

RESEARCH HIGHLIGHTS: Perovskites

By **Prachi Patel**
Feature Editor: **Pabitra K. Nayak**

Research on perovskites has progressed rapidly since the first solar cells with less than 4% efficiency were reported in 2009. *MRS Bulletin* presents the impact of a selection of recent advances in this burgeoning field.

Perovskites are mostly being studied for solar cells. Now chemists at

Columbia University and the University of Wisconsin–Madison have made tiny lasers from single-crystal nanowires of methylammonium lead halide perovskites.

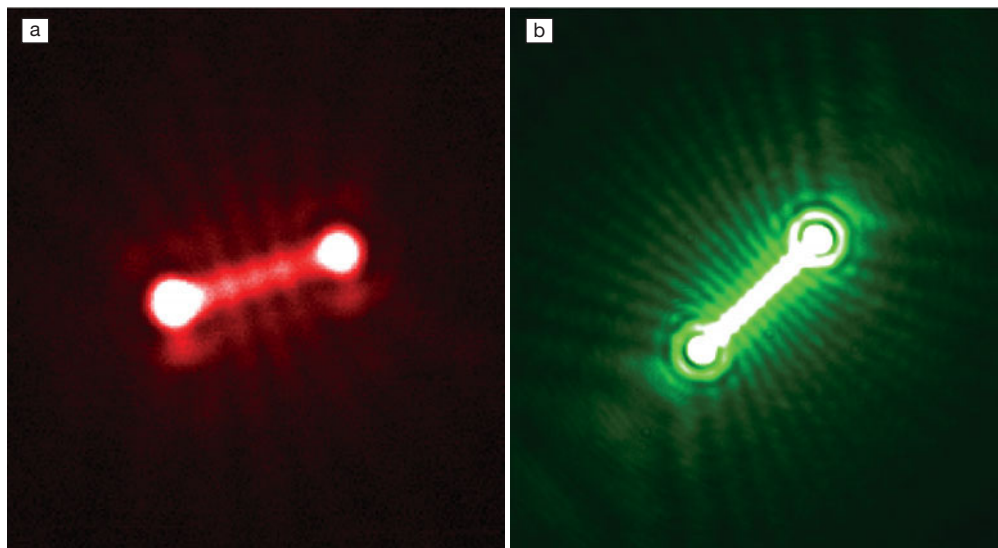
Compared to nanowires made from conventional semiconductors such as zinc oxide and gallium arsenide, perovskite nanowires can be

grown easily at room temperature, says Columbia University chemistry professor Xiaoyang Zhu.

As reported in the June issue of *Nature Materials* (DOI: 10.1038/NMAT4271), the researchers make the single-crystal nanowires by depositing a solid thin film of lead acetate on a glass surface and then

adding a high concentration methylammonium iodide solution. This led to the growth of rectangular nanocrystals of perovskite that were defect-free and had the reflective parallel facets needed to make a laser.

Measurements showed that the perovskite nanowire lasers are 100% efficient at converting absorbed photons to laser light, at least one order of magnitude higher than other nanowire lasers, Zhu says. Another exciting aspect of the lasers is that their color can be tuned simply by changing the composition of the perovskite material.



(a) An 8.5- μm -long methylammonium lead iodide nanowire emits red laser light when excited by a 402-nm pulsed laser beam. (b) A 13.6- μm -long methylammonium lead bromide nanowire, meanwhile, lases green. Credit: *Nature Materials*.

Sang Il Seok and his research team at the Korea Research Institute of Chemical Technology have made perovskite solar cells that have a record 20.1% certified power-conversion efficiency. This efficiency competes with that of commercial silicon solar cells.

Last year, the South Korean team combined the most widely used perovskite, methylammonium lead halide, with formamidinium lead iodide to

make solar cells that were 17.9% efficient. The researchers have now broken their own efficiency record by using the same materials but a new manufacturing method, which they reported in the June issue of *Science* (DOI: 10.1126/science.aaa9272).

Formamidinium-based perovskites absorb a larger portion of the solar spectrum compared to methylammonium-based compounds, leading to

higher efficiency photovoltaic devices. But uniform, dense films of formamidinium lead iodide have been challenging to make. Seok and his colleagues placed a lead(II) iodide–dimethylsulfoxide (DMSO) film into a formamidinium iodide (FAI) solution. An intramolecular exchange results in FAI replacing DMSO in the lattice, resulting in a very high-quality formamidinium lead triiodide film.



Another article published in the May issue of *Science* (DOI: 10.1126/science.aaa5333) contests the popular theory that defects and grain boundaries in perovskites are inert or benign. Perovskite solar cells perform remarkably well partly because light-generated electrons and holes travel through the film for a long period of time. Researchers have attributed this to shallow crystal defects and electrically inactive boundaries between crystal grains that cannot trap the charge carriers for them to recombine.

But when a research team from the University of Washington and the University of Oxford studied methylammonium lead halide perovskites using confocal fluorescence microscopy and scanning electron microscopy, they found

that some regions of the crystal, such as individual grains, interfaces, cracks, and grain boundaries appeared dimmer than other regions. This implied the occurrence of non-radiative recombination, a process in which electrons and holes recombine to generate heat, as opposed to light-generating radiative recombination. Those dim regions also have short carrier lifetimes.

“To make a good semiconductor for a solar cell you want all the recombination in the semiconductor to be radiative so that when you shine light on it you only get recombination events that emit light,” says David Ginger, co-author of the article and chemistry professor at the University of Washington.

The local variations in carrier lifetime in the dim and bright regions of

the perovskite microstructure average out over the entire perovskite film to give it an overall long carrier lifetime, but fast non-radiative recombination is still happening in the dark regions, he explains. Ginger and his colleagues showed that chemical treatment with pyridine makes the dark spots in the crystal brighter by turning off this non-radiative recombination.

The results imply that state-of-the-art perovskite films could be made substantially better by removing those non-radiative recombination losses. “The good news is that by carefully processing the film and by using post-deposition chemical passivation treatments, researchers can eliminate those defective regions and improve efficiency,” Ginger says.

Regardless of application, stability has been a critical issue for perovskites. The materials can degrade easily in humidity. Scientists led by Tao Xu at the Northern Illinois University in Dekalb, Ill., have now proposed a solution. In an article published online in the May issue of *Angewandte Chemie* (DOI: 10.1002/anie.201503038),

they report that replacing two of three iodide ions in a methylammonium lead iodide perovskite with thiocyanate ions (SCN⁻) maintains the perovskite structure, while making the films much more moisture-resistant than conventional ones.

Solar cells made with the SCN⁻-containing perovskite film showed

no significant degradation after being exposed to air with relative humidity of 95% for over four hours. By contrast, devices made with the conventional material degraded in less than 1.5 hours, the researchers reported. Devices made from both materials had the same efficiency of 8.5%.

For daily *Materials News* updates, visit www.materials360online.com

RECENT ARTICLES

Clear, anti-smudge coatings could keep electronics, buildings, and windows clean

Prachi Patel | *Materials Research Society* | Published: 10 June 2015

A duo of chemists has come up with a simple technique to make invisible coatings that repel water, greasy organic liquids, inks, and fingerprints. Such oil- and water-repelling coatings could be painted on buildings as an anti-graffiti measure. They could be applied to electronic gadgets and displays to keep them free of fingerprints, and could be used as protective stain-repelling layers on windows and windshields.

Electron optics in graphene explore whispering-gallery modes

Adam Hill | *Materials Research Society* | Published: 16 June 2015

Electromagnetism is the basis of modern technology, and we manipulate it in a variety of different ways: To control light, optics uses lenses, mirrors, and resonators to bend beams of photons. To control electrical current, electronics uses switches, transistors, and diodes. Now an international research team has manipulated electrons at the nanoscale to apply optics techniques to an electrical current.

5 Materials innovations for new medical devices

Neil Savage | *IEEE Spectrum* | Published: 17 June 2015

The next frontier for electronics could lie inside the human body, with sensors that keep track of biomarkers and brain activity, systems to deliver drugs or monitor exercise levels, and communications networks that allow such devices to call on the processing power of your smartphone and send your data to the doctor's office.

A wavelength-independent “universal” substrate brings SERS into the mainstream

Arthur L. Robinson | *Materials Research Society* | Published: 26 June 2015

Surface-enhanced Raman spectroscopy (SERS) has proven to be a sensitive laser-based technique for detecting and identifying small concentrations of chemical species and biomolecules deposited on substrates. Not just any substrate will do, however, and the lack of inexpensive substrates that work over a substantial range of laser wavelengths has been a thorn in the side of those confronted with mixtures of unknown species to analyze. A new “universal” substrate promises to overcome both the wavelength and cost obstacles while maintaining high sensitivity.

materials360online your premier source for materials science news