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# ２接合タンデム太陽電池効率の内部発光量子収率依存性

# Conversion Efficiency of Double-Junction Tandem Solar Cells Depending on Internal Luminescence Quantum Yields

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Shockley and Queisser, in their seminal paper[1], not only formulated the conversion efficiency $\eta_{sc}$ of single junction solar cells in the detailed-balance limit (S-Q limit), but also calculated the effects of finite external luminescence quantum yield ($y_{ext}$) less than 100%. Calculated results of the solar cell efficiency $\eta_{sc}$ for various values of $y_{ext}$ are often compared with reported record efficiencies of various solar cells [2]. Recently, Miller and coworkers [3] pointed out that the approach to the S-Q limit needs a high value of the external yield $y_{ext}$, which then needs an extremely high internal luminescence quantum yield ($y_{int}$) and bottom-surface reflectivity $R$. They also analyzed the sensitivities of $\eta_{sc}$ on $y_{int}$ and $R$.

In this work, we theoretically analyzed the efficiency $\eta_{sc}$ of double-junction tandem solar cells for the optimized band gap energies ($E_{g1}$ and $E_{g2}$) including their dependence on the internal yields ($y_{int1}$ and $y_{int2}$) of the top and bottom sub-cells. As the internal yields decrease from 1, the calculated $\eta_{sc}$ first decreases drastically for high internal yields, and relatively slowly for low internal yields, as shown in Fig. 1 (a-c). The optimal bandgap energies $E_{g1}$ and $E_{g2}$, shown in Fig. 1 (d, e), increase in a very similar way. When $y_{int1}$ and $y_{int2}$ are both less than 0.9, their effects on $\eta_{sc}$ are symmetric. When at least one of $y_{int1}$ and $y_{int2}$ is greater than 0.9, however, their effects on $\eta_{sc}$ are asymmetric: The $\eta_{sc}$ is more sensitive to $y_{int2}$ of bottom cell than $y_{int1}$ of top cell. When the $y_{int1}$ and $y_{int2}$ are both less than 0.3, there exists a linear logarithmic relation between $\eta_{sc}$ and the geometric mean $y_{int}{*}=(y_{int1}\, y_{int2})^{0.5}$, as shown in Fig. 1 (b).

References: [1] W. Shockley and H. J. Queisser, J. Appl. Phys. 32, 510 (1961). [2] M. A. Green, Prog. Photovolt. Res. Appl. 20, 472 (2012). [3] O. D. Miller et al., IEEE J. Photovoltaics 2, 303 (2012).

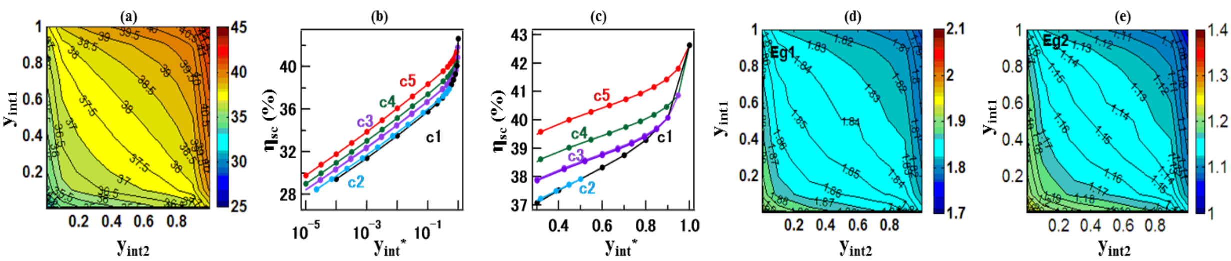


Figure 1 (a, d, e) The $\eta_{sc}$ (%), the optimal $E_{g1}$, $E_{g2}$ as a function of the two internal yields ($y_{int1}$ and $y_{int2}$). (b, c) The change tendency of $\eta_{sc}$ with $y_{int}$* in the follow conditions: c1 is $y_{int1}$=$y_{int2}$; c2 is $y_{int1}$=0.5 and $y_{int2}$=0.5; c3 is $y_{int1}$=0.9 and $y_{int2}$=0.9; c4 is $y_{int1}$=1; c5 is $y_{int2}$=1, respectively. Reflectivity of 0 and 1 was assumed for the top and bottom surfaces. Optical thickness $\alpha l$=5 was assumed for both of the top and bottom sub cells.