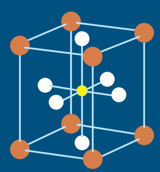

# RESEARCH HIGHLIGHTS: Perovskites

By **Prachi Patel**
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*Research on perovskites has progressed rapidly since the first perovskite-based solar cells with ~4% efficiency were reported in 2009.* MRS Bulletin *presents a selection of recent advances in this burgeoning field.*

The discovery of a rare property in perovskites has allowed researchers to rapidly grow centimeter-scale, good-quality single crystals of the material. Salts generally tend to dissolve more in a solvent when temperature increases. But a few research groups have independently found that the solubility of perovskites in certain solvents decreases with a rise in temperature, leading to the formation of single crystals in the solution at high temperatures.

While conventional growth methods take weeks to grow such large crystals, the new method yields results in just a few hours. This finding could lead to perovskite single-crystal-based optoelectronic devices with superior performances.

Salts generally tend to dissolve faster in a solvent when temperature increases. But a few research groups have independently found that the solubility of perovskites in certain solvents decreases with rise in temperature, leading to the formation of single crystals in the solution at high temperatures.

Researchers at the Swiss Federal Institute of Technology in Lausanne reported the phenomenon in perovskites in *Scientific Reports* (DOI: 10.1038/srep11654). The research team, led by chemical science and engineering professor Anders Hagfeldt, found that heating a concentrated (1:1 molar ratio) solution of methylammonium iodide and lead iodide in the solvent gamma γ-butyrolactone (GBL) to 190°C led to the formation of freestanding methylammonium lead iodide ($CH_3NH_3PbI_3$) perovskite crystals. Once the crystals reached the desired size, the researchers removed them from the hot solution because the crystals dissolve back into the solution upon cooling. They report making crystals over 1-mm long in 25 minutes.

This initial report was followed by similar advances published in *Nature Communications* (DOI: 10.1038/ncomms8586) by a group at the King Abdullah University of Science and Technology (KAUST), and then in *Advanced Materials* (DOI: 10.1002/adma.201502597) by researchers at the Shaanxi Normal University in Xi'an, China.

Materials science and engineering professor Osman Bakr and his colleagues at KAUST reported the crystallization of $CH_3NH_3PbBr_3$ from *N*,*N*-dimethylformamide solvent and the creation of $CH_3NH_3PbI_3$ crystals from GBL. They calculated the speed of crystal growth to be as high as 20 $mm^3$/h for $CH_3NH_3PbI_3$ and 38 $mm^3$/h for $CH_3NH_3PbBr_3$. Conventional solution growth gives a highest speed of 1 $mm^3$/h. Meanwhile, Zhou Yang, Shengzhong (Frank) Liu, and their colleagues at Shaanxi Normal University were able to grow $CH_3NH_3PbI_3$ crystals with a diagonal length of 28 mm in 12 hours and crystals as large as 71 mm (over 2.5 in.) in length over a period of 48 hours.

Another exciting application of perovskites comes from two independent research teams, which have used the material to make low-cost narrow-band light detectors that selectively detect specific colors across the visible light spectrum.

Photodetectors, which are used in imaging, sensing, and optical communication, are typically made of a semiconductor such as silicon. These materials absorb a wide swathe of wavelengths, and in order to sense specific colors, photodetectors employ expensive optical filters that require complicated optical design and integration.

In order to make filterless photodetectors, Jinsong Huang and his fellow materials engineers at the University of Nebraska–Lincoln used single-crystal perovskites in a conventional, planar diode architecture. They used single-halide as well as mixed-halide perovskites. Depending on the perovskite composition, the devices could detect light of different colors ranging from red all the way to deep blue.

Researchers Paul L. Burn, Paul Meredith, and their colleagues at The University of Queensland in Australia, meanwhile, made red, green, and blue photodiodes by adding various organic macromolecules to mixed-halide perovskite films. The articles were published in *Nature Photonics* (DOI: 10.1038/nphoton.2015.156 and DOI: 10.1038/nphoton.2015.175).

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Austrian physicists have made ultra-thin, lightweight, and highly flexible perovskite solar cells using low-cost materials, and used them to power a model airplane. The solar cells, reported in *Nature Materials* (DOI: 10.1038/nmat4388), could find applications in unmanned aerial vehicles, and monitoring and security applications.

Perovskite solar cells are typically unstable in air without heavy and costly encapsulation. But with a clever selection of thin, lightweight materials, physicist Martin Kaltenbrunner and his colleagues from Johannes Kepler University Linz made solar-cell arrays that are 3-μm thick, have a record power per weight of 23 W/g, and can operate for days under normal environmental conditions.

An ultralight perovskite solar panel integrated on the horizontal stabilizer of a model airplane's tail powers a DC motor with a propeller. The 64-cell solar panel generates 75 mW under ambient light conditions, enough to fly the airplane, which is 28-cm long with a wingspan of 58 cm. Credit: Martin Kaltenbrunner/Johannes Kepler University Linz.

To make the lightweight device, the researchers use thin PET foil as a substrate on which they deposit a conductive polymer film as the hole-collecting electrode; a perovskite light-absorbing layer, an organic electron-transporting material, $Cr_2O_3$/Cr, and metal contacts. The $Cr_2O_3$/Cr interlayer prevents reactions between the perovskite and the metal top contacts, which makes the device air-stable.

By embedding lead sulfide quantum dots inside a perovskite matrix, Zhijun Ning, Xiwen Gong, Riccardo Comin, and their colleagues at the University of Toronto have created a hyper-efficient and highly radiant hybrid crystal. Quantum dots are important photovoltaic materials that have been used to increase the efficiency of solar cells and light-emitting devices (LEDs). Combining the excellent charge-carrier transport properties of perovskites with the luminescent efficiency of quantum dots yields a material with record power-to-light efficiency for near-infrared LEDs and other optoelectronic devices, the researchers say.

The new material, reported in *Nature* (DOI:10.1038/nature14563), is made of $CH_3NH_3PbI_3$ heterocrystals a large as 60 nm in size containing at least 20 mutually aligned quantum dots embedded inside such that the crystal faces of the two materials are aligned. The perovskite funnels electrons into the quantum dots, which shine brightly.





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