SpringerBriefs in Applied Sciences and Technology
Nanoscience and Nanotechnology

Zhenglong Zhang

Plasmonic Photocatalysis

Principles and Applications

清華大学出版社
TSINGHUA UNIVERSITY PRESS

Springer

SpringerBriefs in Applied Sciences and Technology

Nanoscience and Nanotechnology

Indexed by SCOPUS Nanoscience and nanotechnology offer means to assemble and study superstructures, composed of nanocomponents such as nanocrystals and biomolecules, exhibiting interesting unique properties. Also, nanoscience and nanotechnology enable ways to make and explore design-based artificial structures that do not exist in nature such as metamaterials and metasurfaces. Furthermore, nanoscience and nanotechnology allow us to make and understand tightly confined quasi-zero-dimensional to two-dimensional quantum structures such as nanopalettes and graphene with unique electronic structures. For example, today by using a biomolecular linker, one can assemble crystalline nanoparticles and nanowires into complex surfaces or composite structures with new electronic and optical properties. The unique properties of these superstructures result from the chemical composition and physical arrangement of such nanocomponents (e.g., semiconductor nanocrystals, metal nanoparticles, and biomolecules). Interactions between these elements (donor and acceptor) may further enhance such properties of the resulting hybrid superstructures. One of the important mechanisms is excitonics (enabled through energy transfer of exciton-exciton coupling) and another one is plasmonics (enabled by plasmon-exciton coupling). Also, in such nanoengineered structures, the light-material interactions at the nanoscale can be modified and enhanced, giving rise to nanophotonic effects.

These emerging topics of energy transfer, plasmonics, metastructuring and the like have now reached a level of wide-scale use and popularity that they are no longer the topics of a specialist, but now span the interests of all "end-users" of the new findings in these topics including those parties in biology, medicine, materials science and engineerings. Many technical books and reports have been published on individual topics in the specialized fields, and the existing literature have been typically written in a specialized manner for those in the field of interest (e.g., for only the physicists, only the chemists, etc.). However, currently there is no brief series available, which covers these topics in a way uniting all fields of interest including physics, chemistry, material science, biology, medicine, engineering, and the others.

The proposed new series in "Nanoscience and Nanotechnology" uniquely supports this cross-sectional platform spanning all of these fields. The proposed briefs series is intended to target a diverse readership and to serve as an important reference for both the specialized and general audience. This is not possible to achieve under the series of an engineering field (for example, electrical engineering) or under the series of a technical field (for example, physics and applied physics), which would have been very intimidating for biologists, medical doctors, materials scientists, etc.

The Briefs in NANOSCIENCE AND NANOTECHNOLOGY thus offers a great potential by itself, which will be interesting both for the specialists and the non-specialists.

Zhenglong Zhang

Plasmonic Photocatalysis

Principles and Applications

清華大学出版社
TSINGHUA UNIVERSITY PRESS

Springer

Zhenglong Zhang
Shaanxi Normal University
Xi'an, China

ISSN 2191-530X ISSN 2191-5318 (electronic)
SpringerBriefs in Applied Sciences and Technology
ISSN 2196-1670 ISSN 2196-1689 (electronic)
Nanoscience and Nanotechnology
ISBN 978-981-19-5187-9 ISBN 978-981-19-5188-6 (eBook)
https://doi.org/10.1007/978-981-19-5188-6

Jointly published with Tsinghua University Press
The print edition is not for sale in China (Mainland). Customers from China (Mainland) please order the print book from: Tsinghua University Press.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Acknowledgments

The author thanks heartily Ting Kong, Tingting Zhang, Zhengkun Fu and Hairong Zheng for their valuable contributions to this book. This work was supported by the Projects of Postgraduate Education Reform Foundation Shaanxi Province (YJSZG2020039), the Postgraduate Textbook Foundation (GERP2017) and the Excellent Books Publishing Foundation of Shaanxi Normal University.

Contents

Chapter 1
Introduction

In recent years, such fundamental issues as high-energy utilization, fossil-fuel consumption, and environmental pollution have become major challenges being faced globally [1, 2]. The production of sustainable fuels and chemicals using clean and renewable energy is therefore becoming increasingly urgent. Solar energy is considered to be an ideal option in the field of catalysis [3]. Semiconductor photocatalysts under the electrons interband excitation have received extensive attention in the fields of photothermal conversion and environmental governance [4–6]. However, due to the wide band gap and the faster charge carrier recombination of semiconductor materials with an ultraviolet band gap, a weakened ultraviolet-conversion efficiency is observed [7, 8]. Moreover, semiconductor photocatalysts have low-energy utilization and low quantum efficiency for visible-light and near-infrared photons, hindering the development and application of photocatalysts. Therefore, a promising catalyst is significant to break the limitations of semiconductors and realize large-scale applications employed in the catalytic field.

Since the early twentieth century, noble-metal nanostructures have emerged as promising photocatalysts in the field of plasmonic nano-optics, as they are capable of collecting solar energy and promoting efficient energy conversion [9]. Owing to the unique features of the localized surface-plasmon resonance (LSPR) of noble-metal nanostructures, an enhanced electromagnetic (EM) field is formed because its energy is effectively transformed into the collective vibrational energy of free electrons on the metal surface, simultaneously, hot carriers can be induced by the energy stored in the plasmonic field for the metal nanostructures [10]. The hot carriers eventually dissipate through phonon mode coupling, leading to a higher lattice temperature of the metal nanostructures. The field-effect enhancement, hot electrons, and thermal effects in plasmonic nanostructures have been successfully applied to enhance the catalysis of chemical reactions and material growth [11–13]. In particular, plasmonic nanostructures exhibit advantageous properties such as tunable size and shape, crystalline properties, and a unique composition; thus they offer enhanced reaction rates,

Z. Zhang, *Plasmonic Photocatalysis*, Nanoscience and Nanotechnology,
https://doi.org/10.1007/978-981-19-5188-6_1