



# Nanostructure, Nanosystems, and Nanostructured Materials

Theory, Production, and Development

P. M. Sivakumar, PhD  
Vladimir I. Kodolov, DSc  
Gennady E. Zaikov, DSc  
A. K. Haghi, PhD  
Editors



Apple Academic Press

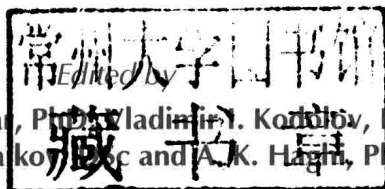


CRC Press  
Taylor & Francis Group

# NANOSTRUCTURE, NANOSYSTEMS, AND NANOSTRUCTURED MATERIALS

Theory, Production, and Development

P. M. Sivakumar, PhD, Vladimir I. Kozlov, DSc  
Gennady E. Zakharenko, DSc and A. K. Haghi, PhD



Apple Academic Press

TORONTO NEW JERSEY

Apple Academic Press Inc. 3333 Mistwell Crescent Oakville, ON L6L 0A2 Canada	Apple Academic Press Inc. 9 Spinnaker Way Waretown, NJ 08758 USA
---	---

©2014 by Apple Academic Press, Inc.

*Exclusive worldwide distribution by CRC Press, a member of Taylor & Francis Group*

No claim to original U.S. Government works

Printed in the United States of America on acid-free paper

International Standard Book Number-13: 978-1-926895-49-9 (Hardcover)

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission and sources are indicated. Copyright for individual articles remains with the authors as indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the authors, editors, and the publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors, editors, and the publisher have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged, please write and let us know so we may rectify in any future reprint.

**Trademark Notice:** Registered trademark of products or corporate names are used only for explanation and identification without intent to infringe.

**Library of Congress Control Number: 2013945479**

---

#### Library and Archives Canada Cataloguing in Publication

---

Nanostructure, nanosystems, and nanostructured materials: theory, production, and development/edited by Prof. P.M. Sivakumar, Dr. Vladimir Ivanovitch Kodolov, Dr. Gennady E. Zaikov, and Dr. A.K. Haghi.

Includes bibliographical references and index.

ISBN 978-1-926895-49-9

1. Nanocomposites (Materials). 2. Nanostructured materials.  
3. Carbon composites. 4. Metallic composites. 5. Nanochemistry.  
I. Sivakumar, P. M., writer of preface, editor of compilation

TA418.9.N35N42 2013

620.1'18

C2013-904998-3

---

Apple Academic Press also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic format. For information about Apple Academic Press products, visit our website at **[www.appleacademicpress.com](http://www.appleacademicpress.com)** and the CRC Press website at **[www.crcpress.com](http://www.crcpress.com)**

# **NANOSTRUCTURE, NANOSYSTEMS, AND NANOSTRUCTURED MATERIALS**

Theory, Production, and Development



# ABOUT THE EDITORS

---

## **P. M. Sivakumar, PhD**

P. M. Sivakumar, PhD, is a Foreign Postdoctoral Researcher (FPR) at RIKEN, Wako Campus, in Japan. RIKEN is Japan's largest comprehensive research institution renowned for high-quality research in a diverse range of scientific disciplines. He received his PhD from the Department of Biotechnology, Indian Institute of Technology Madras, India. He is a member of the editorial boards of several journals and has published papers in international peer-reviewed journals and professional conferences. His research interests include bioinformatics and computational approaches for drug design, small molecule synthesis and their biological evaluation, and bionanotechnology and biomaterials.

## **Vladimir I. Kodolov, DSc**

Vladimir I. Kodolov, DSc, is Professor and Head of the Department of Chemistry and Chemical Technology at M. I. Kalashnikov Izhevsk State Technical University in Izhevsk, Russia, as well as Chief of Basic Research at the High Educational Center of Chemical Physics and Mesoscopy at the Udmurt Scientific Center, Ural Division at the Russian Academy of Sciences. He is also the Scientific Head of Innovation Center at the Izhevsk Electromechanical Plant in Izhevsk, Russia.

## **Gennady E. Zaikov, DSc**

Gennady E. Zaikov, DSc, is Head of the Polymer Division at the N. M. Emanuel Institute of Biochemical Physics, Russian Academy of Sciences, Moscow, Russia, and professor at Moscow State Academy of Fine Chemical Technology, Russia, as well as professor at Kazan National Research Technological University, Kazan, Russia. He is also a prolific author, researcher, and lecturer. He has received several awards for his work, including the Russian Federation Scholarship for Outstanding Scientists. He has been a member of many professional organizations and on the editorial boards of many international science journals.

**A. K. Haghi, PhD**

A. K. Haghi, PhD, holds a BSc in urban and environmental engineering from University of North Carolina (USA); a MSc in mechanical engineering from North Carolina A&T State University (USA); a DEA in applied mechanics, acoustics and materials from Université de Technologie de Compiègne (France); and a PhD in engineering sciences from Université de Franche-Comté (France). He is the author and editor of 65 books as well as 1000 published papers in various journals and conference proceedings. Dr. Haghi has received several grants, consulted for a number of major corporations, and is a frequent speaker to national and international audiences. Since 1983, he served as a professor at several universities. He is currently Editor-in-Chief of the *International Journal of Chemoinformatics and Chemical Engineering* and *Polymers Research Journal* and on the editorial boards of many international journals. He is also a faculty member of University of Guilan (Iran) and a member of the Canadian Research and Development Center of Sciences and Cultures (CRDCSC), Montreal, Quebec, Canada.

# LIST OF CONTRIBUTORS

---

## **L. F. Akhmetshina**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk  
OJSC “Izhevsk Electromechanical Plant—Kupol”

## **I. I. Blagodatskikh**

M. T. Kalashnikov Izhevsk State Technical University

## **A. Yu. Bondar**

M. T. Kalashnikov Izhevsk State Technical University

## **M. A. Chashkin**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk  
OJSC “Izhevsk Electromechanical Plant—Kupol”

## **Siva Chidambaram**

Division of Nanoscience and Technology, Anna University-BIT Campus, Thiruchirapalli, 620024, India

## **Ramasamy Jayavel**

Centre for Nanoscience and Technology, Anna University, Chennai, 600025, India

## **Park Jinsub**

Department of Electronic and Computer Engineering, Hanyang University, Seoul 133791, Korea

## **Jayaraman Kandasamy**

Defence Research and Development Organization (DRDO), New Delhi, India

## **Jin Kawakita**

Electronics Material Centre, National Institute for Materials Science, Namiki, Tsukuba 305-0044, Japan

## **N. V. Khokhriakov**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk  
Izhevsk State Agricultural Academy

## **V. I. Kodolov**

M. T. Kalashnikov Izhevsk State Technical University  
Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk

## **G. A. Korablev**

Izhevsk Agricultural Academy  
Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk



**Ganesan Mohan Kumar**

Department of Electronic and Computer Engineering, Hanyang University, Seoul 133791, Korea, E-mail: mobhuu@gmail.com  
Centre for Nanoscience and Technology, Anna University, Chennai, 600025, India

**V. I. Ladyanov**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk

**A. M. Lipanov**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Ural Division, Udmurt Scientific Centre, Russian Academy of Sciences, Izhevsk  
Institute of Mechanics, Ural Division, Russian Academy of Sciences, Izhevsk

**L. G. Makarova**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk

**E. A. Naimushina**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk

**Sreevidya Narasimhan**

Women Scientist—C, Lakshmi Kumaran and Sridharan Attorneys, No. 2, Wallace garden 2nd street, Nungambakkam, Chennai, TamilNadu India

**Kasi Nehru**

Department of chemistry, Anna University-BIT Campus, Thiruchirapalli 620024, India

**R. M. Nikonova**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk

**Ramesh Chandra Pandey**

Ph. D., Department of Pediatric Pneumology and Neonatology, Hannover Medical School, Hannover 30625, Germany, E-mail: rcpandey.vs@gmail.com

**Yu. V. Pershin**

M.T. Kalashnikov Izhevsk State Technical University  
Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Ural Division, Udmurt Scientific Centre, Russian Academy of Sciences, Izhevsk

**Ya. A. Polyotov**

M.T. Kalashnikov Izhevsk State Technical University  
Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk

**V. I. Ryabova**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk

**G. V. Sapozhnikov**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk

**Vijay Kumar Saxena**

M. VSc., Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India  
Dr. An A. SeongSoo  
Associate Professor, Ph. D., Department of Bionano Technology, Gachon University, Sunghnam, Korea, E-mail: seongaan@gachon.ac.kr

**I. N. Shabanova**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk  
Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Ural Division, Udmurt Scientific Centre, Russian Academy of Sciences, Izhevsk

**Vishwas Sharma**

M. Sc., Hannover Medical School, Hannover 30625, Germany

**Muthusamy Sivakumar**

Division of Nanoscience and Technology, Anna University-BIT Campus, Thiruchirapalli 620024, India, E-mail: siva.may3@gmail.com, muthusiva@gmail.com

**N. S. Terebova**

Ural Division, Physical Technical Institute, Russian Academy of Sciences, Izhevsk  
Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Ural Division, Udmurt Scientific Centre, Russian Academy of Sciences, Izhevsk

**Rajangam Thanavel**

M. pharm, (Ph.D candidate), Department of Bionano Technology, Gachon Bionano Research Institute, Gachon University, Sungnam, Korea, E-mail address: thana.vel2009@gmail.com

**V. V. Trineeva**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Ural Division, Udmurt Scientific Centre, Russian Academy of Sciences, Izhevsk  
Institute of Mechanics, Ural Division, Russian Academy of Sciences, Izhevsk

**M. A. Vakhrushina**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Udmurt Scientific Centre, Ural Division, Russian Academy of Sciences, Izhevsk  
OJSC “Izhevsk Electromechanical Plant—Kupol”

**Yu. M. Vasil’chenko**

Basic Research—High Educational Centre of Chemical Physics and Mesoscopy, Ural Division, Udmurt Scientific Centre, Russian Academy of Sciences, Izhevsk  
M. T. Kalashnikov Izhevsk State Technical University  
OJSC “Izhevsk Electromechanical Plant—Kupol”

**G. E. Zaikov**

N. M. Emanuel Institute of Biochemical Physics, Russian Academy of Sciences, Moscow



# LIST OF ABBREVIATIONS

---

AA	Acetylacetone
Adv-hBMP-2	Adenovirus-mediated human BMP-2 gene
AEM	Aryl ethynylene macrocycle
AES	Auger-electron spectroscopy
AFM	Atomic force microscopy
AP	Ammonium perchlorate
APP	Ammonium polyphosphate
APPh	Ammonium polyphosphate
ARDB	Aeronautical Research and Development Board
AcAc	Acetylacetone
bFGF	Basic fibroblast growth factor
BHK	Baby-hamster kidney
BMP	Bone morphogenic protein
BMSC	Bone marrow stromal cell
BSSE	Basis sets of complex molecules
CHEC	Cold-hardened epoxy composition
CTAB	Cetyltrimethyl ammonium bromide
CVs	Cyclic voltammograms
DAA	Diacetonealcohol
DRDO	Defence Research and Development Organisation
DSSC	Dye sensitized solar cells
EC	Endothelial cell
ECM	Extracellular matrix
ED	Electron diffraction
EDAX	Energy Dispersive Analysis by X-Rays
EDR	Epoxy diene resin
EGF	Epidermal growth factors
ER	Epoxy resin
eV	Electron-volts
FDA	Food and Drug Administration
FET	Field-effect transistor
FGF	Fibroblast growth factor
FN	Fibronectin
FS	Fine suspensions
GATET	Gas Turbine Enabling Technology Initiative

GN	Gadolinium nitrate
GTRE	Gas Turbine Research and Establishment
HA	Hydrogen bonding agent
HBBA	2-(4'-Hydroxybenzeneazo) benzoic acid
hES	Human embryonic stem cells
IEP	Isoelectric point
IR MDCIR	Infrared microscopy of multiply disturbed complete inner reflection
KGF	Keratinocyte growth factor
LED	Light-emitting diode
LFE	Linear dependencies of free energies
LMMA	Laser microprobe mass-analysis
MPC	Monolayer protected cluster
MRI	Magnetic resonance imaging
MRSA	Methicillin-resistant <i>S. aureus</i>
MSs	Mesenchymal stem cell
nAl	Nano Al particle
NGF	Nerve growth factors
NS	Nanostructures
OFET	Organic field effect transistors
OLED	Organic light-emitting diode
P3HT	Poly (3-hexylthiophene)
PAGA	Poly (-[4-aminobutyl]-l-glycolic acid)
PAMAM	Poly (amido amine)
PAP	Polyammonium-phosphate
PC	Polycarbonate
PCM	Polymeric composite materials
PEG	Polyethylene glycol
PEPA	Polyethylene polyamine
PFR	Phenol-formaldehyde resins
PGA	Polyglycolic acid
PHA	Polyhydroxyalkanoate
PHB	Polyhydroxybutyrate
PHBV	Polyhydroxy-co-valerate
PLA	Poly-lactic acid
PLGA	Polyglycolic-co-lactic acid
PMMA	Polymethyl methacrylate
PPF	Polypropylene fumarate
PPI	Poly(propylene-imine)
PPy	Polypyrrole
PS-PVP	Polystyrene-b-polyvinylpyridine
PTCDI	Perylene tetracarboxylic diimide

PV	Photovoltaic
PVA	Polyvinyl alcohol
PVAc	Polyvinyl acetate
PVC	Polyvinyl chloride
rhVEGF	Recombinant human vascular endothelial growth factor
RS	Raman spectroscopy
SAM	Self-assembled monolayer
Sc	Coked surface
SC	Schwann cell
SCD	Spectroscopy of combination dissipation
SED	Spectroscopy of ionic dissipation
SEM	Scanning electron microscopy
SEP	Spatial-energy parameter
SFD	Squeeze Film Damper
SIMS	Secondary ionic mass-spectrometry
siRNA	Small interference RNA
SMD	Sauter mean diameter
SREM	Scanning raster electron microscopy
TEM	Tunnel electron microscopy
TEMEMD	Transmission electron microscopy with electron microdiffraction
TG-DTA	Thermo-gravimetric and differential thermal analyze
TGF	Transforming growth factor
TiO <sub>2</sub>	Titanium dioxide
TU	Technical condition
UPS	Ultraviolet photoelectron spectroscopy
UPSIO	Ultra small particulars of iron oxide
UVES	Ultraviolet electron spectroscopy
WF	Work function
XPS	X-Ray photoelectron spectroscopy
ZN	Zirconyl nitrate
ZPVE	Zero-point vibration energy



# PREFACE

---

This volume accumulates the most important information about new trends in nanochemistry and also in the science about materials modified by nanostructures.

The editors selected papers, including reviewed articles, in the field of chemical physics of metal/carbon nanocomposites.

The book includes information on the new classes of metal/carbon nanocomposites and their new production methods in the nanoreactors of polymeric matrixes. In recent years, the chemistry in nanoreactors of polymeric matrixes has successfully been developed. For synthesis of metal containing nanophases in carbon or polymeric shells, it is expedient to evaluate the possibilities of redox reactions with the participation of metal containing phases and organic (or polymeric) compounds (matrixes).

The book raises discussion of the following topics:

1. The place of metal/carbon nanocomposites besides other nanostructures.
2. Main notions and characteristics of metal/carbon nanocomposites and nanosystems including them.
3. Nanochemistry principles for nanostructures synthesis in nanoreactors of polymeric matrixes.
4. Modeling of processes for obtaining nanocomposites, nanosystems and nanostructured materials.
5. Dependence of nanocomposites activity on their composition, sizes, forms and synthesis methods.
6. Experimental features of metal/carbon nanocomposite redox synthesis.
7. Types of fine dispersed suspensions and the interaction of metal/carbon nanocomposites with different media.
8. Material modification methods by super small quantities of metal/carbon nanocomposites.
9. The investigation of properties of materials modified by fine dispersed suspensions of metal/carbon nanocomposites.



The specific features of this book include:

- Computer prognosis, including quantum chemical modeling, for metal/carbon nanocomposites synthesis processes as well as fine dispersed suspensions obtaining processes and material modification processes
- Determination of new notions for metal/carbon nanocomposites and estimation of their activity
- Redox synthesis of metal/carbon nanocomposites in nanoreactors of polymeric matrixes
- Application of Avrami equations to determine the conditions for processes of metal/carbon nanocomposites synthesis and material modification
- Mechanic-chemical functionalization methods for increasing nanocomposite surface energy electronic component
- Modification methods for changing different materials properties

This book is unique and important because the new trends in nanochemistry and new objects of nanostructures are discussed. Its appeal to potential readers consists of its full information about new perspective nanostructures, new methods of synthesis in nanoreactors of polymeric matrixes and also different material modification by super small quantities of metal/carbon nanocomposites. Researchers, professors, post and undergraduates, students and other readers will find a lot of interesting information and obtain new knowledge in chemical physics of metal/carbon nanocomposites.

The editors and contributors will be happy to receive comments from readers, which we can use in our research and studies in future.

— **P. M. Sivakumar, Vladimir I. Kodolov,  
Gennady E. Zaikov, and A. K. Haghi**