Contents

Abstract v

Kurzfassung vii

Acknowledgements ix

1 Introduction 1

1.1 Redox-flow batteries for stationary energy storage 3

1.2 Vanadium redox-flow battery – basic properties 7

1.3 Overview of mathematical modelling and model validation 11

2 Overview of publications 15

3 Polarization curve measurements combined with potential probe sensing for determining current density distribution in vanadium redox-flow batteries 17

4 Kinetic studies at carbon felt electrodes for vanadium redox-flow batteries under controlled transfer current density conditions 27

5 Combination of impedance spectroscopy and potential probe sensing to characterize vanadium redox-flow batteries 43

6 Mass transport parameter estimation and model validation for vanadium redox-flow batteries 59

6.1 Introduction 61

6.2 Setup of the mathematical model 67

6.3 Experimental setup for cell & electrolyte characterization 73

6.4 Evaluation of electrolyte properties, open circuit cell voltage, kinetic data, membrane and bipolar plate resistance 74

6.5 Evaluating reasonable diffusion coefficients from literature data 79

6.6 Mass transport parameter estimation & model validation 80

6.7 Conclusion 88
6.8 Symbols and Subscripts applied in the model 89
7 Concluding discussion & outlook 93
References 99
Appendix 113
A.1 Detailed overview for measured and modeled potential probe signals 113
A.2 gPROMS code 126