Perovskites take steps to industrialization

Although several companies are now working on the industrialization of perovskite solar cells, important questions around module reliability remain.

Metal halide perovskite solar cells have dominated photovoltaic (PV) research in recent years. Scientific and industrial interest has been attracted by the fast improvements in power conversion efficiency (with a current lab record of 25.2%¹) and long-term device stability at both research and commercial cell scales, as well as the development of fabrication processes compatible with industrial manufacturing. Several PV manufacturers are now working on bringing perovskite solar cells to market. In this initial phase of industrialization, each company is exploring different ways forward in terms of device configuration and processing to make perovskite solar cells suitable for various applications, from mainstream to niche markets.

In contrast to crystalline silicon (c-Si) — the PV technology with the largest market share — perovskite solar cells are a thin-film technology. Thin-film devices can be made flexible, lightweight and semi-transparent. Perovskite thin films are compatible with sheet-to-sheet and roll-to-roll printing, which offers advantages such as low manufacturing cost, high throughput and continuous production. Perovskite solar cells also perform well under low and diffuse light. These features are particularly attractive for niche markets, such as building-integrated PV, indoor applications, Internet of Things (IoT) devices or transport.

The IoT market is particularly promising, as its size is expected to grow substantially in the next few years. The first commercial perovskite-based products for the IoT are expected to appear on the market in the near future². For this kind of application, inkjet printing is a suitable manufacturing process as it allows for high-volume, large-area production and custom layouts. The added value of customization can be exploited in niche markets where the aesthetics of a solar panel may create an effective value proposition for the technology.

Perovskite solar cells can also be combined with other PV technologies, such as c-Si or copper indium gallium selenide (CIGS), into so-called two-junction (or tandem) solar cells to deliver efficiencies beyond the limit of single-junction devices. The combination of perovskite and silicon technologies is currently viewed as the most promising and fastest route to market for perovskites not

only because of the large market share held by silicon, but also due to the high efficiencies.

Silicon solar cells are close to their practical efficiency limit of 26.7% in laboratory devices. Oxford PV has demonstrated perovskite/silicon tandems that reach lab efficiencies up to 28%¹, outperforming both perovskite and silicon single-junction devices. These tandems can also exploit new silicon technologies, such as passivated emitter and rear cells and silicon heterojunction cells with back contacts, which enable bifacial design — semi-transparent devices that harvest light from both sides of the panel — and hence further improve performance³.

Perovskite/silicon solar cells are expected to appear in mass production as early as 2021⁴, with companies commencing their low-volume production lines, around the few hundreds of megawatts, by the end of this year⁵. Perovskites can also be combined in a tandem configuration with other thin-film technologies, such as CIGS, enabling lab efficiencies up to 23% but with the advantages over c-Si-based devices discussed above⁶. Recently, all-perovskite tandems have also achieved comparable lab efficiencies⁷.

Industrial interest in the technology has acted as a pull for researchers to tackle challenges faced by companies. Yet, further research efforts are needed to push towards industrialization of perovskite solar cells. These include controlling the crystallization of perovskite films over large areas, developing robust encapsulation designs and, more importantly, ensuring the long-term reliability of solar cells.

Several academic and industrial research groups have now reported that research and commercial perovskite-based solar cells have passed the International Electrotechnical Commission (IEC) accelerated stress tests developed for silicon PV technology. While passing the IEC tests gives an indication of the reliability of the solar cell in the field, the tests are not able to identify all the failure modes that perovskite PV devices could face under real-world operating conditions. The reliability of the product thus remains an open question.

Until now, the perovskite community lacked cohesion and consistency in identifying key tests that could reveal failure modes specific to perovskite cells, which is both cause and consequence of the limited

understanding of device degradation. More effort is needed to understand degradation mechanisms in the first instance. To address this challenge, Monica Lira-Cantu and Eugene Katz brought together a wide number of researchers in the field from universities, research centres and companies to reach a consensus on how to test perovskite solar cells for stability and how to accurately report data. The resulting *Consensus Statement* is published in this issue.

The systematic approach outlined in the *Consensus Statement* will hopefully help uncover degradation pathways of perovskite solar cells and foster transparency and reproducibility in the field. Deeper knowledge of degradation factors and mechanisms will mainly benefit researchers in the immediate future; the adoption of the protocols proposed in the *Consensus Statement* should enable the identification of flaws in the materials, device configurations and fabrication processes that lead to failures in the field. In the long term, the ability to control failure modes will determine the commercial success of the technology.

Perovskite PV technology has entered its industrialization phase and is beginning to explore the feasibility of various device architectures and manufacturing processes for different markets. Companies are setting up low-volume production lines, partnering with silicon and CIGS solar cell manufacturers and attracting the interest of investors and stakeholders. Nonetheless, the commercial success of perovskite solar cells still depends on the ability to avoid premature field failures. The upcoming years will be crucial for the future of perovskite PV technology.

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