



Review

Recent Developments in ZnS-Based Nanostructures Photocatalysts for Wastewater Treatment

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Abstract: The continuous growth of the world population has led to the constant increase of environmental pollution, with serious consequences for human health. Toxic, non-biodegradable, and recalcitrant organic pollutants (e.g., dyes, pharmaceuticals, pesticides) are discharged into water resources from various industries, such as textiles, leather, pharmaceuticals, plastics, etc. Consequently, the treatment of industrial wastewater, via a sustainable technology, represents a great challenge for worldwide research. Photocatalytic technology, an innovative technique based on advanced oxidation process (AOP), is considered a green technology with promising prospects in the remediation of global environmental issues. In photocatalysis, a very important role is attributed to the photocatalyst, usually a semiconductor material with high solar light absorption capacity and conductivity for photogenerated-charge carriers. Zinc sulfide (ZnS), as n-type semiconductor with different morphologies and band gap energies ($E_g = 3.2\text{--}3.71\text{ eV}$), is recognized as a promising photocatalyst for the removal of organic pollutants from wastewater, especially under UV light irradiation. This review deals with the recent developments (the last five years) in ZnS nanostructures (0D, 1D, 3D) and ZnS-based heterojunctions (n-n, n-p, Z-scheme) used as photocatalysts for organic pollutants' degradation under simulated (UV, Vis) and sunlight irradiation in wastewater treatment. The effects of different synthesis parameters (precursors' type and concentration, capping agents' dosages, reaction time and temperature, metal doping, ZnS concentration in heterostructures, etc.) and properties (particle size, morphology, band gap energy, and surface properties) on the photocatalytic performance of ZnS-based photocatalysts for various organic pollutants' degradation are extensively discussed.

Keywords: ZnS nanostructures; heterojunctions; photocatalysis; organic pollutants; wastewater treatment



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1. Introduction

Wastewater loaded with toxic, non-biodegradable organic pollutants represents a real problem, both for aquatic environments and for human life and development. Industrial wastewater originates mainly from the textile industry, but also from the plastics, paper, food, and cosmetic industries, due to the large amount of water used in the various technological stages, especially during the dyeing process [1]. It has been estimated that the wastewater from textile production contributes approximately 20% of the total industrial polluted water [2].

The presence of a very small concentration of organic dyes in water (less than 1 ppm for some dyes) may have serious consequences for the environment, but more for the population health, such as skin and eyes irritations, respiratory and gastric tracts affections, quadriplegia, tachycardia, tissue necrosis, and cancer [3–4].

The dyes most used industrially are azo dyes (usually with an aromatic structure) which, under natural conditions, require a long time to degrade due to their high photosta-

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Stefano Bellucci



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Recent Advances in Analytical Techniques Volume 1 Atta -ur- Rahman,2017-09-06 Recent Advances in Analytical Techniques is a collection of updates in techniques used in chemical analysis This volume presents information about a selection of analytical techniques Readers will find information about New methods of sample preparation in biological and environmental analysis Developments in electrochemical sensors In vivo cytometry for detection of tumor cells Flow discharge spectroscopy for depth profile analysis Advances in photodynamic therapy New methods to analyze volatility in alcoholic beverages Advanced Energy Materials Ashutosh Tiwari,Sergiy Valyukh,2014-02-12 An essential resource for scientists designing new energy materials for the vast landscape of solar energy conversion as well as materials processing and characterization Based on the new and fundamental research on novel energy materials with tailor made photonic properties the role of materials engineering has been to provide much needed support in the development of photovoltaic devices Advanced Energy Materials offers a unique state of the art look at the new world of novel energy materials science shedding light on the subject s vast multi disciplinary approach The book focuses particularly on photovoltaics efficient light sources fuel cells energy saving technologies energy storage technologies nanostructured materials as well as innovating materials and techniques for future nanoscale electronics Pathways to future development are also discussed Critical cutting edge subjects are addressed including Non imaging focusing heliostat state of the art of nanostructures Metal oxide semiconductors and their nanocomposites Superionic solids polymer nanocomposites solid electrolytes advanced electronics Electronic and optical properties of lead sulfide High electron mobility transistors and light emitting diodes Anti ferroelectric liquid crystals PEEK membrane for fuel cells Advanced phosphors for energy efficient lighting Molecular computation photovoltaics and photocatalysts Photovoltaic device technology and non conventional energy applications Readership The book is written for a large and broad readership including researchers and university graduate students from diverse backgrounds such as chemistry materials science physics and engineering working in the fields of nanotechnology photovoltaic device technology and non conventional energy **Enabling Biomaterials for New Biomedical Technologies and Clinical Therapies** Hasan Uludag,Abhay Pandit,Liisa Kuhn,2020-07-14 **Energy Research Abstracts** ,1995 Semiannual with semiannual and annual indexes References to all scientific and technical literature coming from DOE its laboratories energy centers and contractors Includes all works deriving from DOE other related government sponsored information and foreign nonnuclear information Arranged under 39 categories e g Biomedical sciences basic studies Biomedical sciences applied studies Health and safety and Fusion energy Entry gives bibliographical information and abstract Corporate author subject report number indexes Applications of Fluorescence in Surgery and Interventional Diagnostics Mark Preul,Evgenii Belykh,David Leslie Carr-Locke,Quyen Nguyen,2021-06-04 **Rational Design and Characterization of Innovative Multifunctional Biomimetic Materials** Lia Rimondini,Lorenzo Moroni,Andrea

Cochis,2021-04-13 **Biomimetic Materials for Tissue Regenerations, 2nd edition** Mariappan Rajan,Stevo J. Najman,Naresh Kumar Rajendran,2022-10-20 In tissue engineering the ultimate goal is to engineer an entire functioning organ that requires building complex structures of different tissue types A three dimensional scaffold seeded with desired cell types In order to resemble the natural formations of the organs cells have to be correctly located in relation to one another It has been shown in cocultures that cells have the capability of spontaneous tissue like organization when seeded into the scaffold The ideal scaffolds should have an interconnected porous structure well designed pore size and adequate porosity to allow cell attachment proliferation and differentiation Moreover effective bioactive agents and nutrient exchange are crucial during new tissue development Thus the individual organ cell is a specific mechanism for the construction or regeneration of the cells Artificial scaffolds have been applied and used as supporting structures for cell cultures as well as for the domination of cell growth in the repair of impaired tissues or organs During the cell regeneration the scaffold temporarily helps in cell regeneration and gradually biodegrade either in the course of the healing process or after and a new tissue with a desired shape and properties is produced The challenge of tissue engineering is to mimic what happens in nature Attempts are being made to engineer in vitro practically every tissue and organ in the body Work is proceeding in creating tissue engineered liver nerve kidney intestine pancreas and even heart muscle and valves In the area of connective tissues work has been ongoing worldwide for many years in the engineering of tendon ligament bone and cartilage Recently the number of reports was succeeded in skin bladder airway and bone where tissue engineered constructs have been used successfully in patients This Research Topic is the collection of body organ regeneration materials and their cell adhesion and migration for the development and regeneration of tissues Biomimetic materials promise to advance in current understanding of organ regeneration and repair by providing tools to recapitulate and monitor relevant properties of cellular microenvironment interactions Although cell adhesion migration and development aspects of tissues have shown success in the clinic better more intricate models are needed to understand drivers of tissue repair and regeneration fully Tissue engineering bears tremendous potential toward gaining a complete understanding of the underlying biological and physical mechanisms advancing the treatment of damaged organs The following Research Topic Bio mimetic materials for tissue regenerations discusses examples of progress toward this objective Bio mimicking scaffold materials for tissue regeneration Cell adhesion to scaffold materials Role of materials for the migration of cells Mechanisms of cell growth for organ development **Directory of Graduate Research** ,2001 Faculties publications and doctoral theses in departments or divisions of chemistry chemical engineering biochemistry and pharmaceutical and or medicinal chemistry at universities in the United States and Canada *Index to Theses with Abstracts Accepted for Higher Degrees by the Universities of Great Britain and Ireland and the Council for National Academic Awards* ,1997 Theses on any subject submitted by the academic libraries in the UK and Ireland **Recent Research Developments in Nano Structures** ,1999 *Recent Progress and*

Development in Nanostructures, 2025-05-07 Recent Progress and Development in Nanostructures is a comprehensive exploration of the latest advancements in the rapidly evolving field of nanotechnology. This book investigates nanostructure synthesis, characterization, and applications, showcasing their transformative potential in energy, environment, healthcare, and beyond. With contributions from leading experts, the book highlights the crucial role of nanostructures in addressing global challenges. Topics include innovative synthesis methods, advanced characterization techniques, and emerging applications in catalysis, sensors, drug delivery, and energy storage systems. It also explores hybrid nanostructures, self-assembled materials, and the integration of nanotechnology into sustainable and green solutions. Tailored for researchers, professionals, and students, the book balances theoretical insights and practical applications. Each chapter provides a detailed discussion of recent breakthroughs, supported by in-depth analysis and experimental findings. Special emphasis is placed on interdisciplinary approaches that bridge chemistry, physics, and material science, underscoring the collaborative nature of modern nanotechnology research. The book also addresses the challenges in scalability, cost effectiveness, and environmental impact associated with nanostructures, offering solutions and future directions. With an engaging narrative and illustrative content, *Recent Progress and Development in Nanostructures* is an invaluable resource for advancing knowledge and fostering innovation in this dynamic field. Whether you are an academic, industry professional, or enthusiast, this book will inspire and guide your journey into the fascinating world of nanostructures.

New Developments in Nanotechnology Research Eugene V. Dirote, 2007 Nanotechnology is a catch-all description of activities at the level of atoms and molecules that have applications in the real world. A nanometer is a billionth of a metre, about 1/80,000 of the diameter of a human hair or 10 times the diameter of a hydrogen atom. Nanotechnology is now used in precision engineering, new materials development, as well as in electronics, electromechanical systems, as well as mainstream biomedical applications in areas such as gene therapy, drug delivery, and novel drug discovery techniques. This book presents the latest research in this frontier field.

Advances in Nanostructured Materials for Multifunctional Applications Luz Stella Gomez-Villalba, 2019 This volume presents the recent research progress in the synthesis, characterization, techniques, properties, and interactions of nanostructured materials for multifunctional applications. The opportunity to apply singular or hybrid nanomaterials proves to be a constant challenge in order to optimize its use, achieving simultaneous results for its application in different branches of research. It is focused on the study of structures and their effect on the properties of solids using different experimental techniques and practical applications of nanostructured materials in the context of the latest achievements in the area of research of solid-state phenomena. Multifunctional Nanomaterials: Synthesis, Morpho-Structural, and Chemical Properties; Experimental Characterization Techniques; Optical Properties; Electrical Properties; Cultural Heritage Conservation; Construction Materials; Materials Science.

DNA Nanotechnology Chunhai Fan, Yonggang Ke, 2020-09-07 The series *Topics in Current Chemistry Collections* presents critical reviews from the journal *Topics in Current Chemistry*, organized in

topical volumes The scope of coverage is all areas of chemical science including the interfaces with related disciplines such as biology medicine and materials science The goal of each thematic volume is to give the non specialist reader whether in academia or industry a comprehensive insight into an area where new research is emerging which is of interest to a larger scientific audience Each review within the volume critically surveys one aspect of that topic and places it within the context of the volume as a whole The most significant developments of the last 5 to 10 years are presented using selected examples to illustrate the principles discussed The coverage is not intended to be an exhaustive summary of the field or include large quantities of data but should rather be conceptual concentrating on the methodological thinking that will allow the non specialist reader to understand the information presented Contributions also offer an outlook on potential future developments in the field The chapter DNA Programmed Chemical Synthesis of Polymers and Inorganic Nanomaterials is available open access under a CC BY 4.0 License via link [springer.com](https://www.springer.com)

Leading Edge Nanotechnology Research Developments Donald M. Sabatini, 2007 Nanotechnology is briefly introduced as a general term for activities at the level of atoms and molecules about 1/80 000th of a human hair in which there is now intense interest International contributors to a dozen illustrated chapters elaborate on research progress involving a variety of nanomaterials and their applications in electronics new materials development and biomedicine e.g. nanofluids that have unique thermal properties nanoscale optical effects nanowires for advanced electronics nanotubes of self organized inorganic structures polymer nanocrystal interfaces for potentially producing low cost flexible solar cells and other new methods A theoretical paper presents the concept of super carbon nanotube No background information is provided on the editor

Self-Assembly of Nanostructures Stefano Bellucci, 2011-10-26 This is the third volume in a series of books on selected topics in Nanoscale Science and Technology based on lectures given at the well known Istituto Nazionale di Fisica Nucleare INFN schools of the same name The present set of notes stems in particular from the participation and dedication of prestigious lecturers such as Nunzio Motta Fulvia Patella Alexandr Toropov and Anna Sgarlata All lectures have been carefully edited and reworked taking into account extensive follow up discussions A tutorial lecture by Motta et al. presents the analysis of the Poly(3-hexylthiophene) self assembly on carbon nanotubes and discusses how the interaction between the two materials forms a new hybrid nanostructure with potential application to future solar cells technology In their contribution Patella et al. review quantum dots of III-V compounds which offer appealing perspectives for more sophisticated applications in new generation devices such as single photon emitters for nano photonics and quantum computing Focusing on self assembled quantum dots the chapter by Alexandr Toropov et al. provides a comprehensive review of some important aspects in the formation of quantum dots and presents the results of the authors extensive investigation of the features of droplet epitaxy The fourth contribution by Sgarlata et al. focuses on recent progress toward controlled growth of self assembled nanostructures dealing with the shaping ordering and localization in Ge/Si heteroepitaxy and reviewing recent results on the self organization of Ge

nanostructures at Si surfaces *Handbook of Nanostructured Materials and Nanotechnology, Five-Volume Set* Hari Singh Nalwa, 1999-10-29 Nanostructured materials is one of the hottest and fastest growing areas in today's materials science field along with the related field of solid state physics Nanostructured materials and their based technologies have opened up exciting new possibilities for future applications in a number of areas including aerospace automotive x ray technology batteries sensors color imaging printing computer chips medical implants pharmacy and cosmetics The ability to change properties on the atomic level promises a revolution in many realms of science and technology Thus this book details the high level of activity and significant findings are available for those involved in research and development in the field It also covers industrial findings and corporate support This five volume set summarizes fundamentals of nano science in a comprehensive way The contributors enlisted by the editor are at elite institutions worldwide Key Features Provides comprehensive coverage of the dominant technology of the 21st century Written by 127 authors from 16 countries making this truly international First and only reference to cover all aspects of nanostructured materials and nanotechnology **New Topics in Nanotechnology Research** Matthew F. Ginobili, 2007 Nanotechnology is a catch all description of activities at the level of atoms and molecules that have applications in the real world A nanometer is a billionth of a meter about 1/80 000 of the diameter of a human hair or 10 times the diameter of a hydrogen atom Nanotechnology is now used in precision engineering new materials development as well as in electronics electromechanical systems as well as mainstream biomedical applications in areas such as gene therapy drug delivery and novel drug discovery techniques This book presents the latest research in this frontier field **Selected Topics in Nanoscience and Nanotechnology** Andrew T. S. Wee, 2009 Scanning probe techniques Scanning probe microscopy based nanoscale patterning and fabrication X N Xie H J Chung and A T S Wee Nanoscale characterization by scanning tunneling microscopy H Xu et al Nanofabrication EUV lithography for semiconductor manufacturing and nanofabrication H Kinoshita Synchrotron radiation supported high aspect ratio nanofabrication A Chen et al Functional nanomaterials Chemical interactions at noble metal nanoparticle surfaces catalysis sensors and devices A S Nair Diamond like carbon a new material base for nano architectures X Li and D H C Chua Hotplate technique for nanomaterials Y Zhu and C H Sow Molecular engineering Pie symbol d interaction based molecular conducting magnets how to increase the effects of the Pie symbol d interaction A Miyazaki and T Enoki Recent developments on porphyrin assemblies R Charvet et al Bionanotechnology and nanomedicine Nanostructures from designer peptides B T Ong P K Ajikumar and S Valiyaveetil Nanotechnology and human diseases G Y H Lee and C T Lim Nanomedicine nanoparticles of biodegradable polymers for cancer diagnosis and treatment S S Feng *Emerging Nanomaterials for Advanced Technologies* Anand Krishnan, Balasubramani Ravindran, Balamuralikrishnan Balasubramanian, Hendrik C. Swart, Sarojini Jeeva Panchu, Ram Prasad, 2022-02-22 Over the past decade the world has seen the rise of the fascinating and diverse field currently recognized as nanotechnology This book covers a broad spectrum of topics within nanotechnology including

synthesis techniques various innovative characterization techniques growth mechanisms of nanomaterials the physics and chemistry of nanomaterials diverse functionalization methods and the various applications of nanomaterials in biology therapeutics energy food science and environmental science It also discusses applications of nanostructured materials integrative applications such as nano and micro electronic sensor devices as well as agricultural and environmental remediation applications The book also includes a discussion of advances in functionalized nanomaterials 0D 1D 2D and 3D and covers the early stages of the development of functionalized nanostructures considering the future for 2D nanomaterials and 3D objects Additionally it includes a chapter on nanomaterial research development that highlights work on the life cycle analysis of nanostructured materials and toxicity aspects This book proves useful for researchers and professionals working in the field of nanomaterials and green technology as well as in the field of nanotechnology It should be useful to students and specialized researchers in a number of disciplines ranging from biology chemistry and materials science to engineering and manufacturing in both academia and industry

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