Ahmad Tariq Jameel
Abu Zahrim Yaser *Editors*

Advances in Nanotechnology and Its Applications

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Preface

Advances in nanotechnology have led to the creation of new materials and devices with a vast range of applications in biomedicine, biomaterials, biosensors, nanoelectronics, energy production, food safety, consumer products, among many others. With new researches, there is rapidly increasing list of benefits and applications of nanotechnology. Growing popularity of nanotechnology depends on the fact that it is possible to tailor the structures of materials at extremely small scales to achieve specific properties. Nano-bioengineering of enzymes is aiming to enable conversion of cellulose into ethanol for fuel. Novel nanomaterials are being employed as support for enzyme immobilization to improve stability and efficiency of industrial biocatalysts. Cellulosic nanomaterials have demonstrated potential applications in a wide array of industrial sectors, including electronics, construction, packaging, food, energy, health care, automotive, and defense. Nanoscale materials are also being incorporated to improve performance into a variety of applications such as nano-structured ceramic coatings, nanotechnology-enabled lubricants, nanoparticles in catalysis, nano-engineered materials as household products, and in personal care products. The aim of this book is to bring forth to the audience some of the latest developments in nanotechnology, especially in the fields of engineered nanomaterials for enzyme immobilization for use in biocatalyst and biosensor technology, applications of nanomaterials in electronics, packaging materials industry, environmental technology, etc.

The opening chapter by Jameel and coauthors contributes to the important area of developing novel supports for enzyme immobilization. However, carbon-based nanomaterials (NMs) have gained high popularity among different immobilization support materials owing to its biocompatibility and large specific surface area. Immobilization technology is now increasingly used for enhancing enzyme stability and reuse. Chapter 1 starts with a comprehensive overview of enzyme immobilization on hydrogel/polymeric materials and onto nanoparticles/NMs followed by a detailed review of recent literature on the topic. Then, the authors discuss their research findings on the immobilization of β-glucosidase on multi-walled carbon nanotube (MWCNT) and alginate hydrogel. Kinetic studies reveal a higher enzyme affinity for the substrate immobilized onto MWCNT support compared to

Ca-alginate. It has been demonstrated that despite a general decrease in the enzyme activity due to immobilization, there is greater retention of activity and stability of the immobilized enzyme upon multiple cycles of hydrolysis. Overall, the chapter concludes that employing nanoparticles as support for enzyme immobilization bears distinct economic advantages for large-scale industrial applications.

Graphene owing to its biocompatibility, sensitivity, and fast electron transfer properties is increasingly being employed in electrochemical biosensor. In the second chapter, Sanober et al. have highlighted application of graphene to modify sensing electrodes for immune sensors that are based on the principle of antigen–antibody interaction. The chapter describes different techniques for the synthesis of graphene and its derivatives. Principles and different approaches of antibody immobilization on graphene-coated electrodes are discussed in detail. Pros and cons of each immobilization technique together with its methodology are surveyed.

There has been outpouring of the scientific literature on biosensor technology during last one decade or so. The third chapter by Shah and colleagues presents an extensive review of nanomaterials used in biosensor applications. Firstly, a brief account of the working principles and types of biosensors is provided and then its historical development is summarized. Nanomaterials having 1D, 2D, and 3D configuration and their application as biosensors are described. The working mechanism of biosensors is delineated in the light of the chemistry of biomolecule interaction with nano-structured materials. Biosensors based on different classes of materials are discussed in detail. Broadly, classification is made on: carbon-based nanomaterials covering carbon nanotube, graphene, and carbon nanofiber; metal-based nanoparticles such as functionalized metal nanoparticles and metal oxides; and nanocomposites encompassing hybrid polymer nanocomposites and metal oxide nanohybrid materials. The review specifically focusses on nanomaterials that give higher sensitivity, biocompatibility, improved selectivity and cost-effectiveness in biosensor performance.

The subsequent chapter by Akmal and Ahmad highlights the novel applications of piezoelectric biomaterials in the development of flexible electronic devices in energy harvesting, sensing, and biomedicine. The authors first introduce the very concept of piezoelectricity in crystalline materials and different classes of piezoelectric materials and their applications. The chapter focusses on the biomedical applications of thin film of piezoelectric bio-nanomaterials, as an alternative to the existing electronic health-monitoring devices. The physics of piezoelectricity is briefly but vividly explained. Biomaterials that exhibit piezoelectricity are natural polymers such as amino acid, cellulose, chitin, chitosan, and collagen, and these are described in detail. Different methods of quantifying piezoelectricity of biomaterials at the nanoscale are discussed. Prospects of potential applications such as nanogenerators, biosensors, vibration sensor, and other biomedical applications of piezoelectric nanomaterials are highlighted.

In view of the numerous applications of the nanoparticles (NPs), the synthesis of nanoparticles continues to attract much attention. Contribution of Soroodi et al. in the fifth chapter expounds green synthesis of nanoparticles from plant source as an alternative to chemical route of nanoparticle synthesis. The authors have described

method to synthesize selenium (Se) nanoparticles using cocoa pod husk extract. The presence of biomolecules and phytochemicals in plants is believed to play an important role in the formation of stable nanoparticles. The review covers various plants used and effect of process parameters in the synthesis of nanoparticles. The effect of factors such as concentration of plant extract and salt solution, temperature, pH, etc., is known to influence the size distribution, morphology as well as the yield of the nanoparticles. The study surmised that the phytochemicals and enzymes present in the plant extract might be the primary source for the biosynthesis of Se NPs.

The sixth chapter introduces readers with nanocellulose, which can be prepared from any cellulose source material. Nanocelluloses discussed are of two types: cellulose nanofibril (CNF) or microfibrillated cellulose (MFC), and cellulose nanocrystal (CNC). Here, Jimat et al. describe the synthesis of cellulose nanofiber from cellulose obtained from cocoa pod husks (CPHs) and fibrillated with ultrasonication method. These nanocelluloses find novel applications owing to unique properties of low thermal expansion coefficient, outstanding reinforcing potential and transparency, low density, high aspect ratio, biocompatibility, high strength and stiffness. Especially CNC being amenable to chemical modifications such as fluorescent labeling find potential use in the field of biomedical applications such as biosensors, bioprobes, fluorescence bioassays, bioimaging, and so on. On the contrary, CNF owing to its characteristic morphology and physical properties is seen as a promising material for applications such as filter material, and high gas barrier packaging material. Besides, it finds use in electronic devices, food, medicine, cosmetics, and health care products. The authors have described in detail the experimental methodology and analytical procedures for the synthesis and characterization of nano-structured celluloses.

The seventh chapter extends the scope of nanotechnology to the development of new packaging materials. Conventional packaging materials are mostly non-biodegradable and pose tremendous environmental problems. In quest for biodegradable packaging materials, polylactic acid (PLA), an aliphatic polyester, has been a topic of research lately. Ali et al. studied the synthesis and characterization of polylactic acid/organoclay nanocomposites as a substitute for conventional packaging materials. The agglomeration of organoclay with PLA exhibited improved modulus of the PLA/organoclay nanocomposites.

Finally, the last chapter reviews the potential application of zeolite and chitosan as adsorbents for gross pollutant traps (GPTs) in various water bodies such as storm water runoff and engineered conveyance. Safie et al. have briefly surveyed the GPTs performance in the removal of dissolved pollutants, COD and BOD, as well as the efficacy of zeolite and chitosan as adsorbent media. Though the subject of this chapter does not directly fits in the realm of nanotechnology, zeolite and chitosan can treat dissolved contaminants including those of ionic species by adsorption and ion exchange which are primarily nanoscale processes.

The current book presents different aspects of recent developments and progress in the synthesis and characterization of novel nanomaterials to tackle problems arising in bioprocess industry, biomedicine, and environment. The timely

publication of this book hopefully would be of interest to students, teachers, and practitioners alike in the field of nanotechnology. The subject of nanotechnology is expected to remain at the forefront of cutting-edge research in science and technology throughout the next decades given the increasing integration of nanomaterials in diverse human activities.

I wish to express my deepest gratitude to all of the authors who contributed to this book with pertinent review articles and research chapters on different aspects of nanomaterial development and uses. I hope that the meticulous effort and the long hours of work invested by the authors and editors would prove worthy of reader's interest. Further, constructive suggestions of reviewers toward improving the quality of the manuscript are gratefully acknowledged. It is my pleasure to express my deep appreciation to Dr. Abu Zahrim Yaser for providing editorial support in general and keeping close liaison with the publishers during the preparation of the book. Further, I would like to thank Ms. Megana Dinesh, Mr. Viju Falgon and rest of the editorial staff at Springer Nature Singapore, for their full cooperation throughout the production process.

Kuala Lumpur, Malaysia Ahmad Tariq Jameel
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Abu Zahrim Yaser is Associate Professor of waste processing technology at Universiti Malaysia Sabah (UMS). He obtained his Ph.D. from Swansea University. He has published 4 books, 16 chapters, 34 journals, and 50++ other publications. He was Guest Editor for *Environmental Science and Pollution Research* special issue (Springer). The Elsevier (UK) has recognized him as the Outstanding Reviewer for the Journal of Environmental Chemical Engineering. He was Visiting Scientist at the University of Hull and Member of Board of Engineers (Malaysia) and MyBIOGAS.

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