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Nanomaterials for Luminescent Devices, Sensors, and Bio-imaging Applications

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Preface

Nanomaterials and nanotechnology will permeate all aspects of everyday life in the coming decades. Right from a multitude of memory and storage devices, displays, sensors and transducers, its impact will be phenomenal in the making of nanoscale energy harvesters and tiny implantable devices consisting of nanomotors, nanogears, nanosensors, etc., which can be installed inside the human body while being invisible to naked eyes and even to light microscopes. Exploration of novel nanomaterials with multifunctional properties essential for technological applications and fabrication of functional devices based on them will assume major share in the semiconductor electronics market.

This era is of quantum dots (QDs) and QD-based optical devices including LASERs and LEDs. The tuneable optical properties of these quantum systems make them ideal candidates for designing optical biosensors and bioimaging probes as well. However, their enormous production cost is a great challenge for the popularisation of the technology, and therefore, development of novel wet chemistry strategies for the fabrication of ultrafine nanosystems such as quantum dots, quantum cubes and quantum cages is the need of the hour.

Chapter 2 of this book provides a general review on the optical properties of nanomaterials, especially the quantum confined systems, and explains the scope of such materials in designing and fabrication of different devices like QD LEDs, QDs-based display devices, LASERS, optical sensors and finally will explain their potential in in vitro and in vivo bioimaging.

Tuneable optical band gap is the most appealing property of semiconductor nanoparticles. Especially when the nanoparticles are in the strong confinement regime, (1–5 nm range for most of the semiconductors), tailored band gap can be induced and band engineered nanosystems with core shell geometry can be exploited for their vast technological applications in designing QD LEDs, QD LASERS and display devices by incorporation of defect states that falls inside the band gap, which can create systems with tailor made emissions. Size, surface functionalization, shape, the level of doping and the dielectric environments are the deciding parameters which needs thorough tuning and monitoring. Chapter 2 focuses on the applications of semiconductor quantum structures for luminescent devices like LEDs and LASERs.

Metal nanoparticles possess excellent application potential in optical devices due to their surface plasmon resonance (SPR) and localised surface plasmon resonance (LSPR) properties. Noble metal nanoparticles like gold and silver are the regular choice for these. Plasmonic copper NPs emerge as an economic alternative to noble metals like gold and silver. The metal nanoparticles with enhanced LSPR properties can offer extensive direct application in surface enhanced Raman scattering and related applications like ultra-sensitive detection of molecules. Chapter 3 focuses on the plasmonic nanosystems and their applications in SERS.

Apart from the technological applications of nanomaterials in sensing and luminescent devices, their application in cellular and live bioimaging is also commendable. Search for novel materials and geometries with low toxicity and high luminescence are underway, and non-conventional materials like fluorescent carbon, metallic systems other than gold and silver, core shell semiconductor systems, dye tagged nanosystems, etc. are being developed and employed for biosensing and imaging applications. Chapter 4 discusses the applications of nanomaterials in biology and medicine, especially in biosensing and imaging.

Chapter 6 discusses the nonlinear optical properties of nanomaterials. Quite often, nanomaterials are found to show enhanced optical nonlinearities compared to their bulk counterparts. Metal nanoparticles are known to exhibit both saturable absorption and reverse saturable absorption depending on the wavelength of excitation, optical intensity and sample concentration. While saturable absorbers are essential for sub-nanosecond laser pulse generation, reverse saturable absorbers are potentially useful for protecting human eyes and sensitive detectors from hazardous levels of laser radiation. Semiconductor quantum dots also exhibit interesting nonlinear optical behaviour. The electronic origin of optical nonlinearities and some of the experimental techniques for measuring the nonlinearities are discussed in this chapter.

This book is a comprehensive version of an interdisciplinary research approach towards nanomaterials and its applications, which is the need of the hour. The authors are experts in the area of synthesis, optical characterization and biological application of metal and semiconductor nanoparticles. There exists a knowledge gap between the nanomaterial synthesis and its applications, especially in biological systems ranging from cellular models to whole living systems. While designing the applications, the safety of the environment needs to be ensured by the customisation of nanomaterials for grounding the toxicity to zero percentage. This book is aimed to bridge the gap apart from imparting the technical knowledge in the field to the readers. The authors wish that the book will serve as a knowledge platform for the researchers in the field of nanomaterials and its applications, whereby innovative thoughts will be stimulated to achieve the major ongoing goals of the century such as Internet of things (IoT).

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Contents

1 Introduction to the Optical Applications of Nanomaterials 1
Swapna S. Nair
1.1 Introduction 1
1.1.1 Optical Absorption, Scattering and Emission in Nanomaterials 1
1.1.2 Metal Nanoparticles and Surface Plasmon Resonance (SPR) 4
1.1.3 Semiconductor Nanoparticles for Display Devices 6
1.1.4 Semiconductor and Metallic Nanoparticles for Bioimaging 7
1.1.5 Non Linear Optical Properties of Materials 7
1.2 Conclusion 8
References 8

2 Quantum Wells, Wires and Dotes for Luminescent Device Applications 11
Manikanta Bayal, Neeli Chandran, Rajendra Pilankatta, and Swapna S. Nair
2.1 Introduction 11
2.2 An Overview to the p–n Junction Diode 13
2.2.1 Organic Material Devices 13
2.2.2 Inorganic Devices 16
2.3 Conclusion 22
References 22

3 Semiconductor Quantum Dots and Core Shell Systems for High Contrast Cellular/Bio Imaging 27
Manikanta Bayal, Neeli Chandran, Rajendra Pilankatta, and Swapna S. Nair
3.1 Introduction 27
3.2 Why QDs for Bioimaging? 28
3.3 Applications of Bioimaging 30
3.3.1 Cancer Cell Imaging 31

3.4 Conclusion 36
References 36

4 Tuning of Surface Plasmon Resonance (SPR) in Metallic Nanoparticles for Their Applications in SERS 39
Neeli Chandran, Manikanta Bayal, Rajendra Pilankatta, and Swapna S. Nair
4.1 Introduction 39
4.2 Metal Nanostructures 40
4.2.1 Principle of SPR 40
4.2.2 Localized Surface Plasmons Resonance 42
4.2.3 Metal Nanoparticles and the Theory of Mie 43
4.2.4 Tunability of SPR 44
4.2.5 Surface Enhanced Raman Scattering (SERS) 47
4.2.6 Applications of SERS 55
4.3 Conclusion 59
References 60

5 Advances in Plasmonic Biosensors and Their Futuristic Applications 67
Neeli Chandran, Manikanta Bayal, Rajendra Pilankatta, and Swapna S. Nair
5.1 Introduction 67
5.2 Biosensors 67
5.2.1 Mechanism of Sensing 68
5.2.2 Nanomaterials for Biosensing 69
5.3 Plasmonic Biosensors 69
5.3.1 Surface Plasmon Resonance (SPR) 69
5.3.2 Sensing Strategies 71
5.4 Application 76
5.4.1 Point of Care Diagnostic Devices (POCs) 77
5.4.2 Environmental Monitoring 78
5.4.3 Food Safety 78
5.4.4 Substrate Characterization 79
5.5 Conclusion 79
References 80

6 Nonlinear Optical Properties of Nanomaterials 83
Pranitha Sankar and Reji Philip
6.1 Introduction 83
6.2 The Nonlinear Susceptibility 84
6.3 Nonlinear Refraction and Absorption 85
6.4 Measurement of Second Order Nonlinearities 87
6.5 Measurement of Third Order Nonlinearities 87
6.6 Enhancement of Optical Nonlinearities in Nanomaterials 91
6.6.1 Maxwell-Garnett Geometry 91

6.6.2 Bruggeman Geometry 92
6.6.3 Layered Geometry 93
6.6.4 Fractal Structures 94
6.7 Optical Nonlinearity Measurements in Nanomaterials 94
6.7.1 Second Order Nonlinearities 95
6.7.2 Third Order Nonlinearities 97
6.7.3 Applications of Optical Nonlinearity in Nanoparticles 103
6.8 Conclusion 105
References 105

Conclusions 111