

Preface

Metal nanoparticles and clusters constitute a remarkable set of nanomaterials that have permeated crucial fields of science and technology and are one of the most active areas of research. The interest in the chemistry and physics of these systems spans a century. Considering this rich and diverse history, it is indeed a challenge to bring a status update to the field and highlight recent important advances in the field, which makes this compilation all the more challenging.

Nanotechnology promises to usher in a technological revolution due to the possibility of maximizing the properties of a material in the nanometer scale. Metal nanocrystals with dimensions above 2 nm show smoothly scaling, size-dependent properties converging to the bulk when size increases. However, what happens when the nanoparticle's size is comparable to the Fermi wavelength of an electron? Would the properties be the expected ones? It has been observed that particles in this sub-nano regime do not follow the size-dependent behavior of nanoparticles; instead, they present totally new and fascinating properties owing to their specific geometrical and electric structures. Such species are more aptly called atomic quantum clusters (AQC) because the origin of the new intriguing properties lies in the quantum effects that cause a splitting (band gap) of energies at the Fermi level. This band gap makes metal AQC behave like atomic-level semiconductors. As an example, fluorescence, magnetism, circular dichroism, and high-efficiency catalysis have been seen in metal AQC, M_n , with $n \leq 200$ atoms and with sizes below ≈ 2 nm. Properties presented by small AQC cannot be attributed to the increase of the surface area, but to the abovementioned new electronic properties displayed by these AQC. These are some of the key points discussed in the first chapter "From Nano- to Angstrom Technology" by Arturo and coworkers. In the second chapter "Advances in Synthesis of Metal Nanocrystals," John and coworkers discuss different schemes which yield metal nanocrystals. In this context, recent developments that have sparked new interest are highlighted. These include being able to control size, shape, and composition of particulates. The chapter reviews the contemporary synthetic advances over the past decade and provides brief perspectives on the advances responsible for this upsurge in interest.

In the third chapter, entitled “Spectroscopic and Computational Studies on Metal Nanoparticles and Clusters” by Maurizio et al., the spectroscopic properties of silver and gold nanoparticles and clusters, functionalized with organic ligands, are investigated by different characterization techniques, including Raman scattering, fluorescence, and X-ray photoelectron spectroscopy measurements. The results are interpreted by employing different computational approaches. The fourth chapter “Surface-Enhanced Raman Spectroscopy: Principles, Substrates and Applications” by Roberto et al. gives a historical overview of SERS including a theoretical background and its principles. It also presents a wide variety of applications to different fields including sensing, detection of chemical warfare agents, environmental pollutants, food contaminants, illicit drugs, art preservation, forensic science, and medical diagnosis.

Of the various applications, the role of metal NPs and clusters in the field of catalysis has had sizable implications. This aspect is summarized in the chapter “Model Nanoparticles in Catalysis” by Vinod et al. In this chapter, the applications of metal nanoparticles in heterogeneous catalysis are highlighted, and several key reactions of industrial significance (hydrogenation, oxidation, and coupling reactions) have been outlined. This chapter is followed by the contribution of Hector, entitled “Catalytic Efficiency of Metallic Nanoparticles: A Computational Approach,” which describes the different computational methods that have been developed to complement the experimental effort in the design of novel nanocatalysts. These include density functional theory (DFT), kinetic Monte Carlo (KMC), and classical molecular dynamics (CMD) simulations. These theoretical studies enable the description of catalytic activity for diverse reactions in different catalytically active nanoparticles.

The complete atomic-scale characterization of individual clusters and nanoparticles is presented in the chapter “Advanced Electron Microscopy Techniques Toward the Understanding of Metal Nanoparticles and Clusters” by Deepak et al. Current trends which include the 3D analysis of the morphological and chemical composition of complex nanoalloys, dynamical observations of the growth and assembly of nanoparticles in solution – facilitated by recent developments in *In situ* capabilities – and the simulation of nanoparticles as catalysts which are close to real operating conditions by employing *in operando* TEM techniques, are highlighted in this chapter. Subsequently, Sergio Mejia in the chapter “Simulations of Metal Clusters and Nanostructures” emphasizes the importance of computational simulations and numerical methods, which enable researchers to better understand experimental observations.

Nagamalai and Maria Fernandez discuss the applications of fluorescent Au and Ag clusters as chemical and biological sensors for the detection of heavy metal ions, small molecules, nucleic acids, and proteins in the chapter entitled “Gold and Silver Fluorescent Nanomaterials as Emerging Probes for Toxic and Biological Sensors.” Finally, the chapter “NIR Light-Sensitive Gold Nanomaterials for Cancer Thermal and Chemotherapy Applications” summarizes the recent achievements in the use of plasmonic and NIR light-sensitive nanomaterials as agents for photothermal therapy (PTT).

The book is intended for a diverse readership since the organization of the chapters is intended to reach out to a large audience. The introduction chapters serve to establish the setting for a beginner or an early-stage researcher with interest in the field and who is starting to carry out research. The subsequent chapters of the book set out to establish key points: state-of-the-art synthetic techniques, characterization, emerging applications, theoretical aspects, and modeling. This enables an established researcher in the field who is actively engaged in some of these areas of research to get an update on the field. Thus, this book can readily reach out to graduate students, early-stage researchers, leading researchers, and/or groups active in this area of research.

Braga, Portugal

Francis Leonard Deepak

<http://www.springer.com/978-3-319-68052-1>

Metal Nanoparticles and Clusters

Advances in Synthesis, Properties and Applications

Deepak, F.L. (Ed.)

2018, XII, 426 p. 196 illus., 169 illus. in color.,

Hardcover

ISBN: 978-3-319-68052-1