

---

# In-situ Characterization Techniques for Nanomaterials

---

Challa S. S. R. Kumar  
Editor

# In-situ Characterization Techniques for Nanomaterials

With 210 Figures and 8 Tables

 Springer

*Editor*

Challa S. S. R. Kumar  
Integrated Mesoscale Architectures for Sustainable Catalysis (IMASC)  
Rowland Institute of Science  
Harvard University  
Cambridge, MA, USA

ISBN 978-3-662-56321-2                      ISBN 978-3-662-56322-9 (eBook)  
<https://doi.org/10.1007/978-3-662-56322-9>

Library of Congress Control Number: 2018932039

© Springer-Verlag GmbH Germany, part of Springer Nature 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by the registered company Springer-Verlag GmbH, DE part of Springer Nature.

The registered company address is: Heidelberger Platz 3, 14197 Berlin, Germany

---

# Contents

<b>1</b>	<b>Liquid Cell Electron Microscopy for the Study of Growth Dynamics of Nanomaterials and Structure of Soft Matter</b> . . . . .	<b>1</b>
	Patricia Abellan and Taylor J. Woehl	
<b>2</b>	<b>In Situ X-Ray Studies of Crystallization Kinetics and Ordering in Functional Organic and Hybrid Materials</b> . . . . .	<b>33</b>
	Bin Yang, Jong K. Keum, David B. Geohegan, and Kai Xiao	
<b>3</b>	<b>Wide-Field Surface Plasmon Resonance Microscopy for In-Situ Characterization of Nanoparticle Suspensions</b> . . . . .	<b>61</b>
	Shavkat Nizamov and Vladimir M. Mirsky	
<b>4</b>	<b>In Situ Localized Surface Plasmon Resonance Spectroscopy for Gold and Silver Nanoparticles</b> . . . . .	<b>107</b>
	Ji Zhou and Bin Tang	
<b>5</b>	<b>In Situ X-Ray Absorption Spectroscopy Studies of Functional Nanomaterials</b> . . . . .	<b>159</b>
	Soma Chattopadhyay, Soon Gu Kwon, Elena V. Shevchenko, Jeffrey T. Miller, and Steve M. Heald	
<b>6</b>	<b>In Situ X-Ray Absorption Spectroscopy to Study Growth of Nanoparticles</b> . . . . .	<b>189</b>
	Chandrani Nayak, S. N. Jha, and Dibyendu Bhattacharyya	
<b>7</b>	<b>In Situ Characterization Tools for Bi<sub>2</sub>Te<sub>3</sub> Topological Insulator Nanomaterials</b> . . . . .	<b>223</b>
	P. Ngabonziza, M. P. Stehno, G. Koster, and A. Brinkman	
<b>8</b>	<b>In Situ Characterization of Size, Spatial Distribution, Chemical Composition, and Electroanalytical Response of Hybrid Nanocomposite Materials</b> . . . . .	<b>251</b>
	Julio Bastos-Arrieta, Raquel Montes, Cristina Ocaña, Marisol Espinoza, Maria Muñoz, and Mireia Baeza	

---

<b>9</b>	<b>Quartz Crystal Resonator for Real-Time Characterization of Nanoscale Phenomena Relevant for Biomedical Applications</b> . . . .	289
	Luis Armando Carvajal Ahumada, Oscar Leonardo Herrera Sandoval, Nuria Peña Perez, Felipe Andrés Silva Gómez, Mariano Alberto García-Vellisca, and José Javier Serrano Olmedo	
<b>10</b>	<b>Quartz Crystal Microbalance Application for Characterization of Nanomaterials In Situ</b> . . . . .	351
	Victor S. Popov and Alexander Sopilniak	
<b>11</b>	<b>Tools and Electrochemical In Situ and On-Line Characterization Techniques for Nanomaterials</b> . . . . .	383
	Têko W. Napporn, Laetitia Dubau, Claudia Morais, Mariana R. Camilo, Julien Durst, Fabio H. B. Lima, Frédéric Maillard, and K. Boniface Kokoh	
	<b>Index</b> . . . . .	441

---

## Contributors

**Patricia Abellan** SuperSTEM Laboratory, SciTech Daresbury Campus, Daresbury, UK

**Luis Armando Carvajal Ahumada** Centro de tecnología Biomédica (CTB),  
Universidad Politécnica de Madrid (UPM), Madrid, Spain

Facultad de Ingeniería y Ciencias Básicas, Universidad Central, Bogotá, Colombia  
Centro de investigación y desarrollo tecnológico de la industria electro electrónica y  
TIC, Bogotá, Colombia

**Mireia Baeza** Departament de Química, Facultat de Ciències, Carrer dels Til·lers,  
Edifici C-Entrada Nord, Bellaterra, Barcelona, Spain

**Julio Bastos-Arrieta** Department of Chemical Engineering, Universitat  
Politécnica de Catalunya, Barcelona, Spain

Barcelona Research Center in Multiscale Science and Engineering, Barcelona, Spain  
Physical Chemistry, Technische Universität Dresden, Dresden, Germany

**Dibyendu Bhattacharyya** Atomic and Molecular Physics Division, Bhabha  
Atomic Research Centre, Trombay, Mumbai, India

**K. Boniface Kokoh** IC2MP UMR 7285 CNRS University of Poitiers, Poitiers,  
France

**A. Brinkman** Faculty of Science and Technology and MESA+, Institute for Nano-  
technology, University of Twente, Enschede, The Netherlands

**Mariana R. Camilo** IQSC, University of São Paulo, São Carlos, SP, Brazil

**Soma Chattopadhyay** Elgin Community College, Elgin, IL, USA

**Laetitia Dubau** University of Grenoble Alpes, Grenoble, France  
CNRS, Grenoble, France

**Julien Durst** University of Grenoble Alpes, Grenoble, France  
CNRS, Grenoble, France

**Marisol Espinoza** Department of Chemistry, Universidad Autónoma Metropolitana, México, D. F., México

**Mariano Alberto García-Vellisca** Centro de tecnología Biomédica (CTB), Universidad Politécnica de Madrid (UPM), Madrid, Spain

**David B. Geohegan** Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN, USA

**Felipe Andrés Silva Gómez** Corporación de Alta Tecnología para la Defensa (CODALTEC), Villavicencio, Colombia

**Steve M. Heald** Advanced Photon Source, Argonne National Laboratory, Argonne, IL, USA

**S. N. Jha** Atomic and Molecular Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India

**Jong K. Keum** Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN, USA

Neutron Scattering Division, Oak Ridge National Laboratory, Oak Ridge, TN, USA

**G. Koster** Faculty of Science and Technology and MESA+, Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

**Soon Gu Kwon** Center for Nanoparticle Research, Institute for Basic Science and Seoul National University, Seoul, Republic of Korea

**Fabio H. B. Lima** IQSC, University of São Paulo, São Carlos, SP, Brazil

**Frédéric Maillard** University of Grenoble Alpes, Grenoble, France  
CNRS, Grenoble, France

**Jeffrey T. Miller** School of Chemical Engineering, Purdue University, West Lafayette, IN, USA

**Vladimir M. Mirsky** Institute of Biotechnology, Department of Nanobiotechnology, Brandenburg University of Technology Cottbus-Senftenberg, Senftenberg, Germany

**Raquel Montes** Departament d'Enginyeria Química, Biològica i Ambiental, Escola d'Enginyeria, Universitat Autònoma de Barcelona, Barcelona, Spain

Departament d'Enginyeria Química, Biològica i Ambiental, Carrer de les Sitges S/N, Edifici Q, Escola d'Enginyeria Bellaterra, Barcelona, Spain

**Claudia Morais** IC2MP UMR 7285 CNRS University of Poitiers, Poitiers, France

**Maria Muñoz** Departament de Química, Facultat de Ciències, Carrer dels Til·lers, Edifici C-Entrada Nord, Bellaterra, Barcelona, Spain

**Têko W. Napporn** IC2MP UMR 7285 CNRS University of Poitiers, Poitiers, France

**Chandrani Nayak** Atomic and Molecular Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India

**P. Ngabonziza** Faculty of Science and Technology and MESA+, Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

Department of Physics, University of Johannesburg, Johannesburg, South Africa

**Shavkat Nizamov** Institute of Biotechnology, Department of Nanobiotechnology, Brandenburg University of Technology Cottbus-Senftenberg, Senftenberg, Germany

**Cristina Ocaña** Departament Micronano Sistemes, CSIC, Institute of Microelectronics of Barcelona IMB CNM, Bellaterra, Spain

Johan Gadolin Process Chemistry Centre, c/o Laboratory of Analytical Chemistry, Abo Akademi University, Turku, Finland

**José Javier Serrano Olmedo** Centro de tecnología Biomédica (CTB), Universidad Politécnica de Madrid (UPM), Madrid, Spain

**Nuria Peña Perez** Centro de tecnología Biomédica (CTB), Universidad Politécnica de Madrid (UPM), Madrid, Spain

**Victor S. Popov** Department of advanced research and development, Polyus Research Institute of M.F.Stelmakh, Moscow, Russia

Sector for high-temperature and sensor materials, Kurnakov Institute of General and Inorganic Chemistry, The Russian Academy of Sciences, Moscow, Russia

**Oscar Leonardo Herrera Sandoval** Facultad de Ingeniería y Ciencias Básicas, Universidad Central, Bogotá, Colombia

Centro de investigación y desarrollo tecnológico de la industria electro electrónica y TIC, Bogotá, Colombia

**Elena V. Shevchenko** Nanoscience and Technology division, Argonne National Laboratory, Argonne, IL, USA

**Alexander Sopilniak** The Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem, Israel

**M. P. Stehno** Faculty of Science and Technology and MESA+, Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

**Bin Tang** National Engineering Laboratory for Advanced Yarn and Fabric Formation and Clean Production, Wuhan Textile University, Wuhan, China

Institute for Frontier Materials, Deakin University, Geelong, VIC, Australia

**Taylor J. Woehl** Department of Chemical and Biomolecular Engineering, University of Maryland, College Park, MD, USA



**Kai Xiao** Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN, USA

Department of Electrical Engineering and Computer Science, University of Tennessee, Knoxville, TN, USA

**Bin Yang** Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN, USA

The Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

**Ji Zhou** Hubei Collaborative Innovation Center for Advanced Organic Chemical Materials and Key Laboratory for the Synthesis and Application of Organic Functional Molecules, Ministry of Education and College of Chemistry and Chemical Engineering, Hubei University, Wuhan, China