

Smart Nanomaterials Technology


Azamal Husen *Editor* 

Nanobiosensors for Agricultural and Other Related Sectors

 Springer

Smart Nanomaterials Technology

Series Editors

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Nanotechnology is a rapidly growing scientific field and has attracted a great interest over the last few years because of its abundant applications in different fields like biology, physics and chemistry. This science deals with the production of minute particles called nanomaterials having dimensions between 1 and 100 nm which may serve as building blocks for various physical and biological systems. On the other hand, there is the class of smart materials where the material that can be stimulated by external factors and results in a new kind of functional properties. The combination of these two classes forms a new class of smart nanomaterials, which produces unique functional material properties and a great opportunity to a larger span of application. Smart nanomaterials have been employed by researchers to use it effectively in agricultural production, soil improvement, disease management, energy and environment, medical science, pharmaceuticals, engineering, food, animal husbandry and forestry sectors.

This book series in Smart Nanomaterials Technology aims to comprehensively cover topics in the fabrication, synthesis and application of these materials for applications in the following fields:

- Energy Systems—Renewable energy, energy storage (supercapacitors and electrochemical cells), hydrogen storage, photocatalytic water splitting for hydrogen production
- Biomedical—controlled release of drugs, treatment of various diseases, biosensors,
- Agricultural—agricultural production, soil improvement, disease management, animal feed, egg, milk and meat production/processing,
- Forestry—wood preservation, protection, disease management
- Environment—wastewater treatment, separation of hazardous contaminants from wastewater, indoor air filters.

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Preface

The agricultural sector is a promising area that plays a key role in determining a country's sustainability and economic growth. The main principle of sustainable agriculture practice, which aims to meet present needs without compromising resources for future generations, relies on two key aspects. First, agricultural practices should be self-sustaining by conserving protective resources, for instance maintaining soil fertility, protection of groundwater, developing renewable energy sources, and finding alternatives to cope with the adverse effects of climate change. Second, sustainability should extend to managing surrounding urban areas through proper sewage waste recycling, fostering rural employment, and contributing to the development of a sustainable rural landscape. Positive agricultural productivity is undermined by issues such as soil erosion, groundwater pollution, river eutrophication, weed proliferation, and resistance to chemical controls, all of which have a negative impact on the environment. Thus, for sustainable agricultural practices, it is crucial to further develop emerging technologies that can boost plant yields without depleting resources, causing pollution and so on.

In this connection, nanotechnology-based sensing has gained significant momentum, offering a wide range of applications in the agricultural sector. While both nanosensors and nanobiosensors fall under the broader category of nanotechnology, they differ in their functionality, applications, and the types of materials they interact with. Nanosensors typically consist of nanomaterials (e.g., carbon nanotubes, quantum dots, or nanowires) and a transducer to convert the signal into a readable form. They do not necessarily require biological components. Nanosensors are used in a wide variety of fields, including environmental monitoring, industrial applications, and security. They can monitor pollutants in the air or water, detect explosives or toxic chemicals, and measure physical parameters like pressure and temperature. Some of the example of nanosensors are sensors that used in environmental monitoring to detect gas concentrations such as carbon dioxide, methane, etc. These types of nanosensors are also used a pressure sensors used in mechanical applications and also sensors for detecting water contamination from chemicals or heavy metals. However, nanobiosensors consist of three components. The first component is the biologically sensitized element (probe), which includes biologically

derived substances, namely receptors, enzymes, antibodies, nucleic acids, molecular imprints, lectins, tissues, microorganisms, organelles, and others. These elements, or bio-mimetic constituents, capture signals from the target sample and transmit them to the transducer. The second component is the transducer, which serves as an interface. It detects the physical changes that occur during the reaction at the bioreceptor or sensitive biological element and then converts this energy into a measurable electrical output. The third component is the detector, which captures the signals from the transducer. These signals are then sent to a microprocessor, where they are amplified, analyzed, and converted into a user-friendly output. The data can be displayed or stored for further use. Nanobiosensors can be used to detect a comprehensive range of fertilizers, herbicides, pesticides, and insecticides as well as pathogens, fungicides, moisture, soil pH, soil contaminants, etc. They are also useful in bioremediation, recycling of agricultural wastes, wastewater treatment and disinfection.

Nanobiosensors, when integrated with satellite farming systems, can provide localized, real-time information at the molecular level. For instance, nanosensors deployed in the soil or on the plants can monitor specific variables like nutrient levels, pest activity, or the presence of pathogens. These sensors could be linked to the satellite system, providing a comprehensive overview of farm health and enabling more accurate decision-making. The combination of satellite farming, site-specific crop management, and nanobiosensors in precision agriculture can offer significant potential to improve efficiency, reduce costs, and promote sustainability. Nanobiosensors can provide real-time, localized data on plant health, soil conditions, and environmental factors, allowing farmers to make more informed decisions and tailor their practices to specific needs. This advanced approach not only boosts plant yield and quality but also ensures that farming practices are more environmentally responsible and economically viable. However, there are several challenges to overcome such as regulatory issues, environmental, and technical obstacles, the future of nanosensors in the agricultural sector holds immense potential for transforming farming practices, making them more efficient, sustainable, and environmentally friendly.

Taken together, the aim of the book is to provide an overview on the most important and selected topics related to nanosensors in agricultural system and they are going to be explored. This book will provide valuable information to scientists, researchers, and upper level of students, working specially in agricultural sectors, crop science, plant nanobiotechnology, plant biology, plant biochemistry, plant microbiology, and other allied subjects and or science. I am grateful to all contributors for readily accepting my invitation, sharing their knowledge in specialized areas of research, and readily adjusting the suggestions for improving the shape of their contributions. Finally, my special thanks go to Shagufta, Zaara, Mehwish, and Huzaifa for providing their time and overall extended support to put everything together.

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Nanosensors and Their Role in Recycling of Agricultural Wastes



Mohammad Areeb Siddiqui, Reena Vishvakarma, and Archana Vimal

Abstract A huge of agricultural waste is generated every year throughout the world leading to environmental burden due to pollutant and greenhouse gas emitted by them. The advancement in nanotechnology and uses of nanosensors helps in recycling the agricultural waste and in turn promoting sustainable agriculture practices. Nanosensors are the analytical tools that are highly specific and sensitive and helps tracking and surveillance of important agricultural parameters. In this chapter the various types of nanosensors like optical, chemical, biosensors and their utility in monitoring soil quality, seed quality, plant diseases, plant nutrition, irrigation etc. are discussed. Nanosensors also aids in various process of recycling agriculture wastes like composting, biogas production, mulching. They assists in real time monitoring of biological process and contaminants detection that improves product quality along with cost-effectiveness. They help out in monitoring and regulating various inhibitory factors. They also participates in biomass conversion process like fermentation, pyrolysis, combustion and gasification for better yields and waste valorization. Another important role that biosensors plays is that evaluation of environmental emissions and managing carbon footprint emissions. However, there are still some challenges to be addressed that are scalability, economic viability, specificity, farmers acceptance. Nanosensors are future technology designed to revolutionized agriculture practices by optimizing resources, waste recycling and management in a eco-friendly manner. Scientists are also integrating IoT systems to improve their potential. This chapter deals with the role of nanosensors in sustainable agriculture practices and recycling agricultural products to generate valuable products in a economical way to reduce environmental burden.

Keywords Composting · Chemical nanosensors · Nanotechnology · Precision agriculture · Pesticides

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