

Table of contents

Abstract.....	IV
1 Introduction.....	1
1.1 Motivation – Why is temperature sensitivity important?.....	1
1.2 Thesis structure.....	3
2 Fundamentals	5
2.1 Charge Carrier Lifetimes	5
2.1.1 Charge carrier concentration	5
2.1.2 Recombination	8
2.2 Silicon Solar Cells	15
2.2.1 Silicon	15
2.2.2 Defects in crystalline Silicon.....	18
2.2.3 Structure of Silicon Solar Cells	25
2.3 Temperature Dependence of Silicon Solar Cells	30
2.3.1 Temperature sensitivity of short-circuit current	30
2.3.2 Temperature sensitivity of open-circuit voltage	31
2.3.3 Temperature sensitivity of fill factor	34
2.3.4 Temperature sensitivity of efficiency	35
2.4 Characterization Techniques.....	37
2.4.1 Injection-dependent Lifetime Imaging	37
2.4.2 ELBA	41
2.4.3 Local Analysis of Silicon Solar Cell Performance	43
2.5 Energy Yield of Silicon Solar Cells	48
2.5.1 Optical & Electrical Modelling in SmartCalc.....	48
2.5.2 Integration of Weather Data	49
3 Analysis of Temperature Sensitivity of Silicon Solar Cells	51
3.1 Crystalline Silicon	60
3.1.1 Literature Review	61
3.1.2 Prediction of Local Temperature-Dependent Performance of Silicon Solar Cells	62

3.1.3	Comprehensive Study of Crystalline Silicon's Temperature Sensitivity	71
3.1.4	Origin of Local Temperature Sensitivity	104
3.2	Temperature Sensitivity of Silicon Surface Passivation.....	111
3.2.1	Material and Methods.....	112
3.2.2	Measured Temperature-Dependent Surface Recombination	114
3.2.3	Conclusion.....	119
3.3	Temperature Sensitivity of Diffused Emitter Layers	120
3.3.1	Emitter Recombination.....	120
3.3.2	Characterization of Temperature Sensitivity of Diffused Layers	121
3.3.3	Conclusion.....	129
	Chapter summary	130
4	Sensitivity Analysis – Breakdown of Temperature Sensitivity of Silicon Solar Cells by Simulation Input Parameters.....	134
4.1	Introduction.....	135
4.2	Device Simulation in Quokka3	136
4.3	Bulk Lifetime Measurement	140
4.4	Results	141
4.4.1	Temperature Sensitivity of IV-Parameters	141
4.4.2	Impact on Energy Yield.....	146
	Chapter Summary.....	147
5	From Bottom to Top – Analysis of Energy Yield from Wafer to Module ...	150
5.1	Background.....	151
5.2	Prediction of Cell Performance	152
5.2.1	Modelling of Cell Performance	152
5.2.2	Cell & Wafer Characterization	152
5.3	Module Output Prediction & Verification.....	154
5.4	Experimental	155
5.4.1	Wafer & Cell Level	155
5.4.2	Module Level	155
5.5	Using Output Prediction for Local Material Analysis	158
5.6	Verification of Module Simulation & Yearly Energy Yield Prediction	162
	Chapter Summary.....	165
6	Summary & Outlook.....	168
7	Detaillierte deutsche Zusammenfassung	172

8 Bibliography	177
9 Appendix.....	191
9.1 Nomenclature.....	191
Publications.....	197
Peer-reviewed journal publications	197
Contributions to conferences and workshops.....	198
Acknowledgements.....	200