# DESIGN OF MULTI-JUNCTION SOLAR CELLS USING PC1D

**H. S. Mangarola[1*], N. H. Vasoya[2]**

**ABSTRACT**

The main purpose of this paper is to compare efficiency of the multi-layer solar cell GaAs (2,3,5layer). There are various design parameters such as material type, thickness of the layers, dopingconcentration, type of texturing, and thickness of anti-reflective coating on which efficiency of the multi-layer solar cell depends.one-dimensional solar cell simulation software PC1D (personal computer in one dimension) used for determined the performance of the solar cell. Batch mode of PC1D provide optimization study for a particular parameter. After simulation in PC1D, open circuit voltage, short circuit current, maximum rated power and power conversion efficiency under the one sun, AM1.5G solar radiation and constant intensity of 0.1w/cm$^2$are obtain.

**Keywords:** Gallium arsenide (GaAs), Solar Cells, Simulation

[1*, 2] Department of Balbhavan, Children's University, Sector-20, Gandhinagar 382021, India
himanimangrola@gmail.

***Corresponding Author:** H. S. Mangarola
*Department of Balbhavan, Children's University, Sector-20, Gandhinagar 382021, India
himanimangrola@gmail.

**DOI:**10.53555/ecb/2022.11.9.88

## INTRODUCTION

Energy is the main factor for the development of modern countries. Currently, electricity supply is generated from fossil fuels such as coal, oil and nature gas. However, these energy sources facing lots of issues including the decrease of fossil fuels, security concerns caused by fossil fuel leading to more greenhouse gas emmisions.one solution to these issues is renewable energy sources including wind energy, solar energy, and hydroelectric generation have huge potential to take the place of fossil fuels which have finite resources. Solar energy, considered, as one of the most rapidly growing renewable energy sources. Solar energy is available in most of the areas over the word. solar energy become an ideal energy source because it is free and virtually limitless. The power of sunlight that reaches the earth's surface in one year is more than 10,000 times than the world's yearly energy needs. Goal for scientists is how to harvest this large power in an efficient and inexpensive way.There are many kinds of research on solar technologies are attempted including thin-film, single-junction cells, organiccells, quantum dot cells, and also new kind of material or technologies are emerging every year. [2] Photoelectriceffect, phenomenon in which electrically charged particles are released from or within a material when it absorbs electromagnetic radiation. The effect is often defined as the ejection of electrons from a metal plate when light falls on it.[3]

Photoelectric effect is observed in solar cells [4]. GaAssolar cells are highly efficiency devices. GaAs has direct band gap and high absorption coefficient which is ideally suited for thin solar cells. Along with modeling of crystalline solar cells, PC1D software package enables advanced & improved visualization of cell design & operation. Software's numerical model improves accuracy of the parameters, in addition to efficient results, numerical model reduces valuable amount of time for the experiments carried out in laboratories.[2] The paper is organized as fellowed.Section 2 gives information about PC1D software Section 3 gives the simulation results. Section 4 gives conclusion.

## PC1D SOFTWARE

PC1D is the most commonly used for modeling of the solarcellGOO.PC1D is a software that provides the solution of fully-coupled two-carrier semiconductor transport equations in one dimension using finite element analysis.

### Advantages of PC1D

- High calculation speed
- An intuitive user interface
- extensive list of material and physical parameter
- software allows to insert multiple parameters in a single batch via batch mode.
- Reducing the human errors
- Availability of wide range of material data base
- Optimize the time required for the graph preparation than that of manual method.
- Improved models for generation and recombination effects.

## SIMULATION RESULTS

Three cases are considered namely design of two-layer, three-layer and five-layersolar cells using PC1D software. Input parameters are as given below:

**TABLE (1)** INPUT PARAMETERS

| Layers | Materials | hickness | Doping |
|---|---|---|---|
| **1** | GaAs | 3µm | 1.513e16cm-3(P-type) |
| **2** | GaAs | 10µm | 1.513e16cm-3(P-type) |
| **3** | GaAs | 10µm | 1.513e16cm-3(P-type) |
| **4** | GaAs | 10µm | 1.513e16cm-3(P-type) |
| **5** | GaAs | 10µm | 1.513e16cm-3(P-type) |

**TABLE (2)** INPUTPARAMETERS

| Region | Intrinsic concentration | Free carrier absorption | Bulk recombination |
|---|---|---|---|
| **1-5** | 1e10cm-3(300k) | enabled | 7.208us(tn=tp) |

**TABLE (3)** EXCITATION

| Excitation mode | Transient,16time steps |
|---|---|
| **Temperature** | 25$^{o}$c |
| **Base circuit** | sweep from -0.8v to 0.8v |
| **Collector circuit** | zero |
| **Primary light source** | Enabled |
| **Constant intensity** | 0.1w/cm$^{-2}$ |
| **secondary light source** | Disabled |

**TABLE (4)** INPUT PARAMETERS

| Parameters | 5-layer | 3-layer | 2-layer |
|---|---|---|---|
| **Device area** | $1cm^2$ | $1cm^2$ | $1cm^2$ |
| **Front surface** | 3um | 3um | 3um |
| **Exterior front reflectance** | 90% | 90% | 90% |
| **Emitter contact** | Enabled | enabled | enabled |
| **Base contact** | Enabled | enabled | enabled |
| **Internal conductor** | 0.3S | 0.3S | 0.3S |
| **Light Source** | one-sun.exe | one-sun.exe | one-sun.exe |

**TABLE (5)** OBTAINED ONE-SUN I-V AND POWER(2J)

| Base Voltage | Base Current | Base Power |
|---|---|---|
| **-8.49E-05** | -0.0399958 | 3.40E-06 |
| **-8.49E-05** | -0.0399958 | 3.40E-06 |
| **-7.71E-05** | -0.0349961 | 2.70E-06 |
| **-6.92E-05** | -0.0299965 | 2.08E-06 |
| **-6.14E-05** | -0.0249969 | 1.53E-06 |
| **-5.35E-05** | -0.0199973 | 1.07E-06 |
| **-4.57E-05** | -0.0149977 | 6.85E-07 |
| **-3.78E-05** | -0.00999811 | 3.78E-07 |
| **-3.00E-05** | -0.0049985 | 1.50E-07 |
| **-2.21E-05** | 1.11E-06 | -2.45E-11 |
| **-1.43E-05** | 0.00500071 | -7.13E-08 |
| **-6.42E-06** | 0.0100003 | -6.42E-08 |
| **1.43E-06** | 0.0149999 | 2.15E-08 |
| **9.28E-06** | 0.0199995 | 1.86E-07 |
| **1.71E-05** | 0.0249991 | 4.28E-07 |
| **2.50E-05** | 0.0299988 | 7.49E-07 |
| **3.28E-05** | 0.0349984 | 1.15E-06 |
| **4.07E-05** | 0.039998 | 1.63E-06 |

ONE-SUN I-V AND POWER(2J)

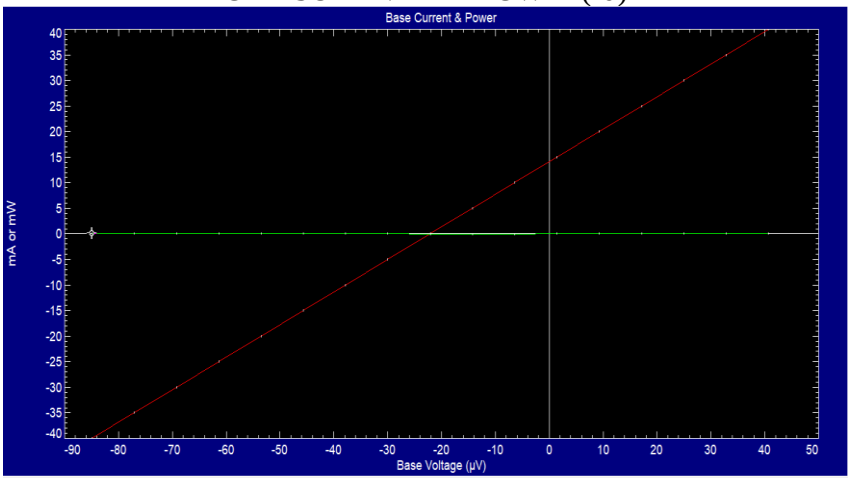


**TABLE (6)** OBTAINED ONE-SUN AND POWER(3J)

| Base Voltage | Base Current | Base Power |
|---|---|---|
| **-0.000248804** | -0.0399876 | $9.95E^{-06}$ |
| **-0.000248804** | -0.0399876 | $9.95E^{-06}$ |
| **-0.000229885** | -0.0349885 | $8.04E^{-06}$ |

| | | |
|---|---|---|
| **-0.000210965** | -0.0299895 | 6.33E$^{-06}$ |
| **-0.000192045** | -0.0249904 | 4.80E$^{-06}$ |
| **-0.000173125** | -0.0199913 | 3.46E$^{-06}$ |
| **-0.000154203** | -0.0149923 | 2.31E$^{-06}$ |
| **-0.000135282** | -0.00999324 | 1.35E$^{-06}$ |
| **-0.000116359** | -0.00499418 | 5.81E$^{-07}$ |
| **-9.74E-05** | 4.87E-06 | -4.75E$^{-10}$ |
| **-7.85E-05** | 0.00500393 | -3.93E$^{-07}$ |
| **-5.96E-05** | 0.010003 | -5.96E$^{-07}$ |
| **-4.07E-05** | 0.015002 | -6.10E$^{-07}$ |
| **-2.17E-05** | 0.0200011 | -4.35E$^{-07}$ |
| **-2.81E-06** | 0.0250001 | -7.03E$^{-08}$ |
| **1.61E-05** | 0.0299992 | 4.83E$^{-07}$ |
| **3.50E-05** | 0.0349982 | 1.23E$^{-06}$ |
| **5.40E-05** | 0.0399973 | 2.16E$^{-06}$ |

ONE-SUN I-V AND POWER(3J)

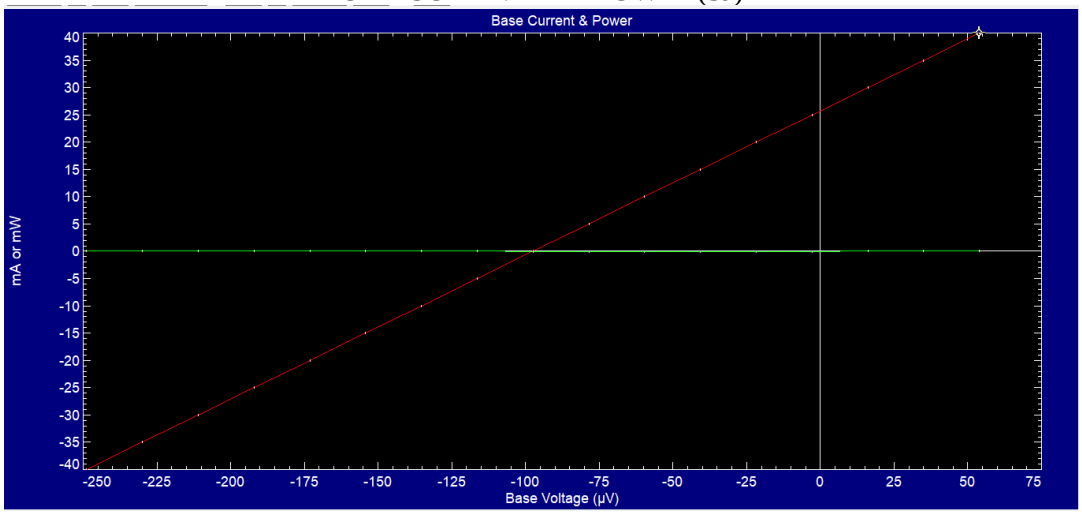


**TABLE (7)** OBTAINED ONE-SUN I-V AND POWER(5J)

| Base Voltage | Base Current | Base Power |
|---|---|---|
| **-0.000387434** | -0.0399806 | 1.55E-05 |
| **-0.000387434** | -0.0399806 | 1.55E-05 |
| **-0.000356007** | -0.0349822 | 1.25E-05 |
| **-0.00032458** | -0.0299838 | 9.73E-06 |
| **-0.000293152** | -0.0249853 | 7.32E-06 |
| **-0.000261724** | -0.0199869 | 5.23E-06 |
| **-0.000230295** | -0.0149885 | 3.45E-06 |
| **-0.000198865** | -0.00999006 | 1.99E-06 |
| **-0.000167435** | -0.00499163 | 8.36E-07 |
| **-0.000136005** | 6.80E-06 | -9.25E-10 |
| **-0.000104573** | 0.00500523 | -5.23E-07 |
| **-7.31E-05** | 0.0100037 | -7.32E-07 |
| **-4.17E-05** | 0.0150021 | -6.26E-07 |
| **-1.03E-05** | 0.0200005 | -2.06E-07 |
| **2.12E-05** | 0.0249989 | 5.29E-07 |
| **5.26E-05** | 0.0299974 | 1.58E-06 |
| **8.40E-05** | 0.0349958 | 2.94E-06 |
| **0.000115461** | 0.0399942 | 4.62E-06 |

ONE-SUN I-V AND POWER(5J)

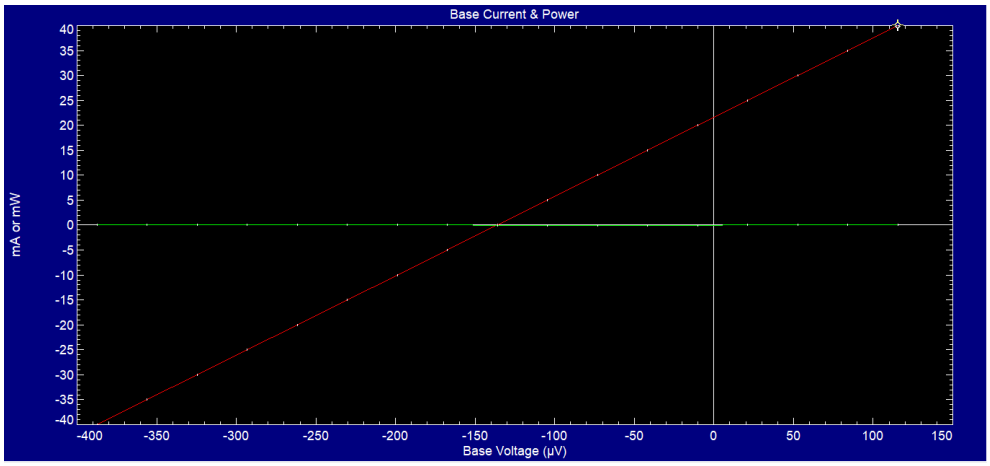


**TABLE (8)** COMPARISON OF EFFICIENCIES

| Performance | 2-j cell | 3-j cell | 5-j cell |
|---|---|---|---|
| **Short circuit current** | 0.0141 A | 0.0257A | 0.0216A |
| **open circuit voltage** | $-2.212e^{-5}$Volts | $-9.745e^{5}$Volts | $-1.36e^{-4}$volts |
| **Pmax** | $7.79e^{-8}$ watts | $6.272e^{-7}$ watts | $7.358e^{-7}$watts |
| **Conversion Efficiency** | $77.9e^{-8}$% | $62.72e^{-7}$% | $73.58e^{-7}$% |

## CONCLUSION

Two junction, three junction and five junction solar cell are designed using one-dimensional solar cell simulation software PC1D in a trial and error method. Obtained efficiency for two junction solar cell was$77.9e^{-8}$%, for three junction solar cell was $62.72e^{-7}$%and for five junction solar cell was $73.58e^{-7}$%

## REFERENCES

1. Meenakshi, S., & Baskar, S. (2013, April). In 2013 International Conference on Energy Efficient Technologies for Sustainability (pp. 443-449). IEEE.
2. Zhang, C. (2014). Arizona State University.
3. www.britannica.com
4. Sikder, U., & Zaman, M. A. (2016). Optics & Laser Technology, 79, 88-94.