المملكة العربية السعودية
وزارة التعليم
جامعة أم القرى
كلية العلوم التطبيقية
قسم الفيزياء

جَامِعَةُ أُمِّ القُرَىٰ

Draft

Effect of operating temperature and Illumination Intensity on multi-junction Cells Parameters

Turki AL Zahrani
Dr. Khalid Althagafi
Class: Wednesday 4-7 Pm

Table of Contents

1. LIST OF FIGURES 2
2. LIST OF TABLES 3
3. ACKNOWLEDGEMENTS 4
4. DECLARATION 5
5. ABSTRACT 6
6. LIST OF SYMBOLS 7
7. INTRODUCTION 8
8. CHAPTER 1: INTRODUCTION 9
9. CHAPTER 2: LITERATURE REVIEW 10
10. CHAPTER 3: HISTORY OF STYLUS SIMULATION 11
11. CHAPTER 4: A BASELINE SOFTWARE TOOL FOR STYLUS CONTACT SIMULATION 12
12. CHAPTER 5: INVESTIGATION INTO NOISE, STIFFNESS AND RESOLUTION AT STYLUS CONTACT 9
13. CHAPTER 6: INVESTIGATION OF THE STYLUS SHAPE IMPERFECTIONS 9
14. CHAPTER 7: EXPERIMENTAL VALIDATION 9
15. CHAPTER 8: IMPLICATION FORM UNCERTAINTY STYLUS PROFILOMETER 9
16. CHAPTER 9: CONCLUSION AND FURTHER WORK 9
17. BIBLIOGRAPHY 13

Abstract

The dependence of InGaP/GaAs/Ge multi- junction solar cell model parameters on concentration and temperature are of interest to solar cell manufacturers. These parameters are related to cell processing and materials. In this work, the cell parameters were estimated by curve fitting of the experimental I–V characteristics to the single diode model equation of the multi-junction cell. The dependence of the cell parameters on light concentration and temperature is shown. Based on the estimated parameters, the performance of multi-junction cells and concentrated photovoltaic arrays under different solar irradiances and temperatures may be predicted.

Keywords:

Multi-junction solar cell parameters, Parameter estimation, Dependence of cell parameters on temperature and concentration

المملكة العربية السعودية
وزارة التعليم
جامعة أم القرى
كلية العلوم التطبيقية
قسم الفيزياء

literature review

Turki AL Zahrani
Dr. Khalid Althagafi
Class: Wednesday 4-7 Pm

Turki Alzahrani **44285817**

Dependence of multi-junction solar cells parameters on concentration and temperature

Journal of Solar Energy Materials & Solar Cells (2014)

Assaf Ben Or, Joseph Appelbaum

Introduction:

Concentrated photovoltaic systems based on high efficiency solar cells are among the technologies promised for large scale solar power generation. Modeling the characteristic equation IV of solar cells an important tool for studying the performance of solar panel cells under different irradiance, temperature, and spectrum. The single-diode model equation of the solar cell InGaP / GaAs / Ge MJ was used in this study to estimate the values of five parameters of the solar cell. Adding to the procedure for estimating the parameters the notion of monotonic behavior of the parameters on different concentrations and temperatures is important to obtain confidence in the results.

Parameter estimation of multi-junction solar cells—Single diode model:

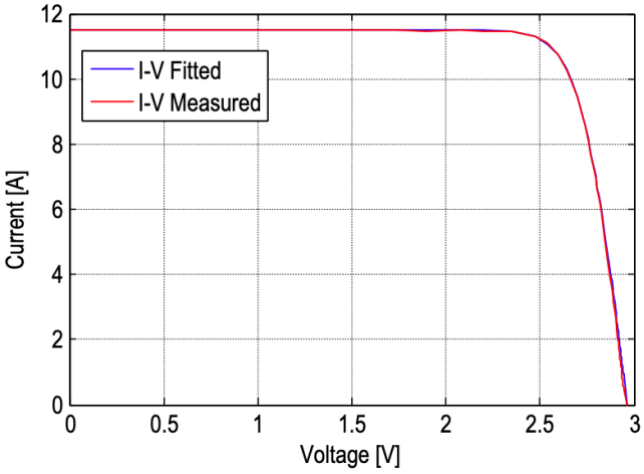
The conventional five parameter model (single diode model) was used to estimate the parameters of the solar cell. where, I and V are the terminals current and voltage, respectively, Iph is the photo-generated current, I0 is the diode reversed saturated current, n is the ideality factor of the diode, Rs and Rsh.

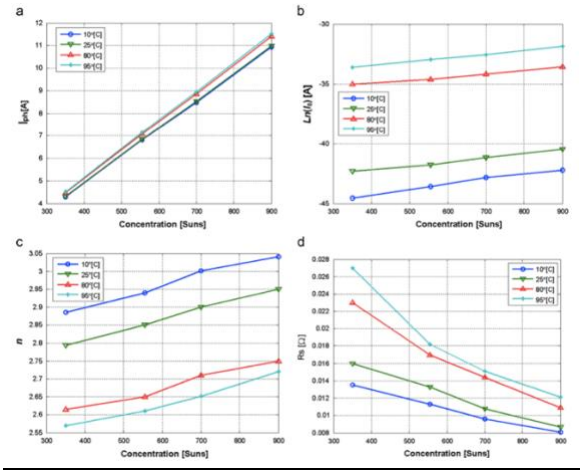
Curve fitting procedure:

Newton–Raphson algorithm was applied for curve fitting between the measured and theoretical I–V characteristics at different concentrations and temperatures. Since the convergence of the algorithm is very sensitive to initial parameter values, these values must be chosen carefully.

Results:

The single diode model may be used to describe the I–V characteristic of a MJ solar cell at different concentrations and temperatures. Although the model is an analy- tical expression, it does not necessarily describe accurately physical mechanisms inside the cell. Some of the equivalent cell parameters may have practical values.





Conclusions:

InGaP/GaAs/Ge MJ solar cell under different light concentration (350–900 Sun) and temperatures (10–90 1C). These parameters are related to cell processing and materials. Based on the estimated parameters, the performance of multi- junction cells and CPV arrays may be predicted.

Reference:

Assaf Ben Joseph Appelbaum. (2014). Dependence of multi-junction solar cells parameters on concentration and temperature. Article no. 64535800.

https://www.researchgate.net/publication/264535800_Dependence_of_multi-junction_solar_cells_parameters_on_concentration_and_temperature

المملكة العربية السعودية
وزارة التعليم
جامعة أم القرى
كلية العلوم التطبيقية
قسم الفيزياء

literature review

Turki AL Zahrani
Dr. Khalid Althagafi
Class: Wednesday 4-7 Pm

Turki Alzahrani **44285817**

Effect of thermal load on performance parameters of solar concentrating photovoltaic: High-efficiency solar cells

Journal of Solar Energy and Built Environment (2021)

Ali.O.M. Maka*, Tadhg S O'Donovan

Introduction:

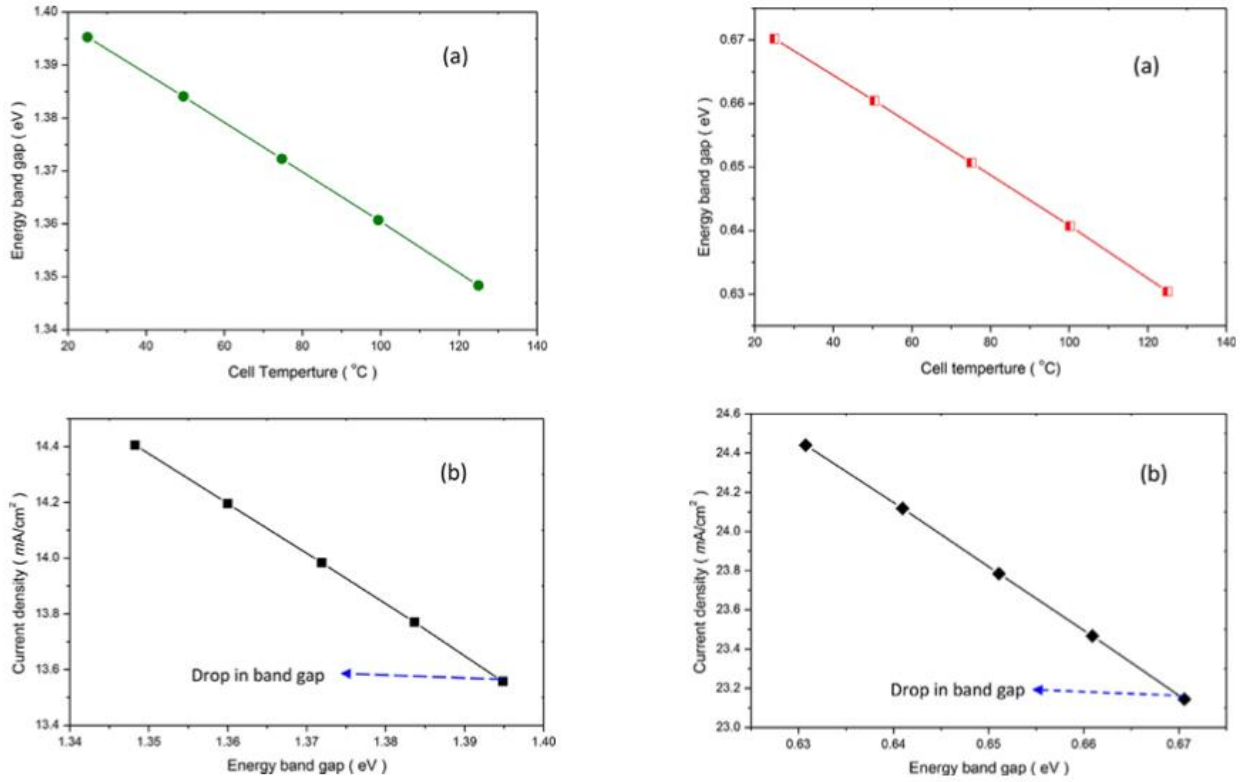
In the technology of CPV, the triple-junction solar cells III-V semi- conductor materials, with different band gaps are commonly used. These are stacked on top of each other to reduce thermalisation losses and to increase conversion efficiency. The accumulation of thermal load leads to increases in the device's temperature, which reduces its efficiency.

Model description:

A monolithically stacked three-layers or subcells were created in MATLAB. The performance of the solar cell was characterised by J-V curves. The optimal energy band gaps of the three-junctions are 1.8 eV, 1.4 eV and 0.7 eV respectively.

Results and discussions:

The band gap of a semiconductor is the minimum energy required to excite an electron into a free state. The majority of semicon- ductor material's band gap decreases as temperature increases. Temperature variations with a band gap in each layer are quantified by how much energy is captured from the Sun.



Conclusions:

Triple-junction solar cells performance changes because of cells temperature increases. The increases in cell temperature led to cell performance degradation. The predicted model gives a de- tailed understanding of the solar cell's operating behaviors. This will lead to enhancing the design and operating performance.

Reference:

Ali.O.M. Maka*, Tadhg S O'Donovan. (2021). Effect of thermal load on performance parameters of solar concentrating photovoltaic: High-efficiency solar cells.

https://www.sciencedirect.com/science/article/pii/S2666123321000118

المملكة العربية السعودية
وزارة التعليم
جامعة أم القرى
كلية العلوم التطبيقية
قسم الفيزياء

literature review

Turki AL Zahrani
Dr. Khalid Althagafi
Class: Wednesday 4-7 Pm

Turki Alzahrani **44285817**

Temperature-Dependent Measurements of an Inverted Metamorphic Multijunction (IMM) Solar Cell

Myles A. Steiner, John F. Geisz, Daniel J. Friedman, Waldo J. Olavarria, Anna Duda, and Tom E. Moriarty National Renewable Energy Laboratory, Golden, CO 80401, USA

Introduction:

The operating temperature of a solar cell is an important parameter for determining the conversion efficiency. The inverted metamorphic multijunction (IMM) solar cell has allowed designers to fabricate high-efficiency solar cells. Several companies are presently developing commercial versions of the IMM.

EXPERIMENT:

The inverted structures were grown at NREL in an atmospheric pressure OMVPE reactor and processed using standard cleanroom lithographic techniques. The structure is grown with the top two sub cells lattice-matched to the GaAs substrate, and the top sub cell thinned to 1 μm to match the photocurrent of the middle sub cell.

Results:

Figure 1 shows the EQE measured at five temperatures. Each subcell plateaus at approximately 85% which includes a 6.7% shadow loss from the grid coverage and a 3-5% reflection loss. We speculate that this tails result from photon coupling between the top and middle sub cells.

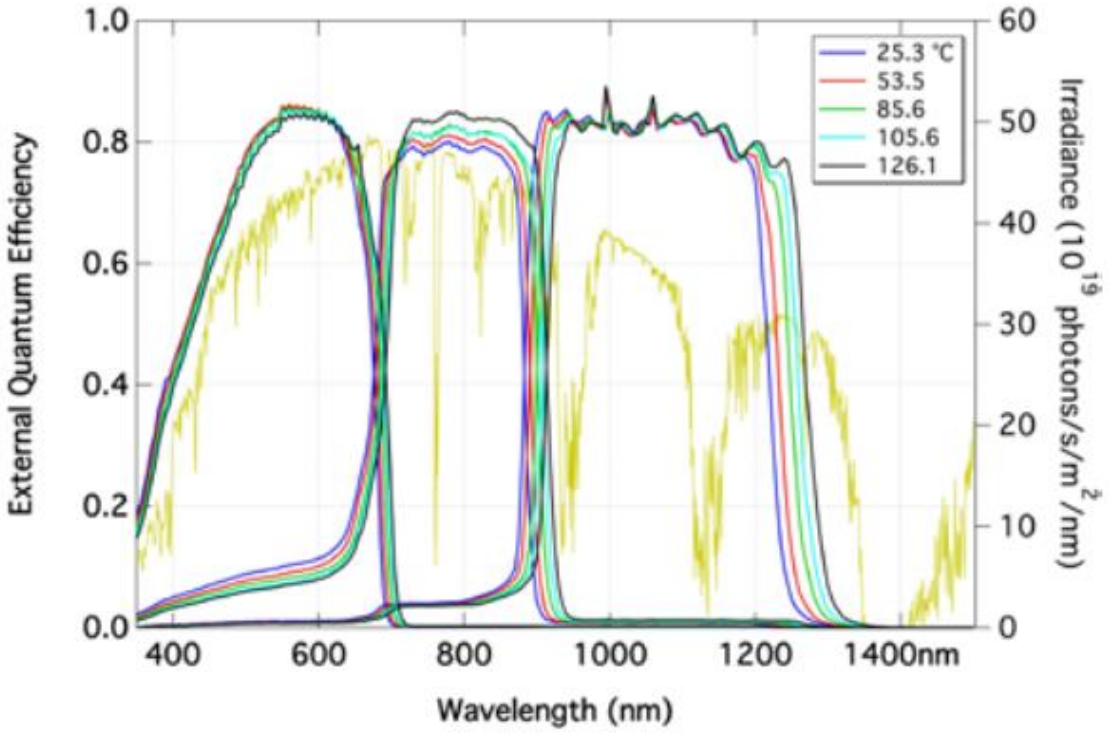


Figure 1 External quantum efficiency as a function of ambient temperature. The bandgaps at 25°C are 1.81, 1.40 and 1.00 eV. The yellow curve is the G173 direct spectrum at 1000 W/m^2.

DISCUSSION:

Mismatched lattice cells (IMM) provide a platform for exploring various bandgap combinations, some of which may be more appropriate for cell performance at elevated temperatures. Figure 5 shows the modeled dependence of cell efficiency on temperature for several different combinations of junction bandgaps, at 500 suns.

Conclusions:

We have conducted a careful measurement of the performance of a solar cell as a function of temperature and concentration. The peak efficiency decreases from 39.5% at 290 suns to 33.8% at 460 suns and 126°C. Jsc(T) of the individual subcells can also be measured and indicate a crossover from top-cell-limited to middle-cell - limited behavior at 100 °C.

Reference:

Myles A. Steiner, John F. Geisz, Daniel J. Friedman, Waldo J. Olavarria, Anna Duda, and Tom E. Moriarty National Renewable Energy Laboratory, Golden, CO 80401, USA. Temperature-Dependent Measurements of an Inverted Metamorphic Multijunction (IMM) Solar Cell.

https://www.nrel.gov/docs/fy11osti/50736.pdf

المملكة العربية السعودية
وزارة التعليم
جامعة أم القرى
كلية العلوم التطبيقية
قسم الفيزياء

literature review

Turki AL Zahrani
Dr. Khalid Althagafi
Class: Wednesday 4-7 Pm

Turki Alzahrani **44285817**

Effects of Nonuniform Incident Illumination on the Thermal Performance of a Concentrating Triple Junction Solar Cell

Fahad Al-Amr and Tapas Kumar Mallick

Introduction:

Concentrated photovoltaic (CPV) systems produce a highly nonuniform irradiance distribution on the solar cells. Electrical and thermal impacts, such as high ohmic drops and the flow of an internal current, affect the solar cell's efficiency and power output. This reduces its potential as an alternative energy source.

Mathematical Formulations:

The solar cells are made up of a triple junction GalnP/GaAs/Ge solar cell, a Cu-Ag-Hg front contact to the solar cell and a glass cover. The efficiency of the triple junction solar cell is 0.38 and the reflectivity is assumed to be zero for all solar cell components except for the front contact metal.

Method of Solution:

Convection field equations are trans-formed into finite difference equations. They are solved using a numericalmarching technique to update the wall temperatures. The details of the solution procedure can be found in Al-Amri and Mallick's [9] technical notes.

DISCUSSION:

Figure 3(a) and 3(b) show the incident illumination profiles obtained using (1) for the concentration ratio C = 100 at three selected standard deviation values (SD = 0.0005, 0.001, Figure 4). The profile of the solar cell becomes thinner and the maximum temperature increases as the SD decreases.

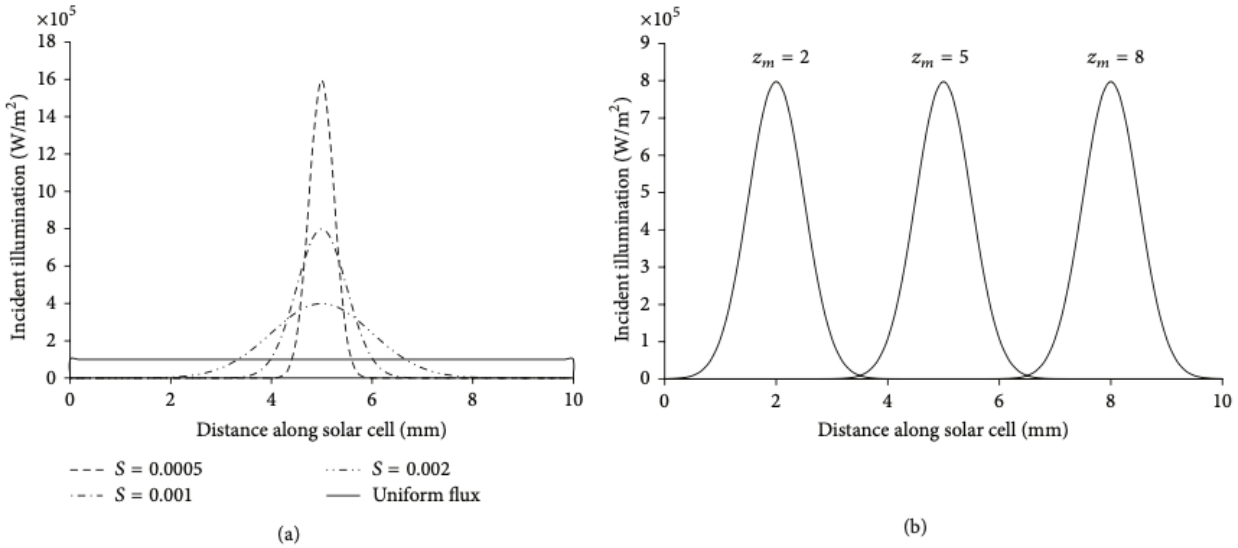


FIGURE 3: Incident illumination profiles for $C = 100$ at (a) different values of SD and (b) different values of z_0.

Conclusions:

The effects of nonuniformity of the incident light on the temperature and fluid bulk temperature of a triple junction solar cell were studied. Solar cell temperatures in the region exposed to the most incident light are high enough to cause degradation in solar cell efficiency at medium concentrations.

Reference:

Effects of Nonuniform Incident Illumination on the Thermal Performance of a Concentrating Triple Junction Solar Cell

https://www.hindawi.com/journals/ijp/2014/642819/

المملكة العربية السعودية
وزارة التعليم
جامعة أم القرى
كلية العلوم التطبيقية
قسم الفيزياء

literature review

Turki AL Zahrani
Dr. Khalid Althagafi
Class: Wednesday 4-7 Pm

Turki Alzahrani **44285817**

influence of temperature on luminescent coupling and material quality evaluation in inverted lattice-matched and metamorphic multi-junction solar cells.

M. Ochoa , M.A. Steiner , I. Garcia , J.F. Geisz , D.J. Friedman and C. Algora

Introduction:

In a photovoltaic system, the cell temperature is affected by many factors such as ambient temperature, irradiance, wind speed, and the heat extraction properties of the module. The accurate measurement of the cell tem- perature is a difficult task, but, in most cases, the estimated operating temperature of solar cells working under concentrated illumination is 50-80°C.

EXPERIMENTAL:

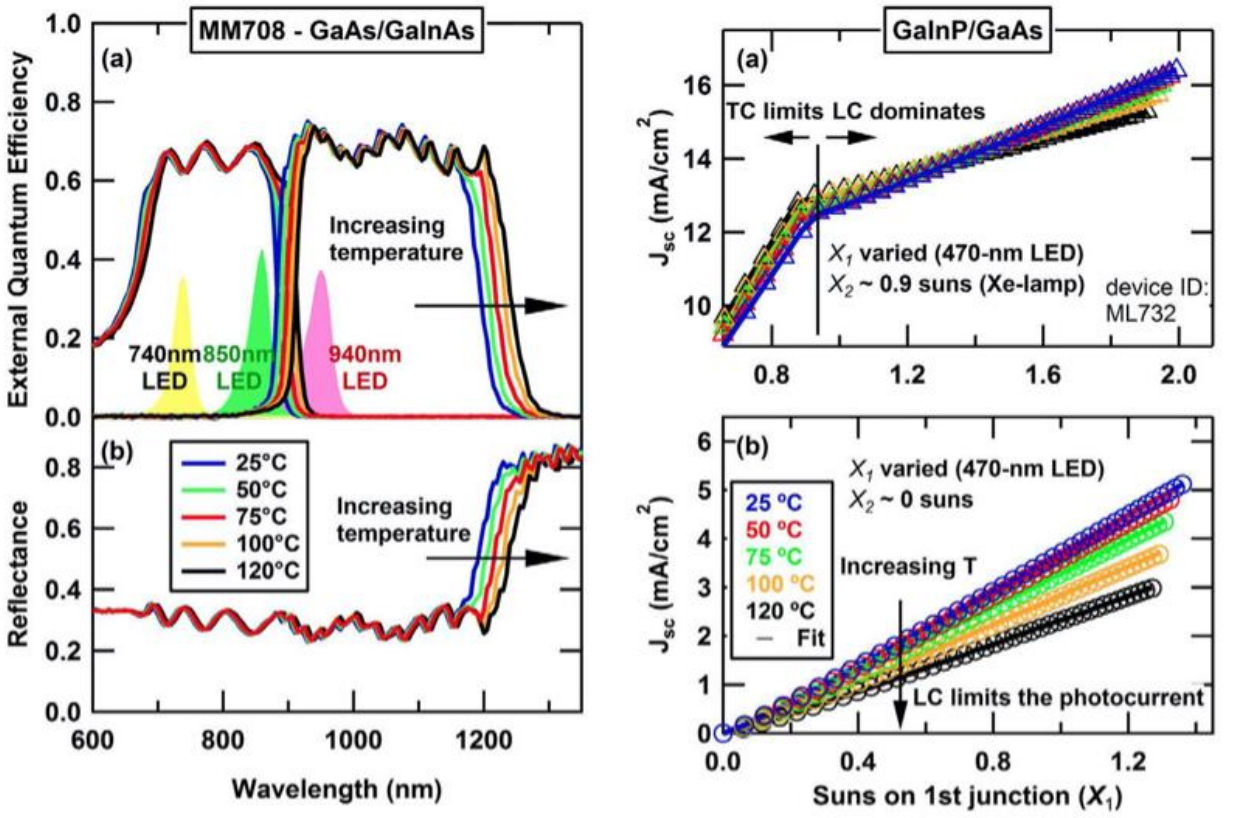
The consideration of LC affects the structural optimization of the solar cell. We examine the dependence of LC with temper-ature within a range typical for real operating conditions (25-120°C). Two components of an IMM 3J solar cell have been analyzed: (1) GalnP/GaAs and GaAs/GalnAs solar cells.

Method of Solution:

Convection field equations are trans-formed into finite difference equations. They are solved using a numericalmarching technique to update the wall temperatures. The details of the solution procedure can be found in Al-Amri and Mallick's [9] technical notes.

RESULTS:

Figure 3(a) and 3(b) show the incident illumination profiles obtained using (1) for the concentration ratio C = 100 at three selected standard deviation values (SD = 0.0005, 0.001, Figure 4). The profile of the solar cell becomes thinner and the maximum temperature increases as the SD decreases.



Conclusions:

The temperature dependence of the LC of multi-junction solar cells has been studied in two tandem solar cells (GaInP/GaAs and GaAs/GaInAs). The study has been carried out by means of LC analysis, dark modeling and optical modeling.

Reference:

influence of temperature on luminescent coupling and material quality evaluation in inverted lattice-matched and metamorphic multi-junction solar cells.M. Ochoa , M.A. Steiner , I. Garcia , J.F. Geisz , D.J. Friedman and C. Algora

https://spectralevolution.s3.us-east-2.amazonaws.com/assets/Influence-of-temp-on-luminescent-coupling-solar-cells.pdf