Séminaire exceptionnel

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Novel Non-radiative Exciton Harvesting Scheme Yields a 15% Efficiency Improvement in High-Efficiency III–V Solar Cells

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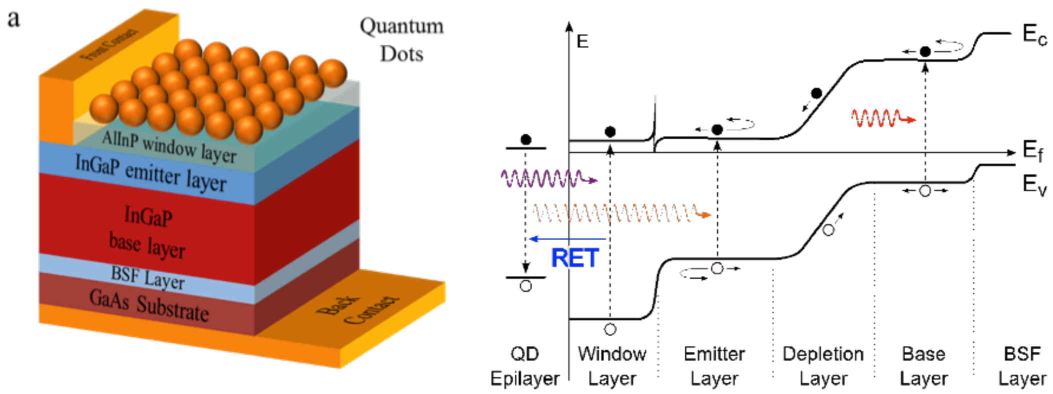
The spectral mismatch between the response of a solar cell and the solar spectrum represents the largest loss contributing factor in all photovoltaic technologies. While sub-bandgap photons cannot be absorbed by the semiconducting material, the excess energy of high energy photons is lost via non radiative relaxation of the carriers in the form of heat. One way to mitigate this limitation is to use luminescence down-shifting (LDS), where high energy photons are absorbed and reemitted at a lower energy by an emitter.

High efficiency III-V solar cells typically incorporate an indirect wide band-gap semiconductor as a passivation layer to limit surface recombination at higher photon energies. However, the poor extraction efficiency of the carriers photogenerated in this window layer limits the performance of the devices in the high energy region of the spectrum. To address this problem, in this work, we deposit an epilayer of colloidal CdS_xSe_{1-x}/ZnS core/shell quantum dots (QDs) onto InGaP solar cells (fig. 1a), emitting below the AlInP band-gap. In this configuration, while the QDs act as a standard LDS layer, excitons are also funneled from the AlInP window layer to the QD epilayer using near-field Resonance Energy Transfer (RET). The transferred excitons can then radiatively recombine in the QDs and the resulting photons can be transmitted through the window layer to generate extractable carriers in the p-n junction. The overall performance of the solar cells is found to be significantly improved after hybridization, with a 15% relative increase in short-circuit current. The Internal Quantum Efficiency (IQE) of the solar cells after hybridization was strongly enhanced in the UV spectral region, exhibiting an almost two fold increase at 325nm (fig. 1b). RET between the window layer and the QDs epilayer was demonstrated using excitation energy dependent rise-time measurements of the QD luminescence. The contribution of RET to the 1-sun photocurrent of the hybridized cell is estimated to be about 4%, while the direct luminescent down-shifting amounted to 5% of the overall photo-current.



(a) Schematic representation of a hybrid InGaP solar cell; (b) Band diagram of the RET enabled luminescent down-shifting scheme.

Reference: M. Brossard et al., Advanced Optical Materials, DOI: 10.1002/adom.201400356 (2014)

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