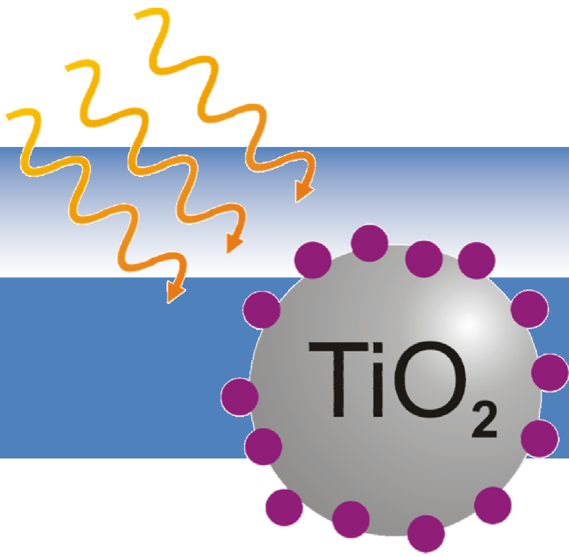
Nanoparticle-Sensitized Solar Cells



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MSE 395

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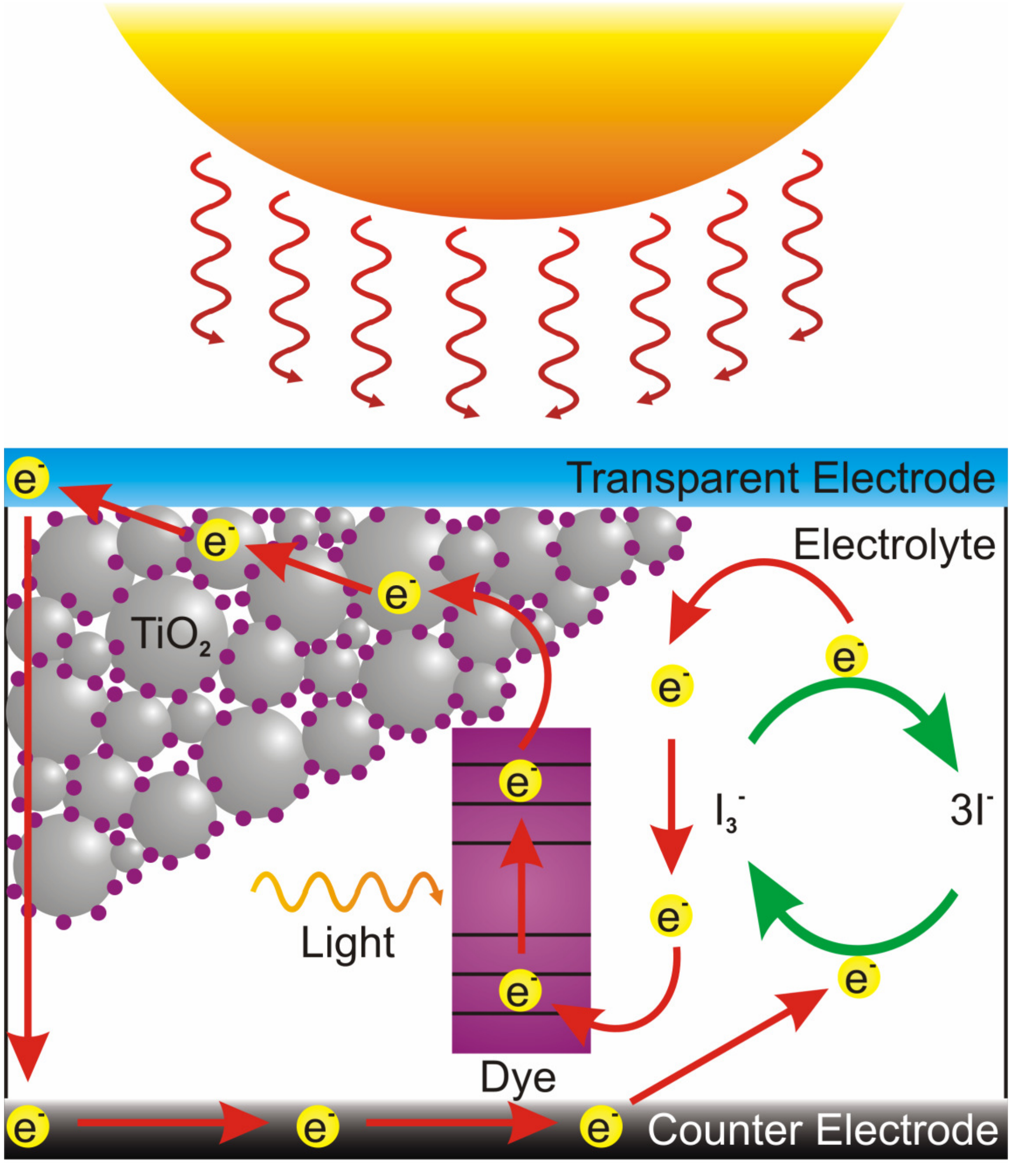
Dye-Sensitized Solar Cell

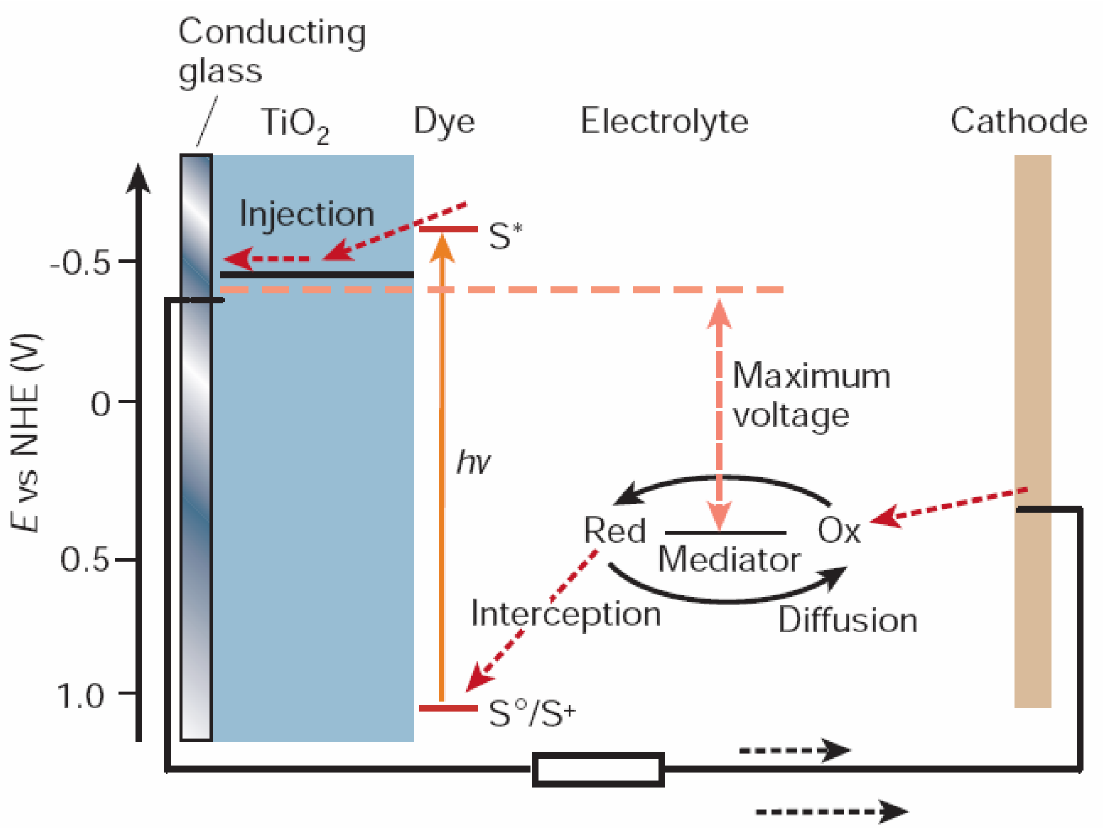
- Cost-effective alternative to silicon
- Lower conversion efficiency (11%) compared to world record (~40%)
- Five Basic Steps
  - Light Absorption
  - Electron Transfer
  - Electrical Conduction
  - Redox Cycle
  - Replenish Dye

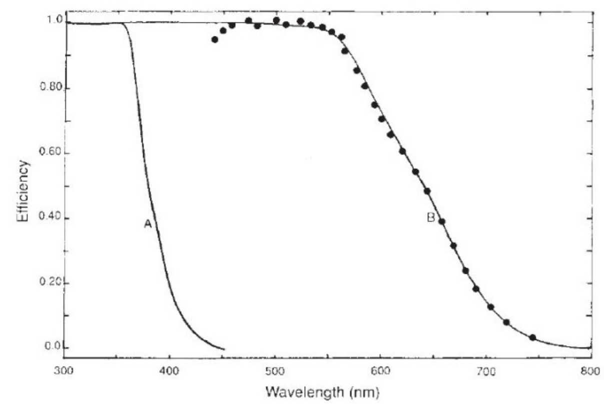


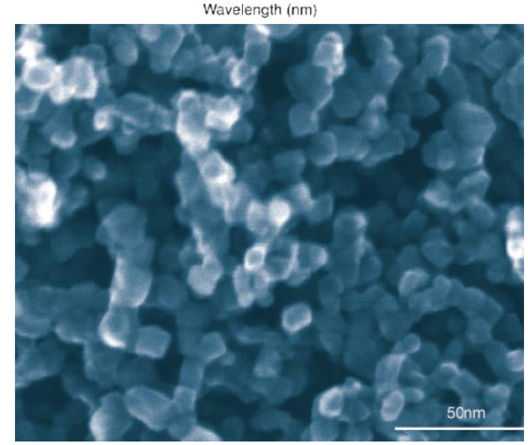
http://en.wikipedia.org/wiki/Solar_cell#Multiple_junction_solar_cells
Grätzel, M. *Nature.* 2001, 414, 338.

Dye-Sensitized Solar Cell - Details

- Injection of electrons from low bandgap to high bandgap
- Nanostructured TiO_2 increases surface area
- Ruthenium dye increases absorption of device

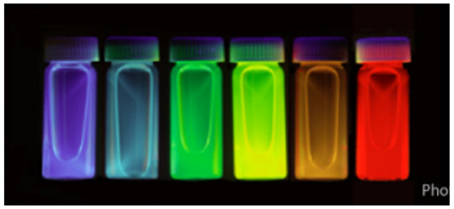


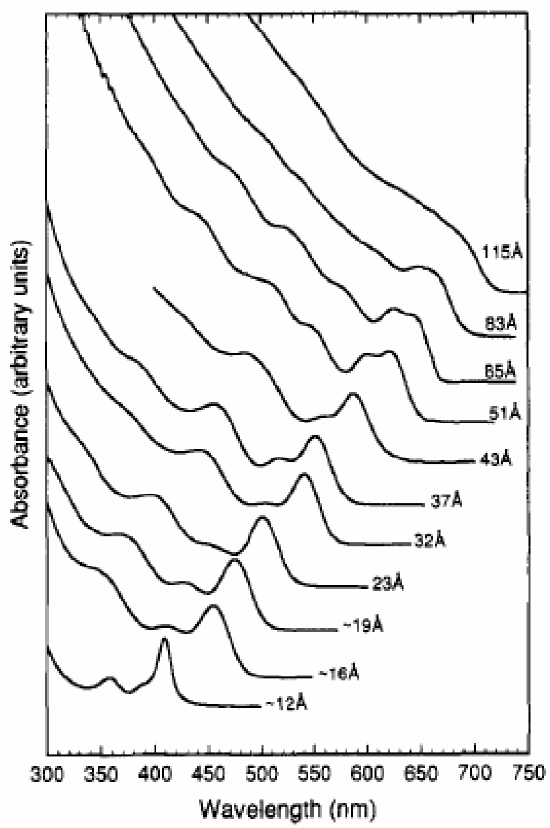




Grätzel, M. *Nature.* 2001, 414, 338.
Grätzel, M., O'Regan, B. *Nature* 1991, 353, 737.

Room for Improvement





Grätzel Cell:

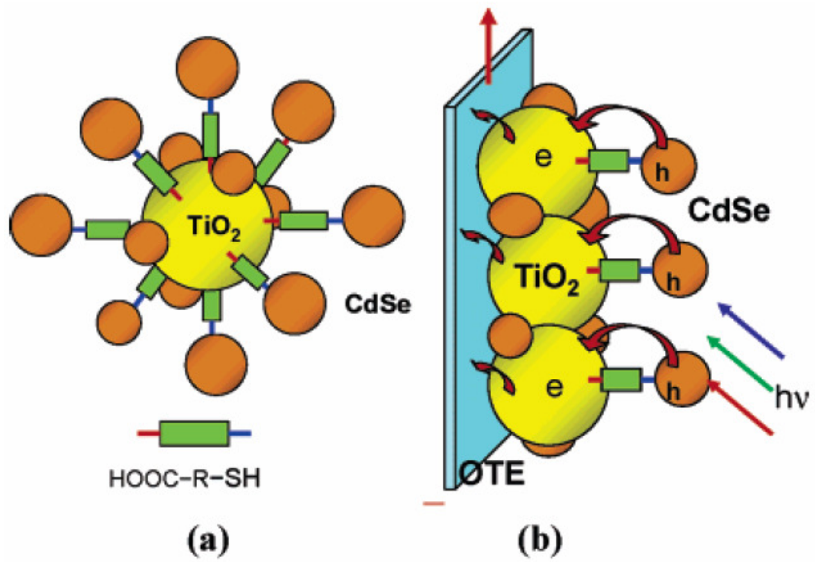
- Ruthenium dye has a single absorption energy
- Dye has low absorption coefficient
- Grain boundaries in TiO_2 can impede conduction
- Redox couple consists of harsh materials

Nanoparticle Sensitized Cell:

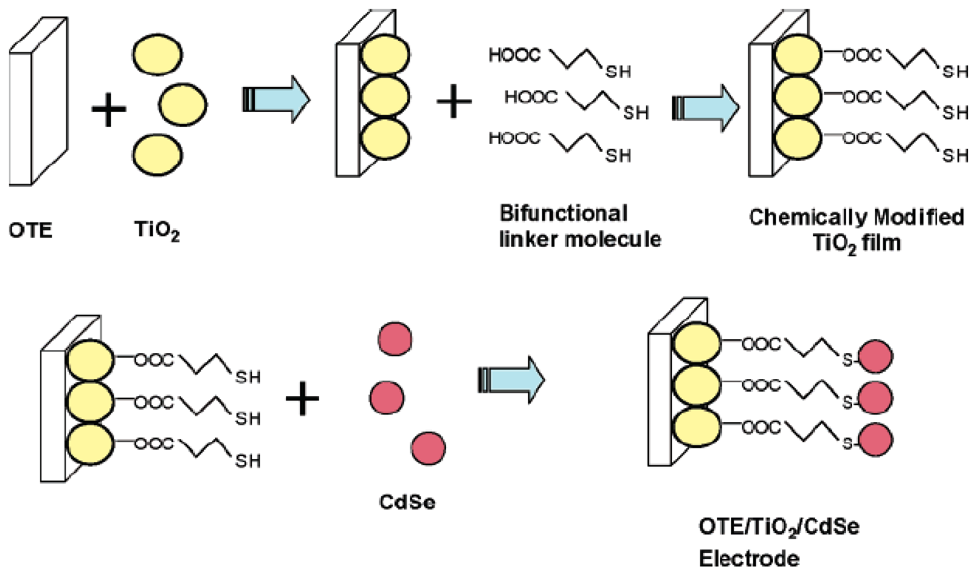
- Semiconductor quantum dots have tunable size-dependent absorption
- Quantum dots have large absorption coefficient
- Possibility for multiple exciton generation (MEG)

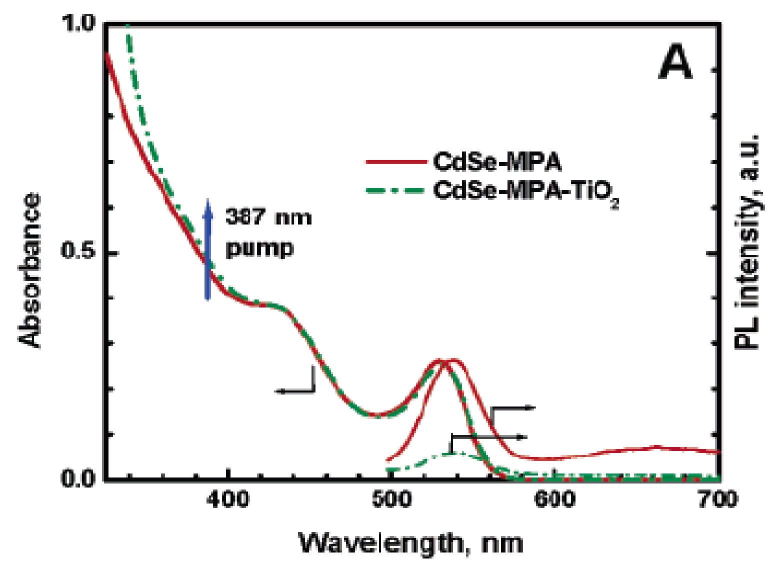
Ozin, G. A. *Nanochemistry* 2005, 268
http://nanocluster.mit.edu/wiki/images/f/ff/Vials3.jpg
Bawendi M. G. et al. *J. Am. Chem. Soc.* 1993, 115, 8706

Quantum Dot Sensitized Cell



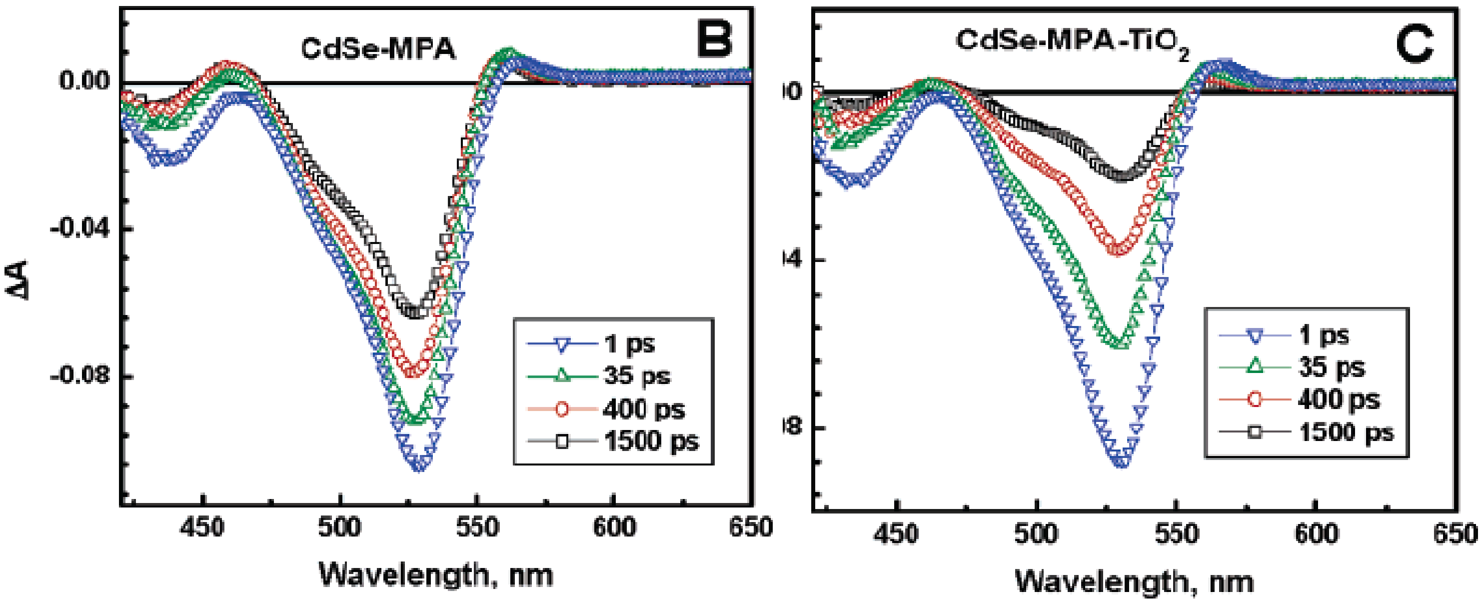
- Conjugate CdSe Quantum Dots (~3nm) to TiO_2 nanoparticles (40-50nm)
- Determine extent of electron transfer from excited quantum dots (E_g=2.25 eV) to TiO_2 (E_g=3.44 eV)

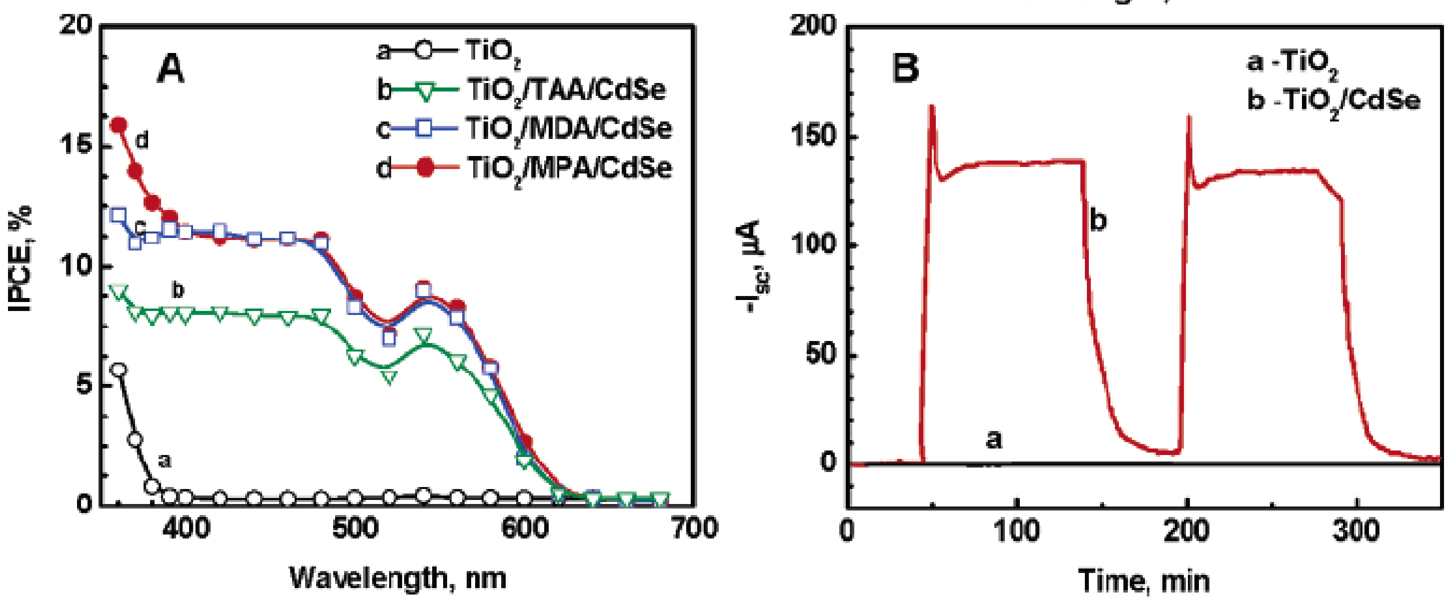




Kamat, P.V. et al. *J. Am. Chem. Soc.* 2006, 128, 2385.

Probing Electron Dynamics





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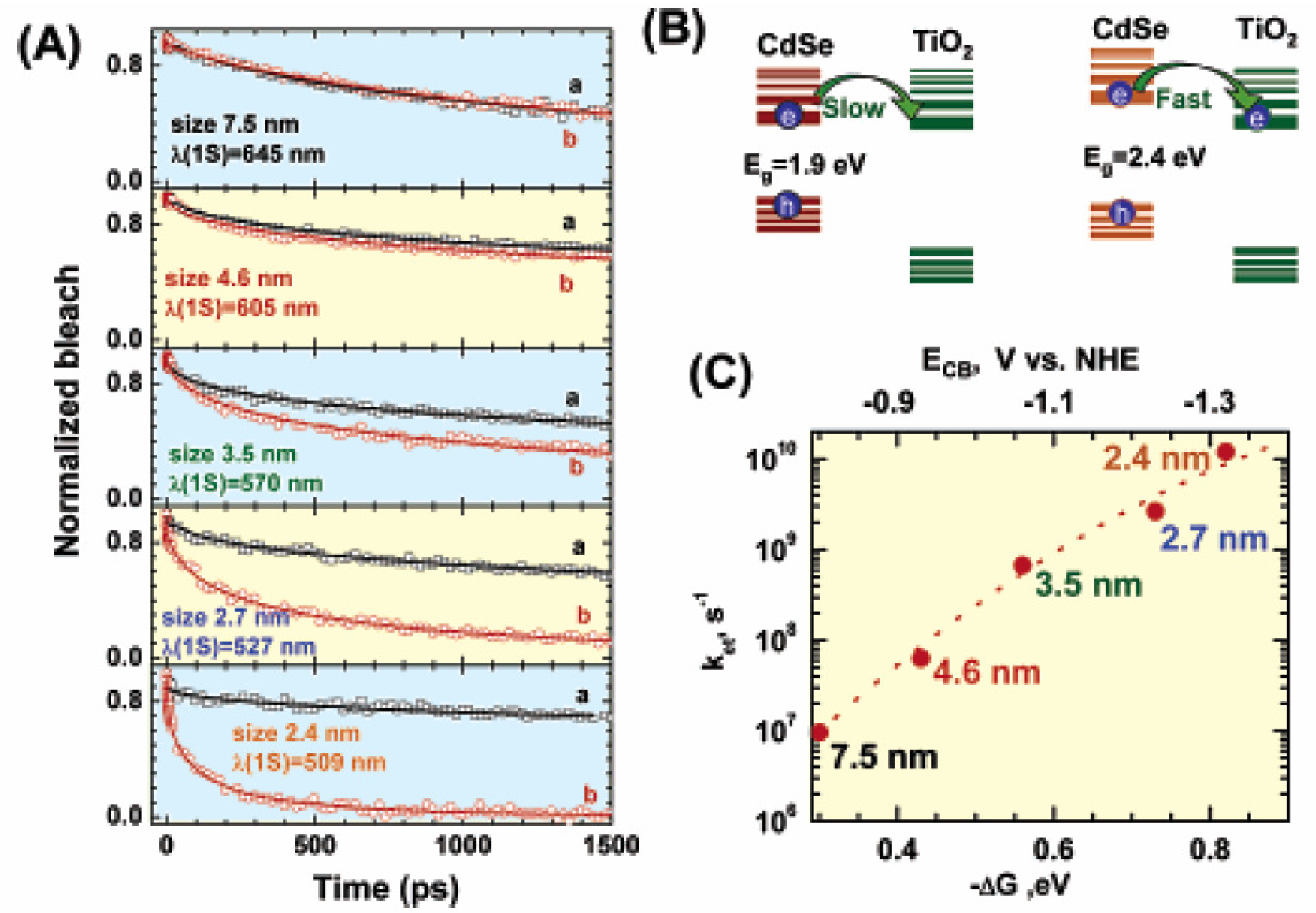
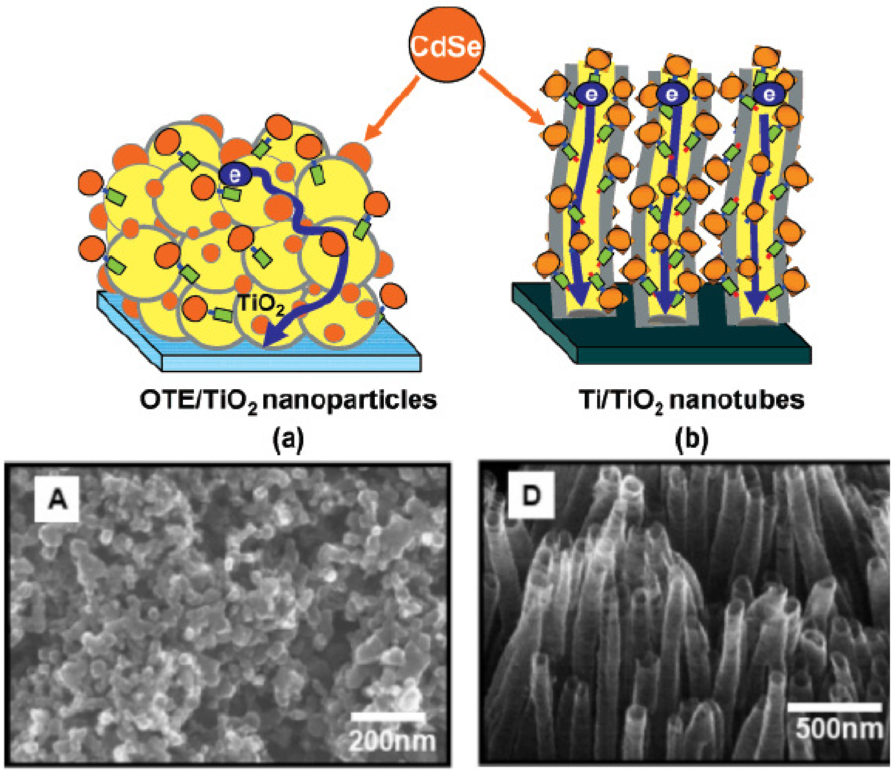
Kamat, P.V. et al. *J. Am. Chem. Soc.* 2006, 128, 2385.

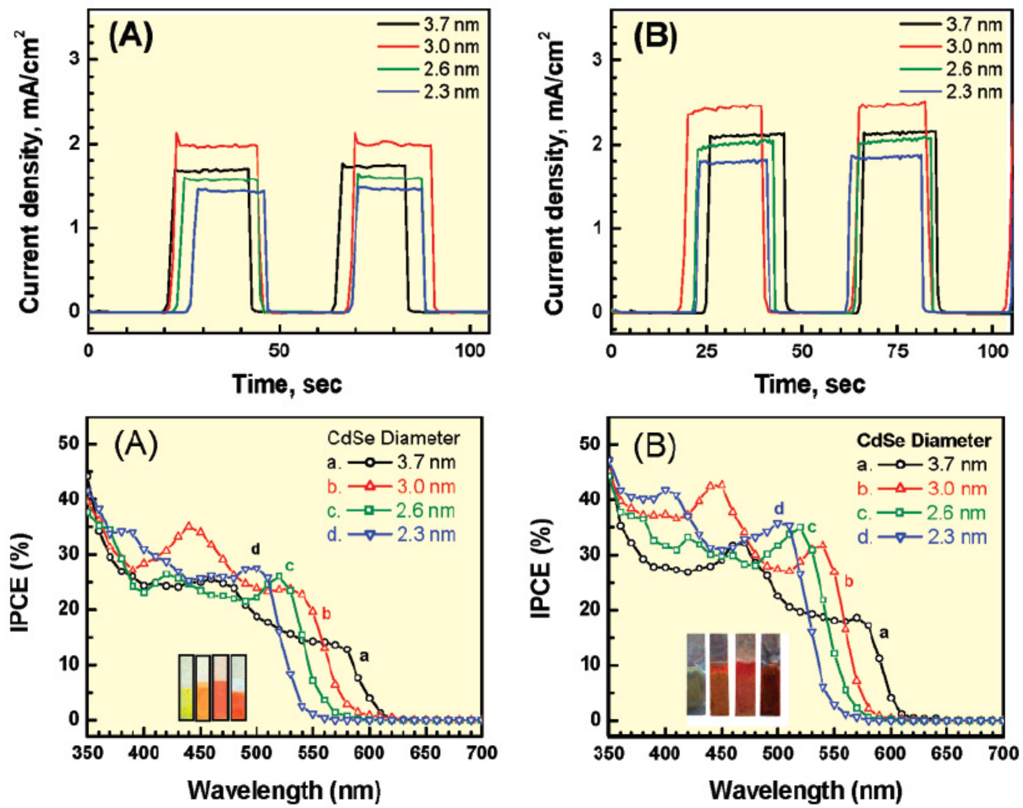
Size Dependent Electron Transfer



Kamat, P.V. et al. *J. Am. Chem. Soc.* 2007, 129, 4136.

Improved Performance





- Changes in TiO_2 morphology affects electrical conduction
- Optimum quantum dot size balances high electron transfer rate with broad absorption in visible spectrum
- IPCE value of 45% and power-conversion efficiency of 1%

Kamat, P.V. et al. *J. Am. Chem. Soc.* 2008, 130, 4007.

Conclusions

- Significant room for improvement in quantum dot sensitized systems
- Understanding of nanoparticle sensitized solar cells remains at the level of fundamental investigations
- Considerable materials science challenges remain:
  - Synthesis of complex, multicomponent nanostructures
  - Band gap engineering for optimum conversion efficiency
  - Incorporation of multiple exciton generating quantum dots