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"Electrochemistry: Volume 14"

Edited by Craig Banks (Manchester Metropolitan University, UK) and Steven McIntosh (Lehigh University, Bethlehem PA, USA), Specialist Periodical Reports in Electrochemistry, Royal Society of Chemistry, Cambridge, UK, 2017, ISBN: 978-1-78262-114-0, £314.95

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Introduction

"Electrochemistry: Volume 14" is a collated book of five papers edited by Craig Banks (Manchester Metropolitan University, UK) and Steven McIntosh (Lehigh University, Bethlehem PA, USA), both of whom are well established in the field with research interests covering the topics in the book. The book is one of a series which aims to collate and summarise the key topics receiving attention within the electrochemical literature.

Electrochemistry and Materials Development

Chapter 1 by Mary Clare Sison Escaño is titled 'Borohydride Electro-Oxidation on Metal Electrodes: Structure, Composition and Solvent Effects from DFT'. Within this work the electro-oxidation of borohydride on well-defined catalytic surfaces is investigated by using density functional theory (DFT) modelling to calculate the adsorption energy of the reactive intermediates onto specific sites on the catalyst surface, Equation (i):

$$BH_4^- + * \text{ (metal site)} \rightarrow BH_y* + (4-y)H* + e^- \quad \text{(i)}$$

This work considers both the direct molecular adsorption and the dissociative adsorption of borohydride with a view to understanding the selectivity of this reaction over the competing hydrogen evolution reaction. The paper looks at surfaces of increasing levels of complexity starting with single facet metal surfaces through to metal alloy surfaces. In all cases robust calculations produce adsorption energies, which are presented along with diagrams showing the catalytic surface and adsorption sites clearly. The correlation of these results to experiment is discussed although not comprehensively compared.

The effects of solvation are next investigated along with some calculations on metal nanoparticles, bringing the discussion onto a more complex but realistic thread. The solvation study highlights effects such as changes in the orientation of the adsorbing molecule with the concomitant change in adsorption energy. The nanoparticle study draws attention not only to the presence of multiple facets which all need to be considered but also to the difference in accessibility to the active sites on nanoparticles and the consequence of this on the selectivity of a given catalyst.

Chapter 2 by Zhongyang Wang *et al*. is 'Recent Progress in the Development of Anion Exchange Membranes for Electrochemical Devices'. This article is a general review of the latest developments in the field of anion exchange membranes (AEM) used in electrochemical devices.

The first two chapters review a number of polymers reporting the advantages and

weaknesses of the backbone and functional group chemistries. The authors highlight the superior durability (1) for a long-alkyl chain quaternary ammonium onto polyphenylene (2) and reports a number of strategies to increase the chemical durability of the functional groups, among others the removal of the alpha hydrogen to suppress the Hoffman elimination (**Figure 1**).

In Chapter 3, 'Anodic Materials for Electrooxidation of Alcohols in Alkaline Media', Sadia Kabir and Alexey Serov have produced a well-rounded overview on the topic that would be useful for people just starting in the field. A summary of the workings of an AEM fuel cell is given that contrasts it nicely with the better known proton-based fuel cells. The different oxidation mechanisms in alkaline media for a range of fuels are presented including methanol, ethanol and ethylene glycol. The advantages of the different fuels are discussed, as well as some of the potential downfalls, such as incomplete oxidation for larger molecules. This section is slightly let down by typographical errors in some of the mechanistic equations presented, though the overall presentation is clear and easy to follow. The authors make good use of tables to highlight important reference data.

The bulk of the chapter gives an in-depth review of both the different catalytic materials capable of electrochemically oxidising alcohols in alkaline media and the advantages of these materials over the traditional platinum catalyst. The review is broken down into two sections, one dealing with Pt alloys and the other palladium alloys. Both sections give a detailed review of the mechanisms of oxidation on the catalyst and how this is altered based on the type, supporting material and morphology of the catalyst used. The material presented is comprehensive and nicely combines multiple analytical techniques to give a well-rounded review of the subject area. Particular attention has been paid to the effect of the morphology of Pd-based catalysts on the electrochemical activity of the materials. This chapter does well in explaining the reasons for the benefits in electrochemical performance seen by combining Pt and Pd with different materials rather than just quoting the higher performance.

In Chapter 4, 'Newer Polymer Electrolytes and Electrocatalysts for Direct Alcohol Fuel Cells', P. Sridhar, S. D. Bhat and A. K. Sahu have produced a good summary of recent advances in membranes and electrocatalysts for direct alcohol fuel cells (DAFC). The chapter is well structured with the material being broken down into proton conducting membranes, anion conducting membranes and catalysts for DAFC.

The section on proton conducting membranes has different membranes and inorganic materials organised into different sections. The authors give clear definitions for the difference between composite and hybrid membranes, highlighting the effects that the different methods for incorporating the inorganic into the membrane have on its properties. These differences in properties are

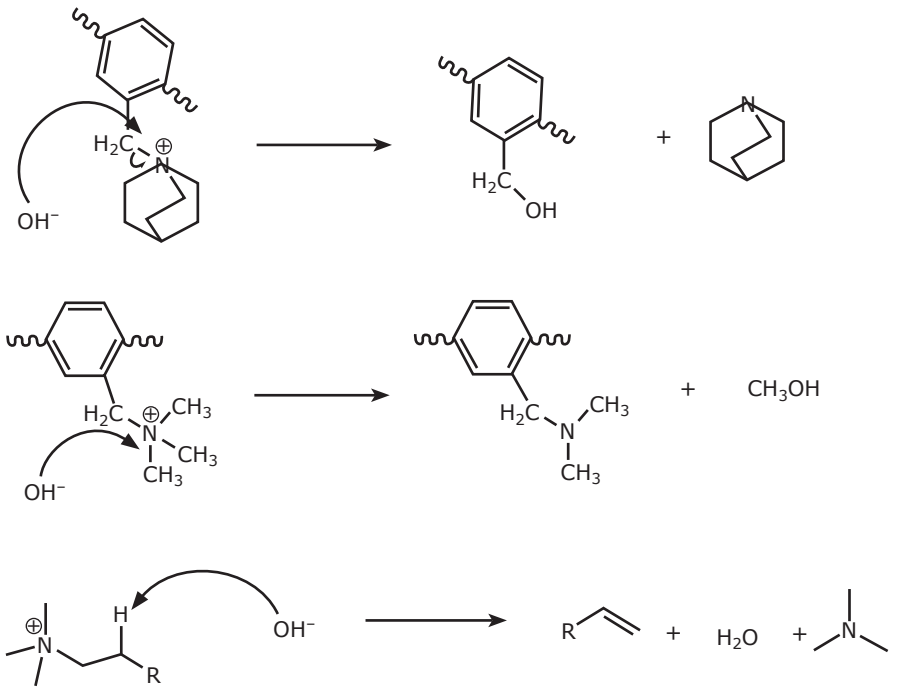


Fig. 1. Degradation mechanism for quaternary ammonium-based anion exchange membranes

then related to in-cell performance data. However, the chapter's reproduction quality lets the subject material down as it can be hard to discern what data belongs to which sample. This is a shame as the structural images of the inorganic materials shown are very crisp and clear.

A whole section is dedicated to sulfonated poly(ether ether ketone) (sPEEK)-based membranes rather than just concentrating on Nafion based materials. The section on sPEEK reviews a range of different materials made by blending additives into the polymer material and the effect these additives have on the structure and properties of the membrane. This section is then nicely rounded off with a direct comparison of the different membrane types. The membrane section ends with a brief overview on alkaline membrane materials.

The authors then move onto presenting a nice summary of recent advances in electrocatalysis for DAFC. This covers catalysts for both methanol and ethanol oxidation, as well as the corresponding tolerant cathode catalysts. Overall the chapter is a good review on the subject matter and would be useful reference material for people interested in this topic.

In the third and fourth chapters the main degradation modes are described along with their impact on the AEM performances related to the loss of ionic exchange capacity (3). The authors also examine key characterisation techniques to detect and quantify mechanical and chemical degradation mechanisms.

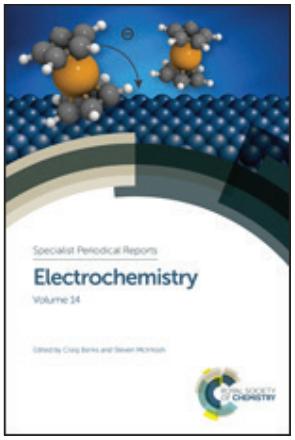
Chapter 5 by Y. Luo and N. Alonso-Vante reports the performances and durabilities of a number of AEM under a well-established test protocol (4, 5). It is titled 'Application of Metal Organic Framework (MOF) in the Electrocatalytic Process'. This chapter starts by providing a simple summation of why MOF materials are becoming of greater interest in the electrocatalytic arena, namely as an alternative to the high cost of the commonly used platinum group metals (pgms). It then goes on to summarise the wide range of MOF materials available containing many complex three dimensional (3D) structures which are of interest in their own right. These materials however can often possess some interesting catalytic properties and with the wide range of structures it could be possible to 'fine tune' these catalytic properties.

Following on from the previously described scene-setting discussion is a number of literature reviews on key areas where MOF materials are being investigated in the academic arena for use within electrocatalysis. These include using MOFs as catalytically active materials and as supports and precursors to electrocatalysts for a number of electrochemical transformations. Similar to previous chapters this article gives a succinct summary of the state of MOF research in the electrochemical literature.

The book highlights other applications for AEM particularly as a separation membrane in vanadium redox flow batteries (VRFB). The increase in demand for VRFB is linked to the increasing demand for storage systems to support renewable energy.

Conclusions

This book gives a good feel for the type of areas in which electrochemistry can be used to develop the understanding of electrocatalysis and materials development. While this book does not give a detailed review of the literature for any specific field of study it does provide an interesting sample of papers across the field. This book is not suitable for a researcher in the field looking for a detailed literature review, however it is successful in providing a glimpse into the key topics and themes currently receiving the most attention.



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