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## Performance Analysis of Quantum Dot Intermediate Band Solar Cell (QD IBSC)

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**Abstract-** Now-a-days quantum dot intermediate band solar cell (QD IBSC) is the most promising approach for increasing the efficiency of the solar cell. In this paper  $\text{In}_x\text{Ga}_{1-x}\text{N}$  & GaAs based p-i-n reference cell and quantum dot intermediate band solar cell where  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  is used in window layer have been studied for high efficiency and evaluated the performance with various parameters. Here quantum dots of  $\text{InAs}$  &  $\text{InN}$  are placed in the i-layer of p-i-n reference cell. V-I characteristics of p-i-n reference cell using GaAs,  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  is observed & maximum efficiency & the short circuit current density is found 32.87% & 350 A/m<sup>2</sup> respectively. Also an increased efficiency of 41.45% & short circuit current density of about 466.07 A/m<sup>2</sup> is to be found for same structure using  $\text{In}_x\text{Ga}_{1-x}\text{N}$  material. Maximum efficiency & short circuit current is to be found 58.77% & 649 A/m<sup>2</sup> respectively for  $\text{In}_x\text{Ga}_{1-x}\text{N}$  based QD IBSC and 51.59% & 543.36 A/m<sup>2</sup> for GaAs based QD IBSC respectively. Comparing all the results we have found that  $\text{In}_x\text{Ga}_{1-x}\text{N}$  based Quantum dot intermediate band solar cell offers the better efficiency.

**Keywords:** reference cell, QD IBSC, window, solar cell efficiency.

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# Performance Analysis of Quantum Dot Intermediate Band Solar Cell (QD IBSC)

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**Abstract-** Now-a-days quantum dot intermediate band solar cell (QD IBSC) is the most promising approach for increasing the efficiency of the solar cell. In this paper InxGa1-xN & GaAs based p-i-n reference cell and quantum dot intermediate band solar cell where AlxGa1-xAs is used in window layer have been studied for high efficiency and evaluated the performance with various parameters. Here quantum dots of InAs&InN are placed in the i-layer of p-i-n reference cell. V-I characteristics of p-i-n reference cell using GaAs, AlxGa1-xAs is observed & maximum efficiency & the short circuit current density is found 32.87% & 350 A/m<sup>2</sup> respectively. Also an increased efficiency of 41.45% & short circuit current density of about 466.07 A/m<sup>2</sup> is to be found for same structure using InxGa1-xN material. Maximum efficiency & short circuit current is to be found 58.77% & 649 A/m<sup>2</sup> respectively for InxGa1-xN based QD IBSC and 51.59% & 543.36 A/m<sup>2</sup> for GaAs based QD IBSC respectively. Comparing all the results we have found that InxGa1-xN based Quantum dot intermediate band solar cell offers the better efficiency.

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## I. INTRODUCTION

The average worldwide power consumption was  $1.6 \times 10^{13}$  W in 2006 [1]. Every day the total solar radiation incident on earth at sea level is approximately  $2 \times 10^{17}$  W, which is over 12500 times the average worldwide power consumption in 2006. This shows the solar energy has great potential in supplying energy to the world in comparison with the fossil fuel. But the drawback of Solar Cell is its high cost per KWH of energy production resulting from low efficiency. The efficiency limit of conventional single gap solar cells is 40.7%. The intermediate band solar cell (IBSC) is a new photovoltaic device with a 63.2% theoretical efficiency limit [2]. Because Intermediate band (IB) solar cells can increase the current of solar cells whereas the voltage would not be decreased [3].

In case of IBSC, the photons whose energy is below the band gap energy of the material can be exploited. This kind of absorption of below band gap energy photons takes place from the valence band to the intermediate band (IB) and from the IB to the conduction band [4]. For implementing the IBSC concept, there are two approach available. The most efficient approach is based on the use of quantum dots,

the IB arising from the confined energy levels of the electrons in the dots. Quantum dots have led to devices that demonstrate the physical operation principles of the IB concept and have allowed identification of the problems to be solved to achieve actual high efficiencies[5]. For this purpose different combination of different materials can be used. To improve the efficiency InAs/AlGaAs QD-based IBSCs has been designed. It overcomes the problems encountered in InAs/GaAsQD-based IBSCs. In this paper the comparison between p-i-n reference solar cell and QD IBSC are performed by modeling the p-i-n reference solar cell as well as the QD IBSC with different materials.

## II. MODEL OF A REFERENCE CELL WITH A DEPLETED I-LAYER

In this paper a model of a single band gap reference p-i-n solar cell with anti-reflective coating (ARC), window, p+-, p, i, n and n+-layers is presented along with a model of an intermediate band solar cell. The model of the intermediate band solar cell contains the same layers as the reference cell, but with the i-layer now having an intermediate energy band in the band gap. Intermediate band can be formed by many ways, quantum dot intermediate band solar cell is one of them & it is the most promising approach to form intermediate band. In this paper the intermediate band can be created by introducing quantum dots to the i-layer. In this paper all the layers in the reference cell are made of GaAs, AlGaAs or InGaN. At the top of the cell we find the front contacts and an anti-reflective coating minimizing the reflection losses. A GaAs-cap layer is then placed as a barrier against oxidation since the following AlGaAs window layer oxides easily. This high band gap window layer reduces the front surface recombination. Beneath the window layer we find a heavily doped p+-layer which further reduces the front surface recombination. The p- and n-layers are then placed with an intrinsic layer sandwiched in between. A heavily doped n+-layer is placed beneath the n-layer to reduce the back surface recombination. At the bottom on the cell we find the substrate where the upper layers are deposited on and where the back contact is placed.

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Figure 1 : Structure of the p-i-n reference cell

### III. OUR PROPOSED MODEL

#### a) Materials used for the proposed model

Maximum efficiency of p-n solar cell is 22% [7] and for 3-layer p-i-n solar cell is to found 23.45% only from the MATLAB simulation result. But seven layer p-i-n reference solar cell offers high efficiency than both p-n and p-i-n solar cell. For the performance analysis we choose different materials for different layers for different types of solar cell. The materials used for the proposed model are given below.

Table 1 : Materials of the proposed model

Type of solar cell	Material used in all layer except window	Material used in window layer	Dot material
p-i-n reference	GaAs	AlGaAs	.....
p-i-n reference	InGaN	AlGaAs	.....
QD IBSC	GaAs	AlGaAs	InAs
QD IBSC	InGaN	AlGaAs	InAs

#### b) Proposed width of various layers

The variations of the width of different layers affect the performance of the solar cell. We choose a fixed width for different layers for the convenience of comparing the performance of different type of solar cells. The proposed width of various layers are given in table 2.

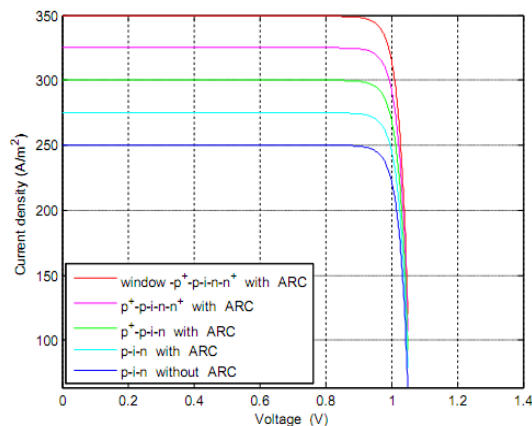
Table 2 : Proposed width of different layers

Layers	width(nm)
Window	5
p+	100
p	200
i	300
n	300
n+	100

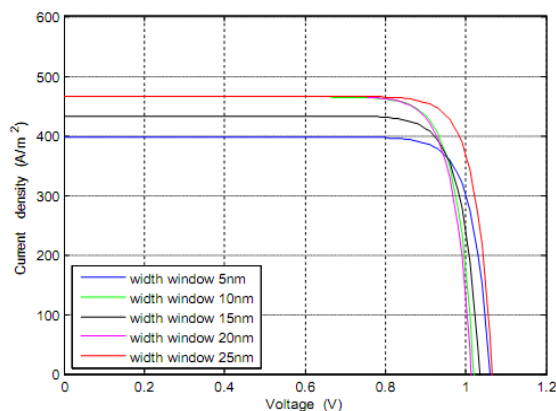
### IV. NUMERICAL RESULTS AND DISCUSSION

#### a) Modeled device for p-i-n reference cell

The performance of the modeled device for p-i-n reference cell is shown here. From fig 2 we can see that, increasing the number of layer in solar cell, increases the efficiency. Here two devices p-i-n reference cell of GaAs, AlxGa1-xAs and InxGa1-xN are used.



(a)



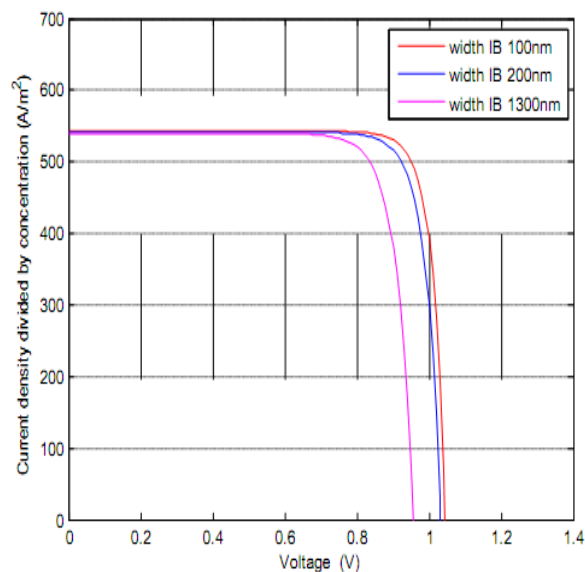
(b)

Figure 2 : Current voltage characteristics of p-i-n solar cells with different additional layers for (a) AlGaAs at window layer & GaAs at other layer. (b) InGaN used in all layer except window layer

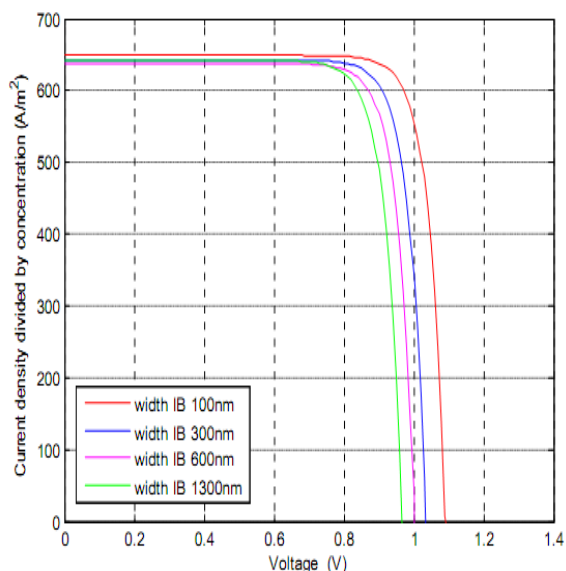
#### b) Modeled device QD IBSC

Here the modeled device of In Ga N and Ga As are used. The Intermediate band is depleted by quantum dot by the materials In As for Ga As and In N for In GaN. Increasing the width of the IB, the efficiency increases for both cases. But the efficiency is found more for In Ga N due to more short circuit current density which is due to additional carrier generation.

Performance of (a) QD IBSC (for dotmaterial InAs) and (b) InGaN based QD IBSC



(a)



(b)

Figure 3 : Current-voltage characteristics of (a) QD IBSC for dot material InAs and (b) InGaN based QD IBSC for dot material InN

### V. COMPARISON OF THE P-I-N REFERENCE CELL & QD IBSC

From the VI characteristics curve we can calculate the efficiency of solar cell. The efficiency for different types of solar cell of different materials are shown in table 3.

Table 3 : Data for comparison of the p-i-n reference solar cell & QD IBSC

Type of solar cell	Material used in all layer except window	Material used in window layer	Dot material	Efficiency (%)
p-i-n reference	GaAs	AlGaAs	.....	32.87
p-i-n reference	InGaN	AlGaAs	.....	41.45
QD IBSC	GaAs	AlGaAs	InAs	51.59
QD IBSC	InGaN	AlGaAs	InN	58.77

### VI. CONCLUSION

The model of the intermediate band solar cell contains the same layers as the reference cell, but with the i-layer now having an intermediate energy band in the band gap. Both of the solar cells are theoretically studied & their performance is evaluated by using MATLAB simulation. In case of p-i-n reference solar cell the efficiency is 32.87% for Ga As, Al Ga As material. We got increased efficiency of 10.87% for using InGaN in the i layer of the p-i-n reference solar cell than the GaAs, AlGaAs based p-i-n reference solar cell. In GaN has high mobility and low surface recombination velocity of 1000 cm/s than Al Ga As. So it has high photocurrent values and as well as high efficiency Dot material of InAs and InN having bandgap of 36eV and 0.70eV respectively are used. This small band gap dot is placed to the large band gap Ga As of 1.42eV. Short circuit current density & efficiency is increased for QD IBSC. Maximum efficiencies for QD IBSC using GaAs, Al GaAs and In GaN, Al GaN material system are found to be 51.59% and 58.77% respectively and performance evaluation against some parameter changes is also performed. An increased efficiency of about 7.18% for In GaN based QD IBSC is found than that of GaAs based QD IBSC. Summarizing all the simulation results we can conclude that In GaN based QD IBSC offers better efficiency.

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