Journal of
Electrical & Electronic Systems
ISSN: 2332-0796

Bedair and Samberg , J Elec Electron 2012, 1:2
DOI: 10.4172/2167-101X.1000e106

Editorial Open Access

Current Matching for High Efficiency Multi-Junction Solar Cells

Joshua P. Samberg* and S.M. Bedair

Department of Electrical and Computer Engineering, North Carolina State University, USA

The rising costs of traditional fossil fuels and the impact of their emissions on the environment has caused a shift in energy production toward more environmentally conscience and renewable sources. One energy technology that displays great potential for contributing to a cleaner energy grid is solar energy. While there are many different solar technologies and materials systems, the technology and system with the greatest promise to reach the $1/W goal set by the Sunshot Initiative, a price point that will make solar energy competitive with fossil fuels, is the Multi-Junction (MJ) Concentrator Photo Voltaics (CPV). The advantage of using MJ over other solar technologies is in the division of the solar spectrum into several spectral regions and converting each region with a subcell which possess a bandgap tuned to said region. This distribution of energies in the cell results in considerable efficiency when compared to single junction (SJ) solar cells in addition to avoiding the usual tradeoff between voltage and current associated with SJ solar cells. This is of importance because efficiency is the most important parameter of a solar cell in CPV systems, as the area of the cell can be decreased considerably, thus greatly reducing the impact that the expensive MJ cell cost per area has on the final CPV system. However, despite the promise of MJ cells they are not without their issues which include lattice matching and current matching among the junctions. Currently, the Ge bottom subcell of MJ solar cells produces approximately twice the current as the middle GaAs subcell. For example the InGaP/GaAs/Ge MJ solar cell, the most studied structure, is very well lattice matched but is not optimally current matched. This current mismatch limits the potential efficiency of the total cell, and it is this current mismatch that must be addressed in order to achieve the $1/W goal.

Metamorphic Structure

One solution to the issue of current matching in MJ solar cells is metamorphic growth. In this method, a graded InGaAs buffer layer is grown metamorphically on top of the Ge bottom subcell. This acts to change the lattice parameter of subsequent growth, and allows for lower bandgap materials for both the middle and top subcell through the use of higher Indium compositions for each. However, metamorphic growth does present challenges. As the InGaAs buffer layer is grown, it relaxes. This relaxation introduces defects and dislocations that propagate along the growth direction, which negatively impacts the performance of the top cell as it is highly susceptible to dislocations. This is especially deleterious due to the fact that the majority of the power produced by the cell comes from the top and middle sub cells. It is for this reason that present metamorphic MJ cells do not reach the efficiencies that would be expected by current matching models.

Inverted Metamorphic Structure

Another growth solution to overcoming the current matching issues in MJ cells is inverted metamorphic growth. Similar to metamorphic growth, a graded InGaAs buffer layer is utilized to change the lattice constant of subsequent growth. However, in this method the solar cell is grown upside down with the top cell grown lattice matched to the substrate. This maintains the top cell as defect free, and also limits the defects from the buffer region into the lower cells which are not as easily affected as the top subcell. Additionally, the substrate is removed which lowers the total weight of inverted metamorphic MJ cells. However, the removal of the substrate adds additional complexity to the processing and fabrication of the cell which consequently results in yield losses and increases the cost of the final product.

Psuedomorphic GaAsi-layer Strain Balanced Strained Layer Superlattice

While both metamorphic and inverted metamorphic growth each suffer to a varying degree from the defects introduced via the InGaAs buffer, it is alternatively possible to improve current matching via pseudomorphic growth. This adds a strained layer superlattice (SLS) in the i-layer of the middle subcell. In fact, it has previously been demonstrated that the current produced by the GaAs subcell may be increased by 2 mA/cm^2 through the use of an InGaAs/GaAsP SLS. This SLS structure uses low Phosphorous barriers which allows for the carriers to be transported via thermal excitation. However, a SLS that uses thermionic emission is severely limited in the number of wells which can be used. By using much higher Phosphorous composition and thinner barriers, carrier transport is accomplished via tunneling. This allows for the number of useful wells in the i-layer to be greatly increased. It is yet to be seen how much of an increase may be realized in the current of the middle subcell for MJ cells using such a SLS and ongoing research is needed.

Dilute Nitride Based Solar Cells

An additional material which may increase current matching in present MJ cells is InGaAsNSb. While this material system originally suffered greatly from poor minority carrier lifetime and diffusion length, it has been improved greatly. However, there still remain some major obstacles to this material becoming a viable option for MJ cells. In particular, the growth is accomplished via molecular beam epitaxy (MBE). MBE is a growth system that is not suited well for large scale industrial applications like metal organic chemical vapor deposition (MOCVD). This is a major hindrance to InGaAsNSb as all commercial MJ solar cells are produced via MOCVD.

Increasing the Number of Junctions

Perhaps the most promising way of improving the current matching in MJ cells in the long run is through the use of more junctions. Currently

***Corresponding author:** Joshua P. Samberg, Department of Electrical and Computer Engineering, North Carolina State University, Raleigh, NC, USA, E mail: bedair@ncsu.edu

Received June 26, 2012; **Accepted** June 27, 2012; **Published** June 29, 2012

Citation: Samberg JP, Bedair SM (2012) Current Matching for High Efficiency Multi-Junction Solar Cells. J Elec Electron 1:e106. doi:10.4172/2167-101X.1000e106

Copyright: © 2012 Samberg JP, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

المنارة للاستشارات
www.manaraa.com

the majority of MJ cells are comprised of 3 junctions. However, by increasing the number of junctions with materials of appropriate bandgaps, the current matching and efficiency can be greatly improved. Yet, increasing the number of junctions is not as trivial as it may seem. For each junction there are auxiliary layers that must also be grown such as windows and tunnel junctions. In increasing the number of junctions these auxiliary layers must also be researched and optimized. Recently, there has been a proposal to increase the number of junctions to 10; however, much more research is first necessary.

Conclusion

MJ solar cells show great promise in contributing to cleaner energy production. However, in order for them to reach their full potential there must be additional research in improving the current matching between the subcells. While there are multiple ways in which this can be done, in the end it is likely to be a combination of the solutions presented herein that will help MJ solar cells break the $1/W goal set forth by the Sunshot Initiative.

المنارة للاستشارات

www.manaraa.com