2008 Solar Annual Review Meeting

Session: OPV, Sensitized, Seed
Company or Organization: NREL
Funding Opportunity: SETP Seed Fund

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NREL/PR-270-43161
Presented at the Solar Energy Technologies Program (SETP) Annual Program Review Meeting held
April 22-24, 2008 in Austin, Texas

Budget and Solar America Initiative Alignment

Novel Nanocrystal-Based Solar Cells to Exploit MEG

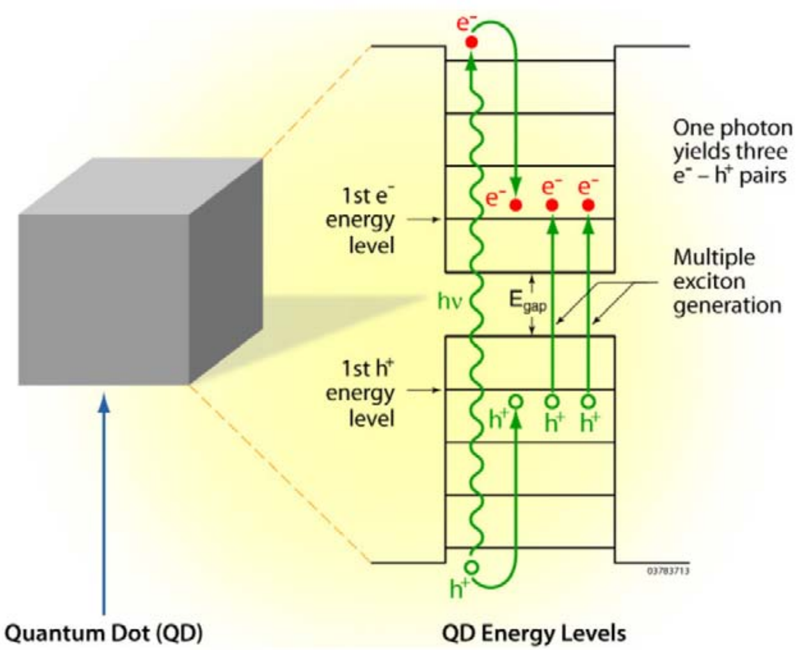
National Renewable Energy Laboratory			
Project Beginning Date	**FY07 Budget**	**FY08 Budget**	**Total Budget**
Jan. 2008	$0	$0.30 millions	$0.30 millions

- This project supports the Solar America Initiative by:
  - Exploring the concept of improving solar cell efficiency by generating and collecting multiple electrons per absorbed photon for $h\nu > 2E_g$ (Multiple Exciton Generation -- MEG).
  - Developing PV cells based on colloidally-synthesized semiconductor nanocrystals (NCs) which may eventually enable inexpensive and highly-efficient devices (single absorber design can potentially exceed Shockley-Queisser limit).

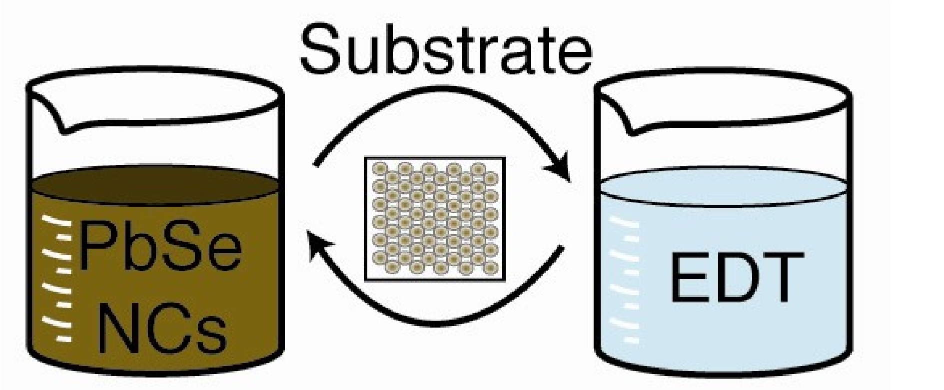
Project Overview

- Goal – demonstrate PV cell utilizing multiple electrons/photon ($h\nu > 2E_g$)
- Intent -- prove concept of MEG-PV (exceeding S-Q limit will take many years)

Multiple exciton generation (MEG) observed in *quantum-confined* NCs of Si, CdSe, PbSe, PbS, PbTe, and InAs/CdSe core/shell.



R. Schaller and V. Klimov, *PRL* **92**, 186601 (2004).
R. Ellingson, M. Beard, A. Efros, A. Nozik, *et al.*, *Nano Lett.* **5**, 865 (2005).

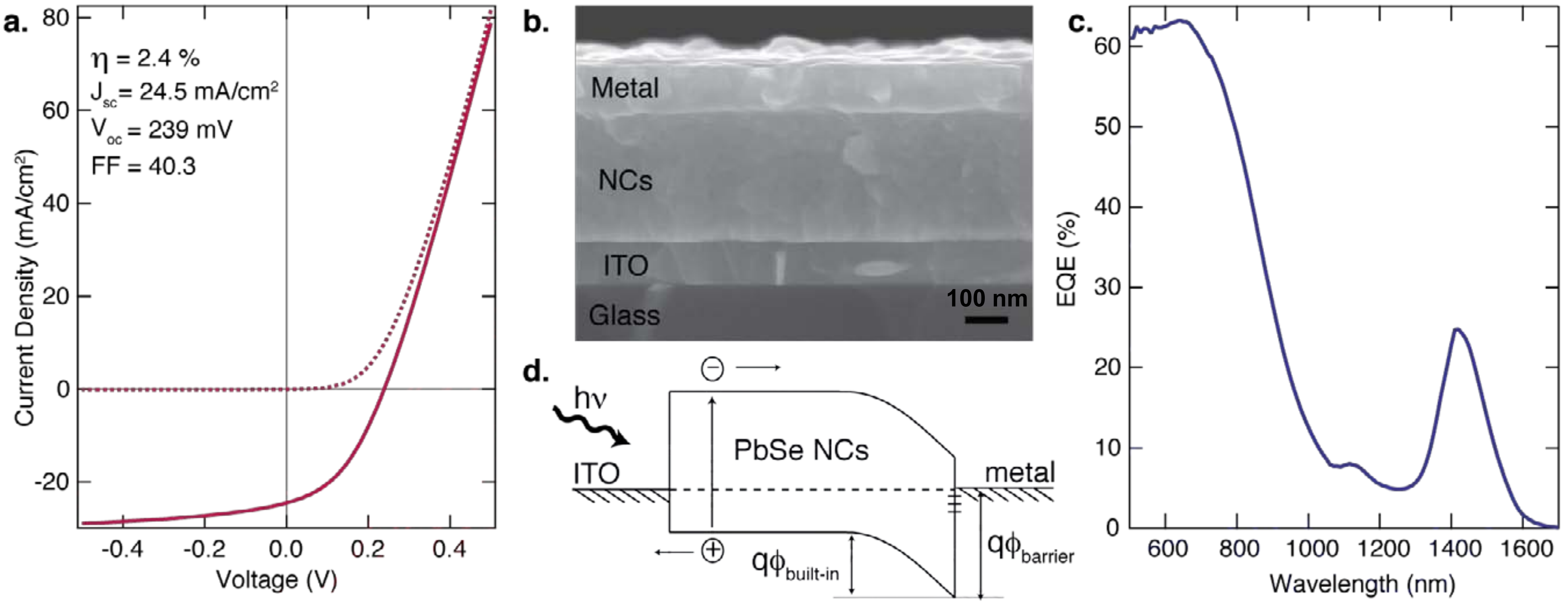


EDT = 1,2-ethanedithiol

Layer by layer (LbL) fabrication of PbSe nanocrystal (NC) films. Nanocrystal films prepared by dip-coating, alternating between (1) PbSe NCs in hexane and (2) 0.1 M EDT in anhydrous acetonitrile, allowing the film to dry between each layer.

J. M. Luther, M. Law *et al.*, "Structural, Optical, and Electrical Properties of Self-Assembled Films of PbSe Nanocrystals Treated with 1,2-Ethanedithiol", *ACS Nano* **2**, 271 (2008).

PbSe nanocrystal-based PV devices



Structure, performance, and schematic diagram of the device. (a) J-V characteristics of a representative device in the dark and under 100 mW cm^{-2} simulated sunlight (E_g = 0.9 eV). **(b)** SEM cross-section of the ITO/NC film/metal device stack. The metal is 20 nm Ca / 100 nm Al. **(c)** External quantum efficiency of a device with a 140 nm-thick film and an efficiency of 2.2% (E_g = 0.95 eV). **(d)** Proposed equilibrium band diagram. Light is incident through the ITO and band bending occurs at the interface between the NCs and evaporated negative electrode.

Project Alignment with Technology Roadmap

What needs in the Technology Roadmap are your project responding to?

From the draft MEG-PV roadmap:

	Need	Significance
1.	Design cells for using MEG	Efficient collection of photocurrent such that MEG contributes to conversion efficiency
2.	Investigate contacting materials	Reduce contact losses to improve V_{oc}; generate a large built-in potential.

What approaches are you using to address those needs?

1. Basing devices on semiconductor NCs which have demonstrated MEG; exploring device designs which allow efficient photocurrent collection in blue/UV.
2. Survey various top electrode metals, assessing impact of work function on performance.

Project Update

	Planned work since last Program Review	Status
Past	Project initiated	Jan-08
Past	Best devices > 2% efficiency (AM1.5G)	Achieved (Jan-08)
Future	reliable air-free EQE characterization (blue/UV)	Anticipated Jun-08
Future	demonstrate MEG within device-quality film using optical spectroscopy.	Anticipated Sep-08
Future	quantitatively assess cell stability; identify air-sensitivity and degradation mechanisms	Anticipated Dec-08
Future	4% cell, air-stable, low-toxicity, with A ≥ 1 cm^2; optimization of IQE, ideally to exceed 100% at short wavelengths; demonstrate MEG-enhanced photocurrent in biased device.	FY09
Future	8% cell, air-stable, low-toxicity, with A ≥ 5 cm^2; demonstration of MEG-enhanced Jsc under AM1.5G.	FY10

Obstacle Discussion

- Barriers encountered or anticipated that may inhibit success of programs
  - Highly air-sensitive devices; requires glove box environment for fabrication and measurement of EQE and J-V.
  - Challenging optical and electrical modeling of device. Reliable IQE requires accurate determination of absorption within the NC film. Ongoing efforts to establish *n, k* of NC film using ellipsometry, and consistency check with analysis of R, T data.