

Perovskite/perovskite tandem solar cells with efficiency higher than 26%

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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 the 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 view point of flexible tandem solar cells, because both top and bottom cells are fabricated by the low temperature-printable process. 28% efficiency has been reported as the all-perovskite tandem solar cells (1).

The all-perovskite tandem solar cells are composed of 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 ($\text{FA}_{0.8}\text{Cs}_{0.2}\text{PbI}_{1.8}\text{Br}_{1.2}$) and the latter is the SnPb-PVK-PV with a narrow bandgap of 1.25 eV ($\text{Cs}_{0.025}\text{FA}_{0.475}\text{MA}_{0.5}\text{Sn}_{0.5}\text{Pb}_{0.5}\text{I}_{2.925}\text{Br}_{0.075}$). The structure of the top cells is as follows: HTL/($\text{FA}_{0.8}\text{Cs}_{0.2}\text{PbI}_{1.8}\text{Br}_{1.2}$)/C60. The bottom layer is composed of HTL/($\text{Cs}_{0.025}\text{FA}_{0.475}\text{MA}_{0.5}\text{Sn}_{0.5}\text{Pb}_{0.5}\text{I}_{2.925}\text{Br}_{0.075}$)/C60. ALD-SnO₂/IZO was used as the interlayer of the top cell and the bottom cell. The ALD-SnO₂ 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 1.7-1.8 eV band gap were needed. The bandgap is wider than that of 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. In this presentation, especially, the relationship between the band energy alignment including the carrier dynamics and the solar cell efficiency is discussed. Finally, the tandem cell with the efficiency over 26% 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.