

传感材料与传感技术丛书

Sensing Material and Sensing Technology Series

# 化学传感器：传感器技术

第 8 册

## 电化学传感器

CHEMICAL SENSORS:  
COMPREHENSIVE SENSOR TECHNOLOGIES

Electrochemical Sensors

Ghenadii Korotcenkov 主编

影印版



哈尔滨工业大学出版社  
HARBIN INSTITUTE OF TECHNOLOGY PRESS

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Ghenadii Korotcenkov

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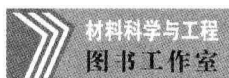
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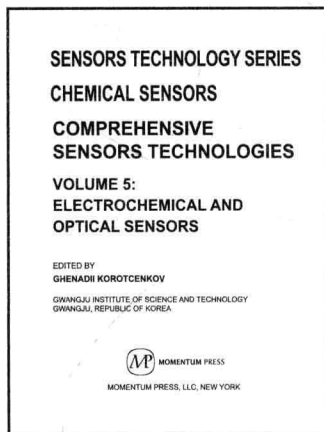
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# PREFACE TO **CHEMICAL SENSORS:** **COMPREHENSIVE SENSORS TECHNOLOGIES**

In spite of their century-long history, chemical sensors appeared on the commercial market only 50 years ago. In recent years, however, the field of chemical sensors has broadened and expanded greatly. At present, chemical sensors are being used in medicine, agriculture, industry, transport, environmental control, and other fields. However, the process of developing new sensors as well as improving older types of chemical sensors is still ongoing. New technologies and the toughening of ecological standards require more sensitive instruments with faster response times, better selectivity, and improved stability. The second half of this six-volume series on chemical sensors, devoted to *comprehensive sensor technologies*, describes these developments and the new processes and applications. These volumes are intended to be a primary source for both fundamental and practical information about where sensor technologies are now and where they are headed for the future. We are sure that Volumes 4–6 in this series will be a useful addition to the first three volumes, on *fundamentals of sensing materials*, in which various sensing materials that can be used in chemical sensors are discussed in detail. Analysis of chemical sensor design, fabrication, and functioning requires other approaches to description in comparison with materials science problems, and therefore we decided that consideration of materials and devices should be carried out separately. From our point of view, dividing the series into two parts as we have done results in more logical narration and more utility for readers who are interested in different aspects of chemical sensor design.

In this series we provide readers with a thorough understanding of the concepts behind chemical sensors, presenting the information necessary to develop such sensors, covering all aspects including fundamental theories, fabrication, functionalization, characterization, and real-world applications, so as to enable them to pursue their research and development requirements. Therefore, we hope that this series will help readers understand the present status of chemical sensors and will also act as an introduction, which may encourage further study, as well as an estimate of the roles that chemical sensors may play in the future.

*Chemical Sensors: Comprehensive Sensor Technologies* is a three-volume series, comprising Volumes 4, 5, and 6 in our series, *Chemical Sensors*. Volume 4 deals with solid-state devices, Volume 5 with electrochemical and optical sensors, and Volume 6 with applications of chemical sensors. The chapters included in the volumes consist of review and overview papers written by experts in the field. The authors

of each of the chapters were chosen very carefully and are all well known throughout the world in their fields of study. Therefore, these books provide an up-to-date account of the present status of chemical sensors, from fundamental science and processing to applications.

Specifically, Volume 4 includes descriptions of solid-state sensors such as conductometric or resistive gas sensors, Schottky-, FET-, capacitance-, and pyroelectric-type chemical sensors. Pellistors, mass-sensitive, and acoustic wave sensors are described as well. Integrated chemical sensors are also discussed in Volume 4. Volume 5 provides information related to electrochemical and optical sensors. Fundamentals of operation, methods of fabrication, and operating characteristics of electrochemical gas sensors, solid electrolyte-based gas sensors, ion-selective electrodes, CHEMFETs, and different types of optical, fiber optical, and chemoluminescence chemical sensors are discussed. Volume 6 is dedicated to detailed examination of opportunities for applications of chemical sensors in various areas of our lives, including medicine, industry, environmental control, agriculture, and transportation. It is the editor's wish that this volume will provide the reader with a detailed understanding of the many applications of chemical sensors in both today's world and that of the future. In these chapters one can also find descriptions of architecture and fundamentals of "electronic noses" and "electronic tongues," principles of wireless chemical sensor design, and possibilities for remote chemical sensing for atmospheric monitoring.

In this three-volume series, the authors present sensors that utilize various sensing materials and phenomena. The terminology and concepts associated with sensors are presented, including some of the relevant physical and chemical phenomena applied in the sensor signal transduction system. As is well known, chemical sensing is multidisciplinary by nature. The role of sensing materials in such phenomena is also detailed.

We need to note that the number of disciplines involved in the research and design of chemical sensors has increased dramatically. New knowledge and approaches are needed to achieve miniaturization, lower power consumption, and the ability to operate in complex environments for more selective, sensitive, and rapid determination of chemical and biological species. Compact analytical systems that have a sensor as one of the system components are becoming more important than individual sensors. Thus, in addition to traditional sensor approaches, a variety of new themes have been introduced to achieve the attractive goal of analyzing chemical species on the micro and nano scales. Therefore, throughout these books, numerous strategies for the fabrication and characterization of sensing materials and sensing structures which are employed in sensing applications are provided, and current approaches for chemical sensing are described.

This series can be utilized as a text for researchers and engineers as well as graduate students who are either entering the field for the first time, or who are already conducting research in these areas but are willing to extend their knowledge of the field of chemical sensors. We hope that these volumes will also be of interest to undergraduate students in chemical engineering, electronics, environmental control, and medicine. These books have been written in a way that final-year and graduate university students in the fields of chemistry, physics, electronics, biology, biotechnology, mechanics, and bioengineering can easily comprehend. We believe that practicing engineers or project managers which would like to use chemical sensors but don't know how to do so, and how to select optimal chemical sensors for specific applications, also will find useful information.

It is necessary here to comment briefly on the coverage of the literature. During our work on this series we tried to cover the field more or less completely. However, we need to acknowledge that an

appreciable number of relevant papers may remain unknown to the authors. Regarding these, the editors and contributing authors express regret, not only to the authors of such works, but also to the readers of our books.

Finally, we wish to thank all those who participated in the preparation of this series, including the contributing authors and copyright owners in Europe, the United States, Asia, and the rest of the world. We also wish to express our gratitude to the staff of Momentum Press, and in particular Joel Stein, for his kind assistance in bringing these volumes to fruition.

Ghenadii Korotcenkov

# **PREFACE TO VOLUME 5: *ELECTROCHEMICAL AND OPTICAL SENSORS***

The present volume considers two major groups of chemical sensors: (1) electrochemical sensors and (2) optical and fiber optic chemical sensors. In particular, this book presents reviews that provide an in-depth analysis of both the fundamentals of electrochemical and optical sensors and the possibilities for full-scale applications of these devices. This volume covers all the principal electrochemical and optical sensor technologies and related fields and provides a platform for new ideas and designs. In this volume one can find detailed descriptions of electrochemical gas sensors (Chapter 1), zirconia-based solid electrolyte gas sensors (Chapter 2), electrochemical sensors for liquid environments (Chapter 3), and ion-sensitive field-effect transistor (FET)-based sensors (Chapter 4). The present trends in approaches to designing microfluidic chip platforms is discussed here as well (Chapter 5). Elaboration of such platforms represents a significant step forward in microminiaturization and integration of multiple functionalities on the same chip. As is known, microfabrication and integrated circuit (IC) technology are key concepts which continue to be explored in all branches of sensor research and development. Discussions of various optical, fiber optic (Chapter 6), and chemiluminescence sensors (Chapter 7) are also included in this volume. These chapters provide detailed discussions of the construction, operating principles, performance, and applications of optical and fiber optic sensors for detection of various analytes.

Chemical sensing using electrochemistry and optical-based approaches are under extensive research all over the world, and many electrochemical and optical sensors are finding increasing application in industry, environmental monitoring, medicine, military, agriculture, transportation, and chemical analysis. This is evidenced by the annual growth in the number of published articles in which advances in the field of electrochemical and optical sensors are reported. The present volume indicates that, in comparison with other gas sensors, in many cases electrochemical and optical sensors have the optimal totality of exploitation parameters for environmental monitoring, for safety, security, and process control in a variety of fields, including industry, transportation, and public sector. It is established that electrochemical and optical sensors can be successfully applied in gas and liquid environments for gas detection, ion monitoring, analysis of seawater, the atmosphere, soils, nuclear fuels, industrial effluents, and pharmaceutical compounds.

Analysis carried out in this volume shows that for chemical sensor development, interdisciplinary activities are necessary, and the knowledge of engineers, materials scientists, physicists, and chemists



has to be combined. This book fulfills this demand, describing in detail processing, devices, materials tested, recognition principles, and concrete realizations. It introduces the reader to the most important technologies to see how up-to-date sensor structures can be fabricated and to clarify which processes are compatible. So, this book provides a central core of knowledge related to electrochemical and optical sensors (fundamentals, design, technology, and applications). The markets for electrochemical and optical sensors and future trends in development of those devices are discussed as well.

We believe that information about chemical sensors included in this book will be of great value to scientists, engineers, and students.

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 eight books and special publications, 11 review papers, 10 book chapters, and more than 180 peer-reviewed articles. He holds 18 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.

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