
Contents

1	Solid Oxide Fuel Cells	1
1.1	Introduction.....	1
1.2	Operation and Performance	2
1.3	SOFC Materials	3
1.3.1	Anode	4
1.3.2	Electrolyte	5
1.3.3	Cathode.....	7
1.3.4	Interconnect	7
1.4	Geometrical Designs.....	8
1.4.1	Flat Planar.....	8
1.4.2	Monolithic Design	8
1.4.3	Tubular Design	9
1.5	Design of an SOFC Stack. The Case of Micro-tubular Solid Oxide Fuel Cell	10
1.5.1	Stack Configuration.....	10
1.5.2	Single Cells Construction	12
1.5.3	Joining Current Collectors and Single Cells.....	13
1.5.4	Stack Design and Expected Performance	15
1.6	Applications	19
1.6.1	Residential Application	20
1.6.2	Power Plant and Grid Support	20
1.6.3	Auxiliary Power Unit.....	21
1.7	References.....	22
2	PEM Fuel Cells	27
2.1	Introduction.....	27
2.2	PEM Fuel Cell Components and Their Properties.....	31
2.2.1	Membrane.....	31
2.2.2	Electrode.....	32
2.2.3	Gas Diffusion Layer	34
2.2.4	Bipolar Plates.....	34
2.3	Stack Design Principles	35
2.4	System Design	38

2.5	Fuel Cell Applications	42
2.5.1	Automotive Applications.....	43
2.5.2	Stationary Power Applications	46
2.5.3	Portable Power Applications	47
2.6	Summary.....	48
2.7	References.....	49
3	Durability and Accelerated Characterization of Fuel Cells	53
3.1	Introduction.....	53
3.2	Strength-based Performance Metrics	55
3.2.1	Failure Functions for Damage Accumulation.....	56
3.3	Polymer-based Systems	58
3.4	Ceramic-based Systems	62
3.4.1	Electrochemical Performance Metrics.....	62
3.4.2	Applying the Electrochemical Model.....	65
3.5	Summary.....	66
3.6	References.....	67
4	Transport and Electrochemical Phenomena	69
4.1	Introduction.....	69
4.2	Modeling of Proton Exchange Membrane Fuel Cells.....	70
4.2.1	Performance Models.....	71
4.2.2	Mechanistic Modeling of PEM Fuel Cell.....	75
4.3	Modeling of Solid Oxide Fuel Cells	117
4.3.1	Component Materials and Electrochemistry.....	119
4.3.2	Performance Models for SOFC	121
4.3.3	Mechanistic Models for SOFC	123
4.3.4	Results and Discussion	127
4.4	Direct Methanol Fuel Cells.....	131
4.4.1	Performance Models.....	133
4.4.2	Mechanistic Models.....	135
4.4.3	Results and Discussion	136
4.5	Application Considerations.....	139
4.5.1	Optimization Based on Parametric Studies	140
4.5.2	Optimization Based on a Numerical Optimizer.....	143
4.5.3	Stochastic Modeling of Fuel Cell Performance under Uncertainty	147
4.6	Concluding Remarks.....	149
4.7	Acknowledgement	151
4.8	References.....	151
5	Fuels and Fuel Processing	165
5.1	Introduction.....	165
5.2	Feedstocks for H ₂ Production	166
5.2.1	Natural Gas.....	166
5.2.2	Liquid Petroleum Gas.....	167

5.2.3	Liquid Hydrocarbon Fuels: Gasoline and Diesel.....	167
5.2.4	Alcohols: Methanol and Ethanol	167
5.2.5	Ammonia	168
5.2.6	Biomass	170
5.3	Fuel Processing for Fuel Cell Application.....	170
5.3.1	Desulfurization	171
5.3.2	Fuel Reforming.....	181
5.3.3	Water-Gas Shift Reaction.....	190
5.3.4	Carbon Monoxide Removal.....	191
5.3.5	HD-5 Propane Processing for Direct Carbonate Fuel Cell (DFC TM) Applications.....	195
5.4	Conclusions and Directions for Future Research.....	201
5.5	References.....	202
6	System-level Modeling of PEM Fuel Cells	213
6.1	Introduction.....	213
6.2	PEMFC System-level Dynamic Modeling	215
6.2.1	Cathode and Anode Channel Control Volumes.....	216
6.2.2	Fuel Cell Body.....	223
6.2.3	Cooling Water	226
6.2.4	Electrochemical Reaction	226
6.3	Model Validation and Analyses.....	227
6.3.1	Validation with Respect to Experimental Data and Comparison.....	227
6.3.2	System-level Dynamic Analyses	230
6.4	References.....	235
7	New Generation of Catalyst Layers for PEMFCs Based on Carbon Aerogel Supported Pt Catalyst (CASPC)	237
7.1	Introduction.....	237
7.2	Experimental.....	238
7.2.1	Characterization of the Aerogel Supported Pt Catalysts....	238
7.2.2	Preparation of Catalyst Pastes and Membrane Electrode Assemblies.....	239
7.2.3	Cyclic Voltammetry Measurements	240
7.2.4	PEM Fuel Cell Testing Procedure	241
7.3	Results and discussion	241
7.3.1	CASPC Morphology and BET Measurements	241
7.3.2	Electrochemical Surface Area of Aerogel Supported Catalysts	242
7.3.3	Evaluation of PEMFC Performance at Elevated and Room Temperatures.....	243
7.3.4	Catalytic Activity of CASPC: Open Circuit Voltage (OCV) and Tafel Slope.....	243
7.4	Conclusion	249

8	Power Conditioning and Control of Fuel Cell Systems	253
8.1	Introduction.....	253
8.2	Fuel Cell Basics	254
8.2.1	Physics.....	254
8.2.2	Power Generation	255
8.2.3	Loss Mechanism.....	256
8.2.4	Equivalent Circuit.....	256
8.3	Power Conditioning	257
8.3.1	Fuel Cell Systems	257
8.3.2	Storage System	259
8.3.3	Voltage Regulation	259
8.3.4	DC/DC and DC/AC Converters.....	260
8.3.5	Power Transistors	260
8.3.6	DC/DC.....	261
8.3.7	DC/AC.....	265
8.3.8	Simulation of Fuel Cell Power Conditioning Systems	268
8.3.9	Low Power Applications	269
8.3.10	Multi-level DC/DC and DC/AC Converter	269
8.4	Small Scale Systems	272
8.4.1	Increased Available Power	272
8.4.2	Size and Weight Reduction	272
8.4.3	Difference in Philosophy	273
8.5	Conclusion	274
8.6	References.....	274
9	Microbial Fuel Cells.....	277
9.1	Microbial Fuel Cells	277
9.1.1	Introduction	277
9.1.2	Historical Perspective	278
9.1.3	MFC Performance	278
9.1.4	MFC Applications	279
9.2	Microbiology Overview.....	280
9.2.1	Bacterial Structure	280
9.2.2	Nutrient Transport	281
9.2.3	Cellular Energy and Electron Carriers.....	281
9.2.4	Coupling Cellular Electrochemistry to the Anode.....	282
9.3	A Theoretical Treatment of MFC Anode Reactions	283
9.3.1	What Limits MFC Electrical Output?.....	283
9.4	Metabolic Engineering.....	285
9.5	References.....	293
	Index.....	297



<http://www.springer.com/978-1-85233-974-6>

Fuel Cell Technology

Reaching Towards Commercialization

(Ed.)N. Sammes

2006, XIV, 298 p. 139 illus., Hardcover

ISBN: 978-1-85233-974-6