EFFICIENCY OF TANDEM SOLAR CELL SYSTEMS AS FUNCTION OF TEMPERATURE AND SOLAR ENERGY CONCENTRATION RATIO

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ABSTRACT

This paper presents the results of a comprehensive theoretical analysis of tandem photovoltaic solar cells as a function of temperature and solar concentration ratio. The I-V characteristics of the solar cells were assumed to be governed by the relation

$$I = I_o(e^{qV/AkT} - 1)$$

with $I_o = Ke^{-E_G/BkT}$ and $A = B$. The overall efficiencies of tandem cell stacks consisting of as many as 24 cells having gaps in the 0.7- to 3.6-eV range were calculated for temperatures of 200, 300, 400, and 500 K and for illumination by an AM0 solar spectrum having concentration ratios C of 1, 100, 500, and 1000 suns. For ideal diodes ($A = B = 1$), the calculations show that the optimized overall efficiency has a limiting value η_{opt} of approximately 70 percent for $T = 200$ K and $C = 1000$. As shown in the accompanying figure, for $T = 300$ K and $C = 1000$, this limiting efficiency approaches 60 percent. The table shows the optimum combination of E_G values for various numbers of solar cells, $T = 300$ K, and various concentration ratios. Most of the gain in efficiency occurs with between 6 and 10 semiconductors in the tandem system (e. g., for $T = 300$ K and $C = 1000$ an optimized, six-cell system has a theoretical limit efficiency of about 53 percent). Calculations were also conducted for the $A = B = 2$ case (nonideal diode behavior); in this case the limiting value of η for a 24-cell system is about 65 percent at 200 K and 55 percent at 300 K.

Variation of optimum efficiency with number of cells

Bandgap Range: 0.7 to 3.0; A=B=1; 300K

100 Suns:

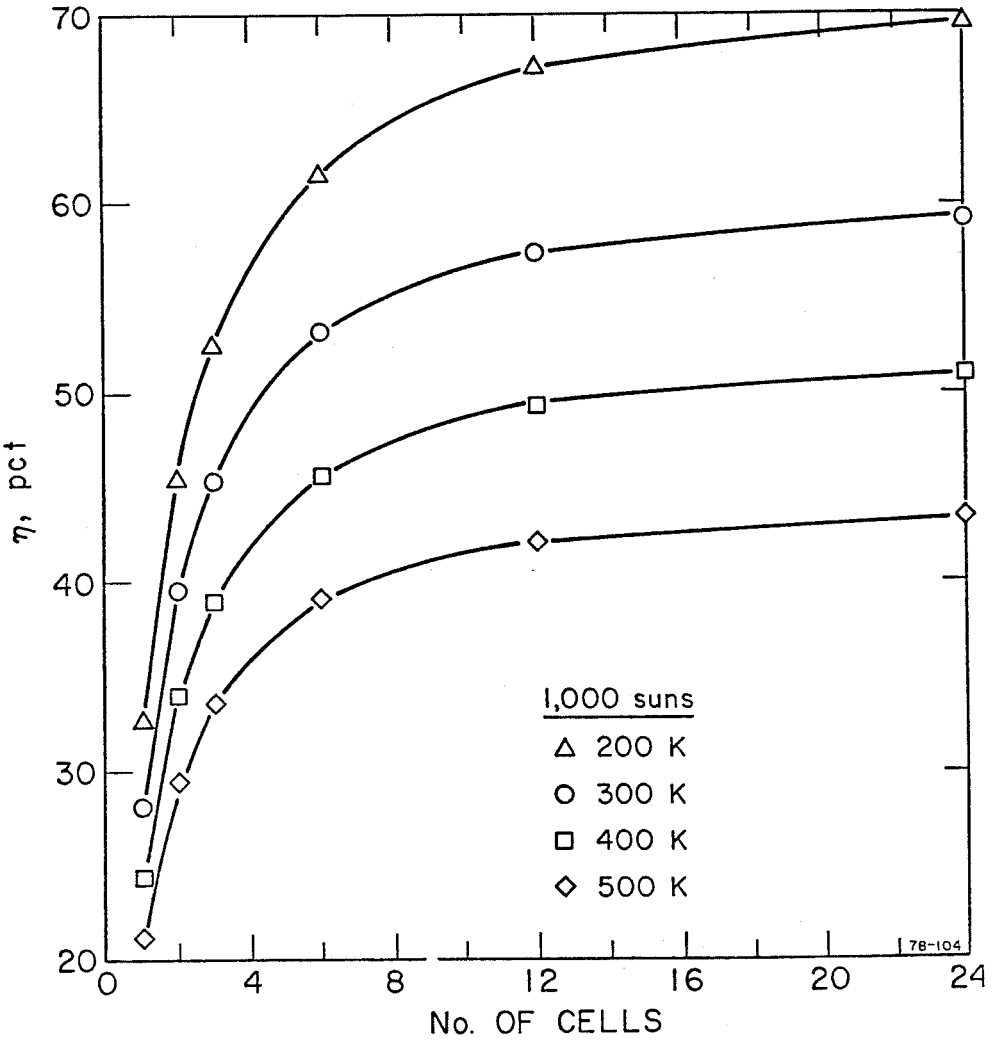
No. of Cells:	1	2	3	6	12	24
E_G values (eV):	1.4	1.8 & 1.0	2.3, 1.5 & 0.9	2.6, 2.1, 1.7 1.3, 1.0, 0.7	0.7 to 2.9 in intervals of 0.2	0.7 to 3.0 in intervals of 0.1
Efficiency:	26.43	37.05	42.52	40.13	54.10	55.96

500 Suns:

No. of Cells:	1	2	3	6	12	24
E_G values (eV):	1.3	1.8 & 1.0	2.2, 1.4 & 0.8	2.6, 2.2, 1.8 1.4, 1.0, 0.7	0.7 to 2.9 in in intervals of 0.2	0.7 to 3.0 in intervals of 0.2
Efficiency:	27.62	38.80	44.46	52.26	56.38	58.21

1000 Suns:

No. of Cells:	1	2	3	6	12	24
E_G values (eV):	1.3	1.8 & 1.0	2.2, 1.4 & 0.8	2.5, 2.1, 1.7 1.0 & 0.7	0.7 to 2.3 in intervals of 0.2	0.7 to 3.0 in intervals 0.2
Efficiency:	28.18	39.56	45.37	53.21	57.37	59.22



Variation of efficiency with number of cells at various temperatures. C = 1000; AMO spectrum.