Graphene Quantum Dot Additives Promote Efficient Perovskite Solar Cells

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Solar photovoltaics are the fastest-growing renewable energy source, expected to account for over 16% of global electricity generation by 2050. Conventional silicon solar cells are more carbon-intensive than perovskite solar cells (PSCs), which are cost-effective and offer ease of fabrication. However, performance losses due to instability remain a critical limitation for PSC commercialization. In this study, graphene quantum dots (GQDs), nanoscale semiconductors (<10 nm) with high chemical stability and tunable band gaps (1-6 eV), are incorporated into the perovskite solar cell to enhance device performance. The research process included two parts, one comprising physics-based modeling of the device and the other including fabrication of GQD-integrated devices. Computational modeling revealed that using 10 nm of GQDs enhanced conduction band alignment with the electron transport layer (SnO2), and resulted in a 3.1% efficiency improvement and reduced charge recombination on the order of 10^18 cm^(-3). Experimental devices were fabricated using spin-coating and thermal annealing for each transport layer, with GQDs directly added to a FAPbI3 perovskite precursor solution at varying concentrations (0-1 wt%). Current-Voltage curves of the devices were evaluated using a xenon arc lamp under AM 1.5G sunlight, revealing the efficiency, open-circuit voltage, short-circuit current, and fill factor. Results showcased an averaged 0.98% efficiency improvement at 1 wt% of graphene quantum dots in FAPbI3, indicating the promise of GQDs as solution-processable enhancers. With the rising demand for cheap and efficient solar energy, this study provides important contributions for the commercial expansion of perovskite photovoltaics via additive engineering.

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