

Preface

Starting from the late 1990s, the field of photon upconversion nanomaterials has undergone significant expansion and has become one of the most active research areas within the nanoscience community. Exciting developments have been made at a very fast pace by many research groups. The vast number of papers published on upconversion nanomaterials over the past two decades clearly witness it, which has increased exponentially, with most of the activity and development happening in the last 10 years. These kinds of materials can emit ultraviolet/visible/near-infrared light under near-infrared excitation (anti-Stokes emission). This unique optical property precludes background fluorescence and light scattering from biological systems. The emission of multiple and narrow emission lines is an additional hallmark of upconversion nanoparticles that opens up new avenues for optical applications. In the past decades, the related theories, methods and techniques have been explored. As a consequence, novel photon upconversion materials are increasingly emerging, and their applications extend from traditional fields, for example, optical communication amplifiers and solid-state lasers to high-tech fields, including biotechnology, sensors, solar cell and photocatalysis, etc. Researchers can therefore give a deep insight into the synthesis strategies, pathways, and phenomena for photon upconversion nanomaterials, and in particular, establish the relationship for structure—function—synthesis.

This book contains 12 chapters. The Introduction (Chap. 1) involves the general introduction of upconversion luminescence materials, including the energy transfer mechanism, category, and chemical composition of such materials. From the viewpoint of the “wet” chemical synthesis for photon upconversion nanomaterials, Chap. 2 summarizes the most widely used synthetic pathways and the formation mechanism of crystallization (including nucleation and growth) for monodisperse nanocrystals, as well as the corresponding characterizations for the optical, chemical, and structural upconversion of nanoparticles. Provided that these factors and mechanisms can be fully grasped, researchers even beginners can easily obtain high-quality upconversion nanomaterials. In Chap. 3, the optical properties of upconversion lanthanide ions doped nanocrystals including the upconversion emission color tunability, enhancement of luminescence efficiency, core@shell

structure-based luminescence engineering, and the optical properties comparison between upconversion nanocrystals and quantum dots and dyes are summarized. In recent years, the development of multifunctional nanomaterials with fantastic physical, chemical, and biological properties has become an attractive research topic. As some of the most important luminescence nanomaterials, upconversion nanomaterials were also used to fabricate multifunctional nanocomposites. In Chap. 4, we summarize recent advanced upconversion nanoparticles-based nanocomposites, including upconversion-mesoporous SiO_2 , upconversion-magnetic nanoparticles, upconversion-metal and upconversion-semiconductor nanocomposites, etc. Chapter 5 is devoted to the surface modification and bioconjugation of upconversion nanoparticles. Surface modification of the UCNPs not only improves the photostability of the nanoparticles with desirable interfacial properties, but also provides a potential platform for attaching biological macromolecules for various biomedical applications. In Chaps. 6–11, we deal with the applications of photon upconversion nanomaterials including biomedical imaging, bioassay, biosensor, thermal sensing, light activated therapy, solar cell and photocatalysis, etc. It is apparent that the photon upconversion nanomaterials field is eager for more and more researchers from other fields to explore attractive applications. Finally, the latest progress in photon upconversion nanomaterials are reviewed, and the next stages are put into outlook.

Photon upconversion nanomaterials have been experiencing rapid development in the past decade. A comprehensive review is thus necessary, and is the main purpose of this book. Besides a review, this book also includes an understanding, induction, and summary from the authors. The book is organized along the following guidelines: (1) following the forefront of current research, and striving to reflect the latest progress and developments; (2) comprehensive review with focus on basic fundamental research; and (3) practical research experience in methodology, experiment skills, and data analysis. Particularly, we spent huge efforts on the basic knowledge of photon upconversion nanomaterials. Therefore, this book is especially readable for beginners and graduate students who have just entered this field. We hope that they can, through reading this book, fully understand the chemistry of photon upconversion nanomaterials, grasp synthesis skills, obtain high-quality materials, and therefore, deeply explore the chemical and physical properties of the materials and their applications. Based on the guidelines, most of the chapters were written by Professor Fan Zhang at Fudan University and his students. Dr. Xiaomin Li helped to draft several chapters and dedicated to editing them for publication (Chaps. 1–4), Ph.D. candidates Rui Wang (Chaps. 1, 6, 10), Chi Yao (Chap. 5), Lei Zhou (Chap. 7), Chengli Wang (Chap. 10), and Master candidate Lei Chen (Chap. 8) and Zhenzhen Guo (Chap. 9) also dedicated to editing several chapters. Master candidates Jichuang Mao and Exchange students Vishaal Varahamurthy and Daniel Yur from University of California, Santa Barbara, dedicated to editing the book for publication. Here I express my heartfelt appreciation to them. The authors also thank the financial support from NSFC.

This book is a distillation of the authors' intelligence and great efforts. We wish that this book will help and inspire researchers working in the fields of chemistry

and materials science, especially on luminescent materials. We also hope it can provide a reference source or serve as a textbook for undergraduate and graduate students who major in chemistry, chemical engineering, physics, materials and biology, as well as for those readers interested in upconversion luminescent materials. As this book covers relatively wide areas and numerous contents connected to complex scientific issues, errors and omissions may be unavoidable due to the limited knowledge and competence of the authors, therefore we sincerely appreciate the criticism and comments from the readers.

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