Si-based tandem cells have been thought as the promising technology to breaking the limit of the performance wall of high-efficiency Si cells. However, it was gradually understood that the performance in the real world may not as excellent as it was expected. One of the issues is lower outdoor performance in the outdoor operation due to spectrum mismatch influenced by fluctuation of sun-height and atmospheric parameters.

To investigate this issue, at first, we estimated the range of the spectrum fluctuation and its influence by the data fitting to the spectrum model. Then, the cell performance calculation considering spectrum mismatching (Figure 1). Spectrum data was also collected from global and domestic database and assumed both the best and the worst distribution of key atmospheric parameters (aerosol density and water precipitation). The, using a Monte Carlo method, the distribution of yearly-averaged efficiency was simulated to both 2-terminal and 4-terminal configuration of the Si-based tandem cells with “optimized-bandgap”. The optimized bandgap means that the numerically-calculated best bandgap combination that maximized the annual energy generation by the spectrum data in the first year. The fluctuation of the atmospheric parameters will not the same in the next year, so that the yearly-averaged efficiency has some variation and distribution (Figure 2).

Apparently, 2-terminal configuration had a significant impact from fluctuation of atmospheric parameters and its yearly-averaged efficiency dropped with wide variation in years. 4-terminal cell had also distribution in the yearly-average efficiency but its influence was less and kept high efficiency. Unlike Ge-based III-V 3-junction cells, the water precipitation did not impact to the annual efficiency drop since the band-edge of Si is higher energy than water absorption bands. On the contrary, thick water depth improved yearly-averaged efficiency because the portion of longer wavelength that is not used for energy generation in Si cell decreases.

Apparently, 4-terminal configuration, typically using mechanical-stack structure has advantage in annual energy generation. Although, the interconnection becomes complicated it has other advantages such as PCSC (partially concentrating onto high-efficiency III-V cell) and no requirement of Si cells fit to monolithic growth and wafer-bonding.

Figure 1: Example of parameter fitting from measured spectrum (top) and fluctuation of the balance of photo-current of two types of multi-junction cells influenced by spectrum.

Figure 2: Yearly-averaged efficiency distribution of the optimized 2-terminal and 4-terminal Si-based 3-junction tandem cells influenced spectrum fluctuation ranging best/worst distribution of atmospheric parameters. Series resistance = 5 Ωcm²