Lead Chalcogenide Solar Cells Inspired by Multiple Exciton Generation

NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

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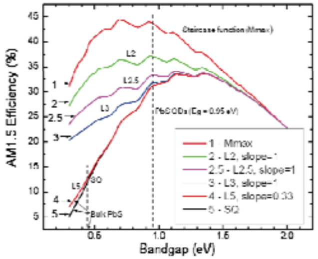
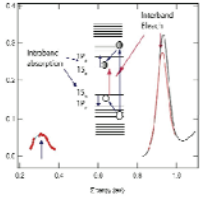
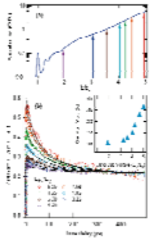
MEG Efficiency Implications



Transient absorption

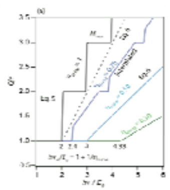
Following photoexcitation across the NC bandgap, the occupation of the |1Se,1Sh> state results in a partial bleach of absorption of a probe pulse due to state-filling as well as a small red-shift due to a Stark effect, leading to a photoinduced bleach.





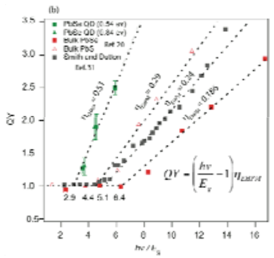
Fast component appears with increasing amplitude for increasing photon energy above an energy threshold. This fast component has the timescale of biexciton.

MEG yield measurements

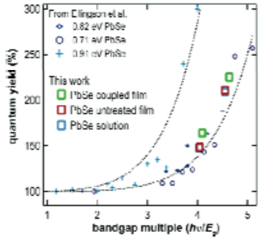


(a) Plots of QY Eq. where the slope is the EHPM efficiency.

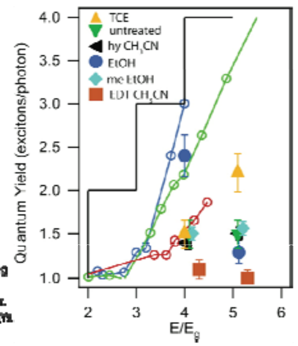
(b) QY data plotted vs. $h\nu/E_g$ with only one adjustable parameter, η_{EHPM}

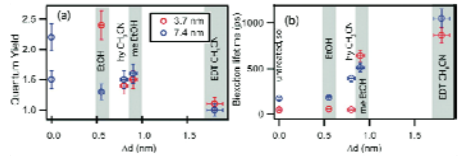


MEG measured spectroscopically in coupled NC films



First study of MEG in coupled films. PbSe QD films were spincoated and soaked in 1 M hydrazine following Talapin and Murray Science 2005. Quantum yield of exciton generation for PbSe QD films and QD solutions. The dotted lines are guides to the eye. Note that the QYs for QDs in solution and untreated films are identical.

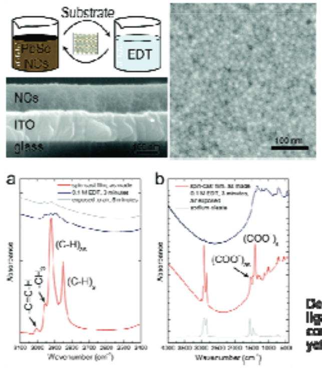


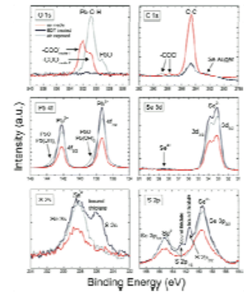


Correlation of QY (a) and biexciton lifetime (b) with the change in average inter-NC distance for the 3.7 nm NC films (red circles) and 7.4 nm NC films (blue circles).

QYs as determined in this work (solid symbols) overlaid with past QYs of PbSe NCs dispersed in solution from NREL. Blue open circles correspond to results for 4.0 nm NCs in TCE and the red open circles are average results for 4.7 and 5.7 nm NCs in TCE. In our original report some variation on either sample preparation or NC size was observed. The green open circles are reported from LANL. The solid black line represents the maximum possible MEG efficiency; achieving n excitons at n times the band gap energy.

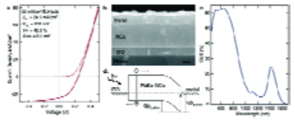
Layer by layer dipcoating with 1,2-ethanedithiol



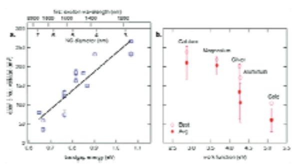


Developed sequential dipcoating procedure to remove oleate ligands layer by layer with EDT. Films are smooth, show complete loss of oleic acid and have bound thiolate ligands yet retain quantum confinement.

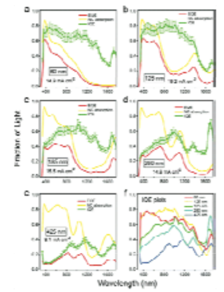
Schottky junction solar cells from PbSe QDs



Using the LbL dipcoating technique, solar cells can be made with PbSe and PbS QDs on ITO substrates. A metal is evaporated on the top which forms a Schottky junction to the QD film

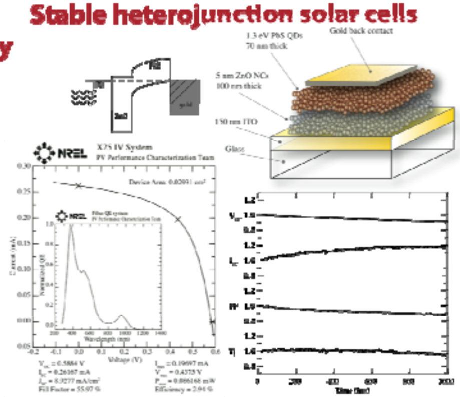


Optical model for the internal quantum efficiency



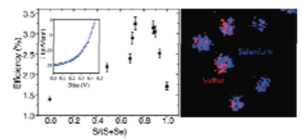
By measuring the optical constants (n and k) for films with ellipsometry, an optical model is built which allows for the internal quantum efficiency to be measured for a series of films. The thicker films show a "dead" region near the incident side due to band bending only at the back contact and not the front.

Stable heterojunction solar cells



The device polarity can also be switched (where holes now get collected at the back electrode). This removes the "dead" region. Using small PbS (1.3 eV) a device with 2.94% NREL certified efficiency was obtained. The device is also relatively stable in air. We show a plot of the PV parameters with 1000 hr degradation study in air. The efficiency retains 95% of the starting value.

Alloyed PbS_xSe_{1-x} Devices



Schottky cells made from PbS show a higher Voc than cells made from PbSe, but PbSe yields a larger Jsc. We have designed a synthesis scheme for the development of ternary PbSSe NCs. EDAX is used to verify the presence of S and Se in each NC. Devices made from a series of the alloys show composition regions with improved efficiency.