Biological and Medical Physics, Biomedical Engineering

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NanoBiosensing

Principles, Development and Application

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Preface

The first decade of the 21st century has been labeled "the sensing decade." Biosensing, based on nanomaterials, is one of the hottest topics in nanotechnology and nanoscience. The unique properties of nanomaterials offer excellent platforms as electronic and optical signal transduction to design a new generation of biosensing devices. Thus, nanobiosensing opens up the novel concepts for basic research and new tools for ultrasensitive biosensing in clinical, environmental, and industrial applications.

With the achievements of nanotechnology and nanoscience, a wide variety of nanoscale materials with different sizes (1–100 nm), shapes, and compositions have been introduced to biosensing. The small sizes of nanoparticles break through the limitation of structure miniaturization, leading to lower detection limits, even reaching zeptomolar concentrations. Furthermore, the biofunctional nanoparticles can produce a synergic effect among catalytic activity, conductivity, and biocompatibility to accelerate the signal transduction. Most importantly, nanoscale materials are in direct contact with the environment, which permits them to act as chemical and biological sensors in the single molecular detection of biomolecules. As of this writing, nanobiosensing is routinely being applied in biological systems. Future efforts on nanomaterial-based biosensing will involve in vivo detection with less cytotoxicity, high sensitivity, and long-term stability for early screening of disease biomarkers and reliable point-of-care diagnostics.

This book introduces novel principles and detection strategies in the area of biosensing based on nanomaterials. Each chapter provides a theoretical overview of a different topic and the interesting bioanalytical application of nanobiosensing devices. The most exciting and unique aspect of the book is that the utilization of nanomaterials not only enhances the biosensing capabilities, but also brings out newer approaches such as biomimetic, reagent-less biosensing, and single molecular detection.

The material is presented in 18 chapters, covering the most successful nanomaterials used so far in biosensing. The first four chapters of the book, contributed by Huangxian Ju (Chap. 1), Songqin Liu and Huangxian Ju (Chap. 2), Zhihui Dai and

Huangxian Ju (Chap. 3), and Jianping Lei and Huangxian Ju (Chap. 4), describe the biofunctionalization of nanomaterials, signal amplification strategies for nanobiosensing, and nanostructured mimicking enzymes. The next six chapters focus on ultrasensitive platforms using various nanomaterials, such as carbon nanofiber, nanoporous silica, carbon nanotubes, quantum dots, molecularly imprinted nanoparticles, and sol–gel nanoparticles; they are contributed by Xueji Zhang and Lei Su (Chap. 5), Shuo Wu and Huangxian Ju (Chap. 6), Jianping Lei and Huangxian Ju (Chap. 7), Guizheng Zou and Huangxian Ju (Chap. 8), Ruizhuo Ouyang and Huangxian Ju (Chap. 9), and Jiuhong Yu and Huangxian Ju (Chap. 10). The last eight chapters illustrate the successful applications of nanobiosensing in environmental screening and clinical diagnosis and have been contributed by Xueji Zhang and Chunyan Wang (Chap. 11), Sichun Zhang and Huangxian Ju (Chap. 12), Dan Du and Huangxian Ju (Chap. 13), Zong Dai, Joseph Wang, and Huangxian Ju (Chap. 14), Zhifeng Fu and Huangxian Ju (Chap. 15), Yongkang Ye, Joseph Wang, and Huangxian Ju (Chap. 16), Lin Ding and Huangxian Ju (Chap. 17), and Jie Wu, Joseph Wang, and Huangxian Ju (Chap. 18). We are very grateful to all the authors who contributed their high-quality work. We also thank Jie Wu for her help in editing the whole book.

This book involves a broad audience, such as those involved in the research, teaching, learning, and practice of biosensing, based on various nanomaterials, in biomedical, military, industrial, and clinical applications. We are fortunate to have had the opportunity to undertake this enormous project. We warmly acknowledge the gracious support of our families. Finally, we also thank Springer's editors for doing a remarkable job to publish this book.

Nanjing, P.R. China — Huangxian Ju
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Chapter 1
Biofunctionalization of Nanomaterials

1.1 Introduction

The unique properties of nanoscale materials (1–200 nm) offer excellent platforms for electronic or optical signal transduction and the design of a new generation of bioelectronic and biosensing devices. However, the drawbacks of nanoparticles (NPs) in biocompatibility and biological recognition ability limit their application in analytical chemistry. The biofunctionalization of nanomaterials can endow them with good biocompatibility for the immobilization of biomolecules, tissue, or cells and high specificity for biological recognition [1–6], which led to stable biosensing systems with good selectivity and reproducibility. Particularly, the biofunctional NPs can produce a synergic effect among catalytic activity, conductivity, and biocompatibility to accelerate signal transduction and achieve a rapid response to target with a very high sensitivity by signal amplification. The need for ultrasensitive bioassays and the trend toward miniaturized assays have made the biofunctionalization of nanomaterials one of the hottest fields. Therefore, seeking suitable methods for the functionalization of nanomaterials with biomolecules such as protein, DNA, small organic molecules, polymer films, and even entire living cells has attracted considerable attention.

Two approaches for the functionalization of NPs have been involved: noncovalent interaction, including physical adsorption and entrapment of biomolecules around the NPs, and covalent interaction to the functional groups on the NP's surface [7–10]. The noncovalent approach via electrostatic interaction, π–π stacking, or van der Waals force, is an efficient immobilization method of biomolecules, which can avoid destruction of the conjugated skeleton and loss of electronic properties of the NPs. The covalent functionalizations of NPs are subdivided into three general strategies: direct chemical reaction, linker strategies, and click chemistry. Covalent binding in general should be preferable to unspecific physisorption in terms of the stability and reproducibility of the surface functionalization.

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