OUTPUT EVALUATION OF A WORLD’S HIGHEST EFFICIENCY FLAT SUB-MODULE WITH InGaP/GaAs/InGaAs INVERTED TRIPLE-JUNCTION SOLAR CELL UNDER OUTDOOR OPERATION

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We discussed the outdoor operation of a fixed flat sub-module with InGaP/GaAs/InGaAs inverted triple-junction solar cell for the first time in the world. The inverted triple-junction solar cell holds the world record for the conversion efficiency of sub-module size and reached 31.17% under the standard test condition. In this paper, the spectral distribution in sun radiation was explained using the average photon energy (APE) index. The relationship between APE index and energy yield of the sub-module with InGaP/GaAs/InGaAs inverted triple-junction solar cell was discussed. The module temperature (Tmod) under the real operating conditions during its operation hours were also taken into account in the observation because the temperature affected the open circuit voltage (Voc) of solar cells.

The flat sub-module with InGaP/GaAs/InGaAs inverted triple-junction solar cell with an aperture area of 986 cm² was fabricated by sharp. The sub-module facing due south with a tilt angle of 35° was installed in University of Miyazaki, Miyazaki, Japan together with spectroradiometer (MS711 and MS712, EKO), which measured the global solar spectral with the wavelength range 300-1700 nm. The Si solar cell module was also installed as a reference. The outputs of solar cells were measured every 3 minutes by IV tracer (MP-160, EKO). The resistance temperature detectors (Pt100) were in direct contact with the back-surface to detect the module temperature (Tmod). The global irradiance with a tilt angle of 35° (GTI) and Tmod were also recorded every 3 minutes. The output characteristics of the modules were analysed using data recorded from August 2016 to February 2017.

Throughout this study, the outdoor environmental condition was represented by APE and Tmod indexes. Frequent conditions of each APE and Tmod were observed, and on the basis of that, an integrated GTI and energy yield map was constructed. Therefore, the relationship of environmental conditions to integrated GTI and energy yield could be determined.

Figure 1 shows the contour maps of conversion efficiency for (a) sub-module with inverted triple-junction solar cell and (b) Si solar cell module as functions of APE and Tmod. The conversion efficiency for inverted triple-junction solar cell was markedly affected by APE rather than by Tmod under real environmental conditions, as shown in Fig. 1 (a). The highest conversion efficiency value of the sub-module was observed at 1.60 eV in APE, which is the value of the AM 1.5 global standard spectral. The conversion efficiency of the sub-module decreased for APE values other than 1.60 eV. A reason of the decreasing conversion efficiency of inverted triple-junction solar cell was the current mismatch of each subcell. Under the red-rich spectral conditions (low APE region), the photocurrent of the top subcell decreases and limits the short circuit current (Isc). On the other hand, under the blue-rich spectral conditions (high APE region), the photocurrent of the bottom subcell decreases and limits Isc. In contrast, the conversion efficiency of Si solar cell module showed no change regardless of the change in the APE value as shown in Fig. 1 (b), because the Si solar cell was composed of a single-junction solar cell.

Figure 1. Contour maps of conversion efficiency for (a) inverted triple-junction solar cell sub-module and (b) Si solar cell module as functions of APE and Tmod.