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Topic of Research: The Study of nano-plasmonics for photovoltaic cells

Findings

This thesis provides a comprehensive examination of photovoltaic (PV) technology, charting its evolution and highlighting its potential. It delves into the various generations of PV cells and the semiconductor physics that govern their operation. The role of plasmonics in PV cells is explored, with a particular focus on utilizing the Finite-Difference Time-Domain (FDTD) method for modeling these effects. The thesis reviews materials used in PV devices, detailing essential simulation tools and their features, including the semiconductor and electromagnetic wave equations that underpin these tools. The research evaluates emitter design parameters for silicon PV cells, emphasizing factors such as depth factor and peak concentration, and highlights the superior performance of the Erfc diffusion profile in enhancing quantum efficiencies and overall efficiency. It investigates the plasmonic effects of metal nanoparticles (Al, Ag, Au, and Cu) on silicon PV cells, demonstrating that optimizing nanoparticle size and arrangement can significantly enhance optical absorption, with gold and copper nanoparticles proving most effective. The inclusion of nanoparticles not only enhances absorption but also reduces surface reflectance, leading to a notable increase in current density. The thesis also explores the impact of exciton dissociation probability (CTS_{dis}) and recombination coefficient (k) on organic photovoltaic cells (OPVs), analyzing quantum efficiencies, photocurrent, and carrier recombination processes. It presents a method for extracting localized states parameters (LSP) for the PTB7-Th:PC71BM blend by fitting experimental dark and light J-V curves and carrier densities using the downhill simplex algorithm, and discusses the effects of compositional variations in the blend. Furthermore, the thesis focuses on enhancing broad-spectrum absorption in OPVs using bimetallic (Ag-Au) nanoparticles, achieving a substantial increase in short-circuit current density by optimizing the radius, interparticle distance, and period of the nanoparticles. It emphasizes the optimization of perovskite PV cells by balancing electrical and optical considerations, focusing on optimizing the thickness of each layer in the device stack to reduce reflection losses and enhance light absorption. Strategies to improve the transport properties of the transport layers (TLs) are provided, and the effect of energetic offsets at the interfaces between the electrodes and TLs is probed.