Inorganic Nanocrystal Solar Cells

Naval Research Laboratory nrl.navy.mil

At a Glance

What is it?

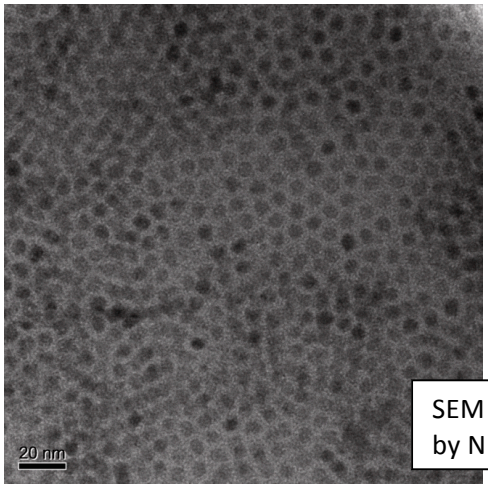
NRL is developing photovoltaics (solar cells) from solution based materials.

How does it work?

The solar cells are formed from nanocrystals that can be engineered to absorb light over a broad wavelength range. The nanocrystals can be manipulated and processed in solution, making it possible to form a photovoltaic film.

What will it accomplish?

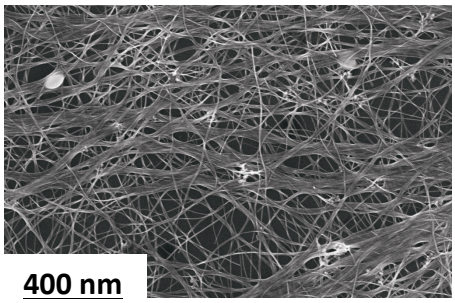
These solar cells will be a man-portable power source. The material can be deposited onto any surface for on-demand power. The process will also form the basis for low-cost fabrication techniques like spin coating, inkjet printing, or reel-to-reel processing.

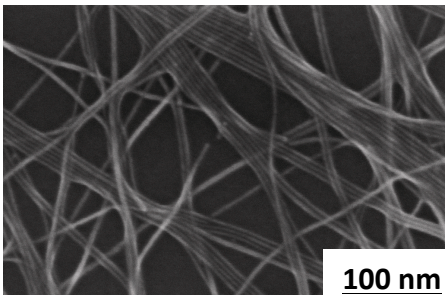


Increasing diameter

SEM image of PbSe nanocrystals fabricated by NRL (diameter = 5.8 ± 0.8 nm

Sunlight-absorbing nanocrystals can be fabricated in a solution, forming essentially a liquid semiconductor that can be sprayed like paint onto an arbitrary surface to form a solar cell. Nanowires (NWs) offer the added advantage of enhanced charge transport. Solar cells based entirely on inorganic nanocrystals have recently been demonstrated. The potential advantages of this system are that it combines the low-cost solution processability of polymer materials with





The NWs are rocksalt, grow in the <100> direction, have diameters between 5.6-26.4 nm and lengths greater than 1 µm.

the many advantages of inorganic materials over organic ones: broader spectral absorbance, higher electron and hole transport rates, and stability under ambient conditions. Using this work as a starting point, NRL has been able to demonstrate function of these solar cells when produced using a spray-based fabrication method and have confirmed their stability when prepared and stored under ambient conditions. Our present research seeks to develop new nanocrystal materials to expand the absorption range and thereby the conversion efficiency.

Research Challenges and Opportunities

- Develop nanocrystal material system that provides broad absorption range
- Develop sprayable TCO material

List of publications:

"Asymmetry between Auger and Inverse-Auger Processes in PbSe Nanorods" P.D. Cunningham, J.E. Boercker, J.G. Tischler, E.E. Foos, J.S. Melinger, in preparation for Nano Letters.
"Inorganic Photovoltaic Devices Fabricated Using Spray Deposition of Nanocrystals", E.E. Foos, W. Yoon, M.P. Lumb and J.G. Tischler, in preparation for ACS Applied Materials and Interfaces.

"Enhanced Open-Circuit Voltage of PbS Nanocrystal Solar Cells," W. Yoon, J.E. Boercker, M.P. Lumb, D. Placencia, E.E. Foos, and J.G. Tischler, submitted to Nature Photonics.

"Oxidization Reduction in PbSe Nanocrystal Thin Film by Remote Plasma Atomic Layer Deposition of Al_2O_3", W. Yoon, A.R. Smith, E.E. Foos, J.E. Boercker, W.N. Heuer and J.G. Tischler, IEEE Transactions on Nanotechnology **2013**, in press.

'The Effect of Ligand Structure on the Optical and Electronic Properties of Nanocrystalline PbSe Films' A.R. Smith, W. Yoon, W.N. Heuer, S.I.M. Baril, J.E. Boercker, J.G. Tischler and E.E. Foos, Journal of Physical Chemistry C, **116**, pp. 6031−6037 (2012)

"Enhanced Multiple Exciton Generation in Quasi One-Dimensional Semiconductors", P.D. Cunningham, J.E. Boercker, E.E. Foos, M.P. Lumb, A.R. Smith, J.G. Tischler and J.S. Melinger, Nano Letters **11**, pp 3476-3481 (2011).

"Synthesis of PbSe Nanowires: The Impact of Alkylphosphonic Acid Addition", E.E. Foos, T.J. Zega, J.G. Tischler, R.M. Stroud and J.E. Boercker, J. Mater. Chem. **21**, pp 2616–2623 (2011).

"Size and Temperature Dependence of Band-Edge Excitons in PbSe Nanowires", J.E. Boercker, E.M. Clifton, J.G. Tischler, E.E. Foos, T.J. Zega, M.E. Twigg, and R.M. Stroud, J. Phys. Chem. Lett. **2**, pp 527–531 (2011).

"Band-Edge Excitons in PbSe Nanocrystals and Nanorods", J.G. Tischler, T.A. Kennedy, E.R. Glaser, Al.L. Efros, E.E. Foos, J.E. Boercker, T.J. Zega, R.M. Stroud and S.C. Erwin, Phys. Rev. B **82**, 245303 (2010).