7

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Series Editor

Prof. Dr. Gerald Urban

IMTEK - Laboratory for Sensors
Institute for Microsystems Engineering
Albert-Ludwigs-University
Georges-Köhler-Allee 103
79110 Freiburg
Germany
urban@imtek.de

Volume Editors

Dr. Mohammed Zourob

GDG ENVIRONNEMENT LTÉE
430, rue Saint-Laurent
Trois-Rivières (Quebec)
G8T 6H3 Canada
mohammed.zourob@gdg.ca

INRS Énergie, Matériaux et Télécommunications
1650, boul. Lionel-Boulet
Varennes, Québec
J3X 1S2 Canada
zourob@emt.inrs.ca

Prof. Dr. Akhlesh Lakhtakia

Pennsylvania State University
Dept. Engineering Science & Mechanics
University Park PA 16802
USA
axl4@psu.edu

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Preface

Optical sensing techniques based on the modification of the refractive index because of either the incursion of a chemical species (analyte) or interactions between two different types of chemical species, one of which is the analyte and the other is the ligand, have had a long history that goes back to beginning of the nineteenth century if not earlier. More recently, fluorescence resulting from an appropriate labeling/modification of the ligand–analyte interaction has been used for optical sensing. Applications of these techniques are commonplace in industry to ascertain the density of a manufactured material in solution; in biomedical labs to detect the presence of a toxin or biological analytes in a fluid; and so on.

Two recent developments have further spurred research on the sensing of chemicals and analytes of biological importance. First, in the aftermath of the horrific events that occurred on September 11, 2001, a major nightmare of homeland-security planners and providers is the deliberate introduction of toxins and pathogens – which include pesticides (e.g., atrazine and 2,4-dichlorophenol) and bacteria (such as *Vibrio cholerae* and *Salmonella paratyphi*) – in a nation's water resources and urban water-distribution systems. Rapidly acting toxins and pathogens may be released in ponds, lakes, and rivers by enemy troops in war-zones to disable the soldiers fighting them. The same strategy may also be employed by guerrilla fighters sneaking behind the forward positions of regular armed forces. Thus, multianalyte sensing systems with remote monitoring capabilities, high sensitivity, and low incidence of false results are urgently needed to quickly assess both internal and external threats implemented by saboteurs.

Second, our air and water are increasingly more polluted from relentless industrialization in many rapidly developing countries and the conversion of farming from a family-based enterprise to agribusiness throughout the world. Water pollution is already a serious global problem, as the contents of wastewaters have become very complex. Chemical mutagens and carcinogens derived from industrial waste, pesticides, and urban sewage are known to cause metabolic damage in living organisms. For example, endocrine-disrupting compounds are able to either mimic or counter antagonize the effects of hormones such as estrogens and androgens. When present in the environment, endocrine-disrupting compounds engender reproductive abnormalities in humans, wild animals, and laboratory animals. Incidences of cancer among humans and domestic animals can also be ascribed to these compounds. Clearly then, endocrine-disrupting compounds can be used by terrorists to debilitate dense population centers as well as damage ecosystem features necessary to grow and harvest food.

Although many sensing modalities exist and are being currently investigated, optical sensors are very attractive for a variety of reasons. Most importantly, optical sensing schemes are very sensitive, so much so that single molecules could eventually be sensed optically. Next, many light signals can be sent over the same optical beam, because light signals at different frequencies do not interfere with one another. Several optical techniques generate an optical signal only when the target analyte is present, which is an attractive feature. The intrinsic amplification in some optical techniques, such as fluorescence, is also very desirable. Finally, optical signals do not require a material medium to travel in.

A variety of optical-sensing mechanisms exist, including luminescence, fluorescence, phosphorescence, absorbance, elastic scattering, Raman scattering, surface-plasmon resonance, guided-wave resonance, interference, and reflection/transmission microscopy. The need to measure multiple parameters has been fulfilled by bundling several sensors together for multiplexing.

A host of surface phenomena are being employed for optical sensing. Local-field effects that are orders of magnitude larger than comparable bulk effects can be obtained at surfaces with high-aspect-ratio features, thereby enabling measurements with much higher sensitivity. Local surface-plasmon resonance, surface-enhanced Raman scattering, and surface-enhanced fluorescence exemplify such phenomena. Smaller particles have larger surface-to-volume ratios and can access more of the analyte than bulk materials can. Some surface-sensitive techniques can detect reactions occurring only at the surface and consequently can be designed to be insensitive to the bulk medium, thereby making such techniques less susceptible to interference from extraneous signals.

The book entitled *Optical Guided-wave Chemical and Biosensors* is devoted to optical sensing techniques employing the phenomenon of guided wave propagation. The structure guiding the wave can be a planar waveguide, a circular waveguide, or an optical fiber. Even the interface of two dissimilar materials can guide the propagation of an optical wave. The characteristic length scale of a guided wave is provided by its angular frequency and its phase speed in the direction of propagation. The phase speed at a specific angular frequency can vary if the constitutive properties of any part of the waveguide are disturbed, either by the presence of an analyte by itself or because of the binding of ligand molecules with the analyte molecules. After calibration, this disturbance can be used to sense the presence and the concentration of the target analyte.

Published in the Springer Series on Chemical Sensors and Biosensors, the book comprises 19 chapters written by 27 researchers actively working in North America, Europe, and Asia. The authors were requested to adopt a pedagogical tone in order to accommodate the needs of novice researchers such as graduate students and postdoctoral scholars as well as of established researchers seeking new avenues. This has resulted in duplication of some material we have chosen to retain, because we know that many a reader will pick only a specific chapter to read at a certain time.

We have divided the book into two volumes comprising six parts. Volume I has two parts and Volume II has four parts. Volume I covers the planar-waveguide and plasmonic platforms. Volume II covers waveguide sensors with periodic structures, optical fiber sensors, hollow-waveguide and microresonator sensors, and finally tetrahertz biosensing.

Volume I: Part I comprises four chapters devoted to planar waveguides for optical sensing. The simplest planar waveguide is a slab between a cover material and a substrate. In the first chapter, Sapsford (Food & Drug Administration, USA) shows that the phenomenon of total internal reflection makes planar waveguides versatile sensing platforms. Schmitt and Hoffmann (Germany) explain, in the second chapter, the use of high-refractive-index-waveguides for different sensing capabilities. Two otherwise identical waveguides, but one with a sensing area, form an interferometric sensor. Interferometers for sensing are described in the third chapter by Campbell (Georgia Tech, USA). In the fourth chapter, Mendes (University of Louisville, USA), Saavedra, and Armstrong (University of Arizona, USA) review the combination of electrochemical analysis and planar-waveguide optical sensors.

Plasmonic phenomena are addressed by the authors of four chapters in Part II. First, Linman and Cheng (University of California, Riverside, USA) present new biointerface designs to exploit the propagation of surface plasmon-polaritons at the planar interface of a dielectric and a metal film. Next, the incorporation of nanoholes in the metal film provides additional sensing modalities, as discussed in the chapter by Brolo, Gordon, and Sinton (University of Victoria, Canada). Similar prospects afforded by periodically texturing one surface of the metal film are reviewed in the chapter by Kim (Yonsei University, South Korea). The dispersal of metal nanoparticles at strategic locations in a waveguide sensor in order to exploit local surface-plasmon resonance is presented in the final chapter of this volume by Mittler (University of Western Ontario, Canada).

We are confident that research on optical sensors for chemicals and biochemicals will lead to label-free, multianalyte, highly reliable, highly sensitive, miniature, and expensive sensors. Waveguide sensors will be among the commonly used ones. We shall be delighted if this two-volume work facilitates the emergence of optical sensors with highly desirable attributes.

University Park and Montreal Akhlesh Lakhtakia and Mohammed Zourob
October 2009

Contents of Volume I

Part I Planar-Waveguide Sensors

Part II Plasmonic-Waveguide Sensors

Contents of Volume II

Part VI Terahertz Biosensing