Preface

Excitonic and photonic processes are responsible for the operation of many optoelectronic devices including solar cells, electroluminescent devices such as LEDs and OLEDs, quantum well and quantum dot lasers, detectors, scintillators, carbon nanotube-based devices and hybrid nanostructures. This book presents state-of-the-art understanding of a selection of excitonic and photonic processes in useful materials from semiconductors to insulators to metal/insulator nanocomposites, both inorganic and organic. Excitonic properties are particularly important in organic photovoltaics and light-emitting devices, as also in questions of the ultimate resolution and efficiency of new-generation scintillators for medical diagnostics, border security, and nuclear nonproliferation. Novel photonic and optoelectronic applications benefit from new material combinations and structures as discussed in this volume. The contents of this volume are expected to benefit all researchers in the field of photovoltaic, electroluminescent devices, light-emitting devices, nanostructure lasers, noncrystalline semiconductors and scintillators, including senior undergraduate and postgraduate students and industry researchers.

Chapter 1 describes the optical properties and carrier recombination dynamics in $SrTiO_3$ bulk crystals. $SrTiO_3$ is regarded to be a key material in oxide electronics because of its unique electrical and optical properties as thoroughly covered in this chapter. In Chap. 2, starting from a historical trace of key developments in the science and engineering of photovoltaics, an overview of photovoltaics and allied photonic architectures is presented. A review of selected recent research results on the integration of wave-optic coupling nanostructures in silicon photovoltaics is given with an emphasis on the use of photonic crystal constructs. In Chap. 3, the relationship between the optical properties of Polyfluorene and the polymer conformation is discussed within the framework of the simple effective conjugation length model. Polyfluorene is well known as an efficient blue emitter for polymer-based light-emitting diodes and is very attractive from a physical point of view because randomly twisted, regularly twisted, or planar conformations can be realized in its solid state. The electronic structure of polyfluorene is discussed based on the electroabsorption (EA) spectra of the three conformations. Chapter 4 presents a comprehensive study of bulk heterojunction organic solar cells (OSCs), which are an attractive alternative to silicon-based solar cells due to low-cost solution fabrication processes. After a brief overview of basics of OSCs, the charge transport properties and different approaches including incorporating metal nanoparticles and surface plasmonic structures to enhance the absorption in OSCs are discussed. A comprehensive study on the degradation mechanisms of OSCs is also presented in this chapter. In Chap. 5 is presented the study of exciton-plasmon interaction in metal-semiconductor nanostructures, which offer a wide range of opportunities to control light-matter interactions and electromagnetic energy flows on nanometer length scales. The chapter emphasizes applications of nanocomposites in biophotonics and in sensing and switching applications. Strong exciton-surface plasmon coupling in metallic nanocomposites can lead to efficient transmission of quantum information between qubits for applications in quantum computing and communication.

In Chap. 6, following a phenomenological approach, the light yield of a scintillator is derived as a function of the rates of both radiative and nonradiative (quenching) excitonic processes to study the nonproportionality occurring in the yield of inorganic scintillators. The results are analyzed with a view to present a recipe for achieving an inorganic scintillator with optimal proportionality in its yield and hence optimal energy resolution. The theory presented here forms the fundamental background desired for understanding the nonproportionality observed in scintillators. Chapter 7 reviews the electronic properties of inorganic noncrystalline semiconductors using the effective mass approach in the real coordinate space. It is shown that many of the properties that can be studied through the effective mass approximation applied in the reciprocal lattice vector **k**-space in crystalline semiconductors can be studied in noncrystalline semiconductors in the real coordinate **r**-space. This includes the derivation of effective masses of charge carriers, mechanism of the double sign reversal leading to the anomalous Hall effect in hydrogenated amorphous silicon (a-Si:H), and the formation of excitons in noncrystalline semiconductors. In Chap. 8 are described the excitonic processes in organic semiconductors and their applications in organic photovoltaic and light-emitting devices. The mechanisms of excitonic absorption, diffusion, and dissociation of excitons at the donor–acceptor interface and their influences on the photovoltaic performance of bulk heterojunction organic solar cells are presented. Chapter 9 presents the important optical and electronic processes which influence the properties of semiconductor photonic devices used for light-emitting applications (lasers and LEDs) operating in a wide spectral range from visible to mid-infrared. The main carrier recombination mechanisms in semiconductor devices are discussed and experimental methodologies for measuring and analyzing these mechanisms are introduced. Finally, Chap. 10 discusses the electron-hole recombination processes that occur in the high excitation densities and strong radial gradients of particle tracks in scintillator detectors of radiation. In energy-resolving radiation detectors, intrinsic proportionality of light yield to gamma ray energy or electron energy is an important concern. This chapter gives special emphasis to understanding the physical basis for nonproportionality, while reviewing recent results on fundamental physics of nonlinear quenching, cooling and capture of hot electrons, co-evolving free-carrier and exciton populations, and diffusion in the dense and highly structured excitation landscape of electron tracks. The readers may find it useful to note that the theory presented in Chap. 6 and discussions in Chap. 10 are expected to provide complementary information on scintillators.

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