# Nanosensors: Physical, Chemical, and Biological


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**Guilherme Garcia Bessegato, Thaís Tasso Guaraldo et al.**

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KOROS PRESS

**KOROS PRESS LIMITED**

**Nanosensors: Physical, Chemical, and Biological**

Contributors: Guilherme Garcia Bessegato, Thaís Tasso Guaraldo et al.

**Published by Koros Press Limited**

**www.korospress.com**

United Kingdom



**Nanosensors: Physical, Chemical, and Biological**

ISBN: 978-1-78569-124-9

British Library Cataloguing in Publication Data
A CIP record for this book is available from the British Library

Printed in the United Kingdom

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# Preface

Nanosensors are any biological, chemical, or surgical sensory points used to convey information about nanoparticles to the macroscopic world. Their use mainly includes various medicinal purposes and as gateways to building other nanoproducts, such as computer chips that work at the nanoscale and nanorobots. Presently, there are several ways proposed to make Nanosensors, including top-down lithography, bottom-up assembly, and molecular self-assembly. Nanosensors: Physical, Chemical, and Biological have been divided into nine chapters. Chapter one review resumes general concepts about enhancement of photoelectrocatalysis efficiency by using nanostructured electrodes, specifically describing fundamental features of photoelectrocatalytic processes, including the basic concepts of the technique, the phenomena at the electrode/electrolyte interface and the development of new materials employed in the last few years related to the specific applications. Second chapter presents the metal oxide nanosensors using polymeric membranes, enzymes and antibody receptors as ion and molecular recognition elements, there is a great opportunity in the near future for metal oxide nanostructure-based miniaturization and the development of engineering sensor devices. Engineering genetically encoded nanosensors for real-time in vivo measurements of citrate concentrations, citrate is an organic acid at the heart of central carbon metabolism have been addressed in third chapter. The chapter four details a novel dna nanosensor based on cdse/zns quantum dots and synthesized Fe3O4 Magnetic Nanoparticles, a successful new method in which DNA binds directly to iron oxide nanoparticles for use in an optical biosensor. Experimental tools to study molecular recognition within the nanoparticle corona, Conventional optical tools have insufficient overlap to study both polymers and nanomaterials simultaneously, which is becoming increasingly necessary to advance fields of research that hinge on polymer-nanoparticle interactions such as the design of SWCNT-based sensors have been discussed in chapter five. The chapter six reviews the highly selective fluorescent sensing of proteins based on a fluorescent molecularly imprinted nanosensor, selective fluorescent sensing of target molecules by combining MIP with a fluorescent reagent or quantum dots have been proven to be highly desirable due to the high selectivity of MIP and sensitivity of fluorescence. The chapter seven outlines in vivo histamine optical nanosensors, in vivo detection and tracking of analytes is central for monitoring specific diseases, as well as a tool to advance knowledge about disease progression, personalized medicine, and biomarker discovery. Optical oxygen micro- and nanosensors for plant applications, the development of oxygen sensors has greatly contributed to our knowledge on the oxygen distribution in plant tissue and the regulation of oxygen consumption by plant cells has been described in chapter eight. The last chapter nine of this book focuses on atomic force microscopy as a tool applied to nano/biosensors, Deflections of the cantilever are due to the stress of molecular adsorption, which can be upward or downward depending on the type of chemical bonding of the molecule.

# Contents

# Chapter 1

# ENHANCEMENT OF PHOTOELECTROCATALYSIS EFFICIENCY BY USING NANOSTRUCTURED ELECTRODES

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## INTRODUCTION

This chapter describes some fundamental features of photoelectrocatalytic processes, including the basic concepts of the technique, the phenomena at the electrode/electrolyte interface and the development of new materials employed in the last few years related to the specific applications. The nanostructured materials used in the photoelectrochemical field can be called photoanodes (n-type) when oxidation reactions take place at the interface, and photocathodes (p-type) when the reduction is the main process [1, 2]. This chapter focuses on photoanode materials and how their surface influences the applications of this technique.

Photoelectrocatalysis could be described as a multidisciplinary field, involving surface science, electrochemistry, solid-state physics and optics. The basic concept is that when a semiconductor surface is irradiated by light ($h\nu \geq E_g$) there is generation of electron/hole pairs ($e^-/h^+$) by the promotion of an electron from the valence band (lower energy level) to the conduction band (higher energy level). The electrons are forwarded to the counter electrode under positive bias potential (n-type) in order to minimize the recombination of these pairs due to the short life-time. When immersed in electrolyte the adsorbed water molecules and/or hydroxyl ions react with the holes on the valence band to generate hydroxyl radicals ($^{\bullet}OH$), which are a powerful oxidizing agent (+2.80 V) [3-5].

The first findings, from 1839, found that the photoelectrochemistry field was stimulated by the Becquerel effect [6]. They observed a photocurrent flow of electrons due to illumination of a material connected by two electrodes immersed in solution. In 1972, the work of Fujishima and Honda had a huge impact on this field. They studied the use of a $TiO_2$ semiconductor on the photoelectrolysis of water (water splitting) under anodic bias potential in a photoelectrochemical (PEC) cell [7, 8]. Nowadays, photoelectrocatalysis is an emerging field with many applications, such as organic compounds oxidation [9-11], inorganic ions reduction [12, 13], disinfection [14, 15] and production of electricity and hydrogen [16-18].

The development of this technique is intimately related to a better understanding of materials' surfaces and properties. Highly ordered nanomaterial arrays have promoted a revolution in applications of these materials as nanotubes, nanowires, nanofibres, nanorods, nanowalls, etc. [19]. The main applications of the technique include the degradation of unwanted environmental pollutants (organic and inorganic compounds) and converting sunlight directly into an energy carrier [4, 19, 20].

This work presents an overview of the fundamentals of photoelectrocatalysis and the huge contribution made by nanostructured architectures, as well as explaining the efficiency of the technique as a treatment method for organic and inorganic compounds and for water splitting.

## PHOTOELECTROCATALYSIS: BASIC CONCEPTS

Advanced oxidation processes (AOPs) have been proposed as alternative methods for the degradation of recalcitrant organic compounds in water [21], air [22] and soil [23] in recent years [4]. AOPs are based on the generation of hydroxyl radicals ($^{\bullet}OH$) as highly oxidant species, which are responsible for the oxidation of the major pollutants [4, 21]. Among the AOPs, heterogeneous photocatalysis deserves particular attention [5]. The method is based on the use of a