

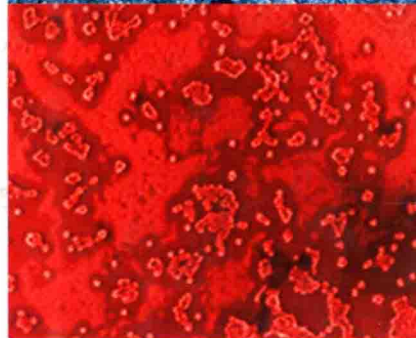
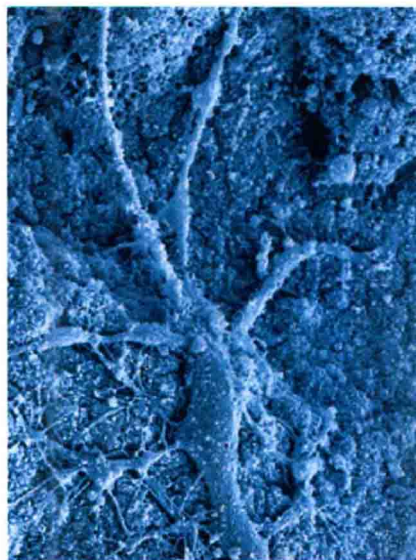
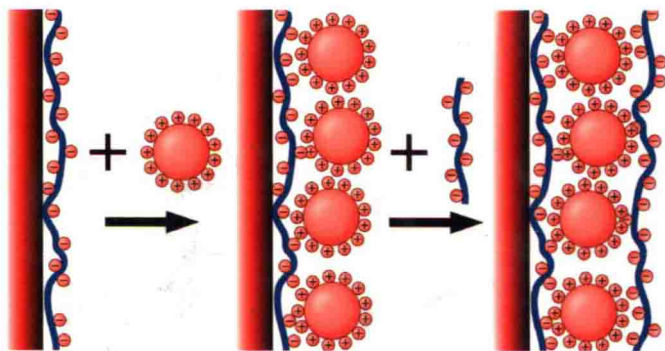
Edited by
Gero Decher and Joseph B. Schlenoff

WILEY-VCH

Multilayer Thin Films

Sequential Assembly of Nanocomposite Materials

Second, Completely Revised and Enlarged Edition



Edited by
Gero Decher and Joseph B. Schlenoff

Multilayer Thin Films

Sequential Assembly of Nanocomposite Materials

Second, Completely Revised and Enlarged Edition



WILEY-VCH Verlag GmbH & Co. KGaA

The Editors

Prof. Gero Decher

Université de Strasbourg
Institut Charles Sadron, UPR 22
23, rue du Loess
67034 Strasbourg Cedex 2
France

Prof. Joseph B. Schlenoff

Florida State University
Chemistry Department
Tallahassee, FL 32306-4390
USA

■ All books published by Wiley-VCH are carefully produced. Nevertheless, authors, editors, and publisher do not warrant the information contained in these books, including this book, to be free of errors. Readers are advised to keep in mind that statements, data, illustrations, procedural details or other items may inadvertently be inaccurate.

Library of Congress Card No.: applied for

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

**Bibliographic information published by
the Deutsche Nationalbibliothek**

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at <http://dnb.d-nb.de>.

© 2012 Wiley-VCH Verlag & Co. KGaA,
Boschstr. 12, 69469 Weinheim, Germany

All rights reserved (including those of translation into other languages). No part of this book may be reproduced in any form – by photoprinting, microfilm, or any other means – nor transmitted or translated into a machine language without written permission from the publishers. Registered names, trademarks, etc. used in this book, even when not specifically marked as such, are not to be considered unprotected by law.

Composition Thomson Digital, Noida, India

Printing and Binding betz-druck GmbH, Darmstadt

Cover Design Schulz Grafik-Design, Fußgönheim

Printed in the Federal Republic of Germany
Printed on acid-free paper

Print ISBN: 978-3-527-31648-9

ePDF ISBN: 978-3-527-64677-7

oBook ISBN: 978-3-527-64674-6

ePub ISBN: 978-3-527-64676-0

Edited by
Gero Decher and
Joseph B. Schlenoff

Multilayer Thin Films

Related Titles

Pacchioni, G., Valeri, S. (eds.)

Oxide Ultrathin Films Science and Technology

2012

ISBN: 978-3-527-33016-4

Friedbacher, G., Bubert, H. (eds.)

Surface and Thin Film Analysis A Compendium of Principles, Instrumentation, and Applications

2011

ISBN: 978-3-527-32047-9

Knoll, W., Advincula, R. C. (eds.)

Functional Polymer Films 2 Volume Set

2011

ISBN: 978-3-527-32190-2

Kumar, C. S. S. R. (ed.)

Polymeric Nanomaterials

2011

ISBN: 978-3-527-32170-4

Urban, M. W. (ed.)

Handbook of Stimuli-Responsive Materials

2011

ISBN: 978-3-527-32700-3

Fernandez-Nieves, A., Wyss, H., Mattsson, J., Weitz, D. A. (eds.)

Microgel Suspensions Fundamentals and Applications

2011

ISBN: 978-3-527-32158-2

Samori, P., Cacialli, F. (eds.)

Functional Supramolecular Architectures for Organic Electronics and Nanotechnology

2011

ISBN: 978-3-527-32611-2

Chujo, Y. (ed.)

Conjugated Polymer Synthesis Methods and Reactions

2011

ISBN: 978-3-527-32267-1

Leclerc, M., Morin, J.-F. (eds.)

Design and Synthesis of Conjugated Polymers

2010

ISBN: 978-3-527-32474-3

List of Contributors

Rigoberto C. Advincula

University of Houston
Departments of Chemistry and
Chemical and Biomolecular
Engineering
136 Fleming Building
Houston, TX 77204-5003
USA

Hioharu Ajiro

Osaka University
Department of Applied Chemistry
2-1 Yamada-oka
Suita, Osaka 565-0871
Japan

Mitsuro Akashi

Osaka University
Department of Applied Chemistry
2-1 Yamada-oka
Suita, Osaka 565-0871
Japan

Maria N. Antipina

Agency for Science, Technology and
Research (A*STAR)
Institute of Materials Research and
Engineering
3 Research Link
Singapore 117602
Singapore

Jun-ichi Anzai

Tohoku University
Graduate School of
Pharmaceutical Sciences
Aramaki, Aoba-ku
Sendai 980-8578
Japan

Pedro H.B. Aoki

Universidade Estadual Paulista
(UNESP)
Faculdade de Ciências e Tecnologia
19060-900 Presidente Prudente, SP
Brazil

Katsuhiko Ariga

National Institute for Materials Science
(NIMS)
World Premier International (WPI)
Research Center for Materials
Nanoarchitectonics (MANA)
1-1 Namiki
Tsukuba 305-0044
Japan

and

JST
CREST
1-1 Namiki
Tsukuba 305-0044
Japan

Jianhao Bai

National University of Singapore
Division of Bioengineering
Singapore 117576
Singapore

Vincent Ball

Centre de Recherche Public
Henri Tudor
Department of Advanced Materials and
Structures
66 rue de Luxembourg
4002 Esch-sur-Alzette
Luxembourg

Sebastian Beyer

National University of Singapore
Division of Bioengineering
Singapore 117576
Singapore

and

National University of Singapore
Graduate School for Integrative
Sciences and Engineering
Singapore 11756
Singapore

Stephan Block

Ernst-Moritz-Arndt Universität
Institut für Physik
Felix-Hausdorff-Str. 6
17487 Greifswald
Germany

Thomas Boudou

Grenoble Institute of Technology and
Centre National de la Recherche
Scientifique
CNRS UMR 5628, LMGP, MINATEC
3 Parvis Louis Néel
38016 Grenoble
France

Merlin L. Bruening

Michigan State University
Department of Chemistry
East Lansing, MI 48824
USA

Cédric C. Buron

Université Catholique de Louvain
Institute of Condensed Matter and
Nanosciences – Bio & Soft Matter
Croix du Sud 1
1348 Louvain-la-Neuve
Belgium

Ernesto J. Calvo

Universidad de Buenos Aires
Departamento de Química Inorgánica
Electrochemistry Group, INQUIMAE
Pabellón 2, Ciudad Universitaria
Buenos Aires 1428
Argentina

Frank Caruso

The University of Melbourne
Department of Chemical and
Biomolecular Engineering
Building 173
Melbourne, Victoria 3010
Australia

Chloe Chevigny

TU Berlin
Department of Chemistry
Straße des 17. Juni 124
10623 Berlin
Germany

Robert E. Cohen

Massachusetts Institute of Technology
Departments of Materials Science and
Engineering and Chemical Engineering
77 Massachusetts Avenue
Cambridge, MA 02139
USA

Carlos J.L. Constantino

Universidade Estadual Paulista
(UNESP)
Faculdade de Ciências e Tecnologia
19060-900 Presidente Prudente, SP
Brazil

Cornelia Cramer

University of Münster
Institute of Physical Chemistry
Corrensstr. 28/30
48149 Münster
Germany

Thomas Crouzier

Grenoble Institute of Technology and
Centre National de la Recherche
Scientifique
CNRS UMR 5628, LMGP, MINATEC
3 Parvis Louis Néel
38016 Grenoble
France

Yue Cui

Chinese Academy of Sciences
Institute of Chemistry
Beijing National Laboratory for
Molecular Sciences (BNLMS)
Zhongguancun North First Street 2
Beijing 100190
China

Chalongrat Daengngam

Virginia Polytechnic Institute and
State University
Department of Physics
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Bruno G. De Geest

Ghent University
Department of Pharmaceutics
Harelbekestraat 72
9000 Ghent
Belgium

Sophie Demoustier-Champagne

Université Catholique de Louvain
Institute of Condensed Matter and
Nanosciences – Bio & Soft Matter
Croix du Sud 1
1348 Louvain-la-Neuve
Belgium

Stefaan C. De Smedt

Ghent University
Department of Pharmaceutics
Harelbekestraat 72
9000 Ghent
Belgium

Wang Dong

Virginia Polytechnic Institute and
State University
Department of Physics
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Ashraf El-Hashani

University of Cologne
Department of Chemistry
Luxemburger Str. 116
50939 Köln
Germany

Nicel Estillore

University of Houston
Departments of Chemistry and
Chemical and Biomolecular
Engineering
136 Fleming Building
Houston, TX 77204-5003
USA

Jinbo Fei

Chinese Academy of Sciences
Institute of Chemistry
Beijing National Laboratory for
Molecular Sciences (BNLMS)
Zhongguancun North First Street 2
Beijing 100190
China

Andreas Fery

University of Bayreuth
Department of Physical Chemistry II
95440 Bayreuth
Germany

Karine Glinel

Université de Rouen, CNRS
Laboratoire Polymères, Biopolymères,
Surfaces
Bd M. de Broglie
7681 Mont Saint Aignan
France

and

Université Catholique de Louvain
Institute of Condensed Matter and
Nanosciences – Bio & Soft Matter
Croix du Sud 1
1348 Louvain-la-Neuve
Belgium

Jaime C. Grunlan

Texas A&M University
Department of Mechanical Engineering
College Station, TX 77843-3123
USA

Aurélien Guyomard

Université de Rouen, CNRS
Laboratoire Polymères, Biopolymères,
Surfaces
Bd M. de Broglie
7681 Mont Saint Aignan
France

Lara Halaoui

American University of Beirut
Department of Chemistry
Beirut
Lebanon

Paula T. Hammond

Massachusetts Institute of Technology
Department of Chemical Engineering
77 Massachusetts Avenue
Cambridge, MA 02139
USA

Qiang He

Harbin Institute of Technology
Micro/Nano Technology Research
Centre
Harbin 150080
China

Randy Heflin

Virginia Polytechnic Institute and
State University
Department of Physics
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Christiane A. Helm

Ernst-Moritz-Arndt Universität
Institut für Physik
Felix-Hausdorff-Str. 6
17487 Greifswald
Germany

Jonathan P. Hill

National Institute for Materials Science
(NIMS)
World Premier International (WPI)
Research Center for Materials
Nanoarchitectonics (MANA)
1-1 Namiki
Tsukuba 305-0044
Japan

and

JST
CREST
1-1 Namiki
Tsukuba 305-0044
Japan

Kristina Hoffmann

University of Cologne
Department of Chemistry
Luxemburger Str. 116
50939 Köln
Germany

Jurriaan Huskens

University of Twente
MESA+ Institute for Nanotechnology
Molecular Nanofabrication Group
7500 AE Enschede
The Netherlands

Md Nasim Hyder

Massachusetts Institute of Technology
Department of Chemical Engineering
77 Massachusetts Avenue
Cambridge, MA 02139
USA

Qingmin Ji

National Institute for Materials Science
(NIMS)
World Premier International (WPI)
Research Center for Materials
Nanoarchitectonics (MANA)
1-1 Namiki
Tsukuba 305-0044
Japan

Chaoyang Jiang

University of South Dakota
Chemistry Department
414 East Clark Street
Vermillion, SD 57069
USA

Alain M. Jonas

Université Catholique de Louvain
Institute of Condensed Matter and
Nanosciences – Bio & Soft Matter
Croix du Sud 1
1348 Louvain-la-Neuve
Belgium

Jouko Kankare

University of Turku
Department of Chemistry
Laboratory of Materials Chemistry and
Chemical Analysis
20014 Turku
Finland

Toshiyuki Kida

Osaka University
Department of Applied Chemistry
2-1 Yamada-oka
Suita, Osaka 565-0871
Japan

Maxim V. Kiryukhin

Agency for Science, Technology and
Research (A*STAR)
Institute of Materials Research and
Engineering
3 Research Link
Singapore 117602
Singapore

Ralf Köhler

TU Berlin
Department of Chemistry
Straße des 17. Juni 124
10623 Berlin
Germany

Nicholas A. Kotov

University of Michigan
Departments of Chemical Engineering,
Materials Science and Engineering, and
Biomedical Engineering
2300 Hayward Street
Ann Arbor, MI 48109
USA

Ilsoo Lee

Michigan State University
Department of Chemical Engineering
and Materials Science
2527 Engineering Building
East Lansing, MI 48824
USA

Junbai Li

Chinese Academy of Sciences
Institute of Chemistry
Beijing National Laboratory for
Molecular Sciences (BNLMS)
Zhongguancun North First Street 2
Beijing 100190
China

Xiaokong Liu

Jilin University
College of Chemistry
State Key Laboratory of Supramolecular
Structure and Materials
Changchun 130012
China

Yuri Lvov

Louisiana Tech University
Institute for Micromanufacturing
911 Hergot Avenue
Ruston, LA 71272
USA

David M. Lynn

University of Wisconsin – Madison
Department of Chemical and Biological
Engineering
1415 Engineering Drive
Madison, WI 53706
USA

Dewang Ma

Université de Montréal
Faculté de Pharmacie
Succursale Centre-Ville
Montréal, Quebec H3C 3J7
Canada

Anna Maier

University of Cologne
Department of Chemistry
Luxemburger Str. 116
50939 Köln
Germany

Michiya Matsusaki

Osaka University
Department of Applied Chemistry
2-1 Yamada-oka
Suita, Osaka 565-0871
Japan

Jonathan Metzman

Virginia Polytechnic Institute and
State University
Department of Materials Science and
Engineering
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Marc Michel

Centre de Recherche Public
Henri Tudor
Department of Advanced Materials and
Structures
66 rue de Luxembourg
4002 Esch-sur-Alzette
Luxembourg

Helmuth Möhwald

Max-Planck Institute of
Colloids and Interfaces
Fraunhofer Institute of
Biomedical Technology
Research Campus Golm
Am Mühlenberg 1
14424 Potsdam-Golm
Germany

Reza Montazami

Virginia Polytechnic Institute and
State University
Department of Materials Science and
Engineering
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Peter Nestler

Ernst-Moritz-Arndt Universität
Institut für Physik
Felix-Hausdorff-Str. 6
17487 Greifswald
Germany

Bernard Nysten

Université Catholique de Louvain
Institute of Condensed Matter and
Nanosciences – Bio & Soft Matter
Croix du Sud 1
1348 Louvain-la-Neuve
Belgium

Oswaldo N. Oliveira Jr.

Universidade de São Paulo
Instituto de Física de São Carlos
13560-970 São Carlos, SP
Brazil

Yong Tae Park

Texas A&M University
Department of Mechanical Engineering
College Station, TX 77843-3123
USA

Pravin Pattekari

Louisiana Tech University
Institute for Micromanufacturing
911 Hergot Avenue
Ruston, LA 71272
USA

Felippe J. Pavinatto

Universidade de São Paulo
Instituto de Física de São Carlos
13560-970 São Carlos, SP
Brazil

Catherine Picart

Grenoble Institute of Technology and
Centre National de la Recherche
Scientifique
CNRS UMR 5628, LMGP, MINATEC
3 Parvis Louis Néel
38016 Grenoble
France

Paul Podsiadlo

University of Michigan
Department of Chemical Engineering
2300 Hayward Street
Ann Arbor, MI 48109
USA

David N. Reinhoudt

University of Twente
MESA+ Institute for Nanotechnology
Molecular Nanofabrication Group
7500 AE Enschede
The Netherlands

Kefeng Ren

Grenoble Institute of Technology and
Centre National de la Recherche
Scientifique
CNRS UMR 5628, LMGP, MINATEC
3 Parvis Louis Néel
38016 Grenoble
France

H.D. Robinson

Virginia Polytechnic Institute and
State University
Department of Physics
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Cécile J. Roy

Université Catholique de Louvain
Institute of Condensed Matter and
Nanosciences – Bio & Soft Matter
Croix du Sud 1
1348 Louvain-la-Neuve
Belgium

Michael F. Rubner

Massachusetts Institute of Technology
Departments of Materials Science and
Engineering and Chemical Engineering
77 Massachusetts Avenue
Cambridge, MA 02139
USA

Mikko Salomäki

University of Turku
Department of Chemistry
Laboratory of Materials Chemistry and
Chemical Analysis
20014 Turku
Finland

Katsuhiko Sato

Tohoku University
Graduate School of
Pharmaceutical Sciences
Aramaki, Aoba-ku
Sendai 980-8578
Japan

Joseph B. Schlenoff

Florida State University
Department of Chemistry and
Biochemistry
95 Chieftan Way
Tallahassee, FL 32306-4390
USA

Monika Schönhof

University of Münster
Institute of Physical Chemistry
Corrensstr. 28/30
48149 Münster
Germany

Takeshi Serizawa

University of Tokyo
Research Center for Advanced Science
and Technology
4-6-1 Komaba, Meguro-ku
Tokyo 153-8904
Japan

Nisarg Shah

Massachusetts Institute of Technology
Department of Chemical Engineering
77 Massachusetts Avenue
Cambridge, MA 02139
USA

Dmitry G. Shchukin

Max-Planck Institute of
Colloids and Interfaces
Research Campus Golm
Am Mühlenberg 1
14424 Potsdam-Golm
Germany

Jiacong Shen

Jilin University
College of Chemistry
State Key Laboratory of Supramolecular
Structure and Materials
Changchun 130012
China

Bong Sup Shim

University of Michigan
Department of Chemical Engineering
2300 Hayward Street
Ann Arbor, MI 48109
USA

Tatsiana Shutava

Louisiana Tech University
Institute for Micromanufacturing
911 Hergot Avenue
Ruston, LA 71272
USA

Andre G. Skirtach

Max-Planck-Institute of
Colloids and Interfaces
Fraunhofer Institute of
Biomedical Technology
Research Campus Golm
Am Mühlenberg 1
14476 Potsdam-Golm
Germany

Olaf Soltwedel

Ernst-Moritz-Arndt Universität
Institut für Physik
Felix-Hausdorff-Str. 6
17487 Greifswald
Germany

Svetlana Sukhishvili

Stevens Institute of Technology
Department of Chemistry, Chemical
Biology and Biomedical Engineering
1 Castle Point on Hudson
Hoboken, NJ 07030
USA

Gleb B. Sukhorukov

Queen Mary University of London
School of Engineering and
Materials Science
Mile End Road
London E1 4NS
UK

Junqi Sun

Jilin University
College of Chemistry
State Key Laboratory of Supramolecular
Structure and Materials
Changchun 130012
China

Shigehiro Takahashi

Tohoku University
Graduate School of
Pharmaceutical Sciences
Aramaki, Aoba-ku
Sendai 980-8578
Japan

Benjamin Thierry

University of South Australia
Ian Wark Research Institute
Mawson Lakes Campus
Mawson Lakes, South Australia 5095
Australia

Bernd Tieke

University of Cologne
Department of Chemistry
Luxemburger Str. 116
50939 Köln
Germany

Dieter Trau

National University of Singapore
Division of Bioengineering
Singapore 117576
Singapore

and

National University of Singapore
Department of Chemical &
Biomolecular Engineering
Singapore 117576
Singapore

Vladimir V. Tsukruk

Georgia Institute of Technology
Materials Science and Engineering
771 Ferst Drive N.W.
Atlanta, GA 30332-0245
USA

Janneke Veerbeek

University of Twente
MESA+ Institute for Nanotechnology
Molecular Nanofabrication Group
7500 AE Enschede
The Netherlands

Dmitry V. Volodkin

Max-Planck-Institute of
Colloids and Interfaces
Fraunhofer Institute of
Biomedical Technology
Research Campus Golm
Am Mühlenberg 1
14476 Potsdam-Golm
Germany

Regine von Klitzing

TU Berlin
Department of Chemistry
Straße des 17. Juni 124
10623 Berlin
Germany

Lars Wågberg

KTH – Royal Institute of Technology
School of Chemical Science and
Engineering
Fibre and Polymer Technology and
The Wallenberg Wood Science Centre
Teknikringen 56–58
10044 Stockholm
Sweden

Françoise M. Winnik

Université de Montréal
Faculté de Pharmacie and
Département de Chimie
Succursale Centre-Ville
Montréal, Quebec H3C 3J7
Canada

and

National Institute for Materials Science
(NIMS)
World Premier International (WPI)
Research Center for Materials
Nanoarchitectonics (MANA)
1-1 Namiki
Tsukuba 305-0044
Japan

Guanglu Wu

Tsinghua University
Department of Chemistry
116 Hetian Building
Beijing 100084
China

Ming Yang

University of Michigan
Department of Chemical Engineering
2300 Hayward Street
Ann Arbor, MI 48109
USA

Xi Zhang

Tsinghua University
Department of Chemistry
308 Hetian Building
Beijing 100084
China

Ziwei Zuo

Virginia Polytechnic Institute and
State University
Department of Physics
Robeson Hall (0435)
Blacksburg, VA 24061-0435
USA

Contents

List of Contributors XXV

Volume 1

1	Layer-by-Layer Assembly (Putting Molecules to Work)	1
	<i>Gero Decher</i>	
1.1	The Whole is More than the Sum of its Parts	1
1.2	From Self-Assembly to Directed Assembly	1
1.3	History and Development of the Layer-by-Layer Assembly Method	4
1.4	LbL-Assembly is the Synthesis of Fuzzy Supramolecular Objects	6
1.5	Reproducibility and Choice of Deposition Conditions	7
1.6	Monitoring Multilayer Build-up	10
1.7	Spray- and Spin-Assisted Multilayer Assembly	13
1.8	Recent Developments	14
1.8.1	Self-patterning LbL-Films	14
1.8.2	Deposition of LbL-Films on Very Small Particles	15
1.8.3	Purely Inorganic LbL-“Films”	17
1.9	Final Remarks	18
	References	19
Part I	Preparation and Characterization	23
2	Layer-by-Layer Processed Multilayers: Challenges and Opportunities	25
	<i>Michael F. Rubner and Robert E. Cohen</i>	
2.1	Introduction	25
2.2	Fundamental Challenges and Opportunities	25
2.2.1	LbL Assembly on Nanoscale Elements and in Confined Geometries	25
2.2.2	Living Cells as Functional Elements of Polyelectrolyte Multilayers	28
2.2.3	Multilayer Cellular Backpacks	28
2.2.4	Direct LbL Processing of Living Cells	29
2.3	Technological Challenges and Opportunities	31
2.3.1	Improving Processing Time and Versatility	31
2.3.2	Towards Mechanically Robust Multilayer Coatings	32
2.4	The Path Forward	36
	References	36

3	Layer-by-Layer Assembly: from Conventional to Unconventional Methods	43
	<i>Guanglu Wu and Xi Zhang</i>	
3.1	Introduction	43
3.2	Conventional LbL Methods	44
3.2.1	Electrostatic LbL Assembly	44
3.2.2	Hydrogen-Bonded LbL Assembly	47
3.2.3	LbL Assembly Driven by Coordination Interaction	50
3.2.4	To Combine LbL Assembly and Post-Chemical Reaction for the Fabrication of Robust Thin Films	50
3.3	Unconventional LbL Methods	52
3.3.1	Electrostatic Complex for Unconventional LbL Assembly	52
3.3.1.1	Nanoreactors with Enhanced Quantum Yield	53
3.3.1.2	“Ion Traps” for Enhancing the Permselectivity and Permeability	53
3.3.1.3	Surface Imprinted LbL Films	54
3.3.1.4	Cation-Selective μ CP Based on SMILbL Film	58
3.3.2	Hydrogen-Bonded Complex for Unconventional LbL Assembly	58
3.3.3	Block Copolymer Micelles for Unconventional LbL Assembly	61
3.3.4	π - π Interaction Complex for Electrostatic LbL Assembly	62
3.4	Summary and Outlook	64
	References	64
4	Novel Multilayer Thin Films: Hierarchic Layer-by-Layer (Hi-LbL) Assemblies	69
	<i>Katsuhiko Ariga, Qingmin Ji, and Jonathan P. Hill</i>	
4.1	Introduction	69
4.2	Hi-LbL for Multi-Cellular Models	70
4.3	Hi-LbL for Unusual Drug Delivery Modes	72
4.4	Hi-LbL for Sensors	75
4.4.1	Mesoporous Carbon Hi-LbL	75
4.4.2	Mesoporous Carbon Capsule Hi-LbL	76
4.4.3	Graphene/Ionic-Liquid Hi-LbL	78
4.5	Future Perspectives	79
	References	80
5	Layer-by-Layer Assembly Using Host-Guest Interactions	83
	<i>Janneke Veerbeek, David N. Reinhoudt, and Jurriaan Huskens</i>	
5.1	Introduction	83
5.2	Supramolecular Layer-by-Layer Assembly	84
5.3	3D Patterned Multilayer Assemblies on Surfaces	85
5.4	3D Supramolecular Nanoparticle Crystal Structures	88
5.5	Porous 3D Supramolecular Assemblies in Solution	90
5.6	Conclusions	95
	References	95