Researchers boost performance quality of perovskites

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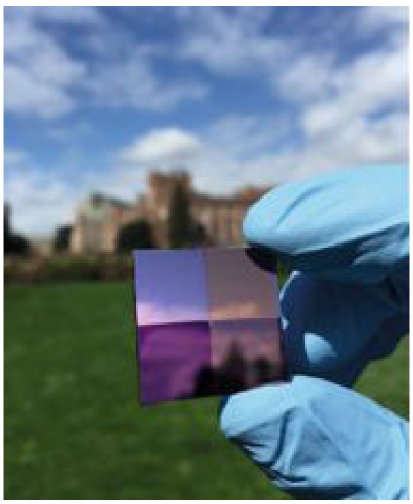

An image of a back-reflector surface used by the researchers to test perovskite performance. Each quadrant is a different surface material — gold, titanium, palladium or a silica compound — upon which the perovskite material would be deposited for experiments. Credit: University of Washington

Solar cells are devices that absorb photons from sunlight and convert their energy to move electrons—enabling the production of clean energy and providing a dependable route to help combat climate change. But most solar cells used widely today are thick, fragile and stiff, which limits their application to flat surfaces and increases the cost to make the solar cell.

"Thin-film solar cells" could be 1/100th the thickness of a piece of paper and flexible enough to festoon surfaces ranging from an aerodynamically sleek car to clothing. To make thin-film solar cells, scientists are moving beyond the "classic" semiconductor compounds, such as gallium arsenide or silicon, and working instead with other light-harvesting compounds that have the potential to be cheaper and easier to mass produce. The compounds could be widely adopted if they could perform as well as today's technology.

In a paper published online this spring in the journal *Nature Photonics*, scientists at the University of Washington report that a prototype semiconductor thin-film has performed even better than today's best solar cell materials at emitting light.

"It may sound odd since solar cells absorb light and turn it into electricity, but the best solar cell materials are also great at emitting light," said co-author and UW chemical engineering professor Hugh Hillhouse, who is also a faculty member with both the UW's Clean Energy Institute and Molecular Engineering & Sciences Institute. "In fact, typically the more efficiently they emit light, the more voltage they generate."

The UW team achieved a record performance in this material, known as a lead-halide perovskite, by chemically treating it through a process known as "surface passivation," which treats imperfections and reduces the likelihood that the absorbed photons will end up wasted rather than converted to useful energy.

"One large problem with perovskite solar cells is that too much absorbed sunlight was ending up as wasted heat, not useful electricity," said co-author David Ginger, a UW professor of chemistry and chief scientist at the CEI. "We are hopeful that surface passivation strategies like this will help improve the performance and stability of perovskite solar cells."

Ginger's and Hillhouse's teams worked together to demonstrate that surface passivation of perovskites sharply boosted performance to levels that would make this material among the best for thin-film solar cells. They experimented with a variety of chemicals for surface passivation before finding one, an organic compound known by its acronym TOPO, that boosted perovskite performance to levels approaching the best gallium arsenide semiconductors.

"Our team at the UW was one of the first to identify performance-limiting defects at the surfaces of perovskite materials, and now we are excited to have discovered an effective way to chemically engineer these surfaces with TOPO molecules," said co-lead author Dane deQuilettes, a postdoctoral researcher at the Massachusetts Institute of Technology who conducted this research as a UW chemistry doctoral student. "At first, we were really surprised to find that the passivated materials seemed to be just as good as gallium arsenide, which holds the solar cell efficiency record. So to double-check our results, we devised a few different approaches to confirm the improvements in perovskite material quality."

DeQuilettes and co-lead author Ian Braly, who conducted this research as a doctoral student in chemical engineering, showed that TOPO-treating a perovskite semiconductor significantly impacted both its internal and external photoluminescence quantum efficiencies—metrics used to determine how good a semiconducting material is at utilizing an absorbed photon's energy rather than losing it as heat. TOPO-treating the perovskite increased the internal photoluminescence quantum efficiencies by tenfold—from 9.4 percent to nearly 92 percent.

"Our measurements observing the efficiency with which passivated hybrid perovskites absorb and emit light show that there are no inherent material flaws preventing further solar cell improvements," said Braly. "Further, by fitting the emission spectra to a theoretical model, we showed that these materials could generate voltages 97 percent of the theoretical maximum, equal to the world record gallium arsenide solar cell and much higher than record silicon cells that only reach 84 percent."

These improvements in material quality are theoretically predicted to enable the light-to-electricity power conversion efficiency to reach 27.9 percent under regular sunlight levels, which would push the perovskite -based photovoltaic record past the best silicon devices.

The next step for perovskites, the researchers said, is to demonstrate a similar chemical passivation that is compatible with easily manufactured electrodes—as well as to experiment with other types of surface passivation.

"Perovskites have already demonstrated unprecedented success in photovoltaic devices, but there is so much room for further improvement," said deQuilettes. "Here we think we have provided a path forward for the community to better harness the sun's energy."

More information: Ian L. Braly et al. Hybrid perovskite films approaching the radiative limit with over 90% photoluminescence quantum efficiency, *Nature Photonics* (2018). DOI: 10.1038/s41566-018-0154-z

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