Sustainable and cost effective solar technology made from Tetrapod Quantum Dot Solar Cells

R. A. Glass
Solterra Renewable Technologies, Inc.
ASU Research Park, 7700 S. River Parkway
Tempe, AZ, USA, drbob@solterrainc.com

ABSTRACT

Solterra is developing 3rd generation solar cells utilizing high volume synthesis of tetrapod quantum dots.[5] Quantum dots have properties between those of large semiconductors and those of discrete molecules A quantum dot solar cell typically uses a thin layer of quantum dot semiconductor material, rather than silicon chips, to convert sunlight into electricity. Quantum Dots, also known as nanocrystals, measure near one billionth of an inch and are a non-traditional type of semiconductor. Our *tetrapod* quantum dot's size, typically range form 5 to 50 nanometers (or about 7 atoms high and 10-20 atoms in diameter) and have "arms" that can range between 5 and 40nm and self assemble. We are using CdSe as our initial compound. Using proprietary techniques including micro reactors [1] will allow us to go from the lab quantities of 1 kg/day to 100 kg/day within 6 months. We expect efficiencies of 6% within one year, 10% within 2 years and greater than 20% within five years.

Keywords: tetrapod quantum dots, quantum dots, solar cells, nanotechnology

1 Quantum Dots Have The Highest potential conversion efficiency

Quantum dots also have several very unique qualities that are the primary result of their small sizes and the optical and electrical effects at these dimensions. One of the most interesting and most significant is their ability to create multiple exciton generation (MEG).[1][2] The MEG effect is important because it creates the potential to harvest 3 electrons per photon from the sun, and some reports have been published of up to 7 electrons for each photon. Like a farmer harvesting corn, solar cells are nothing more than a way to collect photons sent to earth by the sun and collecting these photon so we can harvest electrons from them which we in turn use to produce electricity. Prior to quantum dots, you could only extract one electron from each photon. Now with quantum dots the potential is there to collect 3 or more opening the window for exponential increases in conversion efficiency and not just during that single peak window of sunlight, but throughout the entire day. Although the technology is not there yet, NREL has substantiated to the theoretical conversion efficiency for qdots is 30 percent greater than for other materials. Additionally quantum dots are able to receive energy from both the infrared and ultraviolet spectrum, thus allowing for 24 hour per day energy.

2. Approaches to Developing Solar Cells from Quantum Dots

Companies are pursuing different nanotechnological approaches to developing solar cells, but the general idea is the same for all. When light hits an atom in a semiconductor, those photons of light with lots of energy can push an electron out of its nice stable orbital around the atom. The electron is then free to move from atom to atom, like the electrons in a piece of metal when it conducts electricity. Using nano-size bits of semiconductor embedded in a conductive plastic maximizes the chance that an electron can escape the nanoparticle and reach the conductive plastic before it is "trapped" by another atom that has also been stripped of an electron. Once in the plastic, the electron can travel through wires connecting the solar cell to an electronic device. It can then wander back to the nanocrystal to join an atom that has a positive charge, which scientifically is called *electron hole recombination*. A quantum dot solar cell typically uses a thin layer of quantum dot semiconductor material, rather than silicon chips, to convert sunlight into electricity. Quantum Dots, also known as nanocrystals, measure near one billionth of an inch and are a non-traditional type of semiconductor. Management believes that they can be used as an enabling material across many industries and that quantum dots are unparalleled in versatility and flexible in form.

Solterra intends to design and manufacture solar cells using a proprietary thin film semiconductor technology that we believe will allow us to reduce our average solar cell manufacturing costs and be extremely competitive in this market. Solterra will be one of the first companies to integrate non-silicon quantum dot thin film technology into high volume low cost production using proprietary technologies. Our objective is to become one of the first solar module manufacturer to offer a solar electricity solution that competes on a non-subsidized basis with the price of retail electricity in key markets in North America, Europe, the Middle East and Asia. Recently, entirely new possibilities for improving the efficiency of photovoltaics based on quantum dot technology have opened up. Quantum dots have quantum optical properties that are absent in the bulk material due to the confinement of electron-hole pairs (called excitons) on the particle.

3. Advantages of Quantum Dots for Solar Cells

The first advantage of quantum dots is their tunable bandgap. It means that the wavelength at which they will absorb or emit radiation can be adjusted at will: the larger the size, the longer the wavelength of light absorbed and emitted. The greater the bandgap of a solar cell semiconductor, the more energetic the photons absorbed, and the greater the output voltage.

On the other hand, a lower bandgap results in the capture of more photons including those in the red end of the solar spectrum, resulting in a higher output of current but at a lower output voltage. Thus, there is an optimum bandgap that corresponds to the highest possible solar-electric energy conversion, and this can also be achieved by using a mixture of quantum dots of different sizes for harvesting the maximum proportion of the incident light.

Another advantage of quantum dots is that in contrast to traditional semiconductor materials that are crystalline or rigid, quantum dots can be molded into a variety of different form, in sheets or three-dimensional arrays. They can easily be combined with organic polymers, dyes, or made into porous films in the colloidal form suspended in solution, they can be processed to create junctions on inexpensive substrates such as plastics, glass or metal sheets.

When quantum dots are formed into an ordered three-dimensional array, there will be strong electronic coupling between them so that excitons will have a longer life, facilitating the collection and transport of ‘hot carriers’ to generate electricity at high voltage. In addition, such an array makes it possible to generate multiple excitons from the absorption of a single photon.

Quantum dots are offering the possibilities for improving the efficiency of solar cells in at least two respects, by extending the band gap of solar cells for harvesting more of the light in the solar spectrum, and by generating more charges from a single photon.

Infrared photovoltaic cells – which transform infrared light into electricity - are attracting much attention, as nearly half of the approximately 1000W/m2 of the intensity of sunlight is within the invisible infrared region. So it is possible to use the visible half for direct lighting while harvesting the invisible for generating electricity.

Photovoltaic cells that respond to infrared – ‘thermovoltaics’ - can even capture radiation from a fuel-fire emitter; and co-generation of electricity and heat are said to be quiet, reliable, clean and efficient. A 1 cm2 silicon cell in direct sunlight will generate about 0.01W, but an efficient infrared photovoltaic cell of equal size can produce theoretically 1W in a fuel-fired system.

One development that has made infrared photovoltaics attractive is the availability of light-sensitive conjugated polymers - polymers with alternating single and double carbon-carbon (sometimes carbon-nitrogen) bonds. It was discovered in the 1970s that chemical doping of conjugated polymers increased electronic conductivity several orders of magnitude. Since then, electronically conducting materials based on conjugated polymers have found many applications including sensors, light-emitting diodes, and solar cells.

Conjugated polymers provide ease of processing, low cost, physical flexibility and large area coverage. They now work reasonably well within the visible spectrum.

Researchers led by Arthur Nozik at the National Renewable Energy Laboratory Golden, Colorado in the United States have demonstrated that the absorption of a single photon by their quantum dots yielded - not one exciton as is usually the case, but three of them. [2] [3]

The formation of multiple excitons per absorbed photon happens when the energy of the photon absorbed is far greater than the semiconductor band gap. This phenomenon does not readily occur in bulk semiconductors where the excess energy simply dissipates away as heat before it can cause other electron-hole pairs to form.

In semi-conducting quantum dots, the rate of energy dissipation is significantly reduced, and the charge carriers are confined within a minute volume, thereby increasing their interactions and enhancing the probability for multiple excitons to form.

4. Solterra’s Quantum Dot Solar Cell Architecture

Although there are many different nanotechnological approaches to developing solar cells, the general idea is the same for all. When light hits an atom in a semiconductor which in our case is the quantum dot tetrapod, those photons of light with lots of energy can push an electron out of its nice stable orbital around the atom. The electron is then free to move from atom to atom, like the electrons in a piece of metal when it conducts electricity.

Using nano-size bits of semiconductor, again in our case quantum dots, embedded in a conductive plastic maximizes the chance that an electron can escape the nanoparticle and reach the conductive plastic before it is "trapped" by another atom that has also been stripped of an electron. Once in the plastic, the electron can travel through wires connecting the solar cell to your electronic device. It can then wander back to the nanocrystal to join an atom that has a positive charge.

As stated above, quantum dots improve the efficiency of solar cells in at least two respects, by extending the band gap of solar cells for harvesting more of the light in the solar spectrum, and by generating more charges from a single photon. “We have shown that solar cells based on quantum dots theoretically could convert more than 65 percent of the sun’s energy into electricity, approximately doubling the efficiency of solar cells”, said Arthur Nozik at the National Renewable Energy Laboratory led by Arthur Nozik.[1][2]

This technology is also applicable to other thin-film devices--where it offers a potential four-fold increase in power-to-weight ratio over the state of the art. Intermediate-band gap solar cells require that quantum dots be sandwiched in an intrinsic region between the photovoltaic solar cells ordinary p- and n-type regions. The quantum dots form the intermediate band of discrete states that allow sub-band gap 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.

Solterra’s high quality tetrapod quantum dots provide access to quantum effects that provide for greater power generation potential, and therefore greater efficiency per cell area and thus lower cost per watt produced. Prior research has shown that four-legged quantum dots are many times more efficient at converting sunlight into electricity than regular quantum dots.

Solterra’s manufacturing design relies on state-of-the-art but widely available high volume silkscreen and inkjet printing technologies.[4] Solterra’s cell ingredients will be formulated into an ink medium compatible with such equipment.

5. REFERENCES

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