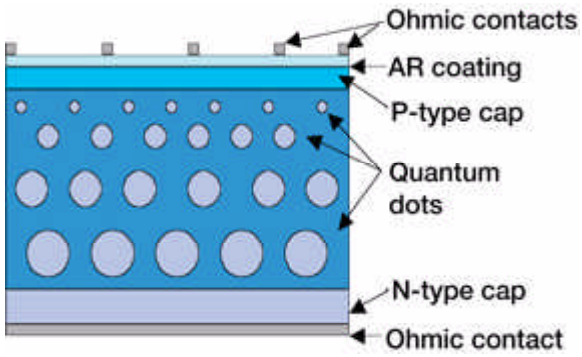
Quantum Dots Investigated for Solar Cells

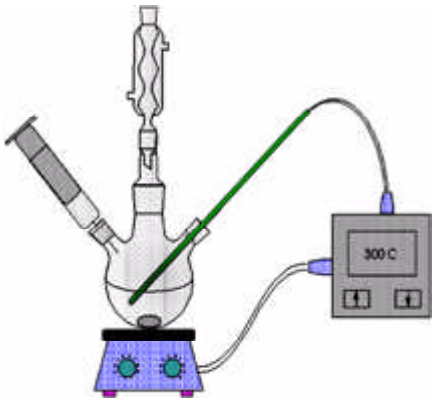


Intermediate-bandgap solar cell. Experimental setup for chemical bath production of quantum dots.

The NASA Glenn Research Center has been investigating the synthesis of quantum dots of CdSe and $CuInS_2$ for use in intermediate-bandgap solar cells. Using quantum dots in a solar cell to create an intermediate band will allow the harvesting of a much larger portion of the available solar spectrum. Theoretical studies predict a potential efficiency of 63.2 percent, which is approximately a factor of 2 better than any state-of-the-art devices available today (ref. 1). This technology is also applicable to thin-film devices--where it offers a potential four-fold increase in power-to-weight ratio over the state of the art.

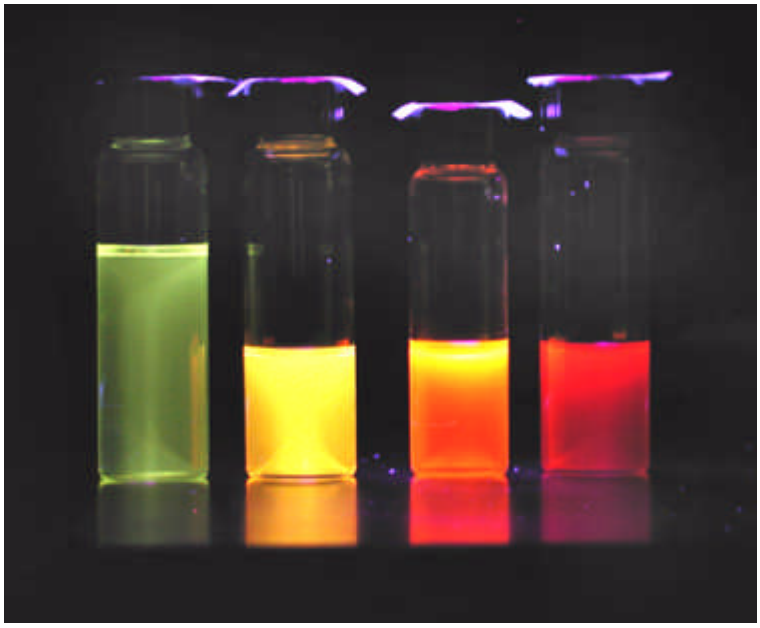
Intermediate-bandgap solar cells require that quantum dots be sandwiched in an intrinsic region between the photovoltaic solar cell's ordinary *p*- and *n*-type regions (see the preceding figure). The quantum dots form the intermediate band of discrete states that allow subbandgap energies to be absorbed. However, when the current is extracted, it is limited by the bandgap, not the individual photon energies. The energy states of the quantum dot can be controlled by controlling the size of the dot. Ironically, the ground-state energy levels are inversely proportional to the size of the quantum dots.

We have prepared a variety of quantum dots using the typical organometallic synthesis routes pioneered by Ba Wendi et al., in the early 1990's (ref. 2). The most studied quantum dots prepared by this method have been of CdSe. To produce these dots, researchers inject a syringe of the desired organometallic precursors into heated triocytlphosphine oxide (TOPO) that has been vigorously stirred under an inert atmosphere (see the following figure). The solution immediately begins to change from colorless to yellow, then orange and red/brown, as the quantum dots increase in size. When the desired size is reached, the heat is removed from the flask. Quantum dots of different sizes can be identified by placing them under a "black light" and observing the various color differences in their fluorescence (see the photograph).



Experimental setup for chemical bath production of quantum dots.

Unlike previous work in this area, Glenn used single-source precursor molecules in this synthesis process. $CuInS_2$ precursor molecules were prepared using a metasthesis reaction of an organoindium reagent in a nonaqueous solution. The precursors were used in the same process just described to produce nanoscale CuInS quantum dots for photovoltaic applications.



CdSe quantum dot fluorescence showing an increase in dot size going from green on the left to red on the right.

References

1. Luque, A.; and Marti, A.: Increasing the Efficiency of Ideal Solar Cells by Photon Induced Transitions at Intermediate Levels. Phys. Rev. Lett., vol. 78, no. 26, 1997, pp. 5014-5017.

2. Murray, C.B.; Norris, D.J.; and Ba Wendi, M.G.: Synthesis and Characterization of Nearly Monodisperse CDE (E

= S, SE, TE) Semi-conductor Nanocrystallites. J. Am. Chem. Soc., vol. 115, no. 19, 1993, pp. 8706-8715.

Glenn contact: Dr. Sheila G. Bailey, 216-433-2228, Sheila.G.Bailey@grc.nasa.gov
RIT contact: Dr. Ryne P. Raffaelle, 716-475-5149, rprsps@rit.edu
OAI contact: Dr. Stephanie L. Castro, 216-433-3820, Stephanie.L.Castro@grc.nasa.gov
Authors: Dr. Ryne P. Raffaelle, Dr. Stephanie L. Castro, Dr. Aloysius F. Hepp, and Dr. Sheila G. Bailey
Headquarters program office: OAT
Programs/Projects: SSP, DDF