Implantable Sensors and Systems

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Editor

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From Theory to Practice

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To my mother, who fought a courageous battle against cancer.

Preface

From passive devices to current generation instruments integrated with sensing, actuation, and drug delivery, surgical implants have undergone a major transformation in the last two decades due to advances in micro-nanofabrication, new materials, microelectronics, wireless transmission, and real-time data analytics. This book is a sequel to the book on *Body Sensor Networks*, first published in 2006 and followed by its second edition in 2013.

By following the principle of "*using the body as the medium, inspiration, and a source of energy to provide continuous sensing, monitoring, and intervention*", our first book was mainly focussed on the development of wearable sensors for providing continuous monitoring of physical, physiological, and biochemical parameters in any environment without activity or behavioral restrictions. With the rapid advances and clinical uptake of low-power, miniaturized, smart implants, it is timely to review and assess the unique challenges imposed and outline future development pathways and new opportunities.

Of particular importance is the use of these devices in surgical applications. For both acute and chronic scenarios, implantable sensing is increasingly used for transient or long-term monitoring of *in vivo* physiological, bioelectrical, biochemical, and metabolic changes. Underpinned by increasingly small, smart, and energy efficient designs, they have become an integral part of surgical prostheses or implants, supporting optimized, context-aware sensing, feedback, or stimulation with due consideration of system-level impact.

Key topics covered in this book include electrochemical sensor designs; electrical and physical sensors; sensor embodiment and flexible electronics; ultralow-power Application-Specific Integrated Circuits (ASICs); optical sensors; power harvesting; and data exchange links, as well as wireless data paths and security. It provides an in-depth explanation of both the theoretical and practical considerations of developing novel implantable sensors and can serve as a comprehensive reference for those working at the forefront of implantable sensing or as an introductory reference for those about to enter this exciting field of research and development. I hope this book will act as a valuable resource to a wide spectrum of readers interested in, or inspired by, this intrinsically multidisciplinary topic.

There has been tremendous effort from all contributors to this book, and I would like to express my sincere thanks to my team at the Hamlyn Centre. Without their enthusiasm, support, and dedication in meeting the tight publishing schedule, this book would not have become possible. I would also like to thank the editorial staff of Springer, the publisher of this volume. In particular, I am grateful to Helen Desmond and her colleagues in helping with all the editorial matters.

This work would not have been possible without the research support from all the funding bodies that supported our work, particularly the UK Engineering and Physical Sciences Research Council (EPSRC). Their ongoing research funding has allowed us to establish and promote this exciting field of research.

Finally, I would like to dedicate this book to my mother, who fought a courageous battle against cancer. Sadly, advances in medicine have not yet reached the stage of eradicating this dreadful disease, but the development of sensing technologies and smart implants could contribute to early detection as well as a targeted and personalized treatment of this disease; prolonging life whilst ensuring improved quality of life for those surviving.

London, UK
August 2017

Guang-Zhong Yang, CBE, FREng

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Editor and Contributors

About the Editor

Prof. Guang-Zhong Yang, CBE, FREng is director and co-founder of the Hamlyn Centre for Robotic Surgery. The Hamlyn Centre (http://www.imperial.ac.uk/hamlyn-centre/) has been established for developing safe, effective, and accessible technologies that can reshape the future of health care for both developing and developed countries. Focusing on technological innovation but with a strong emphasis on clinical translation and direct patient benefit with a global impact, the center is at the forefront of research in imaging, sensing, and robotics for addressing global health challenges associated with demographic, environment, social, and economic changes. The center plays an active role in international collaboration and outreach activities, as well as in the training of surgeons and engineers in sensing, imaging, and robotic technologies, thereby facilitating a fully integrated clinical approach.

Professor Yang's main research interests are in medical imaging, sensing, and robotics. He is a pioneer in wearable and implantable body sensor networks and is internationally recognized for developing novel sensing solutions for providing personalized monitoring platforms that are pervasive, intelligent, context-aware, and "invisible" to the patient. In imaging, he is credited for a number of novel MR phase contrast velocity imaging and computational modeling techniques that have transformed in vivo blood flow quantification and visualization. In robotics, his concept on perceptual docking represents a paradigm shift of learning and knowledge acquisition of motor and perceptual/cognitive behavior for robotics.

Professor Yang has received numerous awards for his work in imaging, sensing, and robotics. These include the ISMRM I. I. Rabi Award, Medical Futures Innovation Award, the Bluetooth Innovation World Cup, and the IEEE EMBS Technical Achievement Award. He is a fellow of the Royal Academy of Engineering, fellow of IEEE, IET, AIMBE, IAMBE, MICCAI, City, and Guilds, and a recipient of the Royal Society Research

Merit Award and listed in The Times Eureka "Top 100" in British Science. He is the founding editor of Science Robotics (http://robotics.sciencemag.org/)—a journal of the Science family dedicated to the latest advances in robotics and how it enables or underpins new scientific discoveries. He was awarded a CBE in Her Majesty the Queen's 2017 New Year Honour for his contribution to biomedical engineering.

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