

Heterojunction Photovoltaics Using Printed Colloidal Quantum Dots as the Photosensitive Layer

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Colloidal quantum dot (QD) systems offer distinct optical and electronic properties that are not easily attained by other nanostructured semiconductors, such as highly saturated emission in QD light-emitting-diodes, access to infrared radiation in QD photodetectors, and the prospect of optically optimized solar cell structures [1]. The prevailing deposition method for colloidal QD systems is spin-casting, which introduces limitations such as solvent incompatibility with underlying films and the inability to pattern side-by-side pixels for multispectral photodetector arrays. In the present work we employ a non-destructive microcontact printing method [2], which allows for deposition of a thin quantum dot film onto a wide-band-gap organic hole transport layer, N,N'-Bis(3-methylphenyl)-N,N'-bis-(phenyl)-9,9-spiro-bifluorene (spiro-TPD), thus producing an inorganic/organic heterojunction that serves to enhance charge separation in the device. The top and bottom contacts are provided by ITO electrodes, allowing for near-transparency (Figure 1).

Restrictions imposed by transport losses in the QD film are found to limit charge generation. Measurements of the external quantum efficiency (EQE) and internal quantum efficiency (IQE) as a function of QD film thickness, plotted in Figure 2, reveal a marked dependence on thickness. The IQE is determined by dividing the EQE by the absorption of the QD film, all of which are measured at the first absorption peak of the QD film ($\lambda = 590$ nm). Following excitation and exciton diffusion to an interface, dissociation of the exciton produces free carriers that must diffuse to opposite electrodes in order to produce a photocurrent. A model that accounts for both exciton and charge diffusion reproduces the general thickness trend, assuming an exciton diffusion length $L_{\text{ex}} = 43$ nm, an electron diffusion length $L_{\text{el}} = 61$ nm, and near-zero contribution from the first two QD monolayers. Further development will require reducing exciton and charge transport losses in order to permit efficient charge-generation from thicker QD films with improved absorption.

REFERENCES

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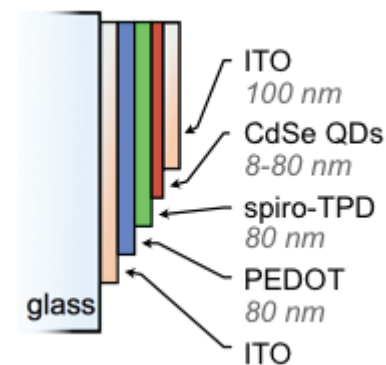


FIGURE 1: The QD heterojunction device architecture used in this work accommodates QD film thicknesses varying from 8 to 80 nm.

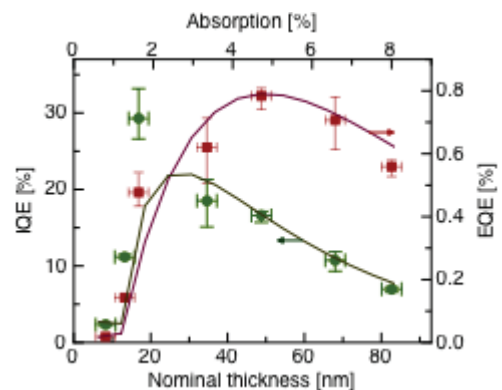


FIGURE 2: External quantum efficiency (EQE) (red squares) and internal quantum efficiency (IQE) (green circles) at $\lambda = 590$ nm versus nominal QD film thickness and device absorption at $\lambda = 590$ nm. An analytical model for the EQE (red line) and IQE (green line) reproduces the general trend with thickness. Nominal thicknesses are calculated assuming an absorption coefficient of 104 cm^{-1} at $\lambda = 590$ nm.