

Preface

The solar light conversion and storage is currently one of the most blossoming interdisciplinary fields of science converging the physical chemistry, physics of solid state, optics, photochemistry, electrochemistry, catalysis, and many other research directions. The present textbook is intended to give a perspective on the current state of photochemical systems for the solar light harvesting based on nanocrystalline semiconductor materials and assemblies. The book chapters provide an account on various aspects of such systems, including the solar water splitting and evolution of molecular hydrogen, the photosynthetic processes of CO_2 and N_2 reduction, and the photoelectrochemical solar cells based on nanoparticulate semiconductor materials. A special focus is made on a “nano” aspect of semiconductor photocatalysis—the role of nanocrystals and size effects in the solar energy conversion, the design of semiconductor nanostructures with tailored photochemical properties, and the perspectives of nanophotocatalysis and photovoltaic systems based on semiconductor quantum dots.

The introduction provides a brief account on various concepts of the solar light harvesting using the bulk and nanocrystalline semiconductors as well as a short historical account on the development of various photochemical and photovoltaic light conversion technologies.

The first chapter is an introduction to the photochemistry of semiconductor nanoparticles (NPs). It highlights basic principles of the selection of semiconductor materials for the applications in the solar light harvesting and requirements to the optical and electrophysical properties of photoactive semiconductor NPs. The chapter is focused on special features of the nanocrystalline semiconductors, in particular, on the quantum size effects and a unique capability of semiconductor NPs for the photoinduced charging. We discuss the most prominent size effects in the photochemistry of semiconductor NPs such as a dramatic enhancement of the photocatalytic/photoelectrochemical activity of nanocrystalline semiconductors as compared to their bulk counterparts, a crucial role of the surface charge traps in the photochemical processes, the effects of NP shape and porosity, the charging-induced changes in the NP photoreactivity, etc.

The second and third chapters provide a review of the current state of the art in the semiconductor-based light-harvesting systems for the water splitting and the reduction of carbon dioxide and dinitrogen. The semiconductor-catalyzed photochemical water splitting for the hydrogen production as a green and sustainable fuel is discussed in detail. A review of the photocatalytic systems for the photosynthetic reduction of water, CO_2 , and N_2 encompasses the systems based on the dye-sensitized oxide nanocrystalline semiconductors, binary semiconductor heterostructures, a survey of the visible-light-sensitive metal-chalcogenide nanophotocatalysts, and new and emerging nanostructured photocatalysts and cocatalysts of these photosynthetic processes.

The fourth chapter introduces the reader to the semiconductor-based photoelectrochemical solar cells designed for the conversion of solar light into electric current. As the topic of dye-sensitized liquid-junction semiconductor solar cells has recently been broadly covered elsewhere, the discussion is limited mostly to the semiconductor nanoparticle-sensitized solar cells with liquid electrolytes, where the light conversion occurs as a result of a cyclic series of photochemical/photocatalytic processes and secondary “dark” redox reactions.

The fifth chapter provides a concise account on typical synthetic approaches used for the preparation of various semiconductor nanomaterials—the colloidal NPs, nanocrystalline powders, thin films, binary and more complex nanoheterostructures, and nanocomposites of semiconductors with other functional components, such as metal NPs, carbonaceous compounds, etc.

The final sixth chapter has a methodological character and acquaints the readers with the experimental methods using light as a probe of the structure, electrophysical, photophysical, and photochemical properties of nanocrystalline semiconductors and related heterostructures. The chapter discusses the methods of absorption and photoluminescence spectroscopy, flash photolysis, and other spectroscopic techniques that can be used to gain insights into the photochemical behavior of semiconductor NPs.

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I hope that the present book will be useful both for a novice reader who starts a journey into the exciting world of the solar light-harvesting science and for an advanced reader who is already familiar with the field and seeks an informative review on principal topics of the solar light conversion, such as the solar cells and semiconductor-based artificial photosynthesis.

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Dr. Oleksandr Stroyuk

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