Perovskite: A New Material for Solar Cells

Scientists at the Energy Department's National Renewable Energy Laboratory (NREL) have demonstrated a way to significantly increase the efficiency of perovskite solar cells by reducing the amount of energy lost to heat. SOLAR TODAY interviews NREL scientist Dr. Jao van de Lagemaat to dig deeper.

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The National Renewable Energy Lab and other research groups are investigating the use of hybrid organic/inorganic perovskite for making solar photovoltaic (PV) cells. Dr. Jao van de Lagemaat of the National Renewable Energy Lab (NREL) in Colorado answered some questions from ASES about perovskite:

ST: What is perovskite?

Perovskites are materials with a crystal structure similar to the naturally occurring mineral calcium titanium oxide ($CaTiO_3$) but with a hybrid organic/inorganic motif that has recently been discovered to work extraordinarily well as a solar absorber material in thin-film solar cells. We've been researching perovskite for a little over two years and have created a number of PV cells from it in our labs.

ST: How efficient are perovskite PV cells?

We have achieved close to 20% efficiency in the lab, using small (1 cm^2) cells. Other researchers have achieved close to 22% for extremely small (mm^2). NREL publishes the official certified records in this chart (see opposite page). Larger area cells are routinely over 15% efficient. We obtain perovskite cells' highest efficiencies when using a solution deposition manufacturing technique, which is unique for solar absorber materials.

ST: What is the market potential for perovskite cells?

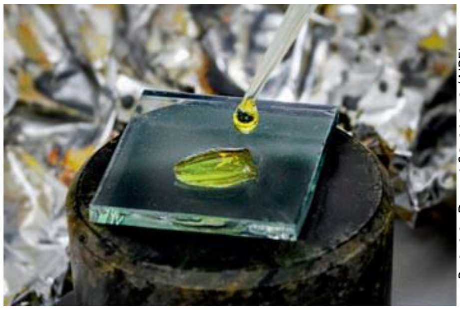
It is potentially a very large market. Perovskite appears to offer a low-capital expenditure way of producing large, relatively efficient solar cells. Successful use of perovskite depends on whether it can be made stable and whether one can deal effectively with the lead that the manufacturing process requires. If those issues can be solved (and researchers are well on their way), the market potential is as large as silicon or cadmium telluride, in my opinion and according to our internal analysis. This is still quite a ways out, though, as we are really only in the initial research stages; bringing a technology to market takes time.

ST: What are pros and cons for commercial vs. residential applications?

Similar to other technologies. As a thin-film technology, it is suitable for low weight applications. For large-scale commercial uses, this is less of an advantage than for residential and mobile applications. There are also other markets such as flexible applications where you need low weight AND high efficiency. That is a quite unique capability that perovskites appear to offer.

ST: What is the chemical stability of perovskite?

The same properties that make it amenable to solution deposition are also the ones that make it vulnerable to degradation. Perovskite itself is water-soluble, so stability in the presence of water vapor is an issue. We can address this by sealing the cells, by either coatings or encapsulation. The material also needs fairly low temperatures for annealing and formation. This is great for production, but it also means that the material is vulnerable to loss of the organic part at higher temperatures, which can evaporate out and result in creation of lead-iodide, a type of semiconductor that leads to loss of efficiency. Sealing and encapsulation can slow down this loss. Researchers have also developed several chemical strategies that slow it down. Some startups in this field have published press releases stating that that they have solved the stability problem, but we'll have to see whether this pans out. NREL and its partners have been working hard to solve this problem, and we are making clear advances. Also, there are many indications that it's not the material itself that's the problem but the electrical contacts. For example, a conductive polymer called spiro-OMeTAD that was originally used as the contact is now thought to be a major cause of instability; replacing it with carbon-based materials such as carbon nanotubes solves this problem. Henry Snaith from Oxford University, for example, likes to demonstrate that he can hold a perovskite cell using carbon nanotubes for contacts under running tap water and have the cell survive. See the paper at http://bit.ly/1JfkcSV for more information. Interestingly, all these contact materials are again solution-depositable.



A dye-sensitized precursor solution to make a perovskite cell

ST: How long can a perovskite solar panel last?

This is unknown at the moment as there really hasn't been any testing of panel longevity that is public. The research teams have tested lifetimes of submodules and have shown that with appropriate sealing and chemistry, these modules could last. There have been some indications that there are no intrinsic limits to the lifetime of these panels; however, it is too early to say.

ST: How green are perovskite cells? Have you identified any environmental issues during fabrication, use, or disposal?

The current most efficient material contains lead, which of course has environmental issues. The solar cells, however, are very thin, and one can calculate that the lead in a single car battery is enough for hundreds of square meters of perovskite solar cells. Also, one can encapsulate and recycle perovskite just as manufacturers of cadmium telluride cells do. Lead is one of the most abundant elements on earth, and the production process is a very low-energy one using commodity chemicals. So the energy investment in a perovskite solar panel is potentially very low, which could be a relative advantage. Many of the research groups are looking for ways of replacing the lead with another earth-abundant element but keeping the high efficiency and the defect tolerance that the lead perovskite exhibits. Obviously if the technology that makes it to market is based on lead, the companies would have to think about using and disposing of it an environmentally responsible way. However, this is no different from any of the other solar technologies where production materials and processes are often environmental issues and where thought has to be given to end-of-life issues. **ST**

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PHOTO BY DENNIS SCHROEDER / NREL

Elisa Miller, a NREL Post-Doc Fellow, works with a photo electron spectrometer in the surface analysis lab at the Solar Energy Research Facility (SERF) at the National Renewable Laboratory in Golden, CO. She is studying perovskite materials and mapping out energy diagrams.