Influence of shell thickness on the charge transfer dynamics from photoexcited PbS/CdS quantum dots to metal oxides

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Outlines

- Application of QDs
- Photovoltaics based on PbS QDs
- Current Results
- Current Project

Solar cells

- The "perfect" single-layer solar cell should have a bandgap of 1.13 eV (33.7% Eff)
- For a two layer cell, one layer should be tuned to 1.64 eV and the other at 0.94 eV, with a theoretical performance of 44%.
- A three-layer cell should be tuned to 1.83, 1.16 and 0.71 eV, with an efficiency of 48%.... 64%

Application of QDs

- QDs have been employed to:
- Photodetectors, light emitting technologies and excitonic (third generation- multi-layer ("tandem") solar cells.

  » Easy to fabricate and low cost

  IR emitting PbS QDs is promising

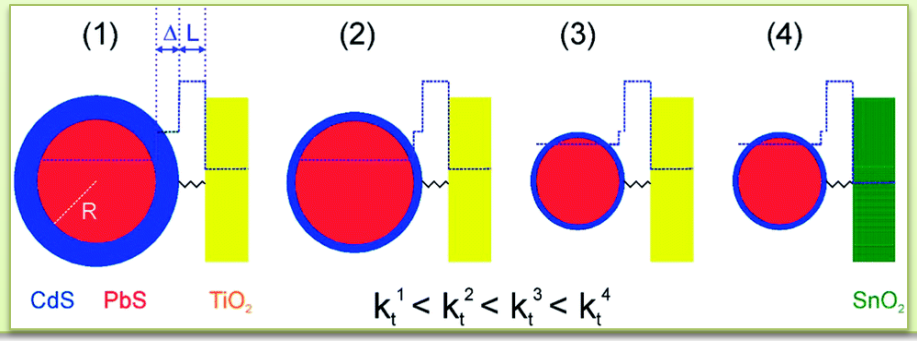
Photovoltaics based on PbS QDs

- N-type metal oxide solar cells sensitized by infrared absorbing PbS quantum dots (QDs) represent a promising alternative to traditional photovoltaic devices.
- Problem: PbS QDs capped with pure organic ligand shells suffer from surface oxidation that affects the long term stability of the cells

Photovoltaics based on PbS QDs

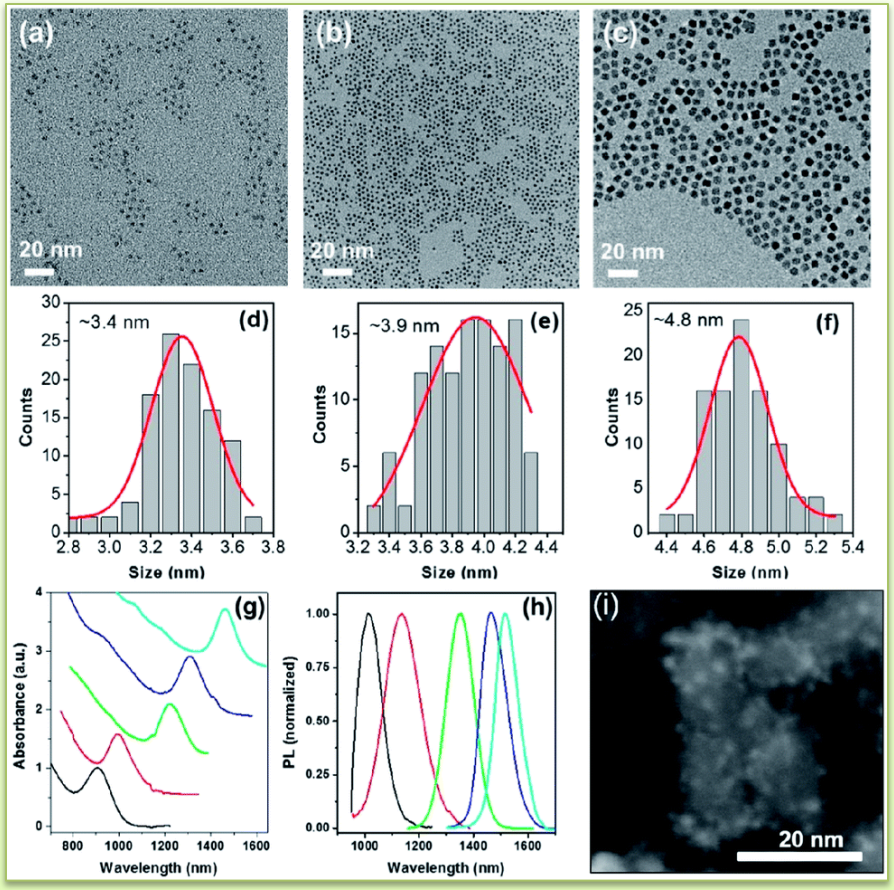
- Solution: Application of a passivating CdS shell
  - increased long term stability of PbS QDs
  - Problem: Negatively affect photoinduced charge transfer from the QD to the oxide and the resulting photoconversion efficiency.
  - Need detail study on electron transfer rate from QDs to metal oxides

Current Results

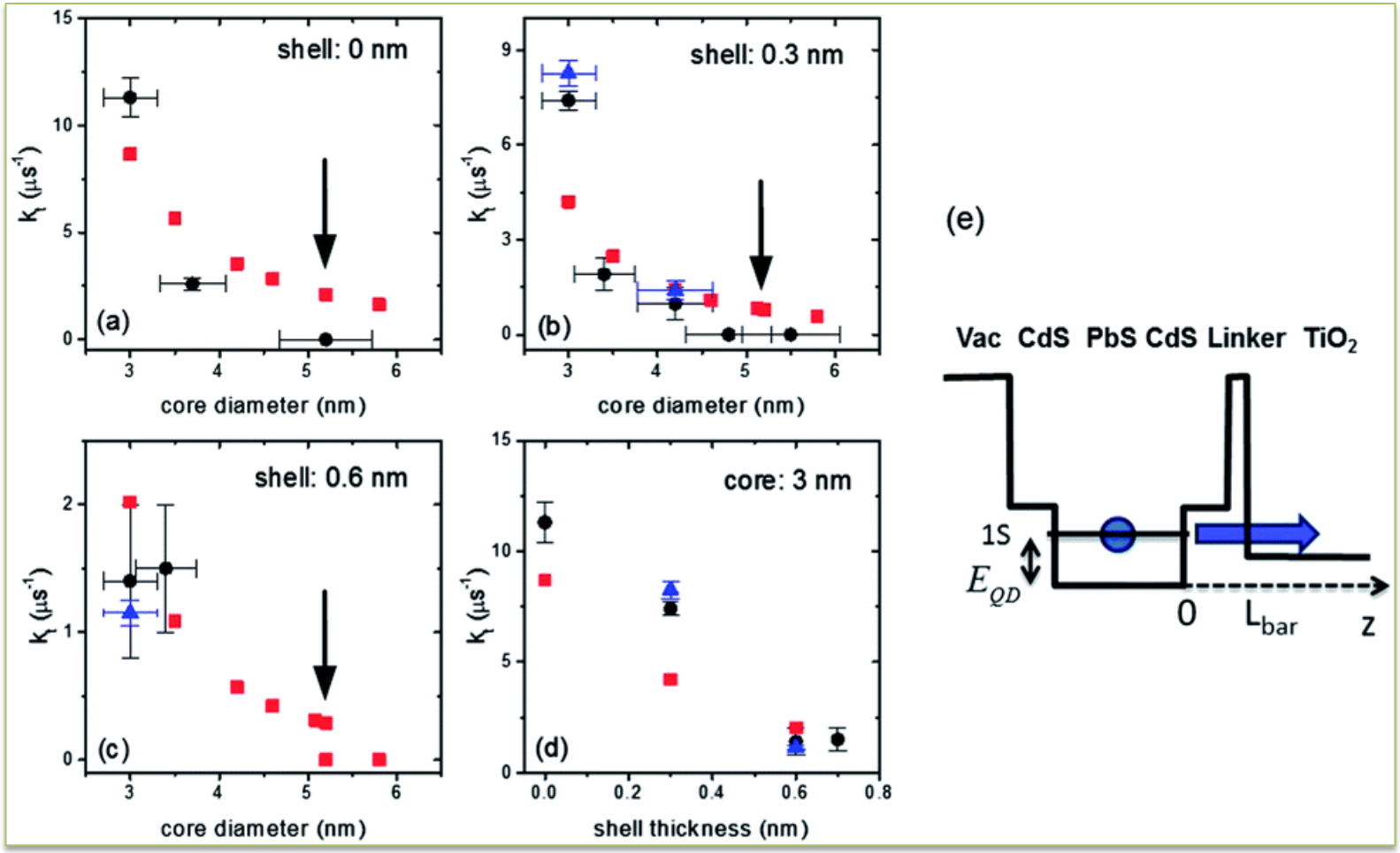
- The different electron affinity of the oxides (SiO2, TiO2 and SnO2), the core size and the shell thickness tune the electron injection rate by determining the width and height of the energy barrier for tunneling from the core to the oxide.
- 

Ref. H. G. Zhao, H. Y. Liang, B. A. Gonfa, M. Chaker, T. Ozaki, P. Tijssen, F. Vidal and D. Ma,

Nanoscale, **6**, 215–225, 2014.

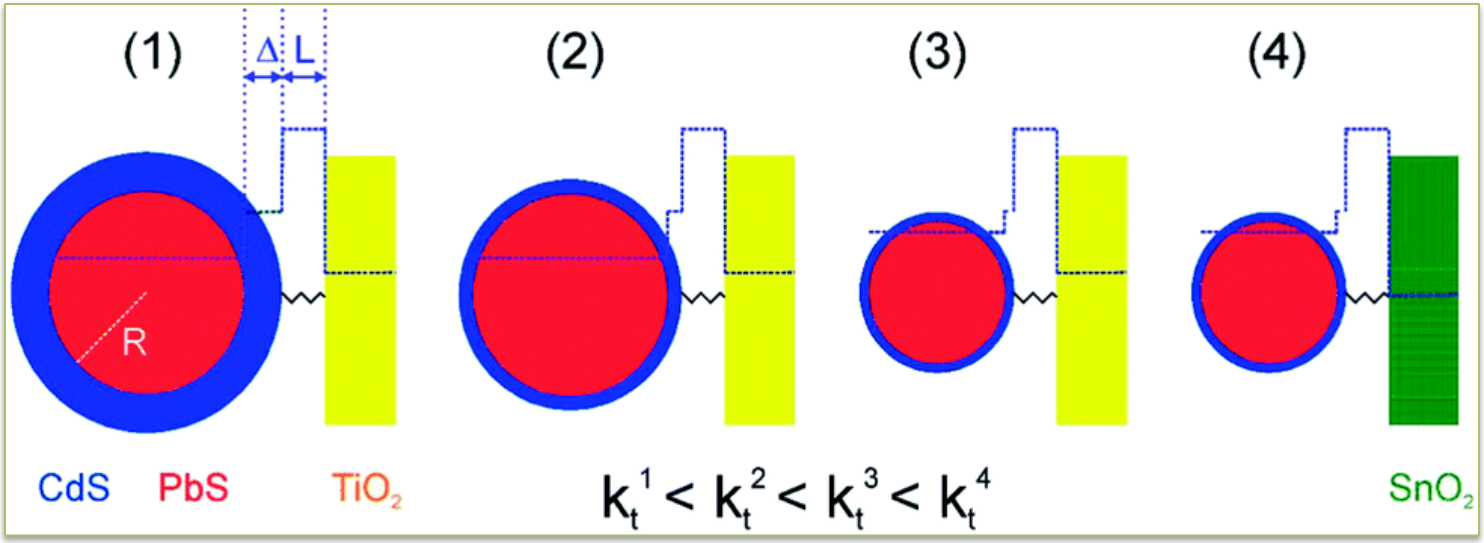
- 

Tunneling rate k_t as a function of core diameter for three different shell thickness



Results..

Threshold size for electron transfer for pure PbS QD is 5.2 ± 0.3 nm. The threshold size reduces to 4.8 ± 0.3 nm in a core/shell system with 0.3 nm thick shell.



Current Project

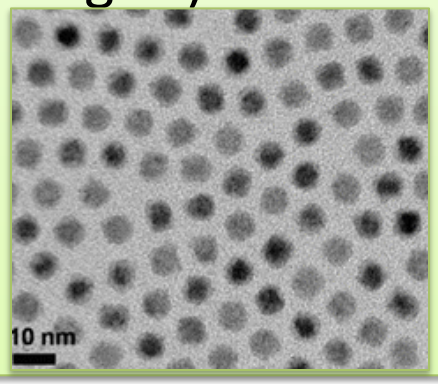
- Charge recombination is a detrimental process that reduces the efficiency of a solar device as photons are lost by charge recombination.
- A compromise is needed between charge separation and charge recombination and this can be achieved by control of the QD shell thickness for optimized functionality of devices based on QD core/shell structures.

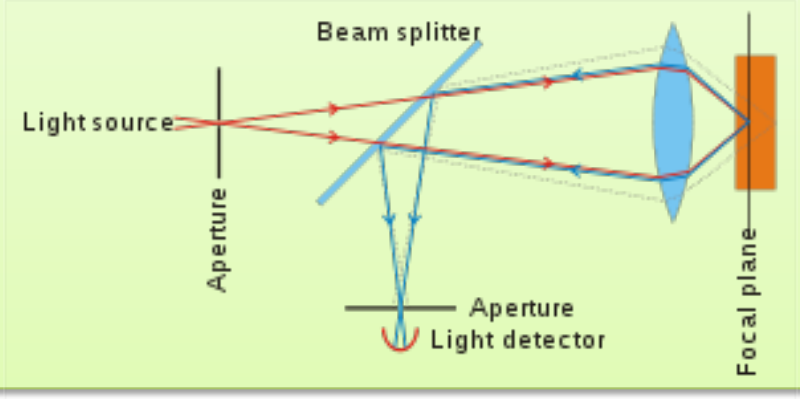
Current VFP project

- Cotlet's group at BNL has demonstrated the ability to perform single particle photoluminescence (PL) studies with NIR emitting PbS/CdS QDs.
- We would like to investigate the effect of shell thickness on the charge transfer between PbS/CdS QDs and metal oxides

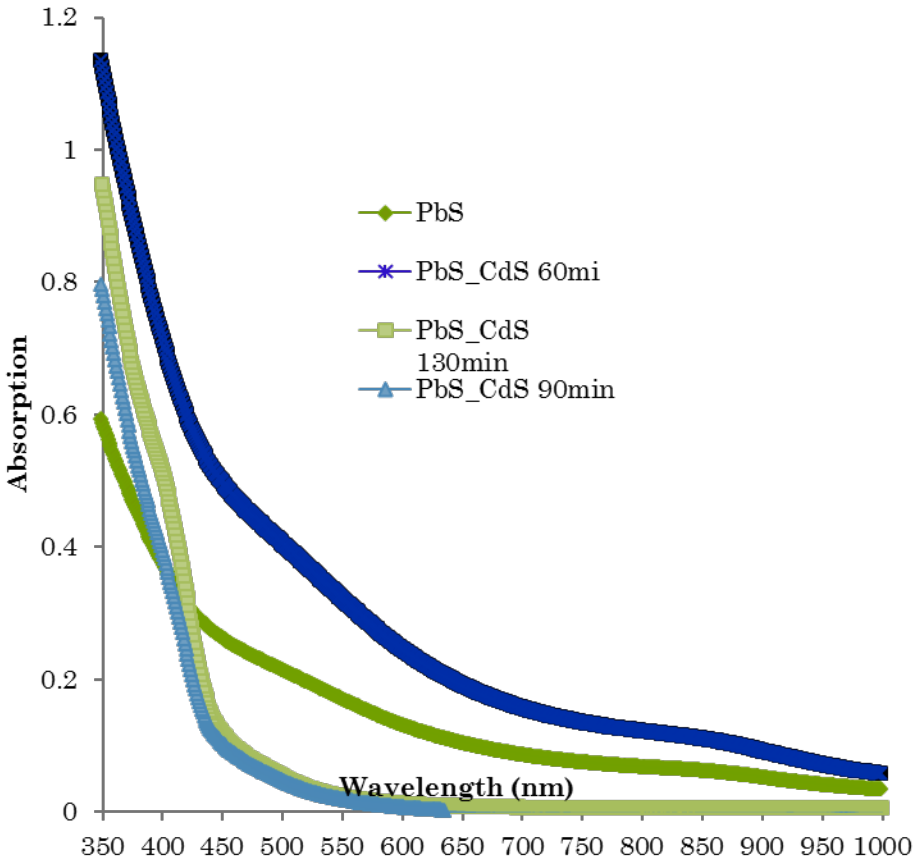
Objectives

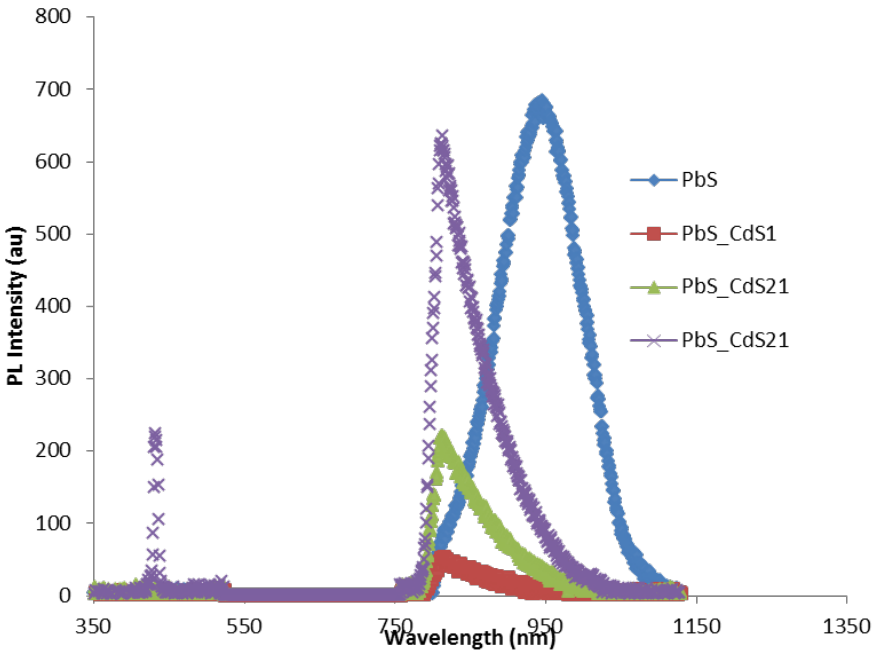
- Synthesis and characterization
- Study as a function of shell thickness
  - Problems PbS/CdS cation exchange
- Single molecule confocal microscopy (uses a spatial pinhole at confocal plane to eliminate out of plane light.)





Synthesized QD structures: Absorbance and Emission Spectra at CFN





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