation' by Shyam Kocha in the "Handbook of Fuel Cells" (2) is recommended, or the book "PEM Fuel Cell Electrocatalysts and Catalyst Layers" edited by Zhang (3).

Chapter 4: 'Diffusion Layers'

Chapter 4 is a contribution from Mauricio Blanco and David Wilkinson (National Research Council of Canada Institute for Fuel Cell Innovation, Vancouver, British Columbia, Canada) and it covers the design, manufacture and fuel cell performance of the diffusion layers in hydrogen- and methanol-fuelled PEMFCs.

After a brief introduction to the purpose of the diffusion layer and the driving forces for improvement, the structures of the various types of diffusion layer are discussed. The conventional carbon-based materials are covered, but more interestingly there are significant sections covering less common approaches, namely metal layers and the use of semiconductor fabrication techniques. As the authors admit, there is frustratingly little comparison between the fuel cell performance of the more exotic layers with the conventional carbon-based technology, but this not an omission; merely an accurate reflection of the state of the literature. There is more comparison of the relative merits of carbon papers and cloths during which, presumably due to the requirement for brevity, there is a tendency for generalisations to be made, based on limited and sometimes quite old literature. This might not reflect the current practice in the industry, but as the references are all provided the more sceptical reader can follow up the points of interest. The lengthy section on microporous layers is a good survey of this often neglected feature of the diffusion layer. The concluding section on characterisation techniques is

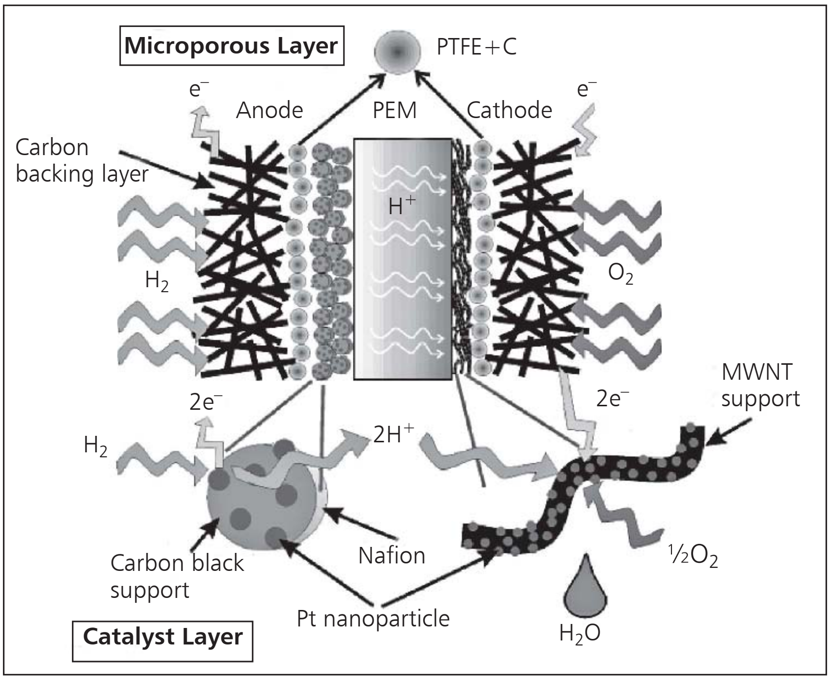

Fig. 2. Schematic of the hydrogen fuel cell architecture using an ultra-low platinum loading thin-film Pt/MWNT (carbon multiwalled nanotube) catalyst layer (Copyright 2010. Reproduced by permission of Taylor and Francis Group, LLC, a division of Informa plc)

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a useful compilation of the relevant properties of the layers and ways of evaluating them.

This chapter is well written and is extensively referenced with 279 citations. It is a useful introduction to those interested in starting work in this field as well as an extensive literature review for the more experienced practitioner.

Conclusions

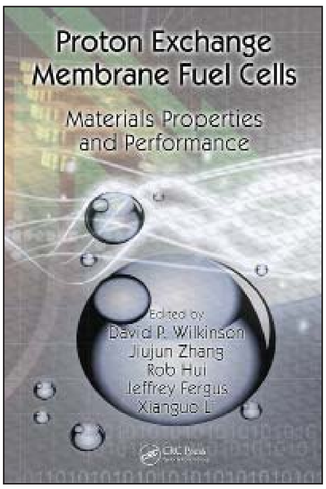
Overall, these chapters of the book provide a useful short introduction suitable for new workers entering the field, together with extensive literature reviews for those looking for more detail on the topics under discussion. The developments that have taken place in the area of fuel cell catalyst materials and properties will provide the background to increase the competitiveness of PEMFCs as one of the long term solutions to reduce reliance on fossil fuels and improve energy sustainability, security and efficiency. New materials, improvements in pgm-based catalysts and the associated engineering design and modelling are closing the technical gaps which will enable this to happen.

References

1 S. Litster and G. McLean, 'PEM Fuel Cell Electrodes', in "Fuel Cells Compendium", eds. N. N. P. Brandon and D. Thompsett, Elsevier, Oxford, UK, 2005

2 S. S. Kocha, 'Principles of MEA Preparation', in "Handbook of Fuel Cells: Fundamentals, Technology and Applications", eds. W. Vielstich, A. Lamm and H. A. Gasteiger, Wiley, Chichester, UK, 2003, Volume 3

3 "PEM Fuel Cell Electrocatalysts and Catalyst Layers: Fundamentals and Applications", ed. J. Zhang, Springer-Verlag, London, UK, 2008



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The Reviewers

Sarah Ball, who reviewed Chapter 1, is a Principal Scientist in the Fuel Cell Research Group at the Johnson Matthey Technology Centre (JMTC), Sonning Common, UK. She is interested in anode catalysis for reformate-tolerant applications, and novel cathode materials and pgm-containing alloys for PEMFCs.

Jonathan Sharman, who reviewed Chapter 2, is Fuel Cell Research Manager at JMTC and leads a group carrying out research into membrane electrode assemblies (MEAs) for PEMFC, DMFC and phosphoric acid fuel cell (PAFC) systems. With a background in materials science and electrochemistry, he has been active in fuel cell research for over nine years and is coauthor of a number of patents and papers on PEMFC MEAs.

Ian Harkness, who reviewed Chapter 4, is a Principal Scientist in the Fuel Cell Research Group at JMTC, where he has worked for more than ten years on the development of MEAs for both hydrogen- and methanol-fuelled PEMFCs.

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