

Table of content

Abstract	.....	I
Zusammenfassung	.....	III
Acknowledgments	.....	V
Table of content	.....	VII
Nomenclature	.....	XI
1. Introduction	.....	1
2. Fuel cells	.....	3
2.1 Working principle	.....	4
2.2 HTPEM fuel cells	.....	5
2.3 PBI/H ₃ PO ₄ MEA	.....	6
2.4 Overall features of a PBI/H ₃ PO ₄ MEA	.....	6
2.5 Future development	.....	8
2.6 Fuel cell thermodynamics	.....	8
2.6.1 Potential of a fuel cell	.....	8
2.6.2 Efficiency of a fuel cell	.....	12
2.7 Fuel cell characterization methods	.....	13
2.7.1 Current-voltage-curve (I-V-curve) of a PEM fuel cell	.....	13
2.7.2 Electrochemical impedance spectroscopy	.....	15
3. PEM fuel cell modeling	.....	19
3.1 Overall modeling aspects	.....	20
3.2 HTPEM fuel cell models – Literature review	.....	21
4. The developed HTPEM fuel cell model	.....	23
4.1 Model geometry	.....	23
4.1.1 Type I flow-field	.....	25
4.1.2 Type II flow-field	.....	25
4.1.3 Type III flow-field	.....	25
4.2 Subdomain transport equations	.....	26
4.2.1 Momentum transport	.....	26
4.2.2 Mass (species) transport	.....	27
4.2.3 Energy transport	.....	27
4.2.4 Charge transport	.....	28
4.2.5 Electrochemistry and transport properties for the spherical agglomerate model	.....	29
4.2.6 Kinetic parameters and transport properties in phosphoric acid	.....	33
4.2.7 PBI/H ₃ PO ₄ sol-gel membrane modeling	.....	37

4.2.8 Fluid-(gas)-, and solid-phase properties and material correlations	38
4.3 Boundary conditions	40
4.4 Initial conditions	42
4.6 Assumptions and simplifications	43
4.6 Modeling parameters	44
5. Solving the model	47
5.1 Meshing	47
5.2 Solution procedure and convergence behaviour	50
6. The segmented HTPEM fuel cell	53
6.1 Segmented measurements – Literature review	53
6.1.1 Temperature measurements	53
6.1.2 Current density measurements	54
6.1.3 EIS measurements	54
6.2 Requirements, manufacturing and assembling	57
6.3 Measuring the solid-phase temperature distribution	60
6.4 Measuring the current density distribution	60
6.5 Segmented EIS measurements	61
6.5.1 The simplified set-up for segmented EIS measurements	61
6.5.2 Note on the experimental set-up	62
6.6 Equivalent circuit modeling	63
6.7 Analysis of the EIS data	64
6.8 Operating the nonsegmented and segmented HTPEM fuel cell	65
7. Characterizing the three types of flow-fields	67
7.1 Fluid-flow distribution and pressure drop	67
7.1.1 Type I flow-field	67
7.1.2 Type II flow-field	69
7.1.3 Type III flow-field	70
7.2 Impedance measurements at no-load operating conditions	72
7.3 Overall performance at reference operating conditions	73
7.3.1 Type I flow-field	74
7.3.2 Type II flow-field	75
7.3.3 Type III flow-field	76
8. Segmented solid-phase temperature and current density measurements	77
8.1 Solid-phase temperature distribution at no-load operating conditions	77
8.1.1 Type I flow-field	77
8.1.2 Type II flow-field	80

8.1.3 Type III flow-field	83
8.2 Load operating conditions – Counter-flow configuration	86
8.2.1 Type I flow-field – Operation with hydrogen and air	86
8.2.2 Type I flow-field – Operation with CO enriched hydrogen and air	95
8.2.3 Type II flow-field – Operation with hydrogen and air	97
8.2.4 Type II flow-field – Operation with CO enriched hydrogen and air	105
8.2.5 Type III flow-field – Operation with hydrogen and air	108
8.2.6 Type III flow-field – Operation with CO enriched hydrogen and air	115
8.3 Load operating conditions – Co-flow configuration	116
8.3.1 Type I flow-field – Operation with hydrogen and air	116
8.3.2 Type I flow-field – Operation with CO enriched hydrogen and air	118
8.3.3 Type II flow-field – Operation with hydrogen and air	120
8.3.4 Type II flow-field – Operation with CO enriched hydrogen and air	123
8.3.5 Type III flow-field – Operation with hydrogen and air	123
8.3.6 Type III flow-field – Operation with CO enriched hydrogen and air	125
9. Segmented EIS measurements in a HTPEM fuel cell	129
9.1 Type I flow-field	129
9.2 Type II flow-field	131
9.3 Type III flow-field	137
10. Conclusion	143
10.1 Modeling and simulation	143
10.2 Experimental	144
10.3 Solid-phase temperature distribution	144
10.4 Current density distribution	146
10.5 Segmented EIS measurements	147
11. References	149