All perovskite tandem solar cells with an efficiency of over 26.5%

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The efficiency of the lead perovskite solar cells (Pb-PVK-PV) is now over 25% (1,2). Tandem cells consisting of the Pb-PVK-PV as the top cell and Si solar cells as the bottom cells have attracted attention as solar cells with an efficiency higher than Pb-PVK-PV. The certified efficiency is now 32.5% (2). In addition, especially, all perovskite tandem solar cells have an advantage over the tandem cells consisting of Pb-PVK-PV(top)/inorganic solar cells(bottom) from the viewpoint of flexible tandem solar cells because the low temperature-printable process fabricates both top and bottom cells. 28% efficiency has been reported as the all-perovskite tandem solar cells (1).

The all-perovskite tandem solar cells comprise Pb-PVK PVs as the top cells and tin-lead alloyed perovskite solar cells (SnPb-PVK-PV) with the bottom layer. The former is the Pb-PVK-PV with a wide bandgap of 1.77 eV ($FA_{0.8}Cs_{0.2}PbI_{1.8}Br_{1.2}$), and the latter is the SnPb-PVK-PV with a narrow bandgap of 1.25 eV ($Cs_{0.025}FA_{0.475}MA_{0.5}Sn_{0.5}Pb_{0.5}I_{2.925}Br_{0.075}$). The structure of the top cells is as follows: HTL/($FA_{0.8}Cs_{0.2}PbI_{1.8}Br_{1.2}$)/C60. The bottom layer is composed of HTL/ ($Cs_{0.025}FA_{0.475}MA_{0.5}Sn_{0.5}Pb_{0.5}I_{2.925}Br_{0.075}$)/C60. ALD-$SnO_2$/IZO was used as the interlayer of the top and bottom cells. The ALD-SnO_2 was employed to decrease the spatter damage against the Pb-PVK-PV during the preparation of the IZO layer. We have already reported the SnPb-PVK solar cells with 23.3% (3). The bottom layer was prepared by the method previously reported (3).

The top layer for the perovskite/Si tandem solar cells is around 1.6 eV. However, in the case of the all-perovskite tandem solar cells, Pb-PVK-PV with a 1.7-1.8 eV band gap was needed. The band gap is wider than the Pb-PVK-PV, showing higher efficiency over 25% (bandgap: 1.55-1.6 eV). The re-optimization of the solar cell structure was needed. We investigated the relationship among the structure of the HTL, the band energy diagram, and the solar cell efficiency, and we optimized the top cell structure. This presentation discusses the relationship between band energy alignment, carrier dynamics, and solar cell efficiency. Finally, the tandem cell with an efficiency of over 26.5% is reported.

Reference

1. Martin Green, et al., Prog Photovolt Res Appl, 2022;30:687–701, Efficiency Table 60.
2. NREL 2021 https://www.nrel.gov/pv/cell-efficiency.html.
3. G. Kapil, T. Bessho, Y. Sanehira, S. R. Sahamir, M. Chen, A. K. Baranwal, D. Liu, Y. Sono, D. Hirotani, D. Nomura, K. Nishimura, M. A. Kamarudin, Q. Shen, H. Segawa, S. Hayase ACS Energy Lett. 2022, 7, 966-974.