INVESTIGATIONS OF INDIUM GALLIUM NITRIDE PROPERTIES FOR ENHANCEMENT OF PERFORMANCE OF SOLAR CELLS

Mohammad asif iqbal and Arun dev dhar dewedi

***Abstract*—This paper investigates the potential use of wurtzite Indium Gallium Nitride as photovoltaic material. Silvaco Atlas was used to simulate a quad-junction solar cell. Each of the junctions was made up of Indium Gallium Nitride. The band gap of each junction was dependent on the composition percentage of Indium Nitride and Gallium Nitride within Indium Gallium Nitride. The findings of this research show that Indium Gallium Nitride is a promising semiconductor for solar cell use. In this work, Double Layer BSF is used for top cell with their varying thickness on GaInP / GaA DJ Solar Cell, using Computational Numerical Modeling TCAD Tool Silvaco Atlas. The objectives of this paper is to simulate electrical and optical characteristics the of these devices and extract the figures of merits like efficiency, open circuit voltage, short circuit current and fill factor and to study the effect of variation of doping concentration dimensions of the device and thickness of active layer on the figures of merits.**

***Index Terms*—Indium Gallium Nitride, atlas**

I. INTRODUCTION

In the 1950s, traditional solar cells were invented and commercialized in the first place. 1960s for use in space programs, Since then the efficiency and reliability of these cells has progressed rapidly. At the same time their cost of construction has decreased significantly. As a result, the photovoltaic industry is growing rapidly. Still, the cost of solar energy is still higher than the cost of electricity from electric grid in industrialized countries. For this reason, there is an increasing amount of dedicated research for potentially less expensive types of solar cells based on organic dyes and polymers.

These cells have been studied since the late 1950s, although it has recently been studied at very low levels. An effective and customized BSF layer is an important layer in both a junction and multifunction solar cells. Major modeling stages have been described and simulation results are validated with published experimental data so that the accuracy of our results can be described.

In today's world, solar energy is seen as the best option for fossil fuels to meet the growing energy needs of people.

A tool is widely used for the use of free and all-time solar energy, solar cells. Solar cell design began with simple single junctions and later went on to multijunction cell which are used in space applications and thin film solar cells. The reason behind such high efficiency in multiplication solar cells is the presence of several junction layers.

Due to this, due to efficient absorption of solar radiation high efficiency is done which is not in the case of single junction cells. To improve the efficiency of multijunction solar cells, much research has been done to increase the junction of the cell, include the back surface area (BSA) and the anti reification coating layer. An optimized BSF layer prevents not only carrier recombination but also helps to increase the efficiency of the solar cell.

Therefore the presence of the BSF layer is important for solar cell performance. Many layers such as multisunction solar cells increase its complexity, so a detailed computational simulation is necessary to understand the mechanism of each layer. In this work, we report the design of InGaP/GaAs DJ solar cells using double layer top BSF with different thickness and compare results obtained with pre-seasonal results, Through optimized values of Open Circuit Voltage (V_{oc}) and Short Circuit Current Density (I_{sc}) Conversion efficiency, short circuit current density and open circuit voltage calculation and other famous solar cell models are compared.

II. PROBLEM STATEMENT:

The fluctuations in the output power due to non-linearity might lead to undesirable performance. These obstacles can be overcome by utilizing the recent technology in developing low cost PV cells and efficient power conditioning system. To maximize the overall power generation of solar PV powered system, the operation point of each PV module is at its own MPP and improves converter conversion efficiency of power conditioning system. As a result, many research works address the development of power conditioning system in recent years with improved performances. Therefore, this research work aims at bridging this gap by presenting an experimental study of some dynamic phenomena that can improve solar cell efficiency. Gallium Nitride (GaN) and Indium Gallium Nitride (InGaN) thin films are now a day's attracting researchers because of its possible use as an active semiconductor material and its immense application potential in short wavelength optoelectronic devices. Gallium Nitride (GaN) and Indium Gallium Nitride (InGaN) is a member of TCO (transparent conductive oxides) family together with indium tin oxide (ITO) and tin oxide (TO). Gallium Nitride (GaN) and Indium Gallium Nitride (InGaN) are very interesting materials, due to their high transmittance in the

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visible region and to its high chemical, thermal and mechanical stability.

III. METHODOLOGY

In this paper the technology used is computer aided design (TCAD) for optical modeling that enables a fast and exhaustive numerical simulation of devices. In Our Proposed work we also presents maximum power point tracking control algorithms and design a physical structure of the various thin film solar cells based on ZnO, III-V materials e.g. GaAs, GaN, InGaN etc., solar cells based on other emerging materials and multi junction solar cells using technology computer aided design (TCAD) tools from Silvaco International. This model can be used to exclude unfavorable parameter combinations for experimental devices and guide the search for new materials and techniques for improved designs. In this way the development of organic tandem solar cells with high performance will be accelerated. Attempts have been made to highlight the current and future issues involved in the development of PV system with improved performance.

Description : Gallium Nitride (GaN)

Gallium nitride (GaN) is a direct bandgap semiconductor belonging to the IIIV group and used commonly in light emitting diodes. The compound is very hard, and has a Wurtzite crystal structure. It has a wide band gap of 3.4 eV enabling it to be used in optoelectronic, high frequency and high power applications.

Applications

- It has a low sensitivity to ionizing radiations hence suitable for solar arrays in satellites.
- It is also suited for space and military applications as devices have been observed to be stable in radiation environments.
- Bluray discs are read using GaNbased violet laser diodes. When doped with manganese, GaN is a promising spintronics material.
- Mixing GaN with In or Al enables manufacture of LEDs with a range of colors from red to the ultraviolet.
- Gallium nitride based MOSFET and MESFET transistors are useful for high power electronics especially electric car and automotive applications.
- GaN nanotubes are used for nanoscale electronics, biochemical sensing and optoelectronics applications.
- They are also useful as active electronically scanned array radars

S. No	Specifications	Rating	Properties
1	Chemical Formula	GaN	Chemical Properties
2	Molecular Weight	83.73	
3	CAS No.	25617974	
4	IUPAC Name	Gallium nitride	
5	Group	III-IV	
6	Band Gap	3.4 eV	
7	Band Gap Type	Direct	
8	Crystal Structure	Wurtzite, Zinc Blende	
9	Symmetry Group	C6v4-P63mc	
10	Lattice Constant	a = 3.186 Å, c = 5.186 Å	
11	Intrinsic Carrier Concentration	1x10 cm-3	Electrical Properties
12	Electron Mobility	≤ 1000 cm2V-1s-1	
13	Hole Mobility	≤ 350 cm2V-1s-1	
14	Electron Diffusion Coefficient	≤ 25 cm2s-1	
15	Hole Diffusion Coefficient	≤ 9 cm2s-1	
16	Melting Point	>2500 °C	Mechanical Properties
17	Density	6.15 g cm-3	
18	Bulk Modulus	20.4 x 1011 dyn cm-2	
19	Specific Heat (@ 298 K)	0.49 J g-1k-1	
20	Thermal Conductivity	1.3 W cm-1 °C-1	Thermal Properties
21	Thermal Diffusivity	0.43 cm2 S-1	
22	Thermal Expansion Coefficient	3.17x10-6 °C-1	
23	Refractive Index (589 nm @ 293 K)	2.29	Optical Properties
24	Radiative Recombination Coefficient (@ 300 K)	1.1x10-8cm3s-1	
25	Hazard Statements	H317 – May cause an allergic skin reaction	Safety Information
26	Safety Precautions	S22 – Do not breathe dust S24 – Avoid contact with skin S25-Avoid contact with eyes	

Description : Indium gallium nitride

Indium gallium nitride is a semiconductor material made of a mixture of indium nitride and gallium nitride. It is a ternary group III/group V direct bandgap semiconductor whose bandgap can be tuned by adjusting the amount of indium in the alloy. Quantum heterostructures of indium gallium nitride are often developed from GaN with InGaN active layers, as InGaN can be combined with other materials such as AlGaN, GaN on SiC, sapphire and silicon. Although the toxicology of InGaN has not been thoroughly investigated, its dust particles are irritants to lungs, eyes and skin.

Applications

Indium gallium nitride finds applications in the following:
Solar photovoltaic devices
Quantum wells
Modern blue and green LEDs.

S.No	Specifications	Rating	Properties
1	Chemical Formula	InGaN	Chemical Properties
2	CAS No.	7440746	
3	Group	III-V	
4	Crystal Structure	Quantum heterostructures	
5	Band Gap Type	Direct	
6	Band Gap	2.5 eV	Electrical Properties
7	Electrical Resistivity (@675°C)	7.81 X 10-3 Ω cm	
8	Lattice Constant	4.360 Å	
9	Intrinsic Carrier Concentration	1018 cm-3	
10	Electron Mobility	≤ 1000 cm2V-1s-1	
11	Hole Mobility	47.3 cm2/Vs	

12	Modulus of Elasticity	57.9 GPa	Mechanical Properties
13	Shear Modulus	6.46 GPa	
14	Refractive Index (589 nm @ 293 K)	2.59	Optical Properties

System Design & Implementation

Design specification:

The PhD work will propose a Design of Solar cell to reduce the real power loss and optimization of performance and economy. The proposed method will be able to Produce Maximum Power with minimum cost.

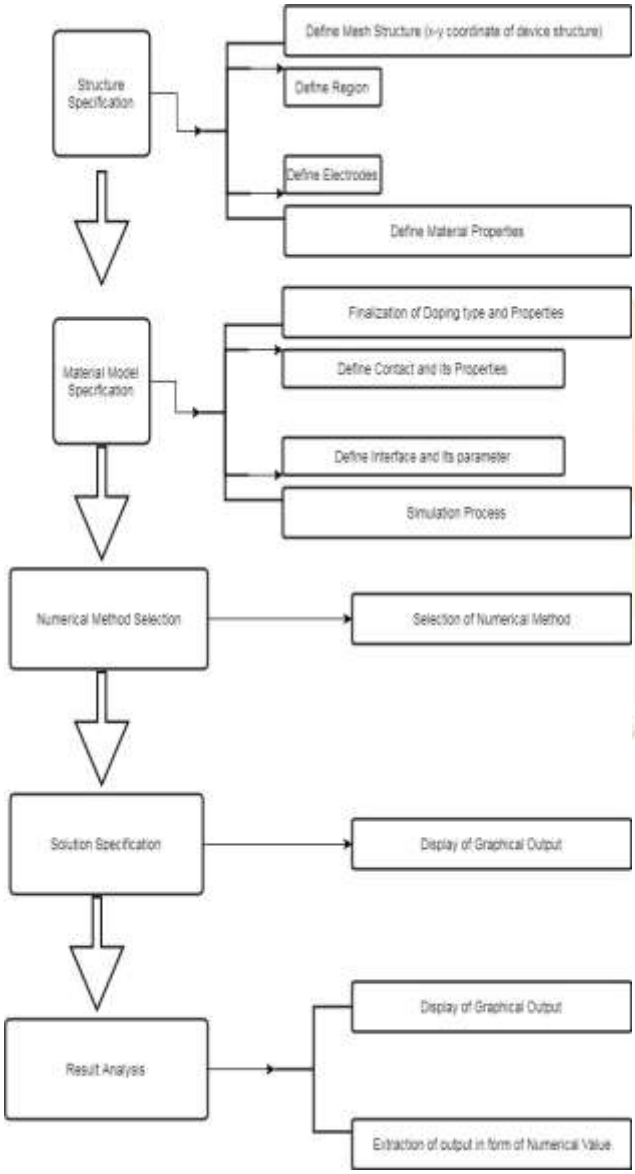

Figure 1 :Flow Chart of Proposed Design specification

Steps followed for Device Implementation:

Step 1: Mesh is defined in order to specify the x and y co-ordinates of device structure.

Step 2: Regions are declared including region no. and materials of the region.

Step 3: Material properties are defined.

Step 4: Doping is defined including doping type and doping concentration.

Step 5: Models are included for simulation.

Step 6: Illumination condition is provided.

Step 7: Condition for obtaining the solution is defined using SOLVE statement.

Step 8: LOG file saved for saving the terminal characteristics of the device.

Step 9: Output is plotted and extracted for analysis.

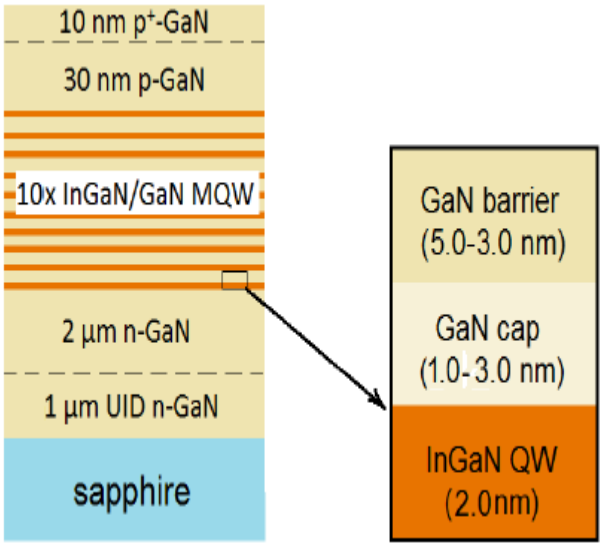

Figure 2: The cross-sectional schematic of modeled GaN/InGaN MQW solar cell

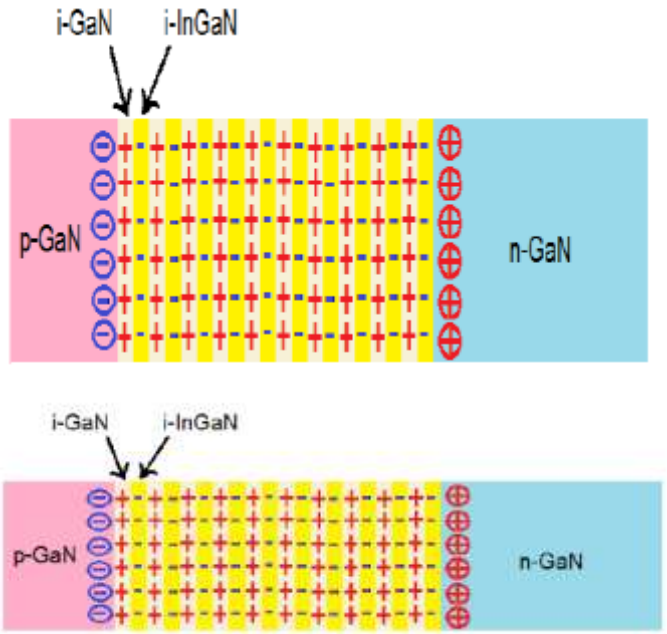

Figure 3: Space charge and polarization induced charge distribution of a GaN/InGaN MQW solar cell

Details of Software used for Experimentation

Computer simulation for various solar cell structure were done on TCAD too ATLAS (SILVACO).

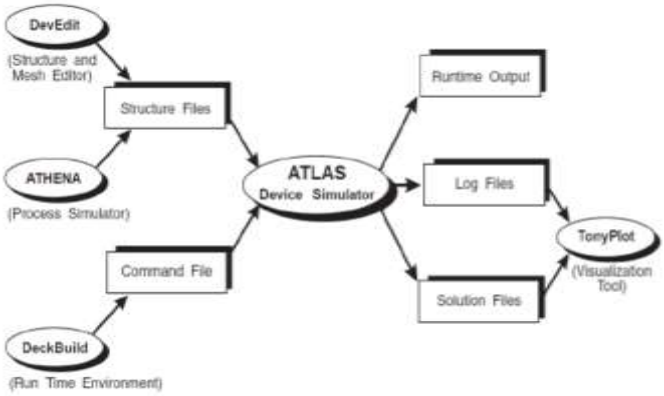

Figure 4: ATLAS inputs and outputs

The basic format of ATLAS is to design a device using a grid of nodes. Several device parameters can be entered using various statements. ATLAS solves second order partial differential equations at each node to determine several characteristics of the device at equilibrium. These characteristics can include voltage, current, charge density, carrier concentration and so on. ATLAS solves these equations by using an iterative method to attempt to converge on a solution. To build a device in ATLAS from scratch, the user must use a program called DeckBuild.

Discussion on Experimentation Results Obtained with different Cap size:

Cap thicknesses	In fraction %	JG(mA/ cm2)	JR(mA/ cm2)	Jsc(mA/ cm2)	Vbi (volt)	Voc 1(volt)	F (%)	Vp (volt)	Voc 2 (volt)	Voc (volt)	F F (%)
1nm	0.09	0.8367	0.4877	0.349	2.56	0.95	0.372	3.97	1.479	2.43	59
2nm	0.15	1.3167	0.667	0.6487	2.56	0.78	0.305	6	1.824	2.6	63.3
3nm	0.21	1.8932	0.8279	1.0563	2.56	0.67	0.26	6.99	1.822	2.49	61.1

Table 3: Experimentation Results Obtained with different Cap size

CONCLUSION:

The study reveals that various developmental states may cause change in the concentration of the trap level density of states and blemish sites. Simulation and comparison of 3 samples of each with different cap layer thickness. We have presented the simulation perspective to examine the effect of the thickness of the cap layer on the performance of a GaN / InGaN MQW solar cell. After solving the relationship equation for electron-hole and acquiring the structure profile, identified two main factors for determining the open circuit voltage of a solar cell: the underlying capacity, which is a function of layers thickness and piezoelectric induced voltage, which is an act of indium molar fraction. The optimum thickness for the cap layer is around 2 nm where the solar cell reaches its best performance with the fill factor of 63.3%.

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