1
Key Materials for Low-Temperature Fuel Cells: An Introduction

Bradley P. Ladewig, Benjamin M. Asquith, and Jochen Meier-Haack

The promise of lower temperature fuel cells as versatile, efficient power sources has been made many times, both in academia and in the corporate world. Their potential as devices capable of converting chemical energy into electrical energy at high efficiency has been known for many years; however, despite an enormous worldwide research effort, they have not achieved mainstream commercial success.

One of the key impediments that is universally recognized is that there remain a series of key materials challenges that must be overcome before low-temperature fuel cells can achieve their full potential. In this book, we present a snapshot of the current state of the art, critically reviewed, as it relates to the materials challenges facing low-temperature fuel cells. In terms of what actually constitutes a low-temperature fuel cell, since there is no universal definition, we adopt here the convention of a fuel cell operating below 200 °C. In most cases, low-temperature fuel cells operate well below 100 °C; however, given the advances that have been made with high-performance polymer membranes (in particular, based on polybenzimidazole, as highlighted in Chapter 5), there now exists the potential to operate some systems with a vapor-phase feed. Clearly, this takes advantage of the superior reaction kinetics at elevated temperatures and allows for greater power density devices.

This book does not seek to be an all-encompassing encyclopedia that addresses every materials aspect of low-temperature fuel cells. Readers seeking a comprehensive reference work should consult the excellent handbook edited by Wolf Vielstich [1]. Rather, we have sought to highlight the key, contemporary challenges of interest to the fuel cell researcher (and those working in industry). We have intentionally sought to focus on the emerging areas of interest, with a particular focus on alkaline exchange (or hydroxide exchange) membrane fuel cells. These fuel cells are a radical departure from the thousands of research works published over the past decades that focused exclusively on proton exchange or cation exchange membrane low-temperature fuel cells (most obviously because the earlier high-performance membranes, from the chloralkali industry, were cation exchange membranes). There are critical materials challenges in advancing alkaline exchange membrane fuel cells, not least of which is the development of a new suite of polymer membranes that selectively transport

Materials for Low-Temperature Fuel Cells, First Edition. Edited by Bradley Ladewig, San P. Jiang, and Yushan Yan.

hydroxide ions. There are also more subtle catalyst selection issues, and these are covered in quite some detail in this book.

Two other specific areas must be mentioned in this introduction: the emerging fields of microbial fuel cells and microfluidic fuel cells. In some ways these two new fields can be considered embodiments of low-temperature fuel cells operating at the extreme size scales – microbial fuel cells have their genesis in the exploration of wastewater treatment in electrochemical and bioelectrochemical systems. These proposed applications are by their nature enormous in size, with reactor volumes measured in the tens of cubic meters (many orders of magnitude larger than the conventional low-temperature fuel cells).

In contrast, microfluidic fuel cells are at the opposite end of the size spectrum, and have come into the realm of fuel cell research in the past decade as the general field of microfluidics has exploded with interest. This has been driven not only through the widespread availability of the tools for fabrication of microfluidic devices but also by the possible application of microfluidic fuel cells in functional devices such as sensors and health care products.

The following chapters address a broad spectrum of topics, and it is hoped that the reader will recognize and appreciate the underlying theme of this book, which is to highlight the key materials challenges facing the field of low-temperature fuel cells, and expertly and concisely review the current state of the art.

Reference

1 Vielstich, W. (2009) *Handbook of Fuel Cells, 6 Volume Set*, John Wiley & Sons, Inc., Hoboken, NJ.