Sensors and Biosensors, MEMS Technologies and its Applications

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Editor

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Book Series: Advances in Sensors: Reviews, Vol. 2

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Preface

It is my great pleasure to present the second volume from the *Advances in Sensors: Reviews* book Series started by the IFSA Publishing in 2012.

The second volume titled '*Sensors and Biosensors, MEMS Technologies and its Applications*' contains eighteen chapters with sensor related state-of-the-art reviews and descriptions of latest achievements written by authors from academia and industry from 12 countries: China, India, Iran, Malaysia, Poland, Singapore, Spain, Taiwan, Thailand, UK, Ukraine and USA.

This book ensures that our readers will stay at the cutting edge of the field and get the right and effective start point and road map for the further researches and developments. By this way, they will be able to save more time for productive research activity and eliminate routine work.

Built upon the series *Advances in Sensors: Reviews* - a premier sensor review source, it presents an overview of highlights in the field and becomes. Coverage includes current developments in physical sensors, biosensors, immunosensors, data acquisition systems, MEMS technologies and its applications.

This volume is divided into three main parts: physical sensors, biosensors, nanoparticles, MEMS technologies and applications. With this unique combination of information in each volume, the Advances in Sensors book Series will be of value for scientists and engineers in industry and at universities, to sensors developers, distributors, and users.

Like the first volume of this book Series, the second volume also has been organized by topics of high interest. In order to offer a fast and easy reading of the state of the art of each topic, every chapter in this book is independent and self-contained. The eighteen chapters have the similar structure: first an introduction to specific topic under study; second particular field description including sensing applications.

Chapter 1 reviews various physical and chemical sensors and sensor systems for smartphones. Coming technological limitations and challenges are outlined. Two design approaches traditional and novel, advanced approach for such sensors are described in details and illustrated by examples. The advanced design approach is based on the smart system integration and allows to eliminate existing technological limitations. It lets to create smart sensor systems faster and easier, which make smartphones smarter and intelligent.

Chapter 2 presents an analysis of synchronization between two coupled nonlinear surface acoustic wave (SAW) delay line oscillators where coupling is provided via another linear phase SAW delay line. The analysis is aimed at determining the sensitivity of synchronization frequency for perturbations in the coupling SAW delay

line, and then to explore whether the coupling SAW device can be used for making a better chemical sensor in comparison to the usual polymer-coated SAW delay line oscillator sensor. The dynamics of coupled system is analyzed for small perturbations in limit cycles under phase approximation. Considering the noise suppression characteristics and high sensitivity regions of synchronization it is found that the coupled SAW oscillators in synchronized states have potential for making high performance SAW sensors.

The main focus of Chapter 3 is to review the existing fingerprint sensing technologies in terms of liveness detection, and discusses hardware based 'liveness detection' techniques reported in the literature for automatic fingerprint biometrics.

Chapter 4 confined about synthesis of conjugated polymer through plasma polymerization process. The merits and demerits associated with plasma polymerization are discussed in comparison with chemical rout polymerization and electrochemical polymerization various aspects regarding the chemical and physical properties of plasma polymer film is different from conventional methods of synthesis of conjugated polymer. Plasma-enhanced chemical vapour deposition (PECVD) is also reviewed within their respective sections. This different structure of plasma polymerized thin film leads to potential application in various fields. The plasma polymerization processes of conjugated polymers are strappingly affected by various parameters such as pressure, separation between two electrodes. These parameters discussed on the basis of Pascen's law. This review shortlisted and discuss some advantages and disadvantages associated with plasma polymerization.

Chapter 5 describes substrate materials its characteristics, fabrication process and application for non-Silicon fabrication micromachining technologies as such as printed circuit board (PCB), low temperature co-fired ceramic (LTCC) and liquid crystal polymers (LCP) in addition to new upcoming technologies such as polymer core conductor and polydimethylsiloxane (PDMS).

Chapter 6 presents the rapidly emerging field of MEMS based instruments used in medical field and discuss its present and future applications.

Chapter 7 is about the development of MEMS switch for RF application in past two decades. Perhaps the most important RF MEMS component is RF MEMS Switch. RF MEMS switches are the fundamental part of the RF systems because these switches provide automatic redirection of RF signals in RF Communication devices. RF MEMS switch design parameters like actuation voltage, insertion loss, isolation, return loss, switch lifetime, switching speed, and temperature sensitivity are discussed in detail inside this chapter. These design parameters show significant impact RF MEMS switch development towards better performance. The motive of the chapter is to provide an overall device picture, current status and the research efforts that carried out to maturing this technology.

Chapter 8 highlights the research carried out during the last 5 years on amperometric acetylcholinesterase (AChE) biosensors for determination of organophosphorous and carbamate pesticides in a wide range of samples. Various immobilization protocols and modified electrode methods used for constructing AChE biosensors are also described in details. Future prospects toward the development of selective, sensitive biosensing systems are discussed.

Chapter 9 reviews quartz crystal microbalance DNA based biosensor for clinical diagnosis and detection.

Chapter 10 presents an overview of electrochemical immunosensors for the detection of pesticides residues and various immobilization protocols of Ab or hapten, such as physical adsorption, covalent coupling, entrapment, oriented immobilization, avidin–biotin affinity reaction, self-assembled monolayer, nanoparticles. Future prospects toward the immobilization protocols for the development of electrochemical immunosensor are discussed.

The objective of Chapter 11 is to have a look on the interaction of electromagnetic field on biological tissue from the view of physiological and electrical engineering. The understanding of the phenomena in the interaction may give clear picture on the fundamental concept of dielectric dispersion in term of suitable frequency application and the reaction of biological tissue to it. The other factors such as thermal effect also will be gone through. This review may provide some useful information to the research of magnetic induction tomography on the biological tissue imaging and electromagnetic therapy which apply electromagnetic field at certain frequency in their application.

The use of miniaturized sensing platform for the analysis of biotoxins is the subject of Chapter 12. Materials for sensing platform and detection methods for biotoxins are discussed in details. Applications to the analysis of phytotoxins, animal toxins, marine toxins, microbial toxins are also described. Finally, future challenges and opportunities are discussed.

Chapter 13 examines the usage of gold nanoshells (GNS), with near infrared (nIR) resonant properties, to improve the detection of antigen/biomarkers/viral vectors using immunoassays that rely upon an adventitious change in the surface plasmon resonance when multiple particles interact with antigens. Methods of producing GNS, conjugation of biomolecules to the nanoparticle surface, quantification of the number of bound antibodies on the gold surface, and two immunoassays for detection of antigen/biomarkers/viral vectors at various concentrations will be presented. The demonstrated techniques allow one to produce GNS with specific nIR resonant properties, allow specific targeting to various antigens, analytes, biomarkers, viral particles, and cells via antibodies or ligands, and have the potential to be used to various applications including photothermal ablation therapy.

Chapter 14 describes the performance of ultra-high performance sensors fabricated with identical biocomposite materials and procedures, except the anchoring conductive

materials. The anchoring materials were glassy carbon, Pt, Au and Ag; the biocomposite layer consisted of polymer/Au nanoparticles/enzyme. The enzymes in the biocomposite layers are specific for the target analytes which enable the coupling (detection) reactions to occur. The enzymes used in this study were lactate dehydrogenase (LDH), glutamate dehydrogenase (GDH), and hemoglobin. The specific target analytes for the detection included lactate, NH_4^+, NO_2^-, and peroxide. The biosensors developed here were tested with solution concentrations ranged from 10^{-4} to 10^{-16} M; however, except for NO2-, the lower concentration limit could be orders of magnitude lower. In all, the anchoring materials have drastic effect to the performance of this ultra-high performance biosensor platform; in addition, nature of the enzymes can alter the stability of these sensors.

Chapter 15 includes an overview of Electronic nose and Electronic Tongue based Biomimetic systems for classification and authentication of beverages. Biomimetic systems, in particular electronic-nose (e-Nose) and electronic-tongue (e-Tongue), show promising utilization and advantages in various fields and for this reason emphasis here is made on electronic-nose and electronic-tongue, the recently added systems in the field of biomimetics. In brief, Electronic-Nose and Electronic-Tongue are the systems which mimic the human olfaction and gustation respectively. They are used for automatic analysis and recognition (classification) of liquids and gases (e-Nose for gases and E-tongue for liquids). The e-Nose can determine the fingerprint of a complex volatile or dissolved compound mixture by an array of non-specific/semi-specific sensors coupled to a pattern recognition system. Similar to the human nose, the electronic nose operates by recognizing the overall pattern of components constituting the given sample stored in a database, in a manner analogous to the recollection of olfaction perception in the human brain. e-Tongue is analogous to e-Nose but related to sense of taste. Much emphasis and importance is given regarding the selection of sensors and sensing methods employed for these biomimetic systems. An optimized selection is made regarding the sensors and sensing methods based upon the application involved, accuracy level to be met, cost and complexity of the system involved. Not only the sensors and the sensing methods involved in these systems but also the pattern recognition algorithms developed for these specific systems are of importance. Despite the optimized selection of sensors and sensing methodology, the performance of these systems is greatly affected by the quality of functioning of its pattern recognition block. Various techniques and methods have been developed and used which serve the purpose. Besides an overview of Electronic Nose and Electronic Tongue systems, basic sensing principles of these systems and the different types of sensors used in these systems are included. Two different case studies have been presented wherein the Electronic Nose system was used for the classification and authentication of Indian Teas while the Electronic Tongue system was used for the classification and authentication of Indian wines. The chapter also deals with Artificial neural networks, and in particular with the probabilistic neural network (PNN) and other data analysis methods like principal component analysis (PCA) and linear discriminant analysis (LDA) which have been used as data analysis methods in the two case studies presented.

Chapter 16 is the compiled description of the design considerations taken while developing the magnetic bead based biosensor systems. The work will show

experimental proof of this determination theory. This work also presents a system that will make use of magnetic particle assay (MPA) as a means of implementing this diagnosis. The work also includes a discussion on the sensor that is used to quantify the number magnetic particles after performing MPA on the sample as well as a prototype developed as a proof of concept for this work.

Chapter 17 discusses a novel sensor for non-invasive determination of body analytes by using ultralow-threshold stimulated Raman lasing in microspheres. We theoretically employed this sensor for non-invasive measuring of blood glucose levels. Also a composite sensing system of an optical microsphere resonator and silver nanoparticles based on surface enhanced Raman scattering and stimulated Raman scattering techniques towards a point of care diagnostic system for acute myocardial infarction using the Troponin I biomarker in HEPES buffered solution is proposed.

Chapter 18 presents a simple and robust multipoint data acquisition bus built on top of the standard RS232 interface with the minimum additional non-standard hardware components. The presented network structure and associated protocol can be used to form a general purpose distributed data acquisition bus. Basic methods of data flow control and failure recovery suitable for the described architecture are described.

Each chapter has been written by different contributors. Many of contributors are members of the editorials board of different journals related to the field and some of them are IFSA members.

We hope that readers enjoy this book and that can be a valuable tool for those who involved in research and development of various MEMS, biosensors, physical, chemical sensors and sensor systems.

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