

University of Groningen

Conjugated molecules

Ye, Gang

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:

2019

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

Citation for published version (APA):

Ye, G. (2019). *Conjugated molecules: Design and synthesis of -conjugated materials for optoelectronic and thermoelectric applications*. [Groningen].

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).

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.

CONJUGATED MOLECULES

Design and synthesis of π -conjugated materials for
optoelectronic and thermoelectric applications

Gang Ye



university of
 groningen

faculty of science
 and engineering

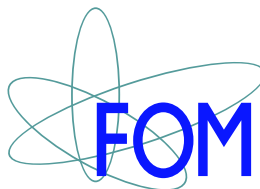
CONJUGATED MOLECULES

Design and synthesis of π -conjugated materials for optoelectronic and thermoelectric applications

Gang Ye

This project was carried out in the research group Chemistry of (Bio)Molecular Materials and Devices which is part of Stratingh Institute for Chemistry and Zernike Institute for Advanced Materials, University of Groningen, The Netherlands.

This work was funded by China Scholarship Council. This work is part of the research program of the Foundation for Fundamental Research on Matter (FOM), which is part of The Netherlands Organization for Scientific Research (NWO).



Printed by: GVO drukkers & vormgevers B.V.

Front & Back: The cover is designed by Gang Ye.

Copyright © 2019 by G. Ye

ISBN: 978-97-034-1659-5 (printed)

ISBN: 978-94-034-1658-8 (electronic)

An electronic version of this dissertation is available at

<http://www.rug.nl/research/portal>.



university of
groningen

CONJUGATED MOLECULES

Design and synthesis of π -conjugated materials for
optoelectronic and thermoelectric applications

PhD Thesis

to obtain the degree of PHD at the
University of Groningen
on the authority of the
Rector Magnificus Prof. E. Sterkrn
and in accordance with
the decision by the College of Deans.

This thesis will be defended in public on

Friday 14 June 2019 at 9:00 hours

by

Gang Ye

born on 12 June 1986
in Hubei, China.

Supervisors

Prof. R.C. Chiechi

Prof. J.C. Hummelen

Assessment Committee

Prof. K.U. Loos

Prof. M.M.G. Kamperman

Prof. H. Zhang

To my dear family

Contents

1	Introduction	1
1.1	The Field of Conjugated Polymers and Organic Electronics Applications	2
1.2	Intrinsic Conjugated Polymers and Polymer Solar Cells	2
1.3	Doped Conjugated Polymers and Thermoelectric Devices	6
1.4	General Routes for Synthesis of Conjugated Polymers	11
1.5	Green Solvents Processable Conjugated Polymers	13
1.6	Thesis Outline	15
	References	17
2	Synthesis, Optical and Electrochemical Properties of High-quality Cross-conjugated Aromatic Polyketones	25
2.1	Introduction	26
2.2	Results and Discussion	27
2.2.1	Synthesis and Characterization	27
2.2.2	Thermal Properties	28
2.2.3	Photophysical Properties	30
2.2.4	Electrochemical Properties	32
2.2.5	Density Functional Theory Calculation	33
2.3	Conclusion	34
2.4	Experimental	34
	References	41
3	Conjugated Polyions Enable Organic Photovoltaics Processed from Green Solvents	43
3.1	Introduction	44
3.2	Results and Discussion	45
3.2.1	Synthesis and Characterization	45
3.2.2	Photophysical Properties	46
3.2.3	Electrochemical Properties	48
3.2.4	Density Functional Theory Calculation	48
3.2.5	Device Characteristic	48
3.3	Conclusion	52
3.4	Experimental	52
	References	64

4	The Effects of Ethylene Glycol Side Chains on Molecular N-doping of Low Bandgap Donor-Acceptor Copolymers	69
4.1	Introduction	70
4.2	Results and Discussion	71
4.3	Conclusions	81
4.4	Experimental	81
4.4.1	Device Fabrication and Characterization	82
4.4.2	Synthesis and Characterization	85
	References	89
5	N-type Organic Thermoelectrics of Donor-Acceptor Copolymers: Improved Power Factor by Molecular Tailoring of the Density of States	93
5.1	Introduction	94
5.2	Results and Discussions	95
5.3	Conclusions	102
5.4	Experimental	102
5.4.1	Synthesis and Characterization of Materials.	102
5.4.2	General Synthetic Procedures for the NDI Based D-A Copolymers	103
5.4.3	Characterization of NDI Based D-A Copolymers.	105
5.4.4	Device Fabrication and Characterization	107
	References	116
6	Molecular Wires Conductance: Linear Conjugation versus Cross Conjugation	121
6.1	Introduction	122
6.2	Results and Discussion	123
6.2.1	Design and Synthesis of Molecular Wires	123
6.2.2	UV-Vis Absorption Spectroscopy	126
6.2.3	Conductance Measurements	127
6.2.4	Transport Calculation	131
6.3	Conclusions	135
6.4	Experimental	136
	References	145
	Summary	151
	Samenvatting	155
	Acknowledgements	159