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Perovskite-Silicon Tandems
Edge Forward

Brandon R. Sutherland1,∗

Crystalline silicon (c-Si) photovoltaics dominate the global solar cell market and will continue to do so in the absence of a major, commercially ready technological breakthrough. Emerging photovoltaic materials have the opportunity to augment silicon in a tandem configuration, where two or more solar cells are connected to more efficiently harvest sunlight. Recently in Science, Xu et al. and Hou et al. reported parallel processes to realize high-efficiency monolithic perovskite/c-Si tandems.

In the wake of a global COVID-19 outbreak, the 2020 demand for solar photovoltaics (PV) may fall below previous year values for the first time in decades. Reduced liquid capital for new installations, disrupted supply chains in the Chinese manufacturing sector—which provides the majority of silicon used in photovoltaics—and lessened global energy demand may stunt the seemingly irreversible momentum of renewables. Bloomberg New Energy Finance has already lowered their 2020 PV demand forecast from a range of 121–152 GW to 108–143 GW.1 The PV industry may have hit some recent snags that could affect near-term demand, but its long-term prospects to provide an increasing proportion of energy production remain promising.

Owing to numerous economic, technological, political, and social factors, the cost of PV has dropped dramatically over the last several decades.2 PV energy generation is now cost competitive with fossil fuels in most parts of the world. Recent estimates have unsubsidized utility-scale PV in the United States at a mean levelized cost of energy (LCOE, a measure of the break-even point of energy generation considering an installation’s entire life-span and cost factors) near 40 US$/MWh, compared to 109 US$/MWh for coal.3 While promising, there remain many challenges to driving PV market share higher, including the need for storage to enable all-day, on-demand electricity access.

To increase the rate of global PV adoption, solar cells must continue to find ways to provide energy more cost efficiently. This requires solar cells to be more efficient, to be lower in cost, or both. As the price of PV has continued to rapidly decrease, the majority of the cost is not in the module itself but in the balance of systems—installation labor, mounting structures, and external electrical components. Perhaps the greatest opportunity to further decrease the LCOE of PV is to increase its efficiency, but this is a challenging undertaking.

Over 90% of global PV market share comprises solar cells made from crystalline silicon (c-Si).4 The intrinsic efficiency limit of silicon PV is approximately 29%. The highest lab-scale results for c-Si to date are 26.7%,5 and most commercial modules are in the 20% efficiency range. Increasing the performance of silicon solar cells is challenging and doing so without radically altering the manufacturing process of existing PV plants adds further complication. An alternative approach is to take a commercial silicon solar cell and connect it in tandem with one or more different solar cells with a complementary absorption profile. Tandem solar cells are designed such that each sub cell harnesses photons closer to its absorption band-edge to reduce thermalization losses.

One of the most active silicon tandem structure presently studied at the research scale uses a silicon bottom cell and a top cell based on a metal halide perovskite absorbing layer. Metal halide perovskites were introduced as a solar-harvesting material roughly a decade ago.6 Today they are the most efficient third-generation photovoltaic technology. Unlike crystalline silicon, metal halide perovskites are strong solar absorbers, enabling thin-film and lightweight PV. They can be manufactured using low-temperature processing from solution or vacuum, potentially enabling low-cost mass manufacturing. Their promising optoelectronic properties have enabled rapid advances in PV performance, boasting efficiencies up to 25.2% single junction and up to 29.1% for tandems with c-Si, both results presently unpublished.7

Recently in Science, Xu et al. and Hou et al. reported 2 parallel advances in perovskite/c-Si tandem solar cells.8,9 These devices (schematics of which are shown in Figure 1) represent the state-of-the-art published results for this technology. The process employed by Xu et al. was to alloy a FA/Cs/Pb/I/Br-based perovskite with MAPbCl3 to increase its bandgap and improve its optoelectronic properties. This was integrated into a single-side textured c-Si bottom cell and capped with a textured polydimethylsiloxane encapsulating layer. The

1. Joule, Cell Press, 50 Hampshire Street, 5th Floor, Cambridge, MA 02139, USA
*Correspondence: bsutherland@cell.com
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best-performing cell achieved a single-scan efficiency of 27% at 1 cm² (certified as 25.8% stabilized efficiency after 1 month of storage in an inert environment). The strategy employed by Hou et al. was to fabricate perovskites directly onto double-sided textured c-Si bottom cells and introduce a top-passivating layer, realizing a best certified efficiency of 25.7%. Unlike previous work that relied on co-evaporation or blade coating, this effort demonstrates that highly accessible spin coating can sufficiently cover fully textured silicon.

For a new material to compete with silicon on the PV market involves displacing a multi-billion-dollar industry that has benefitted from over 40 years of economic scaling. Tandems present an attractive opportunity for perovskites to augment the booming silicon market, rather than compete with it directly. Early reports of perovskite/silicon tandems in 2015 demonstrated efficiencies of up to 13.7%. In 5 years, the published performance results have now nearly doubled. With continued rapid performance advances like what has been reported in these works, the prospects of a commercially viable perovskite/silicon tandem are promising.

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