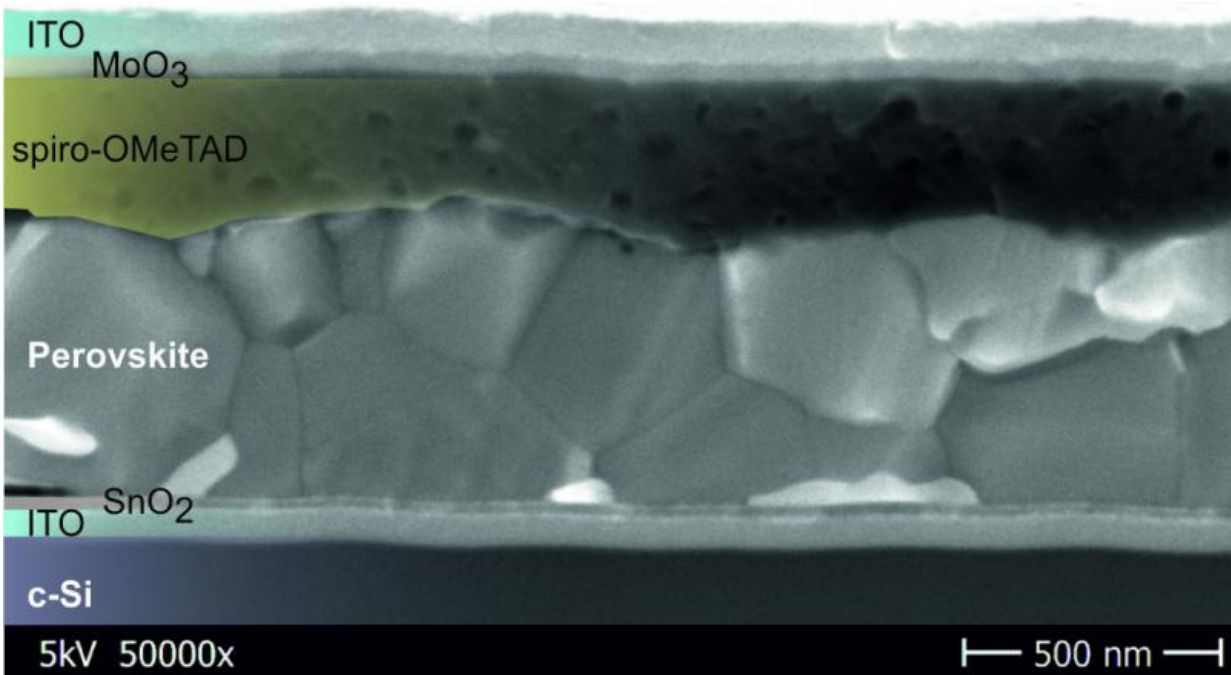


Monolithic perovskite/silicon tandem solar cell achieves record efficiency

October 28 2015



A cross-section through the tandem cell is shown by this SEM-image. Credit: HZB

Teams from the Helmholtz-Zentrum Berlin and École Polytechnique Fédérale de Lausanne, Switzerland, have been the first to successfully combine a silicon heterojunction solar cell with a perovskite solar cell monolithically into a tandem device. The hybrid tandem cell showed an efficiency of 18 percent. That is the highest currently reported value for

this type of device architecture. There are even prospects for the efficiency to reach as much as 30 percent.

Organic-inorganic perovskite materials are one of the biggest surprises in solar cell research. In just six years, the [efficiency](#) of perovskite [solar cells](#) has increased five-fold; moreover, perovskite solar cells can be manufactured from solution and be cost-effectively printed on large areas in the future.

Perovskite with silicon: good team but difficult to combine

Because perovskite layers absorb light in the blue region of the spectrum very efficiently, it is useful to combine these with silicon layers that primarily convert long-wavelength red and near-infrared light.

Nevertheless, the construction of these kinds of tandem cells in a monolithic stack of deposited layers has been difficult. This is because for high efficiency perovskite cells, it is usually required to coat the perovskite onto titanium dioxide layers that must be previously sintered at about 500 degrees Celsius. However, at such high temperatures, the amorphous silicon layers that cover the crystalline silicon wafer in silicon heterojunction degrades.

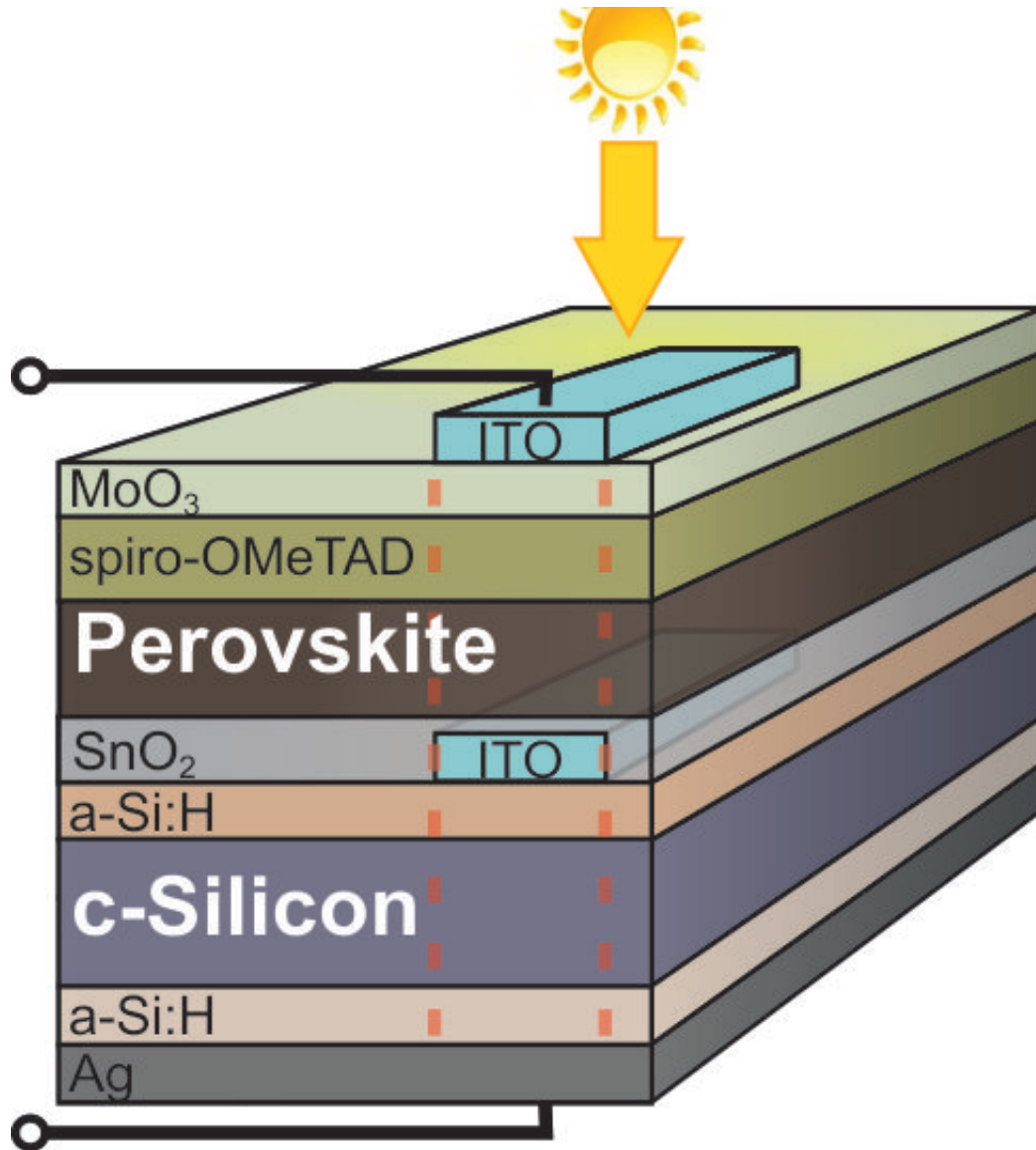
New protective layers

Now a team headed by Prof. Bernd Rech and Dr. Lars Korte at the HZB Institute for Silicon Photovoltaics in cooperation with HZB's PVcomB and a group headed by Prof. Michael Graetzel at the École Polytechnique Fédérale de Lausanne (EPFL) are the first to have fabricated this kind of monolithic tandem cell. They were successful in depositing a layer of tin dioxide at low temperatures to replace the usually used titanium dioxide. A thin layer of perovskite could then be

spin-coated onto this intermediate layer and covered with hole-conductor material. In addition, a crucial element in the device architecture is the transparent top contact. Typically, metal oxides are deposited by sputtering, but this would destroy the sensitive perovskite layer as well as the hole-conductor material. Therefore, the team from HZB modified the fabrication process and incorporated a transparent protective layer.

18 percent and high open circuit voltage

At 18 percent, this tandem cell attained an efficiency level that is nearly 20 percent higher than the efficiency of individual cells. The open-circuit voltage is 1.78 volts. "At that voltage level, this combination of materials could even be used for the generation of hydrogen from sunlight", says Dr. Steve Albrecht, lead author of the paper that has now appeared in the renowned journal *Energy & Environmental Science*.



A heterojunction silicon cell provides the base for the tandem cell. A very thin layer of transparent tin dioxide was deposited on this bottom cell, followed by 500 nm of perovskite as well as 200 nm of spiro-OMeTAD hole-conductor material. Thin MO₃ serves as a protective layer between this hole conductor and the transparent top electrode of ITO. Credit: S. Albrecht / HZB

Additional light catching structures could increase efficiencies up to 30 percent

Steve Albrecht, a postdoc in the group of Bernd Rech, developed the device design of the tandem cell and is coordinating the collaboration with EPFL. "The 18 per-cent efficiency we measured is certainly very good, but light is still being lost at the surface in the present architecture", he explains and is planning further improvements. A textured foil on the front side might be able to catch this light and couple it into the cell, which would further increase the cell's efficiency. The heterojunction silicon solar cell that simultaneously functions as the bottom cell and the substrate for the perovskite top cell offers further potential for improvement. "This perovskite-silicon tandem cell is presently still being fabricated on a polished silicon wafer. By texturing this wafer with light-trapping features, such as random pyramids, the efficiency might be increased further to 25 or even 30 per cent", says Dr. Lars Korte, head of the silicon heterojunction solar cell group at the Institute for Silicon Photovoltaics.

Integration into existing technologies

But almost more important than the maximum efficiency is the integration into existing technologies. "Silicon technology currently dominates 90 percent of the market, which means there are many established production facilities for [silicon](#) cells", says Prof. Bernd Rech. "The perovskite layers could considerably increase the efficiency level. To achieve this, the fabrication techniques only need to be supplemented with a few more production steps. For that reason, our work is also extremely interesting for industry. However, the problems of long-term stability and the lead content of [perovskite solar cells](#) still need to be solved in future research."

More information: Steve Albrecht et al. Monolithic Perovskite/Silicon-Heterojunction Tandem Solar Cells Processed at Low Temperature, *Energy Environ. Sci.* (2015). [DOI: 10.1039/C5EE02965A](https://doi.org/10.1039/C5EE02965A)

Provided by Helmholtz Association of German Research Centres

Citation: Monolithic perovskite/silicon tandem solar cell achieves record efficiency (2015, October 28) retrieved 10 April 2024 from <https://phys.org/news/2015-10-monolithic-perovskitesilicon-tandem-solar-cell.html>

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