

Nanowire-Based Solar Cells: Bridging Physics and Photovoltaics

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Abstract

Nanowire-based solar cells represent an emerging photovoltaic technology that combines nanoscale physics with advanced energy-conversion concepts to improve solar-cell performance. Semiconductor nanowires possess high aspect ratios, tenable electronic properties, and strong light-matter interactions, making them attractive for next-generation photovoltaic devices. Their nanoscale dimensions can enhance optical absorption through light trapping while providing short pathways for charge-carrier transport and collection. Materials such as silicon, gallium arsenide, indium phosphide, and metal-oxide semiconductors have been investigated for nanowire photovoltaic applications. The geometry, diameter, length, crystal structure, surface properties, and doping of nanowires strongly influence important photovoltaic parameters, including current density, open-circuit voltage, fill factor, and power-conversion efficiency. Nanowire arrays can also enable flexible device architectures and reduce material consumption compared with conventional planar solar cells. From a physics perspective, quantum confinement, carrier generation and recombination, surface states, and nanoscale optical effects play important roles in determining device behaviour. Despite these advantages, challenges such as surface recombination, fabrication complexity, contact resistance, material stability, and large-scale manufacturing remain significant. Continued advances in nanowire synthesis, surface passivation, heterostructure design, and device engineering may help overcome these limitations. Overall, nanowire-based solar cells provide an important research platform for connecting fundamental nanoscale phenomena with practical photovoltaic technology and may contribute to the development of efficient, lightweight, and potentially low-material-consumption solar-energy systems.

Keywords: Nanowires, Solar Cells, Photovoltaics, Nanotechnology, Semiconductor Physics, Quantum Confinement, Light Trapping, Charge Carrier Transport, Solar Energy, Power Conversion Efficiency.