

**Developments in  
Heat Transfer**

# **Transport Phenomena in Fuel Cells**

 **WIT**<sub>PRESS</sub>

**Editors: B. Sundén  
and M. Faghri**

# TRANSPORT PHENOMENA IN FUEL CELLS

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**Editors: B. Sundén and M. Faghri**

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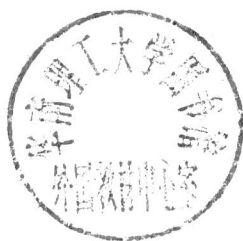
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## Preface

Fuel cells are expected to play a significant role in the next generation of energy systems and road vehicles for transportation. However, substantial progress is required in reducing manufacturing costs and improving the performance. Solid Oxide fuel cells (SOFC), Proton Exchange Membrane fuel cells (PEMFC) and Direct Methanol fuel cells (DMFC) are of current interest.

Many of the associated heat and mass transport processes are not well understood and include multidimensional flow and heat transfer in multi phase flows, multicomponent transport of gaseous species in porous media and electrochemical reactions including heat generation. Depending on the fuel being used, modifications in the design of the next generation of fuel cells are needed. Therefore, additional transport processes even at micro scale level need to be investigated. Other important considerations are air management system for oxygen supply, water management and recovery or rejection of heat of exhaust products.

Currently an extensive amount of research and development activities are carried out for fuel cells worldwide. The dissemination of results is through various generic and specialized journals and conference proceedings. There is no comprehensive book available to address the analysis of transport phenomena in fuel cells.

This book aims to contribute to the understanding of the transport processes in SOFC, PEMFC and DMFC fuel cells. The nine chapters cover a wide range of topics and are invited contributions from some prominent scientists in the field.

The first chapter presents the thermodynamic and electrochemical fundamentals of SOFC. Efficiency, energy distribution, chemical equilibrium, losses of electrical potential, ohmic losses and losses due to mass transfer resistance are discussed. Modeling and numerical simulations of the coupled transport processes which determine the local and overall electromotive force in a SOFC are provided. Chapter 2 discusses various numerical techniques to model single-cells and stacks of planar SOFC. In chapter 3 a numerical model for analysis of a tubular SOFC including indirect internal reforming is presented. Fundamental results and strategies to reduce the maximum temperature and temperature gradient of the cell are discussed. Chapter 4 provides numerical analysis of heat, mass transfer (species flow), two-phase transport and effects on the performance in SOFC and PEMFC. In chapter 5 information on transport



phenomena in the electrodes of PEMFC is provided. The physical characteristics of such electrodes are also discussed. The focus is on two-phase flow in porous media, with a discussion of driving forces and various flow regimes. Also, the mathematical models are summarized. Chapter 6 presents mathematical models and numerical simulations of PEMFC to evaluate effects of various designs and operating parameters on the fuel cell performance. The three-dimensional model can be used for optimisation of design and operation and serve as a building block for modeling and understanding of PEMFC stacks and systems. In chapter 7 scaling analysis, nondimensionalization and asymptotic techniques are used to identify the governing parameters in order to obtain a simplified model. Illustrations are provided for PEMFC and DMFC. In chapter 8 a mathematical model for a PEMFC stack is formulated. Distributions of pressure, fuel and oxidant mass flow rates in the stack are determined by a hydraulic network analysis. Finally chapter 9 provides an overview of the latest developments in the DMFC technology. Experimental and modeling works to elucidate critical transport phenomena, including two-phase microfluidics, heat and mass transport are presented.

All of the chapters follow a unified outline and presentation to aid accessibility and the book provides invaluable information for both graduate research and R & D engineers at industry and consultancy.

We are grateful to the authors and reviewers for their excellent contributions. We also appreciate the cooperation and patience provided by the staff of WIT Press and for their encouragement and assistance in producing this volume. The editors would also like to thank the Wenner-Gren Center Foundation in Sweden for financial support.

B. Sundén and M. Faghri  
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## **Exergy Method Technical and Ecological Applications**

**J. SZARGUT**, *Silesian University of  
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The exergy method makes it possible to detect and quantify the possibilities of improving thermal and chemical processes and systems. The introduction of the concept "thermo-ecological cost" (cumulative consumption of non-renewable natural exergy resources) generated large application possibilities of exergy in ecology.

This book contains a short presentation on the basic principles of exergy analysis and discusses new achievements in the field over the last 15 years. One of the most important issues considered by the distinguished author is the economy of non-renewable natural exergy.

Previously discussed only in scientific journals, other important new problems highlighted include: calculation of the chemical exergy of all the stable chemical elements, global natural and anthropogenic exergy losses, practical guidelines for improvement of the thermodynamic imperfection of thermal processes and systems, development of the determination methods of partial exergy losses in thermal systems, evaluation of the natural mineral capital of the Earth, and the application of exergy for the determination of a pro-ecological tax.

A basic knowledge of thermodynamics is assumed, and the book is therefore most appropriate for graduate students and engineers working in the field of energy and ecological management.

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Providing invaluable information for both graduate researchers and R & D engineers

in industry and consultancy, this book focuses on the modeling and simulation of fluid flow and thermal transport phenomena in turbulent convective flows. Its overall objective is to present state-of-the-art knowledge in order to predict turbulent heat transfer processes in fundamental and idealized flows as well as in engineering applications.

The chapters, which are invited contributions from some of the most prominent scientists in this field, cover a wide range of topics and follow a unified outline and presentation to aid accessibility. **Contents:** An Overview of Turbulence Modeling; Unstructured Large Eddy and Conjugate Heat Transfer Simulations of Wall-Bounded Flows; Numerical Simulation of Turbulence-Radiation Interactions in Turbulent Reacting Flows; Improved Turbulence Modeling of Film Cooling Flow and Heat Transfer; Prediction of Turbulent Heat Transfer in Impinging Jet Geometries; On RANS-Based Models for Prediction of Turbulent Flow and Heat Transfer in Ribbed Ducts; Prediction of Transitional Characteristics of Flow and Heat Transfer in Periodic Fully Developed Ducts; Turbulent and Conjugate Heat Transfer Simulation for Gas Turbine Application; Simulation of Turbulent Flow in a Duct With and Without Rotation-Cooling Passage of Gas-Turbine Blades.

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