

## Preface to the Second Edition

Since I wanted my textbook to serve as an “introduction” to biosensors with hands-on laboratory demonstrations, I deliberately made the first edition of my book as concise as possible. Therefore, many different advanced topics had to be forgone in the first edition. However, some of those advanced topics are too important to be dismissed—for example, pulse oximeter, glucose meter, lateral flow assay, paper-based lab-on-a-chip, nano-biosensors, and microcontroller. These important topics were either very briefly mentioned without laboratory exercises or not mentioned at all in the first edition. Therefore, I decided to add these topics to the second edition with appropriate laboratory exercises, while not compromising the concise nature of this book.

Here is a list of the major additions made to the second edition:

- Most circuit photos were retaken at higher resolution with an easy-to-recognize layout.
- Added a section on op-amp filters.
- The spectrophotometry chapter was fully rewritten to focus on pulse oximeter, not on glucose sensing. Added new laboratory procedures on hemoglobin sensing and meat quality monitoring.
- The fluorescence chapter was fully rewritten to incorporate advanced fluorescent dyes, autofluorescence, and different methods of fluorescence detection. Added a new laboratory procedure on fluorescence detection from urine. The fluorescent lamp measurement laboratory in the first edition was removed.
- Added advanced topics on electrochemical sensors.
- Added a new laboratory procedure on fluoride sensing from tap water and toothpaste to the electrochemical sensor chapter.
- Glucose sensing in the spectrophotometry and electrochemical sensor chapters were consolidated into the new glucose sensor chapter.
- Added additional details on various glucose sensing methods.
- Added a new laboratory procedure on lateral flow assay (pregnancy test) and subsequent smartphone-based quantification to the immunosensors chapter.
- Added advanced topics on lab-on-a-chip.

- Added a section and two new laboratory procedures on paper-based lab-on-a-chip.
- Added a new chapter on nano-biosensor.
- Added a new appendix on microcontroller (Arduino) and two new laboratory procedures.

I hope the newly added materials would provide the most up-to-date and comprehensive introduction to the modern biosensor research and their commercialization efforts.

Some of these newly created laboratory procedures have been implemented in my Sensors and Controls class in Fall 2013, Fall 2014, and Fall 2015, with assistance from my teaching assistants and postdocs—Dr. David You, Dr. Pei-Shih Liang, Dr. Tu San Park, Dr. Christopher Fronczek, Dr. Scott Angus, Dr. Dustin Harshman, Ms. Katrina DeCook, Mr. Tigran Nahapetian, Ms. Katherine McCracken, and Mr. Kevin Okarski, all at the University of Arizona, who provided very important feedback, corrections, and suggestions. I would also like to thank the other students in my research laboratory—Ms. Cayla Baynes, Ms. Ariana Nicolini, Ms. Soohye Cho, Ms. Robin Sweeney, Ms. Alexandra Downs, Mr. Tyler Toth, and Mr. Collin Gilchrist, who have also provided feedback and corrections to the draft manuscript. I also thank my former and current department heads, Dr. Urs Utzinger and Dr. Arthur Gmitro in the Biomedical Engineering Department, and Dr. Donald Slack and Dr. Kathryn Farrell-Poe in the Agricultural and Biosystems Engineering Department, who have supported my class through providing personnel, equipment, and laboratory space at the University of Arizona. Support and suggestions from the editorial office at Springer, especially Ms. Marta Moldvai, is greatly appreciated. Finally, I would like to mention my wife's name one more time, Dr. Sunhi Choi (Mathematics Department at the University of Arizona), for her continuous inspiration and support during the preparation of this second edition.

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The title of this textbook, *Biosensors: From Electric Circuits to Immunosensors*, implies that we are going to learn both electric circuitry (in relation to conventional sensors such as temperature sensors) and biosensors (such as antibody-based immunosensors). The idea of putting these two topics together into a single book came from my decision to add biosensor topics to the “Sensors and Controls” class taught at the University of Arizona. At that time, I realized there was no available textbook that equally addressed these two topics. In typical sensor textbooks, biosensor topics are relatively sparse. In biosensor textbooks, fundamental electric circuitry is rarely addressed. More importantly, none of those textbooks address the necessary link between these two topics. After all, most biosensors require electric circuit components.

This textbook is designed not only for college undergraduate students but also for the scientists and engineers working in the sensor or biosensor industries as a hands-on guide. Although this book may seem to be a collection of laboratory procedures (and certainly can be used for a college-level laboratory class), its primary aim is to deliver hands-on guidance and visual demonstrations of biosensor applications. Readers can complete virtual experiments by reading the lab procedures and viewing the photographs taken during the lab exercises. They can also carry out their own experiments by purchasing the necessary equipment and supplies. This book takes a step-by-step approach towards the end result of building an antibody-based immunosensor from scratch.

Many people have provided invaluable help in creating this textbook. First of all, I wish to express my deepest appreciation to my wife, Dr. Sunhi Choi, for her support and advice throughout the writing of this textbook. I also wish to thank my former graduate student Dr. Lonnie J. Lucas (at Applied Energetics) for all the time he spent with me in shaping the entire book, in providing numerous ideas and suggestions, and in proof-reading the entire draft. This collaboration with Lonnie was one of the most pleasant collaborations in my entire life. Specifically, Chap. 9 was written jointly with Lonnie. I also thank the students enrolled in my Sensors and Controls class in Fall 2009, Fall 2010, and Fall 2011 at the University

of Arizona, who have provided corrections and constructive suggestions on the draft lab procedures. The help of my teaching assistants for this class, Zachary S. Dean, C. Christopher Stemple, and Scott V. Angus, is greatly appreciated as well. Specifically, Zach collected many photographs of lab exercises and proof-read many parts of the manuscript. Dr. David J. You, my former graduate student and current post-doc, provided important help in creating Chap. 15 lab exercise. Other students and post-docs in my lab have also provided numerous corrections and suggestions. My former and current department heads, Dr. Donald C. Slack and Dr. Mark R. Riley, have also provided support and suggestions for my class. I also thank the late Dr. Kenneth Jordan (University of Arizona), who taught the Sensors and Controls class for many years before me and laid the foundations for the lab procedures from Chaps. 2–6. Finally, support and suggestions from the editorial office at Springer, Alison Waldron and Steven M. Elliot, are greatly appreciated. None of this would have been possible without the contributions of all of my students, co-workers and collaborators.

Introduction to Biosensors

From Electric Circuits to Immunosensors

Yoon, J.-Y.

2016, XV, 331 p. 336 illus., 110 illus. in color.,

Hardcover

ISBN: 978-3-319-27411-9