

Contents

1 Introduction	1
2 Fundamentals.....	7
2.1 Structural Properties of Microcrystalline Silicon.....	7
2.2 Electronic Properties	8
2.2.1 Crystalline Silicon.....	9
2.2.2 Amorphous Silicon.....	10
2.2.3 Microcrystalline Silicon	11
2.3 Optical Properties of Microcrystalline Silicon.....	12
2.4 Generation and Recombination Processes	13
2.4.1 Radiative Recombination	14
2.4.2 Non-Radiative Recombination.....	20
2.5 Carrier Densities in Non-equilibrium - quasi-Fermi Levels	22
2.5.1 The 2-Diode Model	24
3 Experimental Details	27
3.1 Material and Solar Cell Preparation.....	27
3.1.1 Very High Frequency PECVD Process.....	27
3.1.2 Hot-Wire CVD Process.....	29
3.1.3 Solar Cell Device Structure.....	32
3.2 Photoluminescence Characterization	34
3.2.1 Fourier Transform-Photoluminescence Spectroscopy	34
3.2.2 Experimental Set-up	35
3.3 Modulation Technique	36
3.4 Optical Generation Rate Measurements.....	38
3.5 Structural Characterization.....	39
3.5.1 Raman Spectroscopy	39
4 Photoluminescence Results on Undoped $\mu\text{c-Si:H}$ Thin Films	43
4.1 Influence of the Silane to Hydrogen Ratio in the Gas Phase on the Photoluminescence Properties.....	43

4.1.1 Photoluminescence Peak Energy and Width of Luminescence Spectra	46
4.1.2 Photoluminescence Intensity	48
4.2 Raman and Photoluminescence Properties of Undoped $\mu\text{c-Si:H}$ Thin Films	49
4.3 Effect of the High Substrate Temperature on the Photoluminescence Properties	51
4.4 Structural Inhomogeneity Along the Growth Direction.....	56
4.5 Separation of Microcrystalline from Amorphous Photoluminescence Bands	60
4.6 Temperature Dependent Measurements	64
4.6.1 Temperature Dependence of the Photoluminescence Intensity	65
4.6.2 Temperature Dependence of the Photoluminescence Peak Energy	67
5 Photoluminescence Results on Microcrystalline Silicon Solar Cells.....	69
5.1 Microstructure and Photoluminescence Properties of $\mu\text{c-Si:H}$ Solar Cells	69
5.2 Modulated Photoluminescence Spectra	71
5.3 Influence of the Silane Concentration	72
5.4 Temperature Dependence.....	73
5.4.1 Short Circuit Current Density j_{sc} and Photoluminescence Intensity of Modulated Spectra.....	74
5.4.2 Open Circuit Voltage and Photoluminescence Energy of Modulated Spectra	75
5.4.3 Comparison with Crystalline and Amorphous Silicon Solar Cells	76
5.5 Effect of the Optical Generation Rate	79
5.5.1 Open Circuit Voltage and Photoluminescence Energy of Modulated Spectra	79
5.5.2 Short Circuit Current Density j_{sc}	80
6 Discussion	83
6.1 Discussion on Photoluminescence Properties of $\mu\text{c-Si:H}$ Thin Films	83
6.1.1 Blueshift of Photoluminescence Peak Energy	85
6.1.2 Temperature Dependent Measurements	86
6.1.3 Crystallinity in Relation to Photoluminescence Peak Energy.....	89
6.2 Discussion on Solar Cells - Link between PL Energy and V_{oc}	93
6.2.1 Comparison between Model Calculated and Experimental Results	98
7 Summary and Conclusions	105
A Simulation of PL Spectra Based on Simple Model.....	111
B Deposition Parameters, Raman and Photoluminescence Properties of Films and Solar Cells	117
B.1 Thin Film Deposition Parameters	117
B.2 Photoluminescence and Raman Proprieties of Thin Films.....	119
B.3 Solar Cells Deposition Parameters, Raman and I-V Proprieties	121

Bibliography	123
Acknowledgments.....	135
Publications Related to the Ph.D. Thesis.....	137