Preface

A fuel cell is a device which converts the chemical energy stored in fuels, such as hydrocarbons, alcohols or hydrogen, into electricity by way of a series of electrochemical-chemical reactions. Since no direct combustion processes are involved, fuel cell efficiencies are not governed by theoretical Carnot efficiencies and electrical work is converted from a substantial fraction of the enthalpy associated with the electrochemical oxidation of the fuel into water and carbon dioxide. Fuel cells are characterized by their electrolyte material; the solid oxide fuel cell (SOFC) has a solid oxide or ceramic electrolyte. Besides having high efficiencies, these fuel cells have long-term stabilities, fuel flexibility, low emissions and relatively low running costs. Their major disadvantage is their high operating temperatures, which results in longer start-up times and mechanical and chemical compatibility issues. Proton exchange membrane fuel cells (PEMFCs) conduct positive hydrogen ions (protons) through a polymer electrolyte from the anode to the cathode, whereas the SOFCs use a solid oxide electrolyte to conduct negative oxygen ions from the cathode to the anode. SOFCs have a wide variety of applications particularly as auxiliary power units in vehicles with outputs from 100 W to 2 MW. Their high operating temperatures make SOFCs suitable candidates for application with heat engine energy recovery devices.

This volume brings together recent developments in the science and technology of fuel cells. Chapter 1 by Xiao-Dong Zhou and Subhas Singhal describes recent developments in the solid state materials used in SOFCs and emphasises the simultaneous improvements in their activities (their system performance), and their durability (stability of their performance). These improvements are based primarily on the structures and bonding characteristics of SOFC components. The role of local structural effects and chemical bonding in the electrochemical performance of the new materials is discussed in detail. Chapter 2 by Hongsen Wang and Hector Abruña provides new insights into the direct alcohol fuel cell related anode electrocatalysis. This work relies heavily on the use of quantitative differential electrochemical mass spectrometry (DEMS) for studying the mechanism of methanol electro-oxidation on platinum and platinum/ruthenium catalysts. The application of this technique to the electro-oxidation of ethanol and acetaldehyde on metal nano-particle catalysts is also discussed. The studies have also shed new light on the mechanism of dissociative adsorption and electro-oxidation of ethanol, acetaldehyde and ethylene glycol. In Chap. 3, Jay Benziger, Andrew Bocarsly, May Jean Cheah, Paul Majsztrik Barclay Satterfield and Qiao Zhao describe the mechanical and transport properties of Naflon. Naflon is an ionomer that has a hydrophobic tetrafluoroethylene (TFE) backbone and perfluoroalkyl ether side chains terminated with hydrophilic sulphonate acid groups. It has been used as a polymer electrolyte membrane (PEM) since the early 1990s. It is more robust than hydrocarbon membranes in fuel cells and the acid form has high proton conductivity. This chapter describes recent studies tracing the effect of water absorption changes on the mechanical and transport properties of Naflon. The unusually large changes in properties are indicative of microstructural changes induced by water absorption. Water absorption is thought to cause clustering of hydrophilic sulphonic groups and water within a hydrophobic PTFE matrix. The hydrophilic domains form a network which facilitates transport and creates physical cross links that stiffen Naflon. Sonny Sachdeva, John Turner, James Horan and Andrew Herring describe the use of heteropolyacids (HPAs) in proton exchange fuel cells in Chap. 4. In this chapter, the fundamental aspects of proton conduction in HPAs are introduced and liquid-based HPA fuel cells are reviewed. Four types of composite proton exchange membranes containing HPAs are identified.

In recent years, hydrogen gas has been promoted as a potential environmentally friendly fuel. Michael Kelly in Chap. 5 reviews the scientific and technical issues associated with generating hydrogen from non-fossil fuel sources and addresses the storage problems associated with this fuel. Whilst molecular hydrogen has the highest energy per unit weight of any known compound, it has a poor energy content per unit volume. Liquefaction of hydrogen results in a substantial volume reduction, but it suffers from the disadvantages of employing a fuel at 20K in a 300K environment. Therefore, hydrogen production and storage represents a complementary problem to the fuel cell scientific and technology issues discussed in the earlier chapters. Taken together, we hope that these chapters provide a timely summary of some exciting developments in hydrogen storage and the utilization of fuel cells for energy generation.

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