High Efficiency Solar System by Current Matched Partitions

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***Abstract*-Current matching in multi-junction solar cells has been an issue that up to now has had few good solutions. It is important to match the current to produce efficient cells. This paper describes partitioning the different junctions to be able to match the current. This is a simple process that will allow triple-junction concentrator cells to become over 46% efficient. The paper also discusses how to use the techniques to make an efficient four-junction solar.**

Index Terms-solar cell and system, current matched partitions

I. Introduction

The efficiency has been improved significantly since the early 1980's, which had solar cells with 15% efficiency to recent reported 42.4% efficiency. This means that solar cell applications will enter new areas for power applications with increased efficiency and the decreasing of cost. This would allow the profound diminishing of environment pollution by reducing other traditional energy sources. Although solar cells today are used significantly for practical and economic reasons, a potential benefit of solar energy is that it is one of the most environmentally friendly of any other electrical generating source. The environmental impact of carbon dioxide as a byproduct for current electricity generation causing the Greenhouse Effect, adds an important reason for research in solar cell and its application.

II. Background

Since the multi-junction solar cell has been developed in past decades, it has been recognized as the high efficient solar cell that have materials with different band gaps and that the current for the different junctions should match as close as possible [1]. With more junctions the problem of matching the current becomes more difficult.

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The electrical power from a multi-junction solar cell with the junctions connected in series is the sum of the voltage times the minimum of the current or for a triple junction cell:

$$P = (V_1 + V_2 + V_3) * \mathrm{Min}\,(C_1, C_2, C_3) \qquad (1)$$

Current matching has in the past been considered a difficult problem. Some of the approaches have been to make the upper layer(s) be thinner or thicker than what would be optimal to get the most power to enable better current matching [1].

III Current partition comparison

A. EXAMPLES USING CONCENTRATOR SOLAR CELLS

We use the ASTM G173 -03 Reference Spectra for all our calculations. In the Spectrolab concentrator cells where the best cells are over 39% efficient, they use band gaps of 1.88 eV, 1.41 eV and 0.67 eV [2] for their triple junction solar cell giving wavelengths of 660 nm, 879 nm, 1851 nm respectively. These band gaps yields the following table:

Table 1. Concentrator solar cell comparison-1

	λ 1	λ 2	λ 3	
Power	298.97	193.3	172.45	Sum= 664.73
Voltage	1.88	1.41	0.67	Sum = 3.96
Current	159.13	137.0	257.42	Min = 137.03
				Electricity=542.56

Note that the different junctions are not current matched very well. The third junction has 1.88 times more current than the second junction. By partitioning the different junctions we have the following results:

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Table 2. Concentrator solar cell comparison-2

Partitions	4	3	6	
V'	7.52	4.23	4.02	Sum= 15.77
C'	39.78	45.68	42.0	Min = 39.78
				Electricity=627.24

This is a 15.6% improvement over the original cell or a 45% efficient concentrator cell assuming that the fill factor would be the same.

By using slightly more partitions for the different junctions we have the following results:

Table 3. Concentrator solar cell comparison-3

Partitions	5	4	8	
V'	9.38	5.64	5.36	Sum= 20.40
C'	31.8	34.26	32.18	Min = 31.8
				Electricity=649.1

The result shows a 19.6% improvement over the original cell or a 46.6% efficient concentrator cell assuming that the fill factor would be the same.

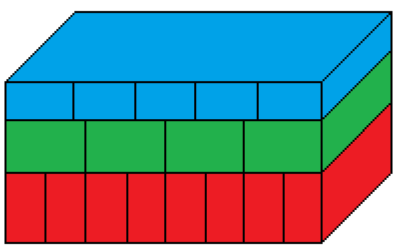

Figure 1. A current matched partitioned concentrator solar cell shows over 46.6% more efficient in current.

This is a 19.6% improvement over the original cell and is now producing 97.7% of the maximum power for the given wavelengths.

B) EXAMPLE FOR SPACE SOLAR CELLS

The Emcore space cells where the best cells are over 29% efficient use band gaps of 1.92 eV, 1.40 eV and 0.664 eV[2] for their triple junction solar cell giving wavelengths of 646nm, 886nm, 1867nm respectively. Using these band gaps produces the following table:

Table 4. Space solar cell comparison-1

	Layer1	Layer2	Layer3	
Power	474.38	253.18	249.02	Sum= 976.59
Voltage	1.92	1.40	0.66	Sum= 3.98
Current	247.14	180.90	374.93	Min=180.90
				Electricity=720.58

Note that the different junctions are not current matched very well. The third junction has 2.07 times more current than the second junction. Partitioning gives the following results:

Table 5. Space solar cell comparison-2

Partitions	4	3	6	
V'	7.68	4.2	3.99	Sum= 15.77
C'	61.78	60.3	62.4	Min = 60.30
				Electricity=956.4

The result shows a 32.7% improvement over the original cell or a 38.5% efficient concentrator cell assuming that the fill factor would be the same.

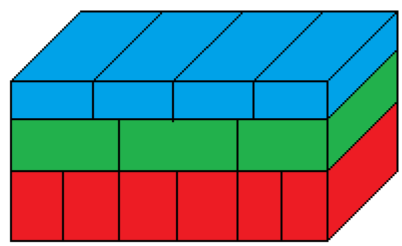

Figure 2. A current matched partitioned space solar cell that is over 46.6% more efficient.

C) EXAMPLE OF FOUR JUNCTION CELLS

For a partitioned four junction solar cell, the optimal cell would have band gaps of 2.49 eV, 1.71 eV, 1.14 eV and 0.73 eV which corresponds to wavelengths of 498nm, 724 nm, 1083 nm and 1792 nm. Looking on a lattice constant graph, we see that it appears that for a lattice matched four junction solar cells, you would want to use a lattice constant of about 6.1 Å.

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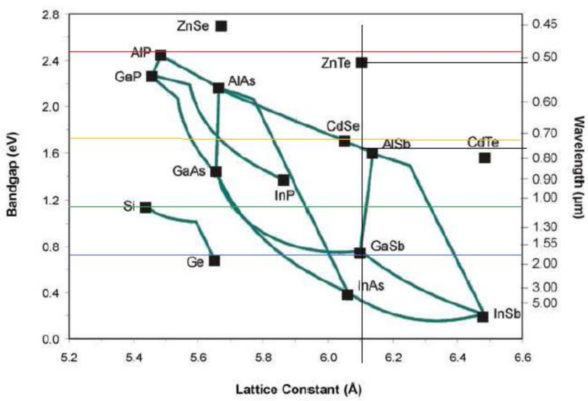

Figure 3. Lattice constants for a four junction solar cell. [2]

Unfortunately, the band gaps do not correspond to actual materials available so we will need to use band gaps of roughly 2.39 eV, 1.61 eV, 1.11 eV and 0.73 eV with corresponding wavelengths of 519 nm, 769 nm, 1115 nm and 1700 nm.

Table 6. Comparison of multijunction cell-1

	L 1	L 2	L 3	L 4	
Power	169.16	251.97	197.7	104.9	
eV	2.39	1.61	1.11	0.73	Sum= 5.8
C	70.80	156.26	177.7	143.9	Min=70.8
					413.70

Without partitioning we get a dismal 413.70 W*m^{-2}. This is mainly because there is so little current in the first layer. Using partitioning with partitions of 3,7,8, and 6 for the first through forth layer respectively, we get:

Table 7. Comparison of multijunction cell-2

	L 1	L 2	L 3	L 4	
Part.	3	7	8	6	
eV'	7.17	11.29	8.90	4.38	Sum= 31.73
C'	23.60	22.32	22.22	23.99	Min=22.22
					705.04

The results showed over 705 W*m^{-2} or a 70% improvement. Partitioning can help make huge improvement s in some solar cell designs.

IV.APPLICATIONS FOR PARTITIONED JUNCTIONS

Solar applications with multiple junctions (especially for three or more junctions) can have increased efficiency, including concentrator cells, space cells, and may make multiple junction thin film solar cells economical[3].

By using current matched partitions besides increased efficiency, there are also the following secondary benefits:

1. The system will run cooler for a given concentration by changing more of the energy into useful electricity and less being changed into heat.
2. By running cooler, a system using this type of solar cell can run at higher concentrations and the system using these cells will typically cost less. For concentrator cells this also means a secondary increase in efficiency due to the higher concentrations.
3. With current matched partitioned junctions, the materials in the different junctions do not have to be designed to be current matched since partitioning can take care of that aspect of the design.

V. RESULTS AND DISCUSSION

The proposed concept of current matched petition was studied and the results are summarized as the following:

a) The calculations have not attempted to factor in the depth of the different layers, or the penetration depth for the differ layers.
b) The calculations are assuming that the fill factor is the same for partitioned and non-partitioned cells.

To simplify the calculations we are estimating relative improvements over existing solar cells. Future investigations should consider different materials.

REFERENCES

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