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Quantum Dot Optoelectronic Devices

Springer

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Preface

Nanoscale semiconductor devices have been extensively studied as next-generation alternatives to conventional devices owing to the achievable high integration and functionality. Semiconductor quantum dot (SQD) is a quasi-zero-dimensional structure composed of a small number of atoms. The carriers are three-dimensionally confined and the exciton Bohr radius is highly crowded, allowing quantum dots to exhibit unique and unusual physical, optical, and electronic properties that are absent in larger samples of a semiconductor material. Due to the quantum confinement effect, the energy level of quantum dots is similar to that of atoms with discontinuous energy level structure. The quantum size effect, quantum tunneling effect, Coulomb blocking effect, quantum interference effect, multi-body correlation, nonlinear optical effect, *etc*., demonstrated by SQDs are of immense significance to the study of basic optical and electrical properties of quantum-confined structures and novel optoelectronic devices [1, 2].

SQD-based novel optoelectronic devices hold promise for current and future information technology applications. Research on quantum dot optoelectronics has extensively evolved over the past three decades alongside the ever-growing technological demands, with huge advancements in solar cell energy conversion [3], laser [4], single photon source [5], photodetector [6], and LED [7]. The goal of this book is to present a comprehensive overview of the current state of the art in quantum dot-based optoelectronics covering a broad range of applications and related technologies.

The main body of the book comprises contributions that focus on the quantum dot and quantum dot-based optoelectronics, including quantum dot-based solar cells, single photon emitters, LEDs, photodetectors, nanolasers, memristor, quantum bit applications, quantum communication, and nonlinear optical applications. Specifically, Chap. 1 provides a comprehensive perspective on quantum dot-based thin film III–V solar cells. Unlike solar cells using III–V and Si materials, solution-processed colloidal quantum dots can overcome the Shockley–Queisser limit through multiple exciton generation. Chapter 2 offers a detailed introduction to chemically synthetized colloidal quantum dots for highly efficient solar cells. Quantum dots are widely considered as the best candidate for quantum emitters due to their advantages on the controllability, purity, brightness, indistinguishability, and coherence [5]. Chapter 3 presents a general review of the development of electrically and optically driven quantum emitters based on SQDs. While the quantum dots, as mentioned above, are obtained by epitaxy and chemical methods, Chap. 4 introduces gate-defined quantum dots obtained by etching and their applications on quantum computing via electrical pumping. In Chap. 5, a progress report on quantum communication with quantum dot-based devices is discussed. This chapter is particularly important for optoelectronic integration. Light-matter interaction is critical for optoelectronics based on quantum dots. In Chap. 6, a comprehensive introduction to cesium lead halide perovskite quantum dots is provided. Chapter 7 deals with recent developments of InAs/GaAs quantum dots and their applications to high-speed and ultrafast lasers. Chapter 8 introduces studies of bioresource derived graphene quantum dots and their applications on optoelectronic and biological applications. Chapter 9 presents influences of quantum confinement effect on the optical and electronic properties of quantum dots and their application for efficient memristor design and performance.

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