University of Groningen

Reducing losses in solution processed organic solar cells

Rahimichatri, Azadeh

DOI:
[10.33612/diss.170159026](https://doi.org/10.33612/diss.170159026)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2021

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):
Rahimichatri, A. (2021). *Reducing losses in solution processed organic solar cells*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen. <https://doi.org/10.33612/diss.170159026>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Reducing losses in solution processed organic solar cells

Azadeh Rahimichatri

university of
 groningen

faculty of science
 and engineering

zernike institute for
 advanced materials

Reducing losses in solution processed organic solar cells

Azadeh Rahimichatri

PhD thesis

University of Groningen, the Netherlands

Zernike Institute PhD thesis series 2021-16

ISSN: 1570-1530

✿ The work described in this thesis was performed in the Photophysics and Opto-Electronics group of the Zernike Institute for Advanced Materials at the University of Groningen, the Netherlands. This work was supported by a grant from STW/NWO (VIDI 13476).

Printed by: Ridderprint

Cover design: Azadeh Rahimichatri

university of
 groningen

Reducing losses in solution processed organic solar cells

PhD thesis

to obtain the degree of PhD at the
 University of Groningen
 on the authority of the
 Rector Magnificus Prof. C. Wijmenga
 and in accordance with
 the decision by the College of Deans.

This thesis will be defended in public on

Friday 4 June 2021 at 14:30 hours

by

Azadeh Rahimichatri

born on 6 September 1985
 in Gonbadekavoos, Iran

Supervisors

Prof. L.J.A. Koster

Prof. M.A. Loi

Assessment committee

Prof. R.M. Hildner

Prof. P. Rudolf

Prof. N. Stingelin

Contents

1	Introduction	1
1.1	Renewable energy	2
1.2	Organic semiconductors	2
1.2.1	Transport of charges in organic semiconductors	4
1.2.2	Measuring the charge carrier mobility	5
1.3	Photovoltaic devices	6
1.4	Organic solar cells	7
1.4.1	Loss mechanisms	8
1.5	Doping in organic photovoltaics	10
1.5.1	Stability of doped organic films	12
1.6	Outline of this thesis	12
	Bibliography	14
2	Impact of electrodes on recombination in solution processed organic solar cells	21
2.1	Introduction	22
2.2	Theoretical background	24
2.2.1	Measurement of the bulk recombination lifetime and recombination coefficient	24
2.2.2	Transient photovoltage measurements	27
2.2.3	Light intensity dependent measurements	28
2.3	Results and discussion	29
2.3.1	Bulk recombination lifetime and the recombination coefficient	29
2.3.2	Transient photovoltage measurements	31
2.3.3	Discussion	31
2.4	Conclusions	33
2.5	Experimental procedures	34
	Appendix	
2.A	Supplementary data	36
	Bibliography	42

3	Non-fullerene organic solar cells: Recombination versus extraction	45
3.1	Introduction	46
3.2	Theoretical background	47
3.3	Results and discussion	48
3.4	Conclusion	53
3.5	Experimental procedures	53
	Bibliography	55
4	Movement of dopants under bias voltage: identifying inefficient organic doping	59
4.1	Introduction	60
4.2	Numerical Case Study	61
4.3	Experimental results	65
4.4	Conclusions	69
4.5	Experimental procedures	69
	Bibliography	71
5	Stability of doped fullerene derivatives: introducing a fullerene derivative with good stability under electrical and thermal stress	73
5.1	Introduction	74
5.2	Results and discussion	75
5.3	Conclusions	80
5.4	Experimental procedures	81
	Appendices	
5.A	Synthesis of the fullerene derivatives	83
5.B	NMR spectra	88
5.C	AFM images	91
5.D	Differential scanning calorimetry (DSC)	92
5.E	Electrical measurements	93
	Bibliography	94
	Summary	97
	Samenvatting	99
	Publications	101
	Acknowledgements	102