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Graphene and other 2D-based materials for organic and hybrid solar cells

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Abstract:

In this talk, I am going to present our recent progress on employing solution processable graphene like materials (GRMs) and other 2D crystals in high efficient organic (OSCs) and perovskite solar cells (PeSCs). The utilization of solution processable 2D crystals can simultaneously or individually optimize the photovoltaic parameters of an OSC by taking advantage of their high charge mobility to provide additional percolated pathways for efficient exciton dissociation and charge transport in the photoactive layer,[1-7] by adopting work-function (WF) tuned interfacial layers,[8-11] capable of providing a perfect energy match for either hole or electron transport, and by fabricating flexible transparent conducive electrodes (TCEs) with tailored optoelectronic properties.[12-13]

In particular, reduced graphene oxide (rGO) micromeshes were used as the TCE in flexible OSCs, achieving a power conversion efficiency (PCE) of 3.05%[12]. A fast, non-destructive and r2r compatible photochemical method for the fabrication of chlorinated graphene oxide (GO-Cl) films with an increased WF of 5.23 eV[8] and a facile process for lithium alkali metal functionalized graphene oxide with reduced WF, from 4.9 eV to 4.3 Ev[9], were presented. The utilization of these graphene-based HT and ET layers in PTB7:$PC_{71}BM$ active layer devices, led to ~19% PCE compared to the reference graphene free devices, resulting in the highest reported PCE for graphene-based buffer layer OSCs of 9.14%.[10]

With respect to the photoactive layer, a photochemical route for the facile synthesis of tunable bandgap graphene-based derivatives, through controlled laser irradiation in liquid phase was demonstrated. Their incorporation as the electron acceptor material led to the highest reported PCE (2.41%) for graphene-based electron acceptors.[3] In addition, functionalized LPE graphene nanoflakes (GNFs) [1] with controlled lateral size and graphene-inorganic nanocrystals hybrid materials (rGO-antimony sulphide, rGO-Sb_2S_3)[2] were demonstrated as electron cascade materials. Extending the research on other 2D materials, situ laser induced anchoring of noble metal nanoparticles onto the surface area of thin WS_2 nanosheets took place, leading to a PCE enhancement of ~13%.[4] Finally, WSe_2 nanoflakes with different lateral sizes were utilized as the third components in high efficiency ternary OSCs, resulting in a PCE by 16%.

The utilization of 2D materials in PeSCs was also studied. In particular, GO-Li has been inserted between the perovskite sensitizer and m-TiO_2 layer, improving the electron injection by remarkably increasing the J_{SC} (+10.5%) and the stability.[13] In another study, we presented a throughout analysis on the incorporation of reduced graphene oxide (rGO) in PeSCs, elucidating its main role in improving the electron transport when mixed with the m-TiO_2.[14] By mixing rGO within the m-TiO_2 matrix, high efficient PeSC with PCE of 19.54% were recently realized.

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