RESEARCH HIGHLIGHTS: Perovskites

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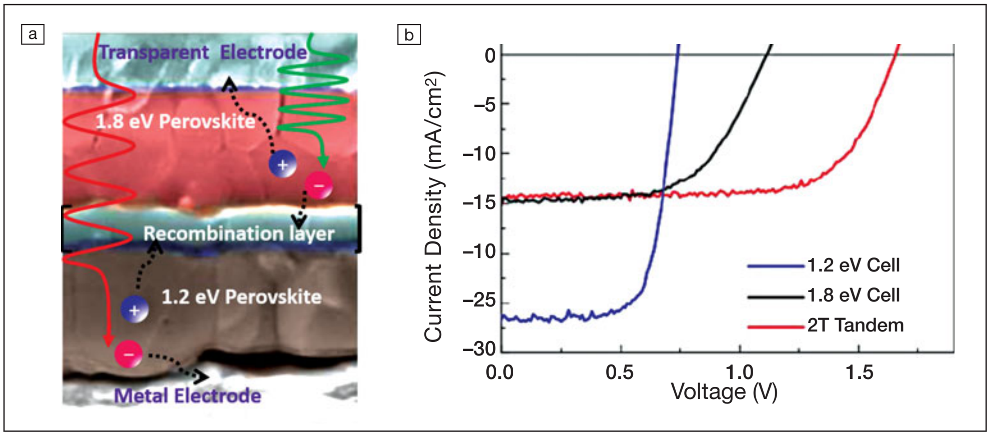
Research on perovskites has progressed rapidly, with solar-cell efficiencies now at 22%, five times higher than first cells reported in 2009. MRS Bulletin *presents the impact of a selection of recent advances in this burgeoning field.*



(a) Scanning electron micrograph of the two-terminal (2T) all-perovskite solar cell with the schematic for the monolithic tandem cell operation; (b) current–voltage curves for the single junction and tandem solar cells. Credit: Pabitra Nayak.

Materials scientists at the University of Oxford and Stanford University report high-performance perovskite–perovskite tandem cells using efficient and stable lead- and tin-based perovskites.

So far, researchers have made tandem cells by putting perovskite cells, which have a wide energy bandgap, on top of low-bandgap silicon cells. Perovskite-only tandem cells would cost less and be easier to produce.

The research team led by Henry Snaith (Oxford) and Michael McGehee (Stanford) used $FA_{0.75}Cs_{0.25}Pb_{0.5}Sn_{0.5}I_3$ as the low-bandgap (1.22 eV) and $FA_{0.83}Cs_{0.17}Pb(I_{0.5}Br_{0.5})_3$ (1.8 eV) as the high-bandgap perovskite. By coupling solar cells made with these two materials, the researchers demonstrated a monolithic two-terminal all-perovskite tandem solar cell (see Figure) with a power-conversion efficiency of 17% and a four-terminal all-perovskite solar cell with an efficiency of 20.3%. The researchers reported their findings in *Science* (doi:10.1126/science.aaf9717).

Thin films of lead halide perovskites are remarkably efficient at converting light to electricity, even when they have defects. A research group has now uncovered the secret behind this trait. Charge carriers in hybrid organic–inorganic perovskites, they argue, acquire a dynamic cloaking screen that allows them to travel through the material without colliding with defects.

Researchers led by Xiaoyang Zhu of Columbia University compared charge dynamics in lead bromide perovskites with three different cations: organic methylammonium and formamidinium, and inorganic cesium. They made single-crystal samples of the materials and conducted time-resolved photoluminescence and time-resolved optical Kerr effect spectroscopy measurements.

Organic cations in the hybrid perovskites are dipoles that rotate freely as in a liquid. The dynamic reorientation of these dipoles creates an effective cloaking field for charged particles, keeping them from scattering by defect centers or optical phonon modes. The researchers report their work in *Science* (doi:10.1126/science.aaf9570).

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University of Oxford researchers have shed light on how perovskites rapidly form macroscopic single crystals at high temperatures from solution. Using this knowledge, they were able to produce higher quality single crystals than ones made so far using the rapid crystallization technique.

Henry Snaith and his colleagues report in *Nature Communications* (doi:10.1038/ncomms13303) that perovskite crystallization is triggered by a change in the acid–base equilibrium of the solvent, which raises the concentration of the solute and results in the perovskite's quick saturation out of the solution as crystals. Understanding the factors that influence and control crystallization is key to making high-performance perovskite optoelectronic devices.

Increasing the stability of perovskites is another key requirement for their commercial success. Michael Grätzel and co-workers at the École Polytechnique Fédérale de Lausanne, Switzerland have now made highly stable, efficient solar cells by integrating rubidium into lead-halide perovskite films.

The resulting solar cells have a power-conversion efficiency of 21.6%. They maintain 95% of their initial performance over 500 continuous hours under full sunlight at 85°C.

Earlier this year, the researchers reported a triple-cation (methylammonium, formamidinium, and cesium) perovskite, yielding a solar efficiency of 21.2% that remained stable for 250 hours. The new advance published in *Science* (doi:10.1126/science.aah5557) takes that work a step further. This time they added rubidium to the mix. The rubidium cations may help relax lattice strain, giving a more defect-free crystal, says the lead author Michael Saliba.

Researchers have used perovskite quantum dots in solar cells to get a relatively high power-conversion efficiency of 10.77%. This is comparable to efficiencies of quantum dot solar cells made of other materials, and higher than that of other reported all-inorganic perovskite solar cells.

Quantum dots are nanocrystals of semiconductor materials. The researchers, led by Joseph M. Luther at the National Renewable Energy Laboratory, made a thin film of nanocrystals of the perovskite cesium lead iodide ($CsPbI_3$) with good electronic coupling among the quantum dots. Low-bandgap all-inorganic perovskites such as $CsPbI_3$ were thought to be stable only at temperatures over 600°F. But the team discovered a method to keep nanocrystals of the material stable at room temperature, which they detail in *Science* (doi:10.1126/science.aag2700). They first mixed a Cs-oleate solution with a PbI_2 precursor. They then purified the nanocrystals using methyl acetate as an anti-solvent that removed excess unreacted precursors, which turned out to be critical to increasing their stability.

2016 Nobel Prizes in physics and chemistry: A materials view

Prachi Patel

This year's Nobel Prizes in Chemistry and Physics, which honor the use of topological concepts, were also a win for materials science and materials research.

The 2016 Nobel Prize in Physics was awarded to David J. Thouless at the University of Washington, F. Duncan M. Haldane at Princeton University, and J. Michael Kosterlitz at Brown University for their explanations of exotic states of matter using the mathematical concept of topology. The Nobel Prize in Chemistry went to Jean-Pierre Sauvage at the University of Strasbourg, France; Sir J. Fraser Stoddart at Northwestern University; and Bernard L. Feringa at the University of Groningen, The Netherlands, for creating the world's smallest machines by synthesizing topologically very challenging structures on the molecular scale.

"This was very joyful to hear because topology is an elegant concept and finally it got recognized," says Avadh Saxena, a physicist at Los Alamos National Laboratory who works in the area of topological concepts in materials science.

Both prizes recognized fundamental research that has led and will continue to fuel materials discoveries. "In a time when funding tends to be skewed toward application-driven research, it's fantastic to see that the Nobel committee has given a nod to basic research with huge amounts of promise," says Alexander Spokoyny regarding the Chemistry Nobel Prize. Spokoyny, a professor of chemistry at the University of California, Los Angeles, studies molecular synthesis.

Topology describes the properties of a material that are preserved under continuous deformation such as stretching. The electrical current through a wire, for instance, remains the same when the wire is deformed, Saxena explains. "Just as geometry is useful for understanding materials, topology is also useful in understanding material behaviors," he says.

The theoretical work that the physics laureates pioneered laid the groundwork for explaining unusual behaviors that