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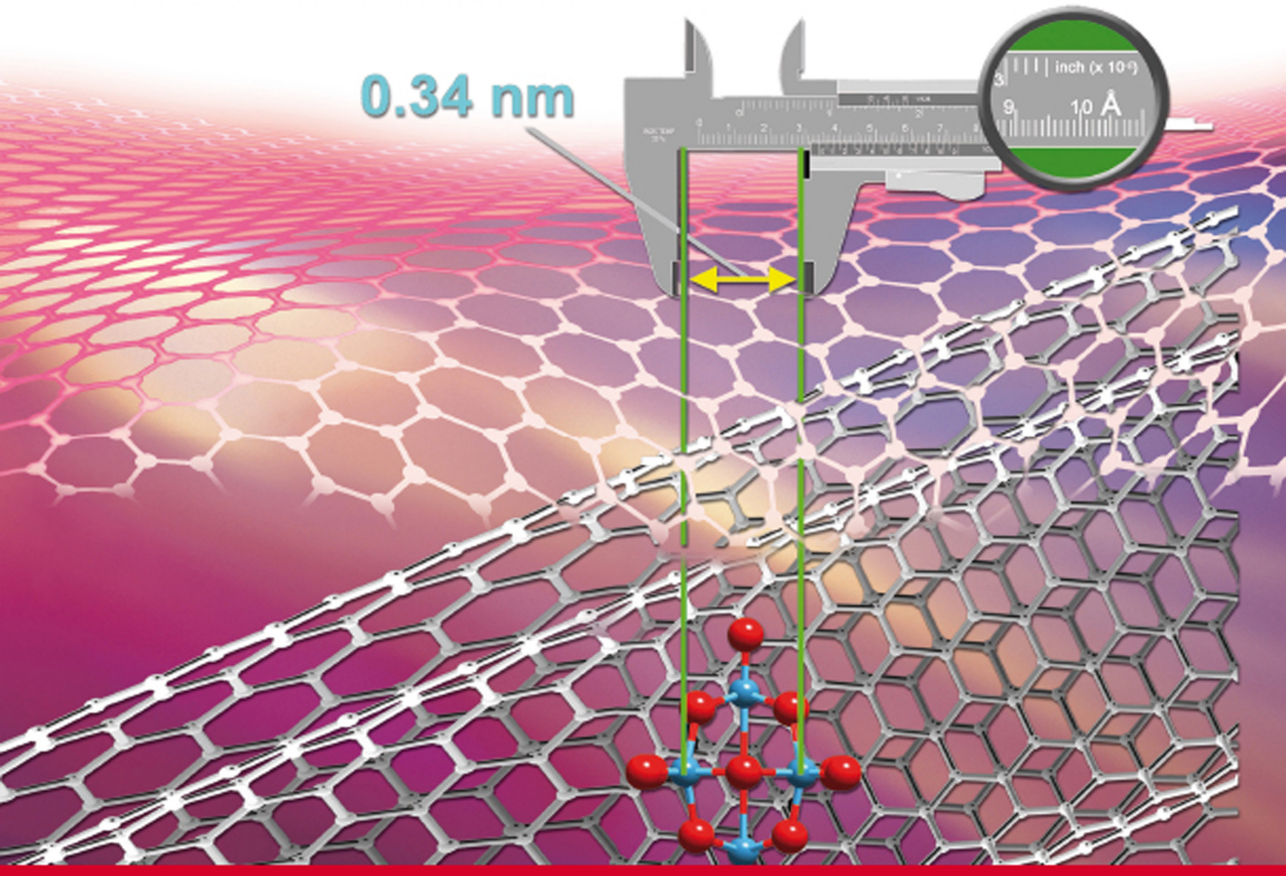
Daisuke Fujita, and Marcel Van de Voorde

Metrology and Standardization for Nanotechnology

Protocols and Industrial Innovations

Series Editor:
Marcel Van de Voorde



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WILEY-VCH
Verlag GmbH & Co. KGaA

Volume Editors

Dr. Elisabeth Mansfield
National Inst. of Standards & Technology
Materials Measurement Laboratory MS 647
325 Broadway
Boulder CO 80305
USA

Dr. Debra L. Kaiser
National Inst. of Standards & Technology
Material Measurement Laboratory MS 8301
100 Bureau Drive
Gaithersburg MD 20899
USA

Prof. Daisuke Fujita
National Inst. for Materials Science
Advanced Key Technologies Division
1-2-1 Sengen
305-0047 Tsukuba, Ibaraki
Japan

Prof. Dr. Dr. h.c. Marcel H. Van de Voorde
Member of the Science Council
of the French Senate and National
Assembly, Paris
Rue du Rhodania, 5
BRISTOL A, Appartement 31
3963 Crans-Montana
Switzerland

Series Editor

Prof. Dr. Dr. h.c. Marcel H. Van de Voorde
Member of the Science Council
of the French Senate and National
Assembly, Paris
Rue du Rhodania, 5
BRISTOL A, Appartement 31
3963 Crans-Montana
Switzerland

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.

Print ISBN: 978-3-527-34039-2
ePDF ISBN: 978-3-527-80005-6
ePub ISBN: 978-3-527-80029-2
Mobi ISBN: 978-3-527-69998-8
oBook ISBN: 978-3-527-80030-8

Cover Design Adam Design
Typesetting Thomson Digital, Noida, India
Printing and Binding

Printed on acid-free paper

Thanks to my wife for her patience with me spending many hours working on the book series through the nights and over weekends.
The assistance of my son Marc Philip related to the complex and large computer files with many sophisticated scientific figures is also greatly appreciated.

Marcel Van de Voorde

Series Editor Preface

Since years, nanoscience and nanotechnology have become particularly an important technology areas worldwide. As a result, there are many universities that offer courses as well as degrees in nanotechnology. Many governments including European institutions and research agencies have vast nanotechnology programmes and many companies file nanotechnology-related patents to protect their innovations. In short, nanoscience is a hot topic!

Nanoscience started in the physics field with electronics as a forerunner, quickly followed by the chemical and pharmacy industries. Today, nanotechnology finds interests in all branches of research and industry worldwide. In addition, governments and consumers are also keen to follow the developments, particularly from a safety and security point of view.

This books series fills the gap between books that are available on various specific topics and the encyclopedias on nanoscience. This well-selected series of books consists of volumes that are all edited by experts in the field from all over the world and assemble top-class contributions. The topical scope of the book is broad, ranging from nanoelectronics and nanocatalysis to nanometrology. Common to all the books in the series is that they represent top-notch research and are highly application-oriented, innovative, and relevant for industry. Finally they collect a valuable source of information on safety aspects for governments, consumer agencies and the society.

The titles of the volumes in the series are as follows:

Human-related nanoscience and nanotechnology

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The book series appeals to a wide range of readers with backgrounds in physics, chemistry, biology, and medicine, from students at universities to scientists at institutes, in industrial companies and government agencies and ministries.

Ever since nanoscience was introduced many years ago, it has greatly changed our lives – and will continue to do so!

March 2016 *Marcel Van de Voorde*

About the Series Editor

Marcel Van de Voorde, Prof. Dr. ir. Ing. Dr. h.c., has 40 years' experience in European Research Organisations, including CERN-Geneva and the European Commission, with 10 years at the Max Planck Institute for Metals Research, Stuttgart. For many years, he was involved in research and research strategies, policy, and management, especially in European research institutions.

He has been a member of many Research Councils and Governing Boards of research institutions across Europe, the United States, and Japan. In addition to his Professorship at the University of Technology in Delft, the Netherlands, he holds multiple visiting professorships in Europe and worldwide. He holds a doctor honoris causa and various honorary professorships.

He is a senator of the European Academy for Sciences and Arts, Salzburg, and Fellow of the World Academy for Sciences. He is a member of the Science Council of the French Senate/National Assembly in Paris. He has also provided executive advisory services to presidents, ministers of science policy, rectors of Universities, and CEOs of technology institutions, for example, to the president and CEO of IMEC, Technology Centre in Leuven, Belgium. He is also a Fellow of various scientific societies. He has been honored by the Belgian King and European authorities, for example, he received an award for European merits in Luxemburg given by the former President of the European Commission. He is author of multiple scientific and technical publications and has coedited multiple books, especially in the field of nanoscience and nanotechnology.

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Foreword

Nanotechnology metrology and standardization are of growing importance in the era of globalization. Applications of nanotechnologies have accelerated in many countries over the past decade, triggered by the US National Nanotechnology Initiative (NNINNI) in 2000. Nanotechnologies are a strong driving force in various industries to improve existing products and create new products. Progress in the development of such products requires advanced metrologies because measurements of nano-objects are very challenging. On the other hand, commercialization and global trade of products requires standardization that gives the basis for the dissemination of nanotechnologies to society.

The importance of international standards and standardization activities is continually increasing. Over 160 countries are members of the World Trade Organization (WTOWTO), which established the rules of trade between nations by the agreement on Technical Barriers to Trade (TBTTBT) signed in 1995. Industrial products are spreading worldwide in the era of globalization and many countries around the world now participate actively in efforts to develop international standards. Standardization of nanotechnologies attracted attention in 2004 led by efforts from CENCEN (European Committee for Standardization), ANSIANSI (American National Standards Institute), and JSAJSA (Japan Standards Association). In 2005–2006, several major standards development organizations (SDOSDOs) established technical committees (TCTCs) focused on nanotechnology: ISO TC 229, CEN TC 352, ASTM International E56, and IECIEC (International Electrotechnical Commission) TC 113. The combined efforts of these Committees have produced a large body of standards concerning terminology, physicochemical and biological measurements, and the environmental, health, and safety of nanomaterials and nanotechnologies.

Standardization of nanotechnology has been accelerated not only to promote industrial application of nanotechnology but also to bring about social acceptance of nanotechnology. The importance of the latter aspect becomes prominent by reports that suggest nanomaterials (nano-objects) may be harmful to human health and ecological systems. Reflecting the increasing interest in precautionary actions for the handling of nanomaterials, efforts among the SDOs mentioned above have been aimed at the implementation of future regulations. Some of the efforts have been already implemented as “list of recognized

standards" by FDA. It has adopted four nanotechnology standards: two technical specifications of ISO (TS 14101 for surface characterization of gold and TS 8004-6 for vocabulary of nano-object characterization) and two ASTM standards (E2490 for measurement of particle size distribution, and E2535 for handling unbound nanoparticle in occupational setting). Moreover, France has set regulations that requests companies and private and public research laboratories to declare the use (producing, distributing, and importing) of substances at the nanoscale beginning January 1, 2013.

With regard to nanometrology, for example, EC regulation (no. 1907/2006) concerns "substances intentionally produced at nanometric scale, containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for a minimum proportion of particles in the number size distribution, one or more external dimensions is in the size range 1–100 nm." It is necessary to show the number size distribution of substance in the size range 1–100 nm, even if the substance contains both particles in unbound and bound/fused states. Since it is a rather hard task to precisely analyze such substances with high-resolution measurement techniques applicable to nanoscale objects, current measurement techniques need further improvement. It follows that the development of nanometrology and nanomaterial standards support further improvement of measurement techniques adaptable to nanoscale characterization, leading to both essential progress of nanotechnology and social acceptance of nanotechnology. It is because the first step of measurement can be considered as "the process of quantitatively comparing a variable characteristic, property, or attribute of a substance, object, or system to some norm." The major targets of nanometrology are, for example, the analysis of dimensional, chemical, mechanical, and electrical properties of thin films and/or nanostructured materials, and also bionano materials. The growing number of journal articles on nanometrology and the growing number of standards clearly suggests that the importance of nanometrology is reaffirmed through the activation of nanotechnology standardization. It is, therefore, necessary to pay great attention to the progress of both nanometrology and nanotechnology standardization, which are described in detail in this excellent book.

Shingo Ichimura

Professor and Director of Strategic Innovation Office
Nagoya University/Japan

and

Special Emeritus Advisor of National Institute of
Advanced Industrial Science and Technology/Japan
July 2016