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RESEARCH ARTICLE

SILICONE V/S GALLIUM ARSENIDE: WAY TO FUTURE

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ABSTRACT

A solar cell can be termed as photovoltaic cell is an electrical device that converts the heat energy of solar light directly into electricity by photovoltaic effect that is a physical and chemical phenomenon. We have different type of solar cells like SILICON is the most dominating semiconductor in the field of PV cells and this paper is about comparative study with its close competing material GALLIUM ARSENIDE in different modules like crystalline, MONOCRYSTALLINE and thin film. As well as different modules of silicon solar cell are also discussed. GALLIUM ARSENIDE has clearly high efficiency and several other advantages over SI but due to high cost (about 1000 times more than of SI's cost) application of such cells is limited to a narrow region. In this paper several ways and methods are also discussed to make silicon and gallium arsenide batter in several aspects.

INTRODUCTION

Solar cells and other electronic devices have traditionally been based on silicon so silicon is most famous material due to its good conduction properties with acceptable cost. Currently we have different type of solar cells like silicon solar cell, gallium arsenide solar cell, CIGS solar cell, CdTe solar cell, In GaP, In GaAs solar cell etc. There are other semiconductors to and GaAs is one of such materials and it have certain technical advantages over silicon like electrons can move faster in crystalline structure of GaAs compare to SI. but silicon has a crushing commercial advantage it is roughly 1000 time cheaper but in some of application like "NICHE APPLICATION" high cost GaAs are acceptable but this is not a case with common used solar cells. For an sub module of SI(crystalline) efficiency is around 25.6 ± 0.5% and for GaAs(thin film) it's 28.8±0.9%.we have different techniques to manufacture solar cell as shown in Figure1. for silicon solar cells, the basic design constraints on surface reflection, carrier collection, recombination and parasitic resistances result in an optimum device of about 25% theoretical efficiency. Crystalline silicon dominates the current photovoltaic market, in part due to the prominence of silicon in the integrated circuit market. As is also the case for transistors, silicon does not have optimum material parameters. In particular, silicon's band gap is slightly too low for an optimum solar cell and since silicon is an indirect material, it has a low absorption co-efficient. While the low absorption co-efficient can be overcome by light trapping, silicon is also difficult to grow into thin sheets. However, silicon's abundance, and its domination of the semiconductor manufacturing industry has made it difficult for other materials to compete. An optimum silicon solar cell with light trapping and very good surface passivation is about 100 μm thick. However, thickness between 200 and 500μm are typically used, partly for practical issues such as making and handling thin wafers, and partly for surface passivation reasons. By Considering table 1(shown above) we can say that silicon is second most abundant material in the earth crust where Gallium and arsenic are on 35th and 55th position respectively so that's why 75% of the total solar cell production is done by silicon only so we can say that silicon is on dominating side. One of the other reasons is that silicon is the semiconductor material of choice in microelectronics is that it forms a unique oxide on the surface when heated to high temperatures. This facilitates device fabrication for two reasons: (1) it neutralizes defects on the silicon surface and (2) it allows for straightforward planar processing. . GALLIUM ARSENIDE is compressed of two elements: gallium and arsenic. When these two elements come together to form GaAs, this compound shows greater saturated electron velocity an electron mobility than that of silicon.

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Table 1. Most abundant elements in the earth crust (1)

S.No	Element	Abundance(% by weight)	Abundance(ppm by weight)
1	Oxygen	46.1%	461,000
2	Silicon*	28.2%	282,000
3	aluminum	8.23%	82,300
4	Iron	5.63%	56,300
5	Calcium	4.15%	41,500
6	Sodium	2.36%	23,600
7	magnesium	2.33%	23,300
8	potassium	2.09%	20,900
9	titanium	0.565%	5,650
10	hydrogen	0.14%	1,400
35	Gallium*	0.0019%	19
55	Arsenic*	0.00018%	1.8

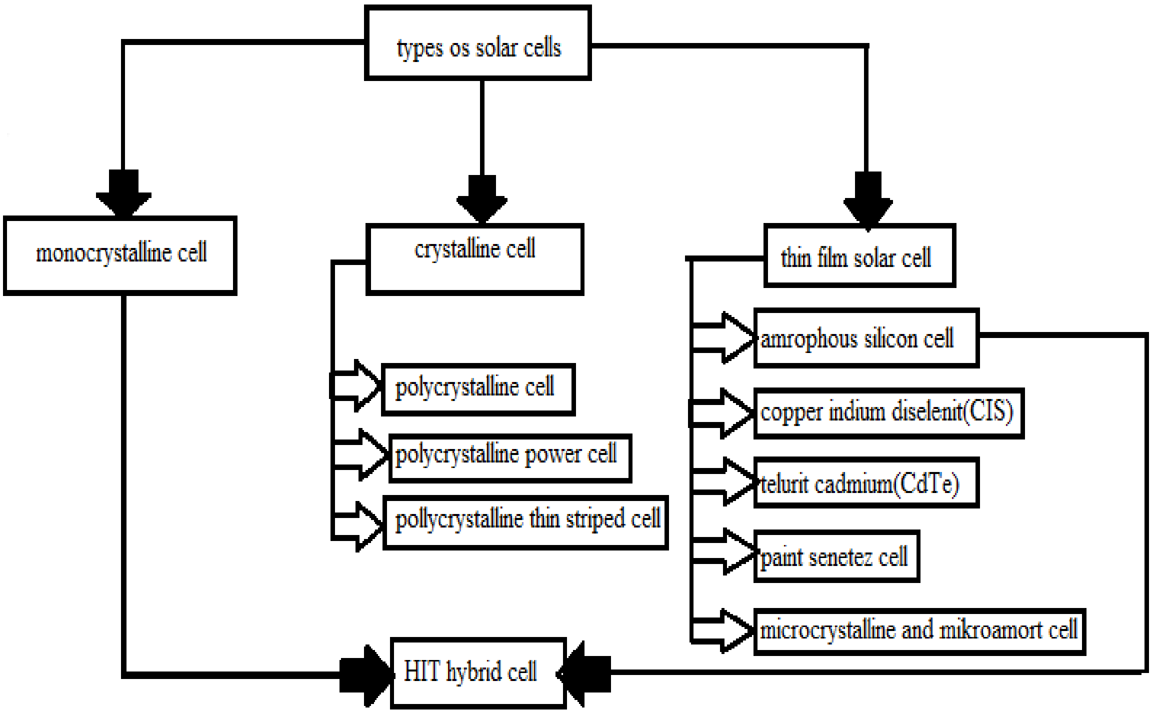


Fig. 1. Solar cell devision

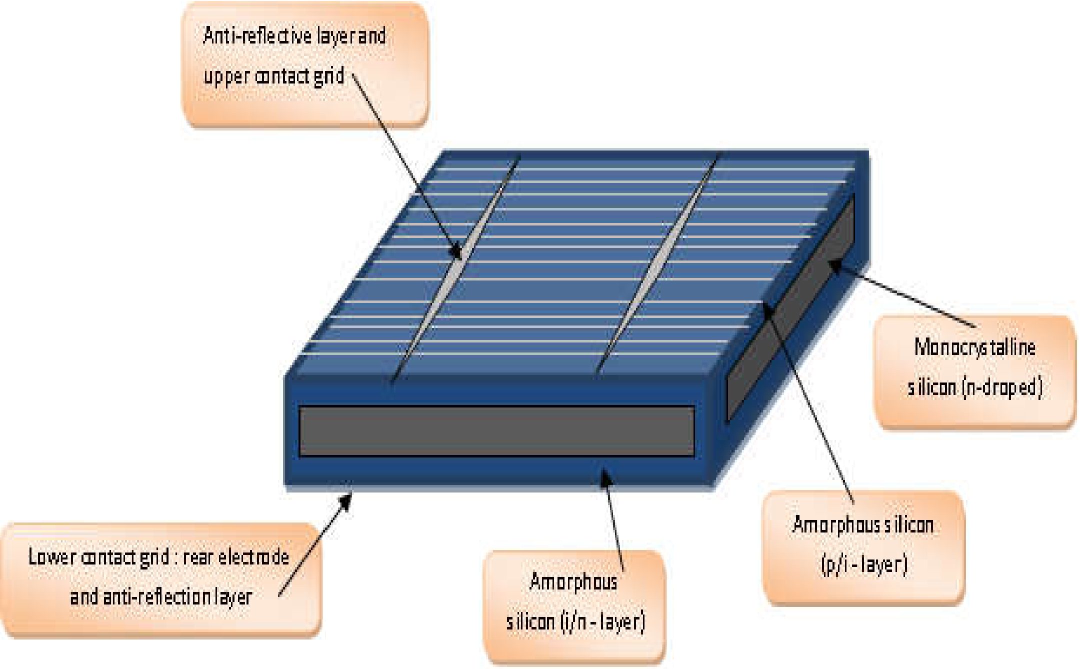


Fig. 2. Monocrystalline silicon solar cell

Types of solar cells

Solar cells can by categorized in several ways like depending on the material used and type of construction .we have many type of solar cells depending on type of material used for fabrication like few of most used material based solar cells are silicon solar cell, GaAs solar cell, CIGS solar cell, CdTe solar cell, InGaP, InGaAs SOLAR CELL etc.but as we know that silicon solar cells dominates the solar cell field due to its several advantages over its other competitors. The other way of division of solar cells is "construction", on the basses of construction they are manly divided into three types as shown in Figure1.

Monocrystalline silicon solar cells

An monocrystalline solar cell is also known as single crystalline silicon solar cell is based on highly pure silicon and that's why this module have high cost among all other module of silicon. "czochralski" process is require to manufacture these cells. Monocrystalline silicon solar cells produce four time more power then thin film solar cells.

Polycrystalline silicon solar cells

polycrystalline solar cell can also be termed as multicrystalline solar cell. To form this type of solar cells raw silicon is melted and poured into a square mold which is cooled and cut into perfectly square wafers and most important thing about polycrystalline solar cell is that we don't need "czochralski" process to manufacture such cells which gives economic advantage over monocrystalline cells.

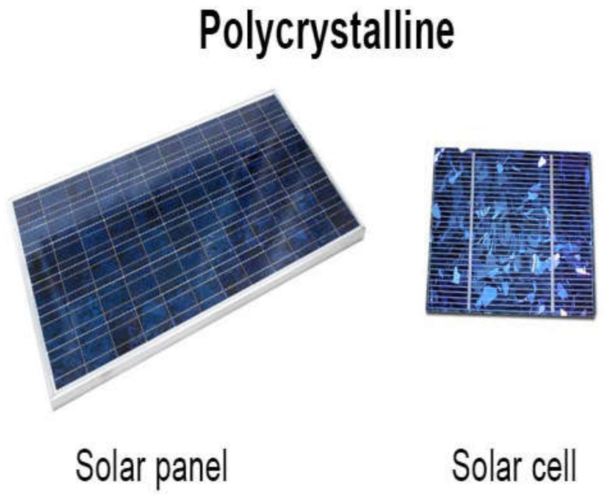


Fig. 3. polycrystalline silicon solar cell

Thin film solar cells

by depositing one or several thin layers of photovoltaic material onto a substrate is the basic gist of how thin film solar cells are manufactured. One of the best thing about TFSC is that this is flexible which opens up new potential application .

Silicon versus gallium arsenide

We have to select any solar cell according to its efficiency and cost because we have to work on both of these factors.

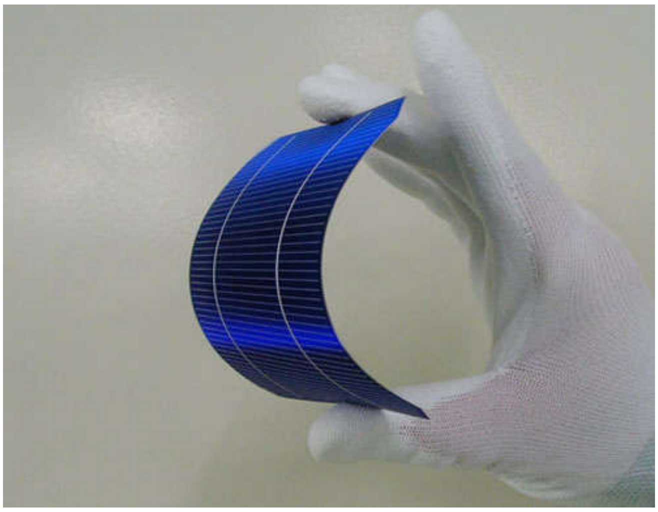


Fig. 4. Thin film solar cell

The performance of solar cell depends on how much amount of sunlight absorbs and converts into electricity. The large scale use of PV devices for electricity generation is prohibitively costly at present. Here we describe PV cells created from low to medium purity materials through low cost process which manifest commercially realistic energy transformation efficiency. The efficiency may be broken down into several parts like reflectance efficiency ,charge carrier separation efficiency and conductive efficiency and overall efficiency is the product of these individual metrics silicon is the most dominating semiconductor in the field of PV cells and this paper is about comparative study with its close competing material GALLIUM ARSENIDE. GALLIUM ARSENIDE have clearly high efficiency and several other advantages over SI but due to high cost (about 1000 times more than of SI's cost) application of such cell's is limited to an narrow region. Consolidated table shows the list of highest efficiency confirmed with respective modules. National Renewable Energy Laboratory (NREL) puts today's topmost performing multicrystalline silicon cell at just more than 21% efficient system. The record for the more costly and less common single-crystal silicon cell lies at 25%.State-of-the-art gallium arsenide-based solar cells boasting efficiencies as high as 46% lie at the very top of the NREL list. But those cells are highly specialized photovoltaic analysis instruments that come with expensive price tags. all data's are collected at 25ºC under the global AM1.5 spectrum (1000W/m²). initially all row data's are calculated like open-circuit voltage , short-circuit current and fill factor then this data is fitted to bellow equation for efficiency calculation.

$$n = (Voc * Isc * FF)/Pin$$

Here FF is fill factor, Voc is open circuit voltage and Isc is short circuited current Pin =The input power can be calculated as for 100mw/cm². For a 100*100mm² cells it is 10W. Simillarly for 143.7cm² it is 14.3W.

Methods to make gallium arsenide cheaper

We know that GaAs is more suitable for solar cell manufacturing but we can't use this with all applications due to its high cost but somehow if we can manage to reduce its cost than we can think of it.

Table 2. Differend cells and their comparison

Type of cell	Silicon purity	Efficiency (%)	Space efficiency	Lifetime	Cost
monocrystalline	High	15-20	Lowest	Highest(about 25 years)	High
Polycrystalline	Low	13-16	High	Medium	Medium
Thin film	Lowest	7-13	Highest	Small	Low

Classification	Efficiency (%)	Area(cm^2)	Voc(V)	ISC(MA/CM^2)	Fill factor
SI(crystalline)	25.60±0.5	143.7	0.740	41.80a	82.7
Si multicrystalline)	21.25±0.4	242.74 (t)	0.6678	39.80b	80.0
Si(thinfilm minimodule)	10.5±0.3	94.0 (ap)	0.492c	29.7c	72.1
III-V cells					
GaAs(thin film)	28.8±0.9	0.99 (ap)	1.122	29.68f	86.5
GaAs (multicrystalline)	18.4±0.5	4.011 (t)	0.994	23.2	79.7

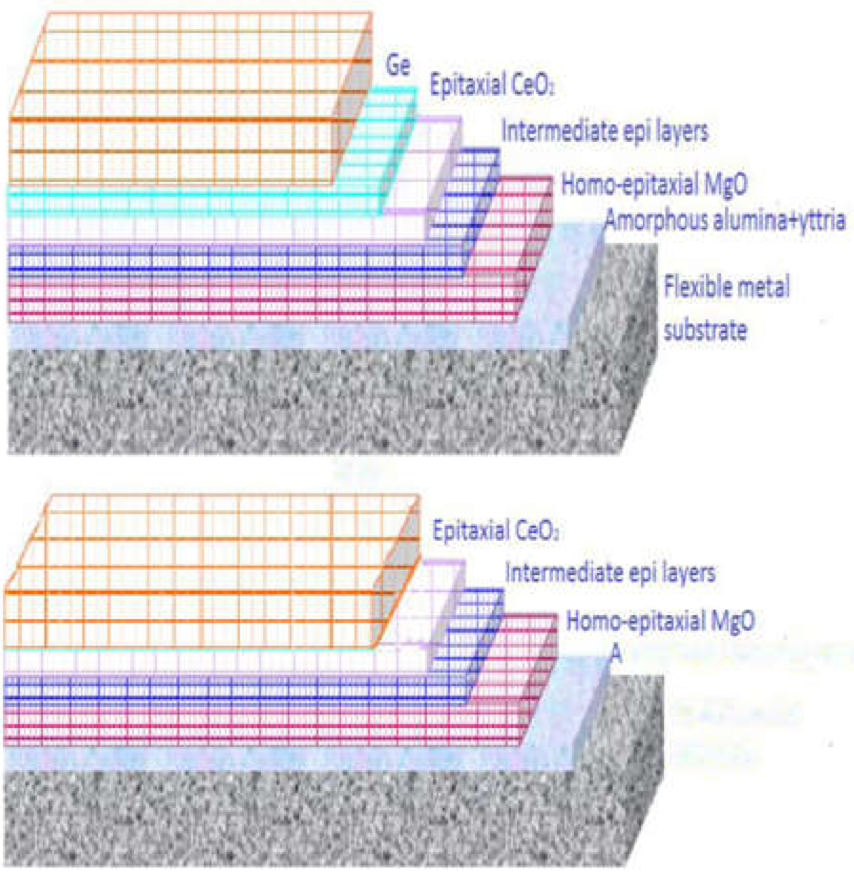
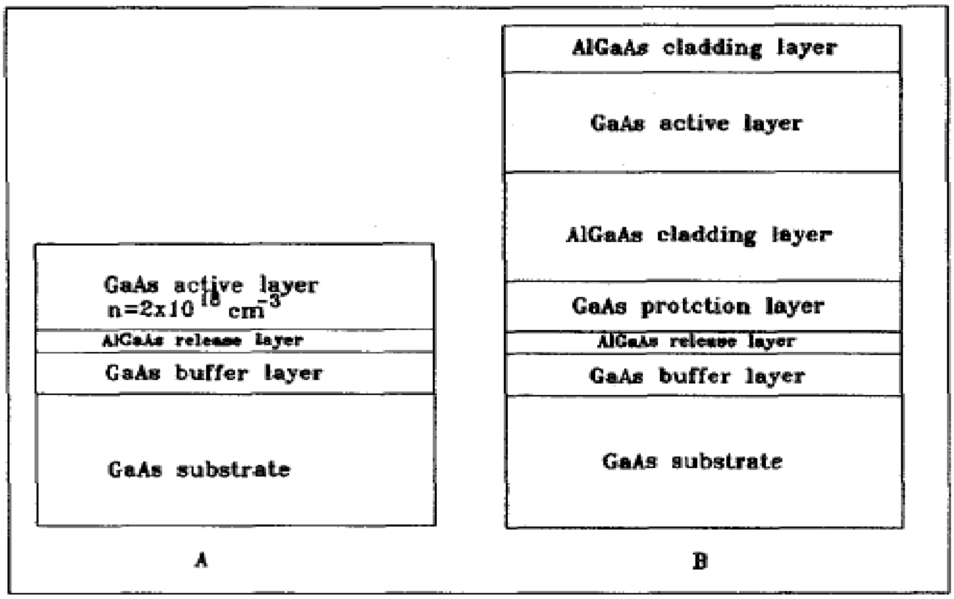


Fig. 2. Schematic of different multilayer architecture for growth of single crystalline GaAs on Ge terminated and Ce02 terminated IBAD templates



We can't crush cost of GaAs on market bases but if we can get some alternate indirect methods then things will me more acceptable. (A) Combining the unsurpassed performance of GaAs based mUlti-junction technologies with a conventional cheap roll to roll processing standards of thin film industry could lead to paradigm-shifting reduction of the cost of solar electricity and increase of specific efficiencies. We show growth of single crystalline GaAs using MBE directly on Ce02 buffer in flexible samples. HRXRD confirms presence of dislocations in GaAs which is directly deposited using MBE on oxide buffer to be comparable to that present in GaAs on Ge intermediate buffer in flexible samples despite of lattice mismatch issues. GaAs solar cell on Ce02 terminated buffer shows shunted diode characteristics while GaAs solar cell on Ge terminated buffer is shorted. (3)

(B) The EL0 method is general considered to be very suitable for separation of the thin epilayer from its substrate.

The used method is very gentle and hardly effects the substrate. We present further improvements on this method resulting in succesful separation of crack free thin films as large as 2" substrates. Re-use of the substrates has been investigated with two dimensional optical step profiling to determine the roughness after the different surface cleaning procedures and after the EL0 lift-off. Also the quality of epilayers after growning on used substrates is determined. In this paper it is demonstrated that substrates can be used several times without loss of epilayer quality.(4)(p.r. hag)

(C) We demonstrate the integration of GaAs thinfilm solar cells with low-cost plastic mini-compound parabolic

Concentrators (CPC) by combing a non-destructive epitaxial liftoff (ND-ELO) technique and a vacuum-assisted thermoforming process. To simplify the thin film III-V active layer transfer and to eliminate the use of adhesives of the epi to the secondary plastic substrate, we employ cold-weld bonding. The integration of thin film GaAs photovoltaic cells with a low-cost plastic mini CPC that can track solar radiation increases energy harvesting by a factor of 2. The Combination of cost effective concentrators with previously demonstrated non-destructive wafer recycling utilizing epitaxial protection layers provides the potential for a dramatic cost reduction in the production of III-V semiconductor photovoltaic cells.(5)(kyusng)

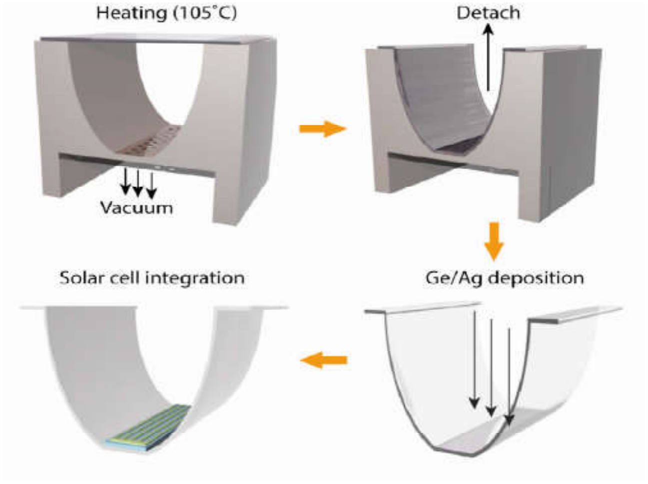


Fig. 1. Fabrication flow for the plastic mini-compound parabolic

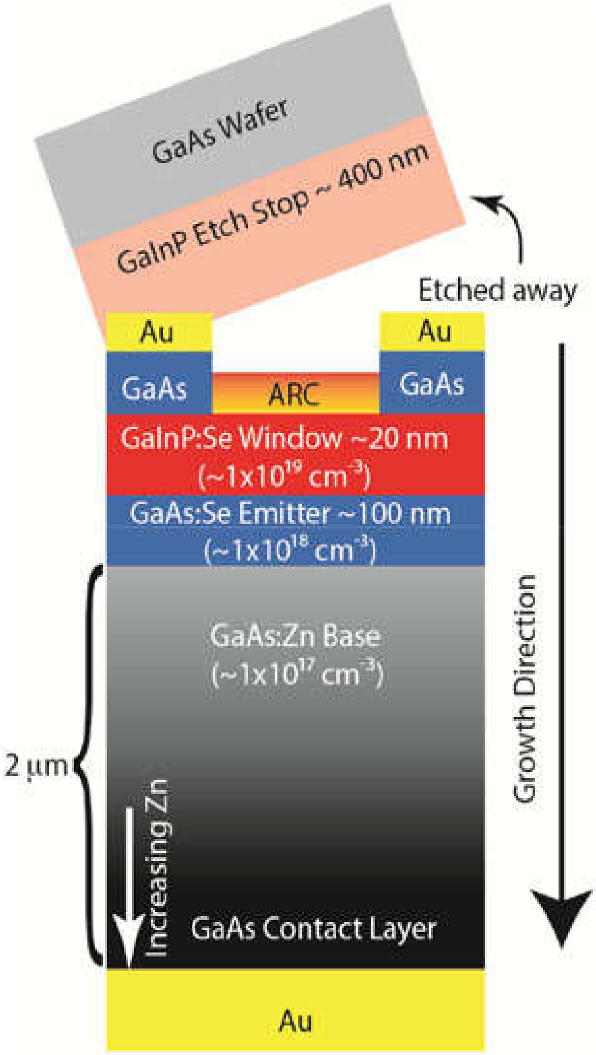


Fig. 3. IQE of HVPE GaAs cells with and without a GaInP window

(D) Hydride vapor phase epitaxy (HVPE) is a low-cost

alternative to conventional metal–organic vapor phase epitaxy (MOVPE) growth of III–V solar cells. In this work, we show continued improvement of the performance of HVPE-grown single junction GaAs solar cells. We show over an order of magnitude improvement in the interface recombination velocity between GaAs and GaInP layers through the elimination of growth interrupts, leading to increased short-circuit current density and open-circuit voltage compared with cells with interrupts. One-sun conversion efficiencies as high as 20.6% were achieved with this improved growth process. Solar cells grown in an inverted configuration that were removed from the substrate showed nearly identical performance to on-wafer cells, demonstrating the viability of HVPE to be used together with conventional wafer reuse techniques for further cost reduction. These devices utilized multiple heterointerfaces, showing the potential of HVPE for the growth of complex and high-quality III–V devices. (6)(john)

Conclusion

In the field of PV cells silicon is a dominating material with greater efficiency along with lower cost where its close competitors like gallium arsenide (GaAs) have high efficiency compare to silicon but lag in the field of economics due to their high cost about one thousand time of silicon. Several technologies like thin film make current scenario of PV-cells more acceptable. This study is more focused about basic concepts, construction, their efficiencies, cost, reliability and various applications. A cheaper material can make solar power a dirt and make its availability to a greater extent however, silicon is dominating this field with its cheap price and effective efficiency but in near future we can hope for a cheaper and high efficient solar material to be discovered like in some states Gallium arsenide shows efficiency as high about 46% that really a positive indication for researchers. with all respective efficiency data's and economic consideration GaAs can be considered more advantages with high efficiency but less economic suitable somehow we can reduce its cost to an far extent by several methods as described in this paper .

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