
Preface

In today's world, the demand for clean and sustainable energy sources has become a strong driving force in continuing economic development, and thus as well in the improvement of human living conditions. Proton exchange membrane (PEM) fuel cells, as clean energy-converting devices, have drawn a great deal of attention in recent years due to their high efficiency, high energy density, and low or zero emissions. PEM fuel cells have several important application areas, including transportation, stationary and portable power, and micro-power. From the 1960s to the present, great progress has been made in the research and development of PEM fuel cells, in terms of stack power density increases and cost reduction. Nonetheless, two major technical gaps hindering commercialization have been identified: high cost and low reliability/durability. Fuel cell catalysts, such as platinum (Pt)-based catalysts and their associated catalyst layers, are the major factors in these challenges. Although a great deal of effort has been put into the exploration of cost-effective, active, and stable fuel cell catalysts, we have not yet had any real breakthroughs. Therefore, exploring new catalysts, improving catalyst activity and stability/durability, and reducing catalyst cost are currently the major tasks in fuel cell technology and commercialization.

In a PEM fuel cell, both the anodic hydrogen (or liquid fuel) oxidation reaction (HOR) and the cathodic oxygen reduction reaction (ORR) take place within the respective catalyst layers. Electrocatalysts and their corresponding catalyst layers thus play critical roles in fuel cell performance. In our present state of technology, the most practical catalysts in PEM fuel cells are highly dispersed Pt-based nanoparticles. However, Pt-based catalysts have several drawbacks, such as high cost, sensitivity to contaminants, no tolerance for methanol oxidation (in a direct methanol fuel cell, DMFC, application), fewer completed four-electron reduction reactions, and Pt dissolution. In the search for alternative low-cost non-Pt catalysts, researchers have looked at several others, including supported platinum group metal (PGM) types such as Pd-, Ru-, and Ir-based catalysts, bimetallic alloy catalysts, transition metal macrocycles, and transition metal chalcogenides. However, these approaches are as yet in the research stage, as the catalyst activities and stabilities are still too low to be practical in comparison with Pt-based catalysts. Another approach is to reduce Pt loading in a catalyst or catalyst layer

using alloying and carbon supports. However, due to rapid increases in the cost of platinum, all efforts to reduce Pt loading have thus far been offset by rising prices. Non-noble metal catalysts would therefore appear to be a possible solution for the sustainable commercialization of PEM fuel cells.

Another significant challenge is gaining a fundamental understanding of fuel cell catalyst structures and their corresponding catalytic reaction mechanisms. Current approaches rely largely on trial and error. To design new, breakthrough catalysts, we need a well-defined theoretical approach. Theoretical studies will provide a platform not only for understanding catalyst performance but also for exploring the structure-activity relationship at the electron/molecular level, and ultimately for rationally designing new catalysts.

To accelerate breakthroughs in the research and development of PEM fuel cells and their sustainable commercialization, a comprehensive and in-depth book that focuses on both fundamental and application aspects of PEM fuel cell electrocatalysts and catalyst layers is definitely needed, to build upon the several important books that have previously been published in the area of electrocatalysts.

This book contains comprehensive information on PEM fuel cell electrocatalysts and catalyst layers, with a particular focus on: (1) the fundamentals of electrochemical catalysis within PEM fuel cells, including both H_2/O_2 (air) and liquid-fuels/ O_2 (air) fuel cells; (2) electrocatalyst/catalyst layer synthesis, characterization, and activity validation and modelling; and (3) the integration of electrocatalysts/catalyst layers into fuel cells, and their performance validation, including catalyst layer structure functioning and optimization, catalyst degradation and diagnosis, and strategies to mitigate failure modes.

The contributors to the volume are fuel cell scientists and engineers with excellent academic records as well as strong industrial fuel cell expertise. This book contains the latest research and development in PEM fuel cell catalysis, and indicates important new directions for fuel cell commercialization. Readers will find numerous figures, photographs, and data tables, as well as comprehensive reference materials for each chapter. We hope that this book will be used by industry researchers, by scientists and engineers working in the areas of energy, electrochemistry science/technology, fuel cells, and electrocatalysis, and by post-secondary students. We have endeavoured to make easily accessible the latest information on fuel cell catalysis fundamentals and applications.

Each chapter is relatively independent of the others, a structure which we hope will help readers quickly find topics of interest without necessarily having to read through the whole book. Unavoidably, however, there is some overlap, reflecting the interconnectedness of the research and development in this dynamic field.

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