Advances in Material Research and Technology

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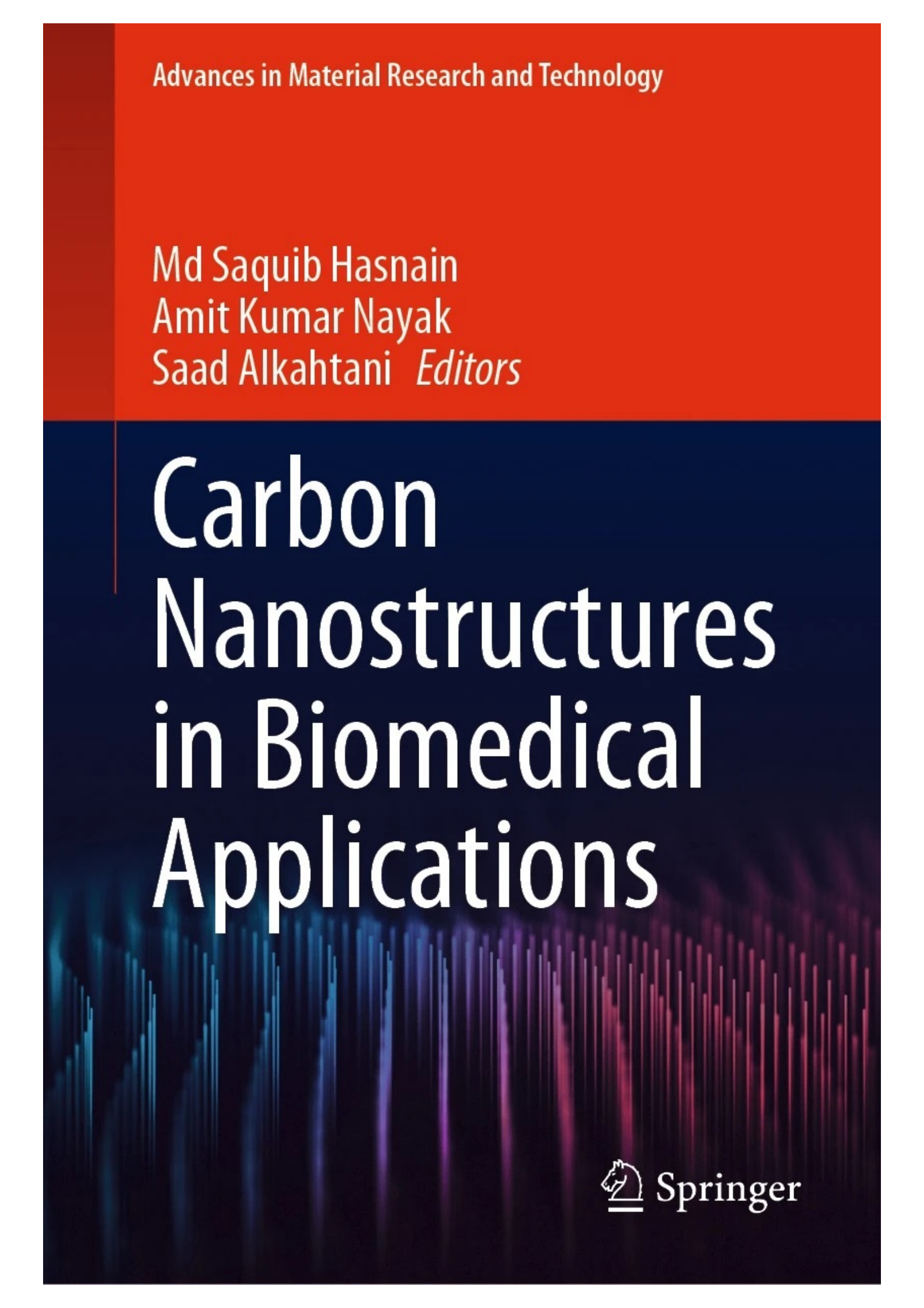
Carbon Nanostructures in Biomedical Applications



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Advances in Material Research and Technology

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Preface

With the innovation in the field of science and technology, advancements in nanotechnology applications have been emerged from material science to healthcare applications. Among the diverse nanomaterials available till date, the exploration of carbon-based systems has gained the considerable momentum. Unique physiochemical, mechanical, electrical, and thermal properties, along with surface tunable characteristics of carbon isotopes possess immense potential for healthcare applications. Several research reports have vouched the applicability of carbon nanostructures, which primarily include drug delivery and biomedical applications. Instances of some of the extensively investigated carbon nanocarriers include carbon nanotubes, graphenes, fullerenes, carbon nanofibres, nanorods, nanohorns, nanotorous, nanodiamonds, etc. Diversified applications of these carriers are a testimony to their multidimensional ability, thus confirming their usage in translational research for healthcare applications. In this context, despite the availability of umpteen literature reports, the present book will endeavor to provide a holistic compilation on applications of carbon nanostructures, especially in advanced healthcare applications.

The current book is a collection of total **14 chapters** presenting different key topics by the academicians and researchers across the world. A concise account on the contents of each chapter has been described to provide a glimpse of the book to the readers.

Chapter One entitled "Fullerenes: Bucky Balls in the Therapeutic Application" describes the many biological applications of fullerenes and their derivatives.

Chapter Two entitled "Nanodiamonds as Next Generation Carriers in Exploring Therapeutic Benefits" aims to inspire readers to explore new avenues for designing and developing next-generation nanodiamond-based materials with advanced functionalities and attractive properties.

Chapter Three entitled "Nanographites as Multidimensional Carriers for Advanced Therapeutic Applications" highlights various nanographite composites with different synthetic approaches in various therapeutic applications, such as drug delivery and cancer treatment.

Chapter Four entitled "Carbon Nanohorns in Drug Delivery and Medical Applications" summarizes the advancement of carbon nanohorns, including their properties, functionalization, and its possible potential in those fields.

Chapter Five entitled "Carbon Nanotorous for Advanced Therapeutic Applications" deals with the advanced therapeutic applications of carbon nanotorous.

Chapter Six entitled "Carbon Nanodots: A Novel Carbon Material with Multifacet Applications in Healthcare" summarizes the synthesis and diverse applications of carbon nanodots in the healthcare sector.

Chapter Seven entitled "Quantum Dots in Biomedical Applications: Recent Advancements and Future Prospects" emphasizes the latest progress available in literature related to various biological and biomedical applications of quantum dots as a potential tool for sensing, biomedical imaging, and drug delivery.

Chapter Eight entitled "Carbon Nanotropes: Potential Nanomaterials for Drug Delivery and Biomedical Applications" summarizes carbon nanotrophes, their unique properties, fabrication methodologies, drug delivery carrier, and other biomedical applications.

Chapter Nine entitled "Carbon Nanofibres in Diversified Healthcare Applications" gives a detailed insight on the healthcare applications of carbon nanofibers.

Chapter Ten entitled "Carbon Nanomaterials in Biosensor Applications for Infectious Disease Diagnostics" highlights the challenges and future considerations to expand the applicability of carbon nanomaterials for commercial point-of-care clinical diagnostic platforms.

Chapter Eleven entitled "Bio-inspired Carbon Nanostructures: Advances and Challenges" is an overview of various bio-inspired carbon nanostructures, nanocomposites, and their specific properties. In addition, their applications in specific biomedical applications, advances, and challenges are also discussed in this chapter.

Chapter Twelve entitled "Natural Polymer-Carbon Dot Nanocomposites for Biomedical Use" describes the preparation of natural carbon dots, composites, and their biomedical applications.

Chapter Thirteen entitled "Clay-Based Composites and Nanocomposites for Drug Delivery" addresses the uses of clays in nanoarchitectonic drug delivery vehicles that are targeted and stimuli-responsive regulated. The advantages and disadvantages of using these nanomaterials along with directions for future study are also discussed in this chapter.

Chapter Fourteen entitled "Biosafety and Toxicity Evaluation of Carbon Nanomaterials" presents a systematic evaluation of the safety and toxicity of various carbon nanomaterials based on recent reports. The possible strategies to minimize the unwanted toxic effects of the carbon nanomaterials in multiple applications are presented.

We would like to convey our sincere thanks to all the authors of the chapters for providing timely and valuable contributions. We thank the publisher-**Springer Nature**. We specially thank **Dr. Shadia Ikhmayies** (Series Editor, **Advances in Material Research and Technology, Springer Nature**), **Mayra Castro**, and **Yogesh** for their invaluable support in organization of the editing process right

through the beginning to finishing point of this book. We gratefully acknowledge the permissions to reproduce copyright materials from various sources. Finally, we would like to thank our family members, all respected teachers, friends, colleagues, and dear students for their continuous encouragements, inspirations, and moral supports during the preparation of the current book. Together with our contributing authors and the publishers, we will be extremely pleased if our endeavor fulfills the needs of academicians, researchers, students, biomedical experts, pharmaceutical students, and drug delivery formulators. In a nutshell, it will also help the health professionals in academia as well as in the industries.

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Carbon Nanodots: A Novel Carbon Material with Multifacet Applications in Healthcare

Anam Khan, Reena Vishvakarma, Archana Vimal, Poonam Sharma, Hassan Usman & Awanish Kumar

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Abstract

Carbon nanodots are quasi-spherical carbon materials with dimensions <10 nm (also termed zero-dimensional) and are endowed with several peculiar physiochemical features and attributes such as excellent biocompatibility and dispersibility, low cytotoxicity and cost, high stability, high photoluminescence and fluorescence, and easily tunable through surface modifications by addition

of functional groups such as carboxyl (–COOH), hydroxyl (–OH), and amino ($–NH_2$). This chapter summarizes the synthesis and diverse applications of carbon nanodots in the healthcare sector. The various strategies utilized for the synthesis of carbon nanodots in the recent past include top-down approaches such as arc-discharge, laser ablation, electrochemical approach, chemical exfoliation, and ultrasonic treatment; and bottom-up approaches such as thermal pyrolysis, microwave heating, chemical vapor deposition, and template method. Further, the functionalization of the carbon nanodots for enhanced photochemical properties for varied applications in the clinical context is discussed. The functionalization is achieved through nanodot surface modification using different functional groups from polymers and ions and heteroatom doping using metals and non-metals. The tunable properties of carbon nanodots have brought a revolution in the health sector where these nanomaterials are finding applications in various bioimaging tools functioning on varied optical principles such as fluorescence, photoacoustic (optical luminance in combination with ultrasound detection) effect, and photothermal effect. The carbon nanodots have been used as antioxidants, antimicrobial agents, tumor detection and treatment, drug and gene delivery vehicle, and as biosensors. This is followed by a detailed account of the application of carbon nanodots in medicine and health care where the use of carbon nanodots