All-perovskite tandem solar cells with 24.8% efficiency

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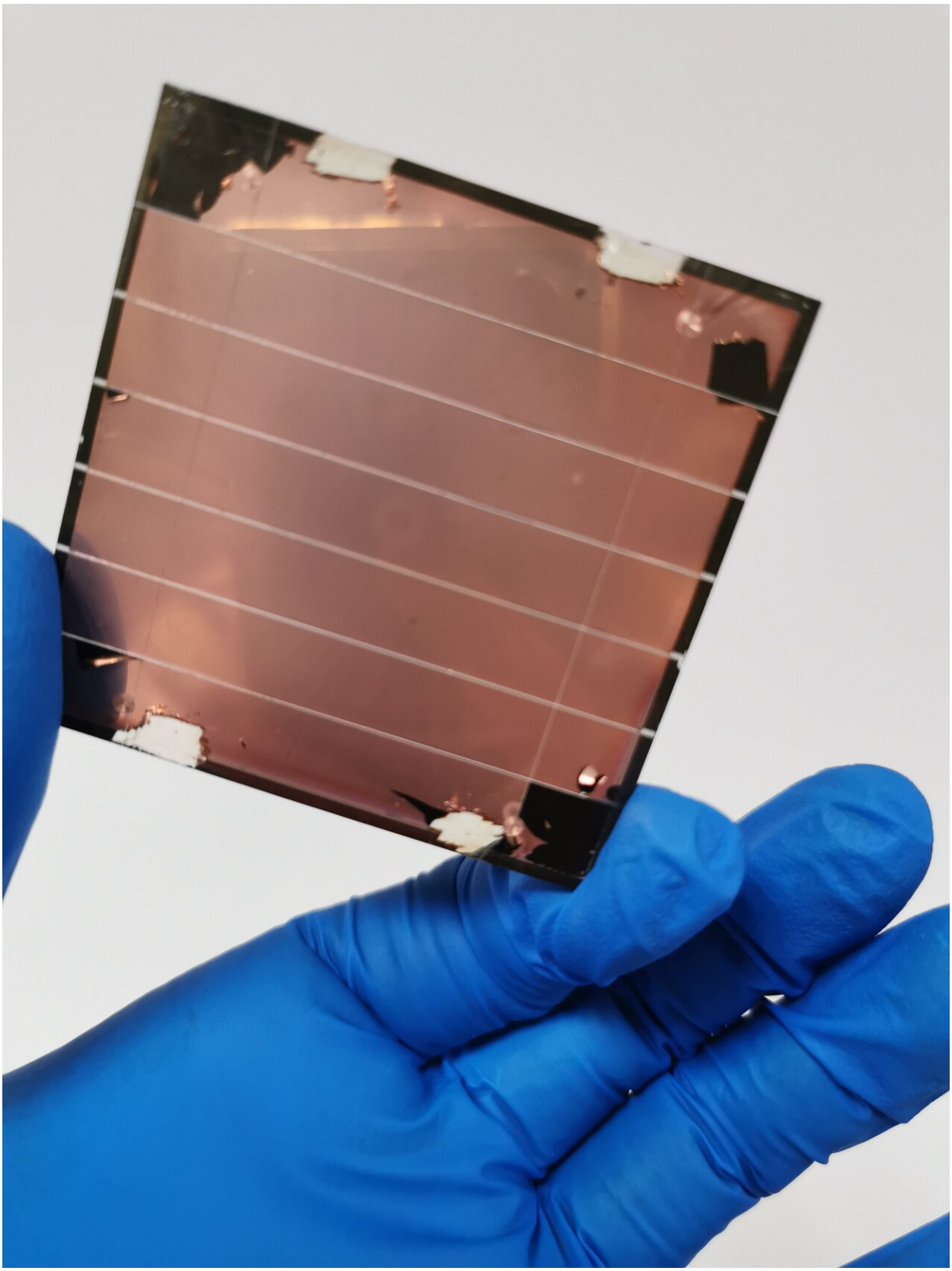

A photograph of an all-perovskite tandem solar cell fabricated by the researchers. Credit: Lin et al.

A team of researchers at Nanjing University in China and the University of Toronto in Canada have recently fabricated all-perovskite tandem solar cells (PSCs), a type of solar cell with a key perovskite structured component. These new solar cells, presented in a paper featured in *Nature Energy*, were achieve remarkable efficiency, outperforming other existing solutions.

"The initial idea for this research work was to make all-perovskite tandem solar cells which could be more efficient than single-junction perovskite solar cells," Hairen Tan, the lead researcher for the study, told TechXplore.

Perovskites are a group of minerals that have the same crystal structure as perovskite, a yellow, brown or black mineral consisting largely of calcium titanate. Over the past few years, several research teams worldwide have been trying to develop solar cells using this material, typically utilizing either wide-bandgap (~1.8 eV) or narrow-bandgap (~1.2 eV) perovskites.

Fabricating all-perovskite tandem solar cells, thus combining wide-bandgap and narrow-bandgap perovskites together, could lead to a higher power conversion efficiency (PCEs) than that attained by single-junction cells without increasing fabrication costs. In order to build this new type of solar cell, however, researchers need to find a way to enhance the performance of each subcell, while also integrating the wide-bandgap and narrow-bandgap cells synergistically.

"Unfortunately, previously reported mixed Pb-Sn narrow-bandgap

perovskite solar cells have exhibited low efficiencies (PCE~18-20 percent) and low short-circuit current densities (J_{sc}~28-30 mA/cm^2)," Tan said. "These lie well below their potential, and below the performance of the best Pb-based single-junction perovskite cells."

The key reason for the poor performance observed in previously developed narrow-bandgap perovskite solar cells is that one of their key components, known as Sn^{2+}, readily oxidizes into Sn^{4+}. As a result, the resultant cell film exhibits high trap densities and short carrier diffusion lengths. In their study, Tan and his colleagues wanted to identify solutions that could help to overcome this limitation.

"Our main objective in this work is initiating a strategy to enlarge the diffusion of narrow-bandgap perovskite solar cells and thus to achieve better performed tandem solar cells," Tan said. "Sn vacancies are typically caused by the incorporation of Sn^{4+} (a product of Sn^{2+} oxidation) in the mixed Pb-Sn perovskites. We took the view that a new strategy to prevent the oxidization of Sn^{2+} in the precursor solution could dramatically improve charge carrier diffusion length."

Tan and his colleagues introduced a new chemical approach that could ultimately enhance the performance of PSCs. This approach is based on a comproportionation reaction that leads to substantial advancements in the charge carrier diffusion lengths of mixed Pb-Sn narrow-bandgap perovskites.

Previously proposed approaches are all characterized by sub-micrometer diffusion lengths, which can impair the cell's overall efficiency. In their work, on the other hand, Tan and his colleagues achieved a 3 μm diffusion length; a remarkable result that enables performance-record-breaking Pb-Sn cells and all-perovskite tandem cells.

"We achieved this by developing a tin-reduced precursor solution

strategy that returns the Sn^{4+} (an oxidization product of Sn^{2+}) back to Sn^{2+} via a comproportionation reaction in the precursor solution," Tan explained.

The oxidation of tin-containing perovskites has been a crucial problem for the development of solar cells with a perovskite component, as it can negatively affect their performance and thus hinder their application in a variety of settings. The new chemical approach introduced by Tan and his colleagues provides an alternative route for fabricating tandem solar cells using tin-containing narrow-bandgap perovskite, which leads to more stable and efficient cells.

"Our work also highlights that the electronic quality of tin-containing perovskites can be comparable to that of lead halide perovskites that has demonstrated efficiency similar to crystalline silicon cells," Tan added. "We have no doubt that our tandem approach will finally offer us an avenue to very cheap, yet highly efficient solar devices."

In their study, Tan and his colleagues used their chemical approach to fabricate monolithic all-perovskite tandem cells and then tested their performance. They found that their tandem cells obtained impressive independently certified PCEs of 24.8 percent for small-area devices (0.049 cm^2) and 22.1 percent for large-area devices (1.05 cm^2).

Moreover, the cells retained 90 percent of their performance after operating for over 400 hours at their maximum power point under full one sun illumination. In the future, the approach introduced by this team of researchers could inform the development of more efficient and cost-effective solar-powered devices.

"We now plan to further improve the power conversion efficiency of all-perovskite tandem solar cells beyond 28 percent," Tan said. "The first possible way to achieve this will be to reduce the photovoltage loss in the

wide-bandgap perovskite solar cell. Another possibility is to reduce the optical losses in the tunneling recombination junction."

More information: Renxing Lin et al. Monolithic all-perovskite tandem solar cells with 24.8% efficiency exploiting comproportionation to suppress Sn(ii) oxidation in precursor ink, *Nature Energy* (2019). DOI: 10.1038/s41560-019-0466-3