Preface

Welcome to the world of nanoscale devices! The fourth volume of the series on Nanotechnologies for the Life Sciences is in front of you, providing glimpses of the exciting possibilities that exist in the world of tiny devices. Nanotechnology and nature are intimately intertwined. Such an intimate partnership is critical for reaping the benefits of nanotechnology by unraveling the mysteries of nature. Therefore, this volume, *Nanodevices for the Life Sciences*, is timely and provides a broader perspective to this partnership and enlightens us on the theory, physics, chemistry, biology and engineering of nanodevices that are being constructed in the laboratory as well those that are already being utilized by nature. See for example a recent article in Science (Vol 312, pp 860–861, 2006) that describes the possibilities to utilize biomolecular motors in nanometer-scale devices to perform mechanical work. Three chapters (chapters 7, 8 & 13) in the book are specifically dedicated to provide glimpses of the power of such natural nanoscale devices and I am certain that these chapters will catalyze development of new ideas and tools for non-biologists interested in utilizing the underlying principles.

Theory and experiments will have to go hand in hand as deeper understanding of the complexities associated with nanoscale devices bring us a step closer to designing devices that are as efficient as in nature. Therefore, the first two chapters have been dedicated to provide theoretical and computational understanding of nanoscale devices with potential applications in life sciences. The first chapter illuminates on *The Physics and Modeling of Biofunctionalized Nanolelectromechanical Systems*. Two leading theoreticicans, M. R. Paul from Virginia Polytechnic Institute and State University in Virginia, USA, and J. E. Solomon from the California Institute of Technology in Pasadena take readers to the realm of theoretical challenges associated with modeling of BioNEMS. I have no doubt that the information provided in this chapter will form a strong basis for deeper understanding of many other nanoscale systems that one encounters in our laboratories as well as in biological systems. The second chapter is a contribution from the laboratories of Vittorio Cristini from the University of California at Irvine delving on intricacies of modeling various components associated with nanoscale drug delivery for the treatment of cancer. The chapter, *Mathematical and Computational Modeling: Towards the Development and Application of Nanodevices for Drug Delivery*, is a great source of information on mathematical models and computer simulations of important steps in the journey of intravenously injected nanovectors into tumoral

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tissue in order to deliver drug in the most effective manner. This chapter is a must for all those interested in utilizing nanotechnologies for drug delivery.

Moving from utilizing theory, modeling and computational tools for fabrication of nanodevices, the rest of the book is a testimony to the rapid advances being made in the application of a variety of experimental techniques and tools for building nanoscale devices and for application of such devices in a number of fields ranging from biosensors to bioelectronics. In the third chapter, which is contributed by J. C. Garno and co-workers from Louisiana State University in Baton Rouge, USA, a detailed description is given of how scanning probe techniques are proving to be versatile tools for fabricating arrays of self-assembled monolayers (SAMs) and proteins. In this chapter, *Nanolithography: Towards Fabrication of Nanodevices for the Life Sciences*, the authors describe how nanolithography is revolutionizing the fabrication of nanoscale biomolecular devices in general and proteins in particular through precise control over chemical functionality, shape, dimensions and spacing on the nanometer scale. Continuing on a similar theme, H. D. Espinosa, K.-H. Kim and N. Moldovan from Northwestern University in Illinois, USA, have carried out a remarkable job in delineating the importance of microcantilevers for biopatterning and biosensing in scanning probe microscopy (SPM)-based techniques. Their contribution in the fourth chapter, entitled *Microcantilever-based Nanodevices in the Life Sciences*, is very unique in the sense that it covers not only various approaches for fabrication of microcantilevers but also their applications in the emerging field of bionanotechnology. The chapter clearly demonstrates the fact that microcantilevers are fundamental tools for biopatterning and biosensing in SPM-based techniques, and with the possibility of integrating micro/nanofludics into microcantilevers, they are in the process of revolutionizing the field of bioanalytical nanodevices.

The fifth chapter in this volume, *Nanobioelectronics*, is a testimony to the fact that there have been several advances made in the field of molecular electronics over the last decade particularly in utilizing biomolecules for fabrication of molecular-scale devices and integrated computers. The authors from the University of Lecce in Italy, R. Rinaldi and G. Maruccio reviewed these advances in the field of nanobiomolecular electronics describing the fabrication of devices such as rectifiers, amplifiers, information storage devices based on biomoleucles in general and DNA and proteins in particular. Highlight of the chapter is the information on interconnecting biomolecules and exploitation of their self-assembly properties leading to nanobiodevices. It is particularly heartening to see that the progress made so far in the field of nanobiolelectronics is very promising and is likely to fill the void in the face of current limitations with CMOS devices and post-optical lithographies. While the fifth chapter focuses on electronic devices using DNA, the sixth chapter provides complete information on the most important properties of DNA and how these properties are being exploited in building functional devices such as DNA-based molecular motors and automata with possible applications in the life sciences. Friedrich Simmel from Ludwig-Maximilians-Universität München, Germany, has provided an up to date review on this subject and is very optimistic that the recent advances are likely to lead to the development of autonomous molecular-scale devices which can sense environmental information, perform compu-

tations and act independently as molecular motors, drug reservoirs, or as signal transducers. The chapter is aptly titled as *DNA Nanodevices: Prototypes and Applications*. While the fifth and sixth chapters provide a broader perspective to build nanoscale devices from DNA and proteins, the next two chapters contain very specific information on nanodevices made from G-protein coupled receptors and Kinesin-microtubule systems respectively. The seventh chapter, *Towards the Realization of Nanobiosensors Based on G-protein-coupled Receptors*, a contribution from the laboratories of Cecilia Pennetta, also from Lecce University, provides a thorough review on G-protein-coupled receptors (GPCRs) including different techniques to prepare and immobilize them on a substrate, followed by utilization of the electrochemical impedance spectroscopy (EIS) technique for the detection of biosensing events at the electrodes. A very unique aspect of the chapter is that it covers several theoretical aspects investigating the current response to an applied AC voltage of a nanodevice realized by a single GPCR embedded in its membrane and in contact with two functionalized metallic nanoelectrodes. The chapter is extremely valuable for nanotechnologists exploring applications in life sciences as GPCRs are one of the widest groups of receptor proteins known and they can be activated by a large variety of extracellular signals, such as light, odorant molecules, hormones, peptides, lipids, neurotransmitters and nucleotides. GPCRs mediate the sense of vision, smell, taste and pain, and are involved in an extraordinary number of physiological processes. Competing for prominence with GPCRs are the Kinesin-microtubule-driven systems as they hold significant potential as molecular motors due to their compactness, high efficiency in vitro in extracting energy from the aqueous environment. The eighth chapter, *Protein-based Nanotechnology: Kinesin–Microtubule-driven Systems for Bioanalytical Applications*, assumes enormous importance in this volume as it has valuable information on how kinesin molecular motors can be integrated with microtubule tracks into microdevices for bioanalytical applications. The chapter is an important contribution for the book as the author, William Hancock from Pennsylvania State University, USA, covers wide-ranging topics from cell biology and biophysics, in vitro assays, theoretical aspects, biofunctionalization of the kinesin–microtubule system in addition to experimental approaches to integrating into functional microscale devices for potential analytical applications.

Carbon Nanotubes (CNTs) are finding extraordinary applications in the field of life sciences especially in biosensing, drug delivery, diagnosis, imaging and so on. These applications are further complimented by recent efforts in fabricating CNT-based nanodevices especially field-effect transistors (FETs) having very interesting performance characteristics. The ninth chapter, *Self-assembly and Bio-directed Approaches of Carbon Nanotubes: Towards Device Fabrication*, begins with a review on important characteristic of CNTs followed by the synthesis methods reported in the literature. The central theme of the chapter, written by Arianna Filoramo from the Laboratory of Electronic Materials in Gif sur Yvette, France, is however the utilization of self-assembly approaches (bio as well as non-bio directed) for fabrication of CNT devices for application in the electronics industry. Alternative strategies to CMOS technologies such as bio-inspired technologies for nanoscale devices as described in this chapter as well as in chapter five are likely to revolutionize the electronics industry in the near future. Focusing primarily on biosensing, chapter

ten explores the possibility of fabricating nanodevices based on nanophotonic/optoelectronic platforms and on nanomechanical platforms. The chapter, *Nanodevices for Biosensing: Design, Fabrication and Applications*, contributed by L. M. Lechuga and co-workers from the Microelectronics National Center (CNM) in Spain, is a valuable source of information for design, fabrication and testing of nanosensors and their integration with microfluidics, optical and electronic functions on a single chip. Chapter eleven, *Fullerene-based Devices for Biological Applications*, written by Dirk M. Guldi from Friedrich Alexander University in Erlangen-Nürnberg, Germany, and his collaborators is complimentary to the ninth chapter, describing in detail the solubility, toxicity and major biological applications of fullerenes and their potential application in nanoscale devices. It provides a basic framework for fabricating fullerene-based nanoscale devices in near future. A more general approach for utilization of nanotechnological principles for the fabrication of biomedical devices is presented in the twelfth chapter, wherein Lars Montelius from Lund University in Sweden describes various types of nanotechnologies that are employed in the biomedical field in general and biomedical engineering in particular, together with suitable examples. The chapter, *Nanotechnology for Biomedical Devices*, provides a fundamentally strong backbone for the realization of nanoscale devices for biomedical applications.

Finally, the book ends with a chapter dedicated to providing an overview of nanoscale devices that nature utilizes. Chapter thirteen, *Nanodevices in Nature*, written by Alexander Volkov and Courtney Brown from Oakwood College in Huntsville, USA, complements more specialized information in chapters seven and eight. The chapter elegantly delineates the role of various nanodevices in a wide variety of biological processes focusing more specifically on cytochrome oxidase, photosynthesis and phototropism, membrane transport, molecular motors, and electroreceptors. In my view the last chapter is a grand finale to the excellent source of information that the authors of this book gathered and reminds me of a great statement from *Vedas*, one of the oldest Indian scriptures, which describes universal power as the smallest of the smallest and biggest of the biggest. Truly, the power that encompasses the universe comes from nanodevices!

As I conclude this preface, there is no doubt in my mind that a book of this magnitude and high quality would not have been possible without the timely contributions of all authors, and I am always grateful to them for sharing my vision for this book as well as for the rest of the series. I am glad to let you know that Volumes 1–3 and 5–6 of this exciting series have already been published and you might have seen them in your library or obtained a personal copy. The remainder of the series, volumes 7–10, is currently in press and will be available to you before the year ends. In addition to the authors, a project of this magnitude is not possible but for unwavering support from my employer, family, friends and Wiley-VCH publishers. This is yet another opportunity for me to convey my thanks to them. Before I take leave, I would like to request you, the reader, who is sharing the knowledge with me and rest of the authors, to let me know your comments, suggestions and constructive criticism to make further improvements to this exciting series.

May 2006, Baton Rouge *Challa S. S. R. Kumar*