Preface

The investigation of nanoscale phenomena and nanomaterials (i.e., Nanoscience) has become one of the most dynamic and interdisciplinary fields in contemporary science, and continues to develop at an astounding rate and in many different directions. Nanoscience is also attracting a growing interest from the general public, as Nanotechnology has been hailed one of the key technologies of the twenty-first century. This intense activity produces vast amounts of new knowledge on a daily basis, which are periodically condensed in authoritative and up-to-date reviews and books covering selected topics within Nanoscience. Nevertheless, the field progresses so fast that topic reviews are needed at increasingly shorter time intervals! Nanoscience is also a dynamic cross-road of many disciplines, and, as a result, its topics do not have sharp boundaries and are continuously evolving and changing. Although this is exactly what makes Nanoscience a very fertile cradle for groundbreaking ideas, it may be overwhelming and bewildering for students and beginner researchers trying to grasp the essence of the field. For those, an *introductory teaching textbook* would be a great asset. However, introductory books to Nanoscience, which are both general and sufficiently deep to be used as textbooks, are scarce, albeit highly needed.

This book aims to address this need by using one particular class of nanomaterials (viz., Nanoparticles) as an exemplary case from which all the fundamental principles of Nanoscience can be derived. The essential feature of nanomaterials is that their physical and chemical properties are size-dependent. Nanoparticles are perfectly suited to illustrate and explain this principle, since they can be made in a variety of sizes and shapes, and from a myriad of different materials ranging from metals to insulators through semiconductors. Further, colloidal nanoparticles beautifully demonstrate the multi- and cross-disciplinary character of Nanoscience, as they integrate concepts from several disciplines within chemistry, physics, and biology (e.g., colloidal science, coordination chemistry, organic chemistry, solid state physics, photophysics, quantum mechanics, magnetism, and interfacial chemistry). We will loosely interchange the terms “nanocrystal” (NC) and “nanoparticle” (NP) throughout the book, even though they are not rigorously synonyms, as nanoparticles also include amorphous materials such as silica.

This work is intended as a basic textbook for graduate students beginning in this field and advanced undergraduate students in Chemistry, Physics, and Materials Science. The overall structure of the book and the treatment of some of the topics reflect my classroom experience teaching a course on Nanomaterials to senior undergraduate students. This course has been taught for several years at Utrecht University, together with some of the contributing authors of this book (de Jongh and Vanmaekelbergh). The chapters are not intended as reviews of the recent scientific literature, but instead convey a comprehensible coverage of the fundamental principles of the subject matter. They also provide a flavor of the state-of-the-art and an outlook on potential developments. Our approach is to emphasize the essential concepts with the objective of developing student understanding. The topics are addressed with conciseness, but without compromising effectiveness and depth. Mathematics are kept to the minimum necessary to ensure proper understanding. For more detailed or rigorous treatments the reader is referred to the literature. To facilitate understanding and highlight the essential concepts, each chapter contains a set of exercises. The student who masters this book will know what Nanoscience is and why it is important, and will also understand its fundamental principles and be able to integrate and combine concepts from different disciplines to address research questions within Nanoscience.

The book can be roughly divided into three parts: fundamental physico-chemical and physical principles of Nanoscience, chemistry and synthesis of nanoparticles, and techniques to study nanoparticles. These parts are however strongly interconnected and intermingled, with the fundamental principles forming a framework that permeates through the whole book.

The first chapter is concerned with the origin of the size dependence of the properties of nanomaterials, explaining it in terms of two fundamental nanoscale effects. This chapter also serves as a general introduction to the book, briefly addressing the definition and classification of nanomaterials and the techniques used to fabricate and study them. Chapter 2 lays out the theoretical framework within which to understand size effects on the properties of semiconductor nanocrystals, with particular emphasis on the quantum confinement effect. The optical properties of metal nanoparticles and metal nanostructures (periodic lattices) are discussed in Chap. 3.

Chapter 4 is devoted to nanoporous materials, treating in detail their synthesis, structure and functional properties, as well as the physical properties of liquids confined in nanopores. The preparation methods, characterization techniques, and applications of supported nanoparticles are covered in Chap. 5. Chapter 6 presents the essential physical-chemical concepts needed to understand the preparation of colloidal inorganic nanoparticles, and the remarkable degree of control that has been achieved over their composition, size, shape and surface.

The last four chapters are dedicated to a few selected characterization techniques that are very valuable tools to study nanoparticles. Chapter 7 concentrates on electron microscopy techniques, while Chap. 8 focuses on scanning probe microscopy and spectroscopy. Electron paramagnetic resonance (EPR) based spectroscopic techniques and their application to nanoparticles are explored in

Chap. 9. Finally, Chap. 10 shows how solution Nuclear Magnetic Resonance (NMR) spectroscopic techniques can be used to unravel the surface chemistry of colloidal nanoparticles.

We have attempted to cover as much as possible of the broad field of Nanoparticles, but had no intention of producing a comprehensive and exhaustive treatise. To keep the length of the book manageable, some topics are not addressed in detail. The most noticeable examples are no doubt superlattices and nanomagnetism, which are briefly mentioned, but not treated in any detail. Further, very actual issues, such as charge transport and multiexciton generation (MEG), are also not discussed. This should not be seen as deliberate omissions from our part, but rather as necessary compromises for the sake of conciseness. These topics are still contained in the book, but the reader is referred to recent literature for a comprehensive treatment.

Most of the excitement about Nanoscience originates from the potential of nanomaterials to lead to a dazzling multitude of applications (e.g., solar energy conversion, optoelectronics, nanophotonics, spintronics, smart catalysts, biomedical applications, etc.). Therefore, it is perhaps surprising that the potential and current applications of nanoparticles are only briefly addressed in this book. This choice was motivated both by our desire to keep the book concise and by the fact that the field is developing so rapidly that the applications section of the book would soon be outdated. In contrast, the fundamental concepts will remain valid, despite the further growth of the field. Our treatment of the applications of nanoparticles should thus be regarded as a blurred snapshot of a fast-moving object. We have made no attempt to sharpen the image, but instead tried to describe it in general terms, highlighting the essential concepts behind the scene. We have left it up to the reader to follow the references provided and fill in the fine details, which are bound to change as progress is made.

In conclusion, it is my pleasant duty to thank all contributors for investing their valuable time into writing exciting and instructive chapters for this book. Thanks are also due to many generations of students for their valuable assistance in the form of questions and remarks that have stimulated me (and certainly also the contributing authors) to seek better ways to present the topics discussed here. I would also like to express my gratitude to Mayra Castro at Springer for inviting me to put together a textbook on Nanomaterials. At the time, it sounded like a very challenging project, and I am glad I took up the challenge. Let us hope this book fulfills its purpose of inspiring many new generations of students and guiding them into the ever changing realms of Nanoscience.

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