
Preface

The concept to utilize an ion-conducting polymer membrane as a solid polymer electrolyte offers several advantages regarding the design and operation of an electrochemical cell, as outlined in Volume 215, Chapter 1 (L. Gubler, G. G. Scherer). Essentially, the solvent and/or transport medium, e.g., H₂O, for the mobile ionic species, e.g., H⁺ for a cation exchange membrane, is taken up by and confined into the nano-dimensional morphology of the ion-containing domains of the polymer. As a consequence, a phase separation into a hydrophilic ion-containing solvent phase and a hydrophobic polymer backbone phase establishes. Because of the narrow solid electrolyte gap in these cells, low ohmic losses reducing the overall cell voltage can be achieved, even at high current densities.

This concept was applied to fuel cell technology at a very early stage; however, performance and reliability of the cells were low due to the dissatisfying membrane properties at that time. The development of perfluoro sulfonate and carboxylate-type membranes, in particular for the chlor-alkali process, directly fostered the further development of proton-conducting membranes and, as a consequence, also the progress in this type of fuel cell technology (polymer electrolyte fuel cell, PEFC).

Within the past 20 years, tremendous progress has been achieved in PEFC technology, in particular since the automotive industry has joined forces to further develop this energy conversion technology with its advantages in efficiency and environmental friendliness. This development has brought about a much deeper understanding of the various functions of the polymer electrolyte in the cell, particularly under duty cycle conditions of automotive applications. As a further and utmost prerequisite, the cost issue came to every one's attention.

Many national and international research programs have recently initiated work on proton-conducting polymer membranes for fuel cell applications. The contributions in these two volumes aim to summarize some major efforts, without claiming to be exhaustive.

Hence, M. Eikerling, A. A. Kornyshev, and E. Spohr start out in Volume 215, Chapter 2 with a general description of proton-conduction in polymer membranes, elucidating the influence of water and charge-bearing species in the polymer environment. Y. Yang, A. Siu, T. J. Peckham, and S. Holdcroft give an

overview on implications of design approaches for synthesis of fuel cell membranes in Volume 215, Chapter 3. Some recent progress in the most prominent class of these membranes, the perfluoro sulfonic acid-type membranes, is described in Volume 215, Chapter 4 from an industrial perspective by M. Yoshitake and A. Watakabe. The development of the radiation grafting process to yield fuel cell membranes is covered in Volume 215, Chapter 5 by S. Alkan Gürsel, L. Gubler, B. Gupta, and G. G. Scherer, based on their long-term experience working in this area. The requirement for operating cell temperatures above 100 °C has led to the approach of composite membranes, combining the advantageous properties of inorganic and polymeric proton conductors (D. J. Jones, J. Rozière, in Volume 215, Chapter 6) to control the water content at these temperatures. On the basis of the promising properties of polymeric aromatic engineering materials and their modification to proton-conducting membranes, G. Maier and J. Meier-Haack review the state-of-art in sulfonated aromatic polymers in Volume 216, Chapter 1. High-temperature applications are also in the focus of the next two contributions. Polymer blends with phosphoric acid allow operating temperatures well above 100 °C, with advantages in water management and electrocatalysis (CO-tolerance), as pointed out in the contribution by J. Mader, L. Xiao, T. J. Schmidt, and B. C. Benicewicz in Volume 216, Chapter 2. A similar approach was followed, introducing the phosphonic acid group directly onto the polymer chain, by A. L. Rusanov, P. V. Kostoglodov, M. J. M. Abadie, V. Y. Voytekunas, and D. Y. Likhachev in Volume 216, Chapter 3. Two new classes of polymers and their properties are addressed in the last two Chapters 4 and 5 in Volume 216. R. Wycisk and P. N. Pintauro describe their view on polyphosphazene-based membranes for fuel cell applications, while C. Marestin, G. Gebel, O. Diat, and R. Mercier report on their and others' work on polyimide-based membranes.

As documented in and expressed by these various contributions, the topic "Polymers for Fuel Cells" is a vast one and concerns numerous synthetic and physico-chemical aspects, derived from the particular application as a solid polymer electrolyte. In this collection of contributions, we have emphasized work which has already led to tests of these polymers in the real fuel cell environment. There exist other synthetic routes for proton-conducting membrane preparation, which are not discussed in this edition. Furthermore, certain polymers are utilized as fuel-cell structure materials, e.g., as gaskets or additives (binder, surface coating) to bipolar plate materials. These aspects are not covered here.

In summary, we endeavored to bring together contributions from several expert groups who have worked in this area for many years to summarize the current state-of-the-art. There still exist many challenges down the road to bring at least some of these developments to commercial fuel cell technology. For an ultimate success, a comprehensive polymer *materials* approach has to be adopted to rationalize all the various aspects of this highly interdisciplinary task.

The editor wishes to thank all the authors for their contribution and the Paul Scherrer Institut for its support of membrane work over many years.

Villigen, May 2008

Günther G. Scherer