

University of Groningen

Development and study of low-dimensional hybrid and nanocomposite materials based on layered nanostructures

Kouloumpis, Antonios

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):

Kouloumpis, A. (2017). Development and study of low-dimensional hybrid and nanocomposite materials based on layered nanostructures [Groningen]: 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).

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.

**Development and study of low-dimensional hybrid and
nanocomposite materials based on layered
nanostructures**

Antonios Kouloumpis

This PhD thesis is the result of an effort started 4 years ago and carried out at the "Ceramics and Composites Laboratory", of Materials Science and Engineering department of University of Ioannina, Greece and at the "Thin Films and Surfaces" group of Zernike Institute for Advanced Materials of Groningen University, Netherlands.

The front cover page represents hybrid nanostructures of 0D moieties within graphene nanosheets.

Zernike Institute PhD thesis series 2017-20

ISSN: 1570-1530

ISBN: 978-90-367-9998-0 (print)

ISBN: 978-90-367-9997-3 (digital)



Development and study of low-dimensional hybrid and nanocomposite materials based on layered nanostructures

PhD thesis

to obtain the degree of PhD of 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.

and

to obtain the degree of PhD of
University of Ioannina
on the authority of the
Rector Prof. G. Kapsalis
and in the accordance with
the decision of the General Meeting
of the Department of Materials Science and Engineering

Double PhD degree

This thesis will be defended in public on
Monday 11 September 2017 at 14.30 hours at University of Groningen
&
Friday 15 September 2017 at 14.30 hours at University of Ioannina

by

Antonios Kouloumpis

born on 2 December 1986
in Ioannina, Greece

Supervisors

Prof. P. Rudolf
Prof. D. Gournis

Assessment committee for University of Groningen

Prof. F. Picchioni
Prof. G. E. Froudakis
Prof. G. S. Düsberg
Prof. A. S. Paipetis

Assessment committee for University of Ioannina

Prof. D. Gournis
Prof. M. A. Karakassides
Prof. A. B. Bourlinos
Prof. P. Rudolf
Prof. A. S. Paipetis
Prof. G. E. Froudakis
Prof. H. Stamatis

Table of Contents

Chapter 1: Introduction.....	1
1.1 Layered nanomaterials	2
1.1.1 Graphene	3
1.1.2 Graphene oxide.....	4
1.1.3 Germanane	4
1.2 0D Carbon Nanoallotropes	5
1.2.1 Fullerenes	6
1.2.2 Carbon Dots	6
1.3 Langmuir-Blodgett technique.....	7
1.4 Outline of the thesis	7
1.5 References	9
Appendix A: Characterization techniques.....	11
A.1 FTIR spectroscopy	11
A.2 Raman spectroscopy	11
A.3 X-ray photoelectron spectroscopy	11
A.4 X-ray diffraction	12
A.5 Thermal analysis	12
A.6 UV-Vis spectroscopy	13
A.7 Photoluminescence spectroscopy	13
A.8 Nuclear magnetic resonance	13
A.9 Contact angle measurements.....	14
A.10 Scanning electron microscopy.....	14
A.11 Electrical conductivity measurements.....	14
A.12 Atomic force microscopy	15
A.13 References of Appendix A.....	15

Chapter 2: Graphene-based hybrids through the Langmuir-Blodgett approach.....	17
2.1 Introduction	18
2.2 Monolayers of Graphene Oxide.....	19
2.3 Nanocomposite films	23
2.4 Applications and properties of LB thin films.....	25
2.5 Conclusions	31
2.6 References	32
Chapter 3: A bottom-up approach for the synthesis of highly ordered fullerene-intercalated graphene hybrids.....	35
3.1 Introduction	36
3.2 Experimental Section.....	38
3.2.1 Materials	38
3.2.2 Synthesis of graphene oxide.....	38
3.2.3 Preparation of hybrid graphene/fullerene multilayers.....	38
3.3 Results and Discussion	40
3.3.1 Structure control of hybrid ODA-GO layer.....	40
3.3.2 Characterization of hybrid graphene/fullerene multilayers	42
3.4 Conclusions	48
3.5 References	49
Chapter 4: Controlled deposition of fullerene derivatives within a graphene template by means of a modified Langmuir-Schaefer method.....	53
4.1 Introduction	54
4.2 Experimental Section.....	56
4.2.1 Materials	56
4.2.2 Synthesis of Graphene Oxide	56
4.2.3 Synthesis of fullerene derivatives.....	57

4.2.4 Preparation of hybrid multilayers of graphene oxide and C ₆₀ -derivatives	57
4.3 Results-discussion.....	59
4.3.1 Structural characterization of C ₆₀ derivatives	59
4.3.2 Structural control of hybrid monolayers.....	62
4.4 Conclusions	70
4.5 References	72

Chapter 5: Graphene/carbon-dot hybrid thin films prepared by a modified Langmuir-Schaefer method.....

5.1 Introduction	80
5.2 Experimental Section	82
5.2.1 Materials	82
5.2.2 Synthesis of graphene oxide.....	82
5.2.3 Synthesis of C-dots	82
5.2.4 Preparation of hybrid graphene/C-dots multilayers.....	83
5.3 Results and Discussion	84
5.3.1 Structural and morphological characterization of pristine C-dots.....	84
5.3.2 Structural control and characterization of hybrid ODA-GO/C-dot monolayers.....	86
5.3.3 Characterization of graphene/C-dot hybrid films.....	88
5.4 Conclusions	94
5.5 References	96

Appendix B.....

B.1 Experimental procedures	101
B.1.1 Preparation of hydrophobic quartz substrates	101
B.1.2 Deposition of isolated C-dots on Si-wafers for the AFM measurements	102
B.2 Characterization of pristine C-dots	103
B.3 References of Appendix B	108

Chapter 6: Germanane: improved synthesis and application as antimicrobial agent.....	109
6.1 Introduction	110
6.2 Experimental Section.....	114
6.2.2 Materials	114
6.2.3 Synthesis of Germanane.....	114
6.2.4 Preparation of germanane monolayers.....	115
6.2.5 Bacterial strains and growth media.....	116
6.2.6 Preparation of bacteria and treatment of germanane	116
6.3 Results and Discussion	118
6.3.1 Structural and morphological characterization of germanane	118
6.3.2 Structural control and characterization of GeH monolayers.....	121
6.3.3 Antimicrobial activity of germanane	125
6.4 Conclusions	128
6.5 References	130
Summary.....	137
Samenvatting.....	141
Περίληψη.....	145
Acknowledgements.....	149
Publications.....	153
Curriculum Vitae.....	157