



Capacitance-Based Methods to Study Charge Transport and Recombination in Organic Solar Cells

Irene Zonno

Energie & Umwelt / Energy & Environment

Band / Volume 530

ISBN 978-3-95806-528-4

Forschungszentrum Jülich GmbH
Institut für Energie- und Klimaforschung
IEK-5 Photovoltaik

Capacitance-Based Methods to Study Charge Transport and Recombination in Organic Solar Cells

Irene Zonno

Schriften des Forschungszentrums Jülich
Reihe Energie & Umwelt / Energy & Environment

Band / Volume 530

ISSN 1866-1793

ISBN 978-3-95806-528-4

Contents

Acknowledgments	i
Abstract	iii
Zusammenfassung	v
1 Introduction	1
2 Organic Photovoltaics	5
2.1 Organic Semiconductors	5
2.2 Organic Solar Cell Structures	6
2.3 Organic Solar Cell Operating Principles	9
2.3.1 Photon Absorption and Exciton Generation	9
2.3.2 Exciton Diffusion and Dissociation	10
2.3.3 Charge-Carrier Transport	11
2.3.4 Charge-Carrier Extraction	12
2.4 Device Physics	12
2.5 Solar Cell Characteristics	17
3 Recombination Dynamics	23
3.1 Geminate Recombination	23
3.2 Nongeminate Recombination	24
3.2.1 Bulk Recombination	24
3.2.2 Surface Recombination	28

4	Experimental Setups and Characterization Techniques	31
4.1	Organic Solar Cell Materials	31
4.1.1	Donor Materials	31
4.1.2	Acceptor Materials	33
4.2	Sample Preparation	33
4.3	J - V Curves	35
4.4	Impedance Measurements: C - V and C - f Curves	35
4.4.1	Mott-Schottky Analysis	37
4.4.2	Analysis of C - f Data	39
4.5	Solar Cell Simulation	42
4.5.1	ASA	42
4.5.2	SCAPS	43
5	Distinguishing between Surface and Bulk Recombination	45
5.1	Introduction	45
5.2	Theoretical Background	46
5.3	Results from Simulation	48
5.4	Experimental Results	52
5.5	Conclusions	54
6	Understanding Mott-Schottky Measurements under Illumination	55
6.1	Introduction	55
6.2	Theoretical Model	56
6.3	Comparison between Models to Extract the Capacitance from the Total Impedance	61
6.4	Results and Discussion	63
6.5	Conclusions	73
7	Deriving the Charge-Carrier Lifetime from the Capacitance under Illumination	75
7.1	Introduction	75
7.2	Photocapacitance at Short Circuit	76
7.3	Determination of the Charge Density at Short Circuit	80
7.4	Lifetime vs Mobility	90

7.5	Experimental Results	93
7.6	Conclusions	95
8	Extracting Recombination Parameters from Impedance Measurements	97
8.1	Introduction	97
8.2	Theoretical Background	98
8.3	Determination of the Average Charge-Carrier Density	101
8.4	Determination of the SRH Lifetime	106
8.5	Determination of the Bimolecular Recombination Coefficient	111
8.6	Experimental Results	114
8.7	Conclusions	120
9	Conclusions	121
	Bibliography	124
	List of Symbols	147
	List of Publications	153

CONTENTS

Energie & Umwelt / Energy & Environment
Band / Volume 530
ISBN 978-3-95806-528-4