Photovoltaic Applications of Colloidal Quantum Dot-Reduced Graphene Oxide Hybrid Materials

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Abstract

The development of solution-processed photovoltaic devices depends strongly on an ongoing search for novel materials. In this respect, PbS quantum dots (QDs) have raised considerable interest due to their small band gap and high NIR absorption. At present, PbS-based solar cells reach power conversion efficiencies (PCE) exceeding 10%, and proper PbS surface treatment significantly improved the air-stability of the devices.[1] To ensure a high carrier mobility throughout the QD film, several ligand exchange strategies have been developed.[2] Another solution lies however with QD - graphene hybrid dispersions. These have an interesting potential due to the combination of tunable optical properties of QDs and improved transport properties throughout the QD solid by incorporation of the graphene. Dispersions of such hybrid materials have recently been developed.[3] Starting from PbS QDs[4] and reduced graphene oxide (rGO), we functionalized the latter with bifunctional mercaptosilane molecules. Subsequent QD anchoring via the exposed thiol head groups led to PbS-rGO with high stability in solution, well-controlled assembly and efficient charge transfer between the materials.[3]

Here, we will present the integration of the PbS-rGO hybrid material in a proof-of-principle QD-based photovoltaic cell. We will discuss the relevance of the different layers used throughout the solar cell stack: (i) the hole and electron blocking layers, (ii) the n- and p-doping PbS films prepared by different ligand exchange strategies, and (iii) the insertion of the hybrid material layer at various intermediate positions in the n- and p-doped layers to improve the overall PCE. The PbS and PbS-rGO films have been prepared by layer-by-layer spin coating onto ITO patterned substrates followed by solid ligand exchange according to established procedures.[2] In the case of the hybrid material, parameters such as the solvent and spin speed have been optimized to obtain homogeneous films with good control over the final film thickness. In the solar cells fabricated with PbS-rGO, we observed an enhancement of the open circuit voltage, yet the fill factor is somewhat smaller at present. Importantly, the solar cell PCE remained stable for at least one month, opening the way to practical applications.

References

[1] Lan, X. et al. Adv. Mater. **28** (2016) 299.
[2] Carey, G.H. et al. Chem Rev. **115** (2015) 12732.
[3] Martín-García, B. et al. J. Mater. Chem. C **3** (2015) 7088.
[4] Moreels, I. et al. ACS Nano **5** (2011) 2004.