传感材料与传感技术丛书

Sensing Material and Sensing Technology Series

化学传感器：传感材料基础

第 2 册

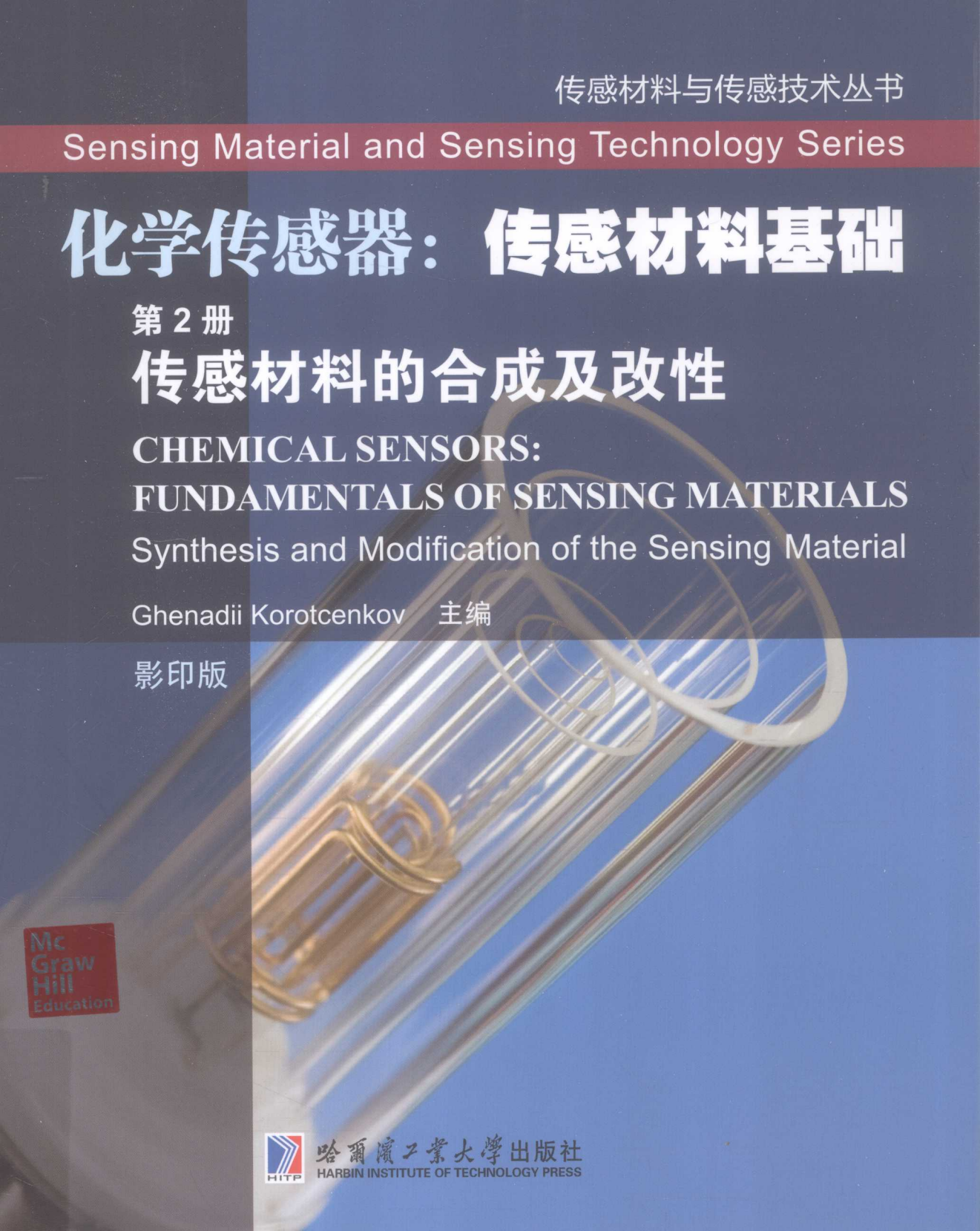
传感材料的合成及改性

CHEMICAL SENSORS: FUNDAMENTALS OF SENSING MATERIALS

Synthesis and Modification of the Sensing Material

Ghenadii Korotcenkov 主编

影印版



哈爾濱工業大學出版社
HARBIN INSTITUTE OF TECHNOLOGY PRESS

传感材料与传感技术丛书

化学传感器：传感材料基础

第2册

传感材料的合成及改性

影印版

Ghenadii Korotcenkov 主编

哈爾濱工業大學出版社
HARBIN INSTITUTE OF TECHNOLOGY PRESS

黑版贸审字08-2013-062号

Ghenadii Korotcenkov
Chemical Sensors:Fundamentals of Sensing Materials,Vol 1:General Approaches
9781606501030

Originally published by Momentum Press, LLC
English reprint rights arranged with Momentum Press, LLC through McGraw-Hill Education (Asia)

图书在版编目（CIP）数据

传感材料的合成及改性 = Synthesis and Modification of the Sensing Material : 英文 /（摩尔）科瑞特森科韦（Korotcenkov,G.）主编. — 影印本.— 哈尔滨 : 哈尔滨工业大学出版社, 2013.9

（传感材料与传感技术丛书；化学传感器：传感材料基础 2）

ISBN 978-7-5603-4150-7

Ⅰ. ①传… Ⅱ. ①科… Ⅲ. ①化学传感器 – 工程材料 – 合成 – 英文②化学传感器 – 工程材料 – 改性 – 英文Ⅳ. ①TP212.2

中国版本图书馆CIP数据核字（2013）第147431号

材料科学与工程
图书工作室

责任编辑 许雅莹 张秀华 杨 桦
出版发行 哈尔滨工业大学出版社
社 址 哈尔滨市南岗区复华四道街10号 邮编 150006
传 真 0451-86414749
网 址 http://hitpress.hit.edu.cn
印 刷 哈尔滨市工大节能印刷厂
开 本 787mm × 960mm 1/16 印张 12.25
版 次 2013年 9 月第 1 版 2013年 9 月第 1次印刷
书 号 ISBN 978-7-5603-4150-7
定 价 58.00元

影印版说明

1.《传感材料与传感技术丛书》为MOMENTUM PRESS的*SENSORS TECHNOLOGY SERIES*的影印版。考虑到使用方便以及内容统一，将原系列6卷分为10册影印。本册是

4、5章的内容。

2.原版各卷的文前介绍、索引、封底内容在其对应的影印版分册中均完整呈现。

3.各册均给出中文参考目录，方便读者快速浏览。

4.各册在页脚重新编排页码，该页码对应中文参考目录。保留了原版页眉及页码，其页码对应原书目录及索引。

5.各册的最后均给出《传感材料与传感技术丛书》的书目及各册的章目录。

材料科学与工程图书工作室

联系电话 0451-86412421
0451-86414559

邮　　箱 yh_bj@aliyun.com
xuyaying81823@gmail.com
zhxh6414559@aliyun.com

PREFACE TO *CHEMICAL SENSORS: FUNDAMENTALS OF SENSING MATERIALS*

Sensing materials play a key role in the successful implementation of chemical and biological sensors. The multidimensional nature of the interactions between function and composition, preparation method, and end-use conditions of sensing materials often makes their rational design for real-world applications very challenging.

The world of sensing materials is very broad. Practically all well-known materials could be used for the elaboration of chemical sensors. Therefore, in this series we have tried to include the widest possible number of materials for these purposes and to evaluate their real advantages and shortcomings. Our main idea was to create a really useful "encyclopedia" or handbook of chemical sensing materials, which could combine in compact editions the basic principles of chemical sensing, the main properties of sensing materials, the particulars of their synthesis and deposition, and their present or potential applications in chemical sensors. Thus, most of the materials used in chemical sensors are considered in the various chapters of these volumes.

It is necessary to note that, notwithstanding the wide interest and use of chemical sensors, at the time the idea to develop these volumes was conceived, there was no recent comprehensive review or any general summing up of the fundamentals of sensing materials The majority of books published in the field of chemical sensors were dedicated mainly to analysis of particular types of devices. This three-volume review series is therefore timely.

This series, *Chemical Sensors: Fundamentals of Sensing Materials,* offers the most recent advances in all key aspects of development and applications of various materials for design of chemical sensors. Regarding the division of this series into three parts, our choice was to devote the first volume to the fundamentals of chemical sensing materials and processes and to devote the second and third volumes to properties and applications of individual types of sensing materials. This explains why, in *Volume 1: General Approaches,* we provide a brief description of chemical sensors, and then detailed discussion of desired properties for sensing materials, followed by chapters devoted to methods of synthesis, deposition, and modification of sensing materials. The first volume also provides general background information about processes that participate in chemical sensing. Thus the aim of this volume, although not

exhaustive, is to provide basic knowledge about sensing materials, technologies used for their preparation, and then a general overview of their application in the development chemical sensors.

Considering the importance of nanostructured materials for further development of chemical sensors, we have selected and collected information about those materials in *Volume 2: Nanostructured Materials.* In this volume, materials such as one-dimension metal oxide nanostructures, carbon nanotubes, fullerenes, metal nanoparticles, and nanoclusters are considered. Nanocomposites, porous semiconductors, ordered mesoporous materials, and zeolites also are among materials of this type.

Volume 3: Polymers and Other Materials, is a compilation of review chapters detailing applications of chemical sensor materials such as polymers, calixarenes, biological and biomimetric systems, novel semiconductor materials, and ionic conductors. Chemical sensors based on these materials comprise a large part of the chemical sensors market.

Of course, not all materials are covered equally. In many cases, the level of detailed elaboration was determined by their significance and interest shown in that class of materials for chemical sensor design.

While the title of this series suggests that the work is aimed mainly at materials scientists, this is not so. Many of those who should find this book useful will be "chemists," "physicists," or "engineers" who are dealing with chemical sensors, analytical chemistry, metal oxides, polymers, and other materials and devices. In fact, some readers may have only a superficial background in chemistry and physics. These volumes are addressed to the rapidly growing number of active practitioners and those who are interested in starting research in the field of materials for chemical sensors and biosensors, directors of industrial and government research centers, laboratory supervisors and managers, students and lecturers.

We believe that this series will be of interest to readers because of its several innovative aspects. First, it provides a detailed description and analysis of strategies for setting up successful processes for screening sensing materials for chemical sensors. Second, it summarizes the advances and the remaining challenges, and then goes on to suggest opportunities for research on chemical sensors based on polymeric, inorganic, and biological sensing materials. Third, it provides insight into how to improve the efficiency of chemical sensing through optimization of sensing material parameters, including composition, structure, electrophysical, chemical, electronic, and catalytic properties.

We express our gratitude to the contributing authors for their efforts in preparing their chapters. We also express our gratitude to Momentum Press for giving us the opportunity to publish this series. We especially thank Joel Stein at Momentum Press for his patience during the development of this project and for encouraging us during the various stages of preparation.

Ghenadii Korotcenkov

PREFACE TO VOLUME 1: GENERAL APPROACHES

This volume provides an introduction to the fundamentals of sensing materials. We have tried to to provide here the basic knowledge necessary for understanding chemical sensing through a brief description of the principles of chemical sensor operation and consideration of the processes that take place in chemical sensors and that are responsible for observed operating characteristics. In spite of the seeming extreme simplicity of chemical sensor operation and application, understanding the mechanisms involved in the process of chemical sensing is usually not so simple. Chemical sensing as a rule is a multistage and multichannel process, which requires a multidisciplinary approach. Therefore, in this volume we provide a description of the important electronic, electrophysical, and chemical properties, as well as diffusion, adsorption/desorption, and catalytic processes.

To our knowledge, this volume is the first attempt to analyze in detail the interrelationships between properties of sensing materials and operating parameters of chemical sensors. This volume describes the properties of sensing materials by emphasizing the specificities of these materials. We consider analyses that have been performed as bridging the gap between scientists studying properties of materials and researchers using these materials for actual chemical sensor design. We hope that the information included in this volume will help readers to approach soundly the selection of either sensing materials or technology for sensing material synthesis or deposition.

Detailed consideration of various materials properties with respect to their application in chemical sensors provides a clear idea of the complexity and ambiguity involved in selecting an optimal sensor material. Research has demonstrated that there is no universal sensing material, and selection of an optimal material is determined by the type of chemical sensor being designed and the requirements that device will have to meet. This volume also illustrates the complementary nature of functionality in sensing materials; for example, high sensitivity usually conflicts with stability. This richness and complexity in behavior cannot be ignored.

This volume is intended to provide readers with a good understanding of the techniques used for synthesis and deposition of sensing materials. Readers will find descriptions of different techniques such as various methods of film deposition, sol-gel technology, deposition from solutions, colloidal processing, the peculiarities of polymers synthesis, techniques used for depositing coatings on fibers, and so on. Description of various methods of synthesis and deposition, accompanied by detailed

analysis of the advantages and shortcomings of those methods, provides the understanding necessary for considered selection of a technology for forming a sensitive layer.

Analysis of metal oxide modification methods highlights the opportunities for control of the properties of sensing materials, and demonstrates that a choice of methods should be based on consideration of all possible consequences of the technical decision that is made.

Combinatorial and high-throughput materials screening approaches analyzed in this volume will be also of interest to researchers working on materials design for chemical sensors.

We are confident that the present volume will be of interest of anyone who works or plans to start activity in the field of chemical sensor design, manufacturing, or application.

Ghenadii Korotcenkov

About the Editor

Ghenadii Korotcenkov received his Ph.D. in Physics and Technology of Semiconductor Materials and Devices in 1976, and his Habilitate Degree (Dr.Sci.) in Physics and Mathematics of Semiconductors and Dielectrics in 1990. For a long time he was a leader of the scientific Gas Sensor Group and manager of various national and international scientific and engineering projects carried out in the Laboratory of Micro- and Optoelectronics, Technical University of Moldova. Currently, he is a research professor at Gwangju Institute of Science and Technology, Gwangju, Republic of Korea.

Specialists from the former Soviet Union know G. Korotcenkov's research results in the study of Schottky barriers, MOS structures, native oxides, and photoreceivers based on Group III–V compounds very well. His current research interests include materials science and surface science, focused on metal oxides and solid-state gas sensor design. He is the author of five books and special publications, nine invited review papers, several book chapters, and more than 180 peer-reviewed articles. He holds 16 patents. He has presented more than 200 reports at national and international conferences. His articles are cited more than 150 times per year. His research activities have been honored by the Award of the Supreme Council of Science and Advanced Technology of the Republic of Moldova (2004), The Prize of the Presidents of Academies of Sciences of Ukraine, Belarus and Moldova (2003), the Senior Research Excellence Award of Technical University of Moldova (2001, 2003, 2005), a Fellowship from the International Research Exchange Board (1998), and the National Youth Prize of the Republic of Moldova (1980), among others.

CONTRIBUTORS

Beongki Cho (Chapter 4)
Department of Material Science and Engineering
Gwangju Institute of Science and Technology
Gwangju, 500-712, Republic of Korea

Ghenadii Korotcenkov (Chapters 1, 2, 4, and 5)
Department of Material Science and Engineering
Gwangju Institute of Science and Technology
Gwangju, 500-712, Republic of Korea
and
Technical University of Moldova
Chisinau, 2004, Republic of Moldova

Massood Zandi Atashbar (Chapter 1)
Department of Electrical and Computer Engineering
Western Michigan University
Kalamazoo, Michigan 49008-5066, USA

Radislav A. Potyrailo (Chapter 3)
Chemical and Biological Sensing Laboratory
Chemistry Technologies and Material Characterization
General Electric Global Research
Niskayuna, New York 12309, USA

Sridevi Krishnamurthy (Chapter 1)
Department of Electrical and Computer Engineering
Western Michigan University
Kalamazoo, Michigan 49008-5066, USA

目　录

Contents

CHAPTER 4

SYNTHESIS AND DEPOSITION OF SENSOR MATERIALS

G. Korotcenkov
B. K. Cho

1. DEPOSITION TECHNOLOGY: INTRODUCTION AND OVERVIEW

The production of high-quality materials suitable for chemical sensors is one of the most important tasks of modern materials science. As shown in previous chapters, materials used in chemical sensors need to fulfill a range of requirements related to the crystallographic structure, chemical composition, electrophysical properties, catalytic activity, and so on. These materials also show a great deal of variation. Materials for chemical sensors can come in a variety of forms, including films, ceramics, or powders. Their structure may be amorphous, glassy, nanocrystalline, polycrystalline, monocrystalline, or epitaxial. They may be either dense or porous. These materials may be elementary substances, complex compounds, or composites. Metals, dielectrics, and semiconductors can also be used as materials for chemical sensors. They may be either organic or inorganic in nature.

This vast amount of variation indicates that it is impossible to produce such a wide range of materials using just one method. The possible differences in the physical-chemical properties of the materials are too great; so too are the resulting differences in the conditions required for the synthesis and deposition of these materials. Therefore, the aim of this survey is to provide a brief overview of the basic technological methods that may be used in sensor technology. The purpose is not to analyze these methods in detail, as there already exists a vast array of quality reviews devoted to the subject (Randhaw 1991; Hitchman and Jensen 1993; Hecht et al. 1994; Bunshah 1994; Brinker et al. 1996;