

University of Groningen

Polymer-wrapped carbon nanotubes for high performance field effect transistors

Derenskyi, Volodymyr

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:

2017

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

Citation for published version (APA):

Derenskyi, V. (2017). *Polymer-wrapped carbon nanotubes for high performance field effect transistors*. University of 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).

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.

**Polymer-wrapped carbon
nanotubes for high performance
field effect transistors**

Volodymyr Derenskyi

Polymer-wrapped carbon nanotubes for high performance field effect transistors

Volodymyr Y. Derenskyi

PhD Thesis

University of Groningen

Cover design: Volodymyr Derenskyi, Vadim Prohorenko

Printing: GVO printers & designers B.V.

Zernike Institute PhD thesis series 2017-14

ISSN: 1570-1530

ISBN: 978-90-367-9887-7 (printed version)

ISBN: 978-90-367-9886-0 (electronic version)



**university of
 groningen**



connecting innovators

The research was carried out in the Photophysics and Optoelectronics research group of the Zernike Institute for Advanced Materials, University of Groningen. The project was financially supported by De Stichting voor de Technische Wetenschappen (STW), which is part of the Netherlands Organisation for Scientific Research (NWO).



university of
 groningen

Polymer-wrapped carbon nanotubes for high performance field effect transistors

PhD thesis

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

This thesis will be defended in public on

Tuesday 11 July 2017 at 09.00 hours

by

Volodymyr Y. Derenskyi

born on 5 September 1988
 in Kaniv, Oekraïne

Supervisor
Prof. M.A. Loi

Assessment Committee
Prof. Y.Y. Noh
Prof. E. Menna
Prof. P. Rudolf

Contents

Chapter 1

Introduction.....	9
1.1 Single-walled carbon nanotubes (SWNT)	10
1.2 Electronic and optical properties of carbon nanotubes	13
1.3 Synthesis of SWNTs.....	16
1.4 SWNTs sorting techniques	18
1.5 SWNT-based electronic devices.....	24
1.5.1 Field-effect transistor.....	24
1.5.2 Ambipolar FET	27
1.6 SWNT field-effect transistor (FET) architectures	29
1.7 Outline of the thesis.....	31
1.8 References	34

Chapter 2

Carbon nanotubes network ambipolar field effect transistors with 10^8 on/off ratio	39
2.1 Introduction	40
2.2 Semi-aligned SWNTs network by blade coating	41
2.3 PF12 and P3DDT-wrapped SWNTs for FETs fabrication	44
2.4 The origin of the charge transport difference	49
2.5 Conclusion.....	53
2.6 Experimental section	53
2.7 References	55

Chapter 3

Anomalous Carrier Transport in Ambipolar Field-Effect Transistor of Large Diameter Single-Walled Carbon Nanotube Network.....	59
3.1 Introduction	60
3.2 Study of the temperature-dependent carrier transport in large-diameter sSWNT networks	61
3.3 Conclusion.....	71
3.4 Experimental Section	71
3.5 References	72
Chapter 4	
Estimation of the purity of polymer-wrapped semiconducting SWNTs by single nanotube transistors fabrication.....	75
4.1 Introduction	76
4.2 Single-SWNT FETs characterization	77
4.3 Conclusions	85
4.4 Experimental section	85
4.5 References	87
Chapter 5	
On-chip chemical self-assembly of semiconducting Single-Walled Carbon Nanotubes (SWNTs): towards robust and scale invariant SWNTs transistors	89
5.1 Introduction	90
5.2 SWNTs selection by thiol-modified polymers.....	92
5.3 Nanotube network FET by SWNT self-assembly.....	98
5.4 Highly reproducible single SWNT FET fabrication.....	108
5.5 Conclusion.....	111
5.6 Experimental section	112
5.7 References	115
Summary	119

Samenvatting.....	121
Acknowledgements.....	124
List of Publications	127

