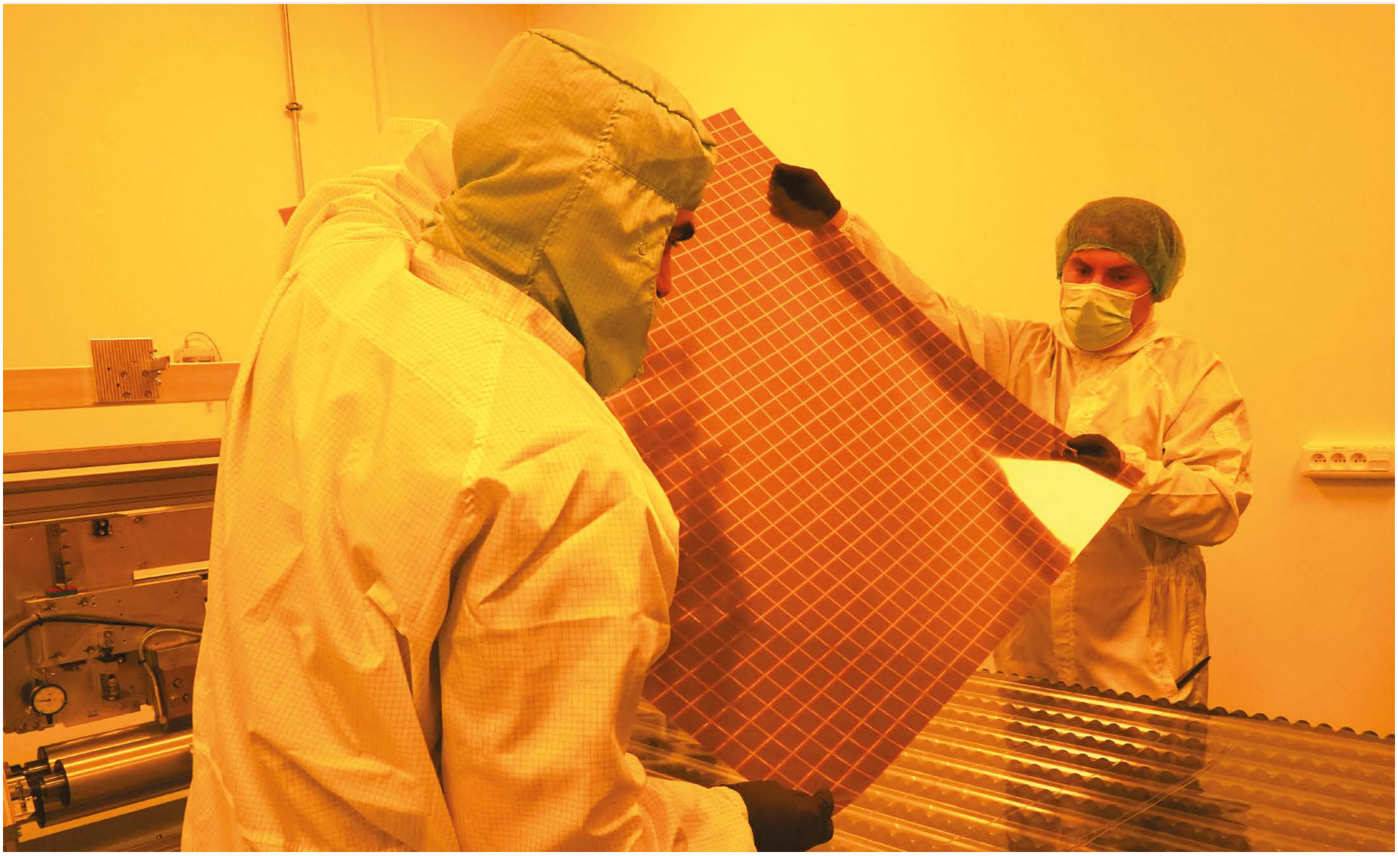

JANEK SKARZYNSKI/GETTY IMAGES

Saule Technologies staff work with their groundbreaking solar panels based on perovskite technology.

The search for solar staying power

Photovoltaic perovskites increasingly combine excellent efficiency with good durability. **By James Mitchell Crow**

As morning sunlight struck the glass façade of the Aliplast aluminium factory in August 2021, it was met by a 40 m^2 wall of louvred blinds rotating into position to intercept the summer sun. Through a thin layer of a solar material called photovoltaic perovskite, the blinds began to harvest the incoming energy at the site in Lublin, Poland.

The perovskite was made by Saule Technologies, a Warsaw company targeting perovskite solar-cell commercialization. The Aliplast installation allows Saule to test the material's performance in real-world conditions over the course of a year.

Several companies and academic research groups around the world have multi-month field tests under way to assess photovoltaic (PV) perovskite durability and performance. This marks a significant milestone for the field.

Perovskites are a broad family of crystalline materials with the generic chemical formula ABX_3. It was not until 2009 that a Japanese research team discovered that certain perovskite formulations have photovoltaic properties, converting incoming light into a voltage[1].

The performance of that first photovoltaic perovskite was modest, its 3.8% solar power conversion efficiency (PCE) far below the 20% PCE of commercial silicon panels. But silicon solar cell production requires specialized multi-day high-temperature processing steps, which makes it time-consuming and costly. Organic–inorganic lead halide perovskites, on the other hand, can be made by mixing simple salt solutions. Other labs tried their hand at photovoltaic perovskite production, and efficiencies soared.

“Right off the bat, these devices were working very well, and very quickly the efficiencies went up,” recalls physicist Sam Stranks, who began working with perovskites in 2012 as a junior research fellow at the University of Oxford, UK, and now develops them at the Cavendish Laboratory at the University of Cambridge, UK, part of the chemical engineering and biotechnology department, also in the UK. Little more than a decade since their discovery, the perovskite PCE record is now close to 26%, not far from the 27% achieved by the best performing silicon solar cells.

For practical applications, however, challenges remain. “The field has made headway in terms of efficiency, but stability has lagged behind,” says Stranks.

The properties that make these materials

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cheaper and simpler to produce make them susceptible to failure, says photovoltaic researcher Monica Lira-Cantu, a group leader at the Catalan Institute of Nanoscience and Nanotechnology in Barcelona, Spain. These photovoltaic perovskites “are soft materials, they have weak bonds”, she says. “That is positive for the fabrication, because you can do it in solution at low temperature.”

But weak bonds mean a propensity for degradation. Ions in the material are prone to wander from their position in the crystal structure, resulting in the accumulation of efficiency-sapping defects. Rooftop silicon solar panels typically carry a 25-year performance guarantee; early perovskites would have been dead within days.

Soaring efficiency

Improving perovskite durability is a challenge. They are susceptible to degradation through extrinsic factors, such as moisture, oxygen, heat and light, as well as intrinsic processes, including structural instability and ion migration, says Jingjing Xue, a perovskite researcher at Zhejiang University in Hangzhou, China. “What’s worse, these pathways can interact, which makes things much more complex,” says Xue. For example, exposure to oxygen can create vacancies in the crystal lattice that accelerate ion migration.

Early papers often trumpeted headline-grabbing PCEs, overlooking stability, says Lira-Cantu. Now, the best papers report materials combining high PCE with good stability, tested under increasingly stringent accelerated ageing conditions, she says. The need to keep moisture out of perovskite PV devices was established, for example, but nobody had considered the need to prevent gases from escaping, says Anita Ho-Baillie, a solar-cell researcher at the University of Sydney, Australia. Ho-Baillie’s team used a technique called gas chromatography/mass spectrometry (GC/MS) to show that, when hot, the organic component that is part of the most common photovoltaic perovskites can break down and be lost as a gas into the surrounding air[2]. “If we stop this outgassing, it stops the degradation,” says Ho-Baillie. Because the breakdown reaction is reversible, blocking the gases’ escape allows the perovskite time to repair itself.

“We were able to torture the cells under 1,800 hours of accelerated testing, through thermal cycles of −40 °C to 85 °C and 85% humidity,” says Ho-Baillie. The cells survived, and the team is now extending its GC/MS analysis to perovskite decomposition under the influence of heat, humidity and light. Some of the most recent advances have come from improvements to the layers around the active perovskite, which help to shepherd electric charges out of the device. “Huge progress has been made on the perovskite active layer,” says Ted Sargent, from the University of Toronto, Canada, who is combining chemistry, physics and engineering to improve perovskite PV performance. “I’m not saying we’re fully done, but the active layer had progressed so much, the charge transport layers needed to catch up.”

In a 2022 study[3] on the 2D layer that makes the electrons exit on the correct side of the active layer of the perovskite PV, Sargent reported a device with a 23.91% PCE that operated at 50% relative humidity for more than 1,000 hours without loss of efficiency.

In a related study[4], also published in 2022, Stefaan De Wolf at KAUST in Thuwal, Saudi Arabia, led a team that achieved 24.3% PCE in a perovskite PV device that retained greater than 95% of that efficiency after 1,000 hours of accelerated ageing testing at 85 °C and 85% relative humidity. “We are seeing promising long-term stability tests under elevated temperature and stress,” says Stranks. The focus now is on ensuring perovskite performance and degradation under indoor accelerated ageing tests translates into long lifetimes. Several companies are closing in on commercialization, often by layering perovskites on top of silicon in ‘tandem’ solar cells, which could theoretically reach more than 40% PCE. Oxford PV, a photovoltaics start-up based in Oxford, UK, and Brandenburg, Germany, is due to begin production at its German factory by the end of the year. California’s Swift Solar, of which Stranks is a co-founder, plans to have products on the market within two years. The first devices will be in applications with shorter lifetime demands than rooftop solar panels, Stanks says. By exploiting the low-weight, thin-film nature of perovskite PV, the company is targeting self-charging solar drones and electric cars, for example. “The first rooftop product will be at the five-year-plus mark, but it’s in the development pipeline,” says Stranks.

In 2020, Microquanta, a start-up based in Hangzhou, China, opened a perovskite PV manufacturing facility. The company, which has claimed several efficiency records for its manufactured perovskite modules, is part of a Chinese Ministry of Science and Technology project targeting 10,000-hour perovskite lifetimes. “Perovskites are a big research focus in China right now,” Xue says. Established players in the silicon PV market, which is dominated by Chinese companies, are also active.

As perovskite PV longevity edges upward, so too is the research funding intended to get it to real-world use, Stranks says. “The United States is committing a lot of money, and there is huge investment in the European Union to build up a perovskite PV industrial base.”

South Korea is another major investor, Sargent says. Funders yet to prioritize perovskites may soon be persuaded to make the jump.

James Mitchell Crow is a freelance writer based in Melbourne, Australia.

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FASTEST RISING IN ENERGY

Chinese institutions dominate the fastest rising ranks in the Nature Index for output related to the United Nations’ Sustainable Development Goal 7 (affordable and clean energy). The Swiss Federal Institute of Technology Zurich and Indian Institute of Science are the fastest rising non-Chinese institutions, at ranks 28 and 29, respectively.

Rank	Institution	Location	Share 2021	Change in Share 2020–21
1	**Chinese Academy of Sciences**	**China**	205.08	30.70
2	**Fudan University**	**China**	47.46	27.75
3	**Tsinghua University**	**China**	71.50	25.95
4	**University of Science and Technology of China**	**China**	64.86	17.53
5	**Sun Yat-sen University**	**China**	28.11	15.65
6	**Jilin University**	**China**	36.43	15.31
7	**Shanghai Jiao Tong University**	**China**	31.52	11.57
8	**Beijing Institute of Technology**	**China**	30.59	11.39
9	**Northeast Normal University**	**China**	15.27	10.93
10	**Wuhan University**	**China**	21.59	10.82

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