

## PROGRESS IN HIGH EFFICIENCY CIGS SOLAR CELL AND MODULE RESEARCH AT SOLAR FRONTIER

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As the largest manufacturer of Cu(In,Ga)(Se,S)<sub>2</sub> (CIGS) thin-film photovoltaic module, Solar Frontier K.K. has continuously improved energy conversion efficiency of both small-area cells and production modules. In 2015–2016, we have achieved 22.0 and 22.3% efficiencies on Cd-free and CdS-buffered small-area cells, respectively, whereas the aperture area efficiency of production modules still remains around 15–16%. To bridge the technology gap between cells and modules, 30 cm × 30 cm-sized submodules have also been intensively developed. Recently, we have achieved a new record aperture area efficiency of 19.2% on a Cd-free CIGS submodule, which was independently confirmed by AIST (Figure 1). This significant leap from our previous record of 17.5% in 2014 was mainly brought about by transferring technologies developed in the record Cd-free cells, such as highly transparent TCO, optical and electronic improvements of CIGS absorber layer, and replacement of undoped ZnO by wide-bandgap (Zn,Mg)O. Furthermore, by applying an alkali metal treatment on the absorber surface, 19.8% aperture area efficiency has been achieved on a 7 cm × 5 cm-sized Cd-free minimodule, which was independently verified by Fraunhofer ISE. The smaller substrate size was due to the limitation of the instruments used for the treatment. The device structure and the fabrication process are basically the same as those of the record submodule except for the treatment. Importantly, these achievements were demonstrated on Cd-free-buffered CIGS sub(mini)modules having identical structure to the production module. In this talk, a brief overview of our R&D activity in the development of CIGS solar cells and sub(mini)modules including technical details of these achievements and the latest status will be presented. By further transferring these technologies, our next-generation production modules with 16–17% aperture area efficiency are expected to appear in the near future.

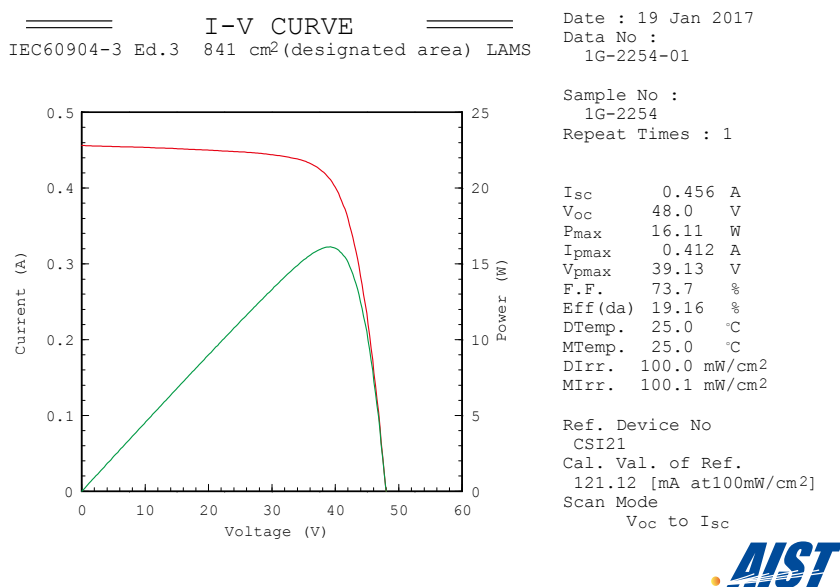


Figure 1: Performance confirmation of a new record Cd-free CIGS submodule measured by AIST.