Improve the Efficiency of Solar Cells Using Hetrojunction and Limiting the Efficiency

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Abstract— This financial disaster is devoted to the methods related with the collection of image-generated businesses in silicon heterojunction (SHJ) sun cells with a focus on the key role of the amorphous silicon/crystalline silicon heterojunction. The motive is to provide an explanation for the position of service inversion at the heterointerface and be part of it with the homes of the SHJ to obtain deeper facts of provider transport houses and series, which goes beyond amorphous silicon-primarily based structures and could make a contribution to knowledge the brand new growing SHJ based on amorphous silicon oxide and steel oxide emitter layers. The test is extended by means of the use of a simulation of the TCO/emitter interface with the purpose to show the impact of parasitic Schottky barrier top at the overall performance of the SHJ solar cell. In addition, the simulation have a look at of SHJ beneath focused light and varied temperatures is outlined to expose the principle limitations and possibilities of SHJ structures for usage beneath focused mild.

Keywords: Hetrojunction, Amorphous Silicon,Carrier Inversion, ASA Simulation, Open Circuit Voltage

I. Introduction

Between the semiconductor materials with right optoelectronics homes for photovoltaic program, silicon have been the most notably regulars and use in the contemporary production of photovoltaic module. The fundamental gains of silicon is its abundances in nature and master silicon wafers fabrications, furthers to the compatibility of the technological technique of sun cells with the microelectronics organization. The developing rate of processed crystalline silicon inside the beyond years have come to be a the usage of stresses lowering the wafers thicknesses for sun mobility fabrication. However, this style modified into stopped because of the bending of skinny wafers for the duration of immoderate temperature processing of desired silicon sun cells, which end up in to the developing effort focused on the technologies with lower silicon usage. Among them, the silicon heterojunction sun cells (SHJ) offer both excessive overall performance collectively with a angle of low-cost fabrications and reduce of silicon wafers thickness bellow a 100 µm. The advantages of heterojunction among formless and crystalline silicon had been first introduced into the so-referred to as HIT concept (Hetero-junction with Intrinsic Thin-layer) with the aid of way of former organization SANYO (presently SANYO is a part of the business enterprises Panasonic) in 1992. The SHJ HIT solar mobile consist of a single skinny crystalline silicon wafers, c-Si surrounded by the use of using extremely-skinny intrinsic silicon layers, a-Si:H(i) and n-type and p-type doped amorphous silicon layers, a-Si:H (Figure 1), which can be deposited at temperature below 100 °C and so can be utilized in processing of skinny wafers. On the two doped layers, obvious undertaking oxide (TCO) layers and metal electrodes are customary with sputtering and display-printing techniques, respectively. The TCO layer on the pinnacle moreover works as an anti-reflected photograph layer.

II. Currents trends in SHJ solar cell development

To make the SHJ sun cells greater carefully good-looking, cutting-edge-day-day efforts are centered on the development of generation and strategies centered on most vital targets (i) to boom the efficiency and (ii) to lower the fabrication charges. The usage of emitters with a massive band hole along with amorphous silicon carbide a-SiC:H , nanocrystalline silicon oxide nc- SiOx: H or micro-crystalline silicon oxide µc-SiOx:H , subsequently reducing slight absorption is a commonplace approach on a manner to boom JSC and as a cease end result the general overall performance of such sun cells. The benefit of this technique is that excellent low adjustment of manufacturing lines is wanted for replacements of a-Si:H emitter by way of a-SiC:H or SiOx:H emitter layers. An increase in JSC through approximately 1 mA/cm2 became hooked up with the resource of converting a-Si:H via a-SiC:H or with the aid of using µc-SiOx:H. However, also in this example the heterojunction with a c-Si substrate performs a essential function and its fabrication wishes to be well mastered to revel in the decrease parasitic absorption of light. Another manner on the way to lower absorption losses is primarily based definitely genuinely at the guidance of the two collection contacts at the bottom aspect of the silicon substrate forming an inter-digitated again contact silicon heterojunction (IBC-SHJ) solar cells. The useful effects of series electrodes at the bottom of the cellular are tested thru the pleasant performance of 25.6% presently completed at SHJ solar cells . High JSC = forty one.Eight mA/cm2 in such sun cells is attained due to the eliminated absorption losses of a-Si:H layers in addition to losses in TCO.

The decrease of fabrication price may be realized thru the possibility of high priced substances with the aid of using cheaper options. Several agencies have investigated opportunity materials together with zinc oxide, ZnO, and indium zinc oxide, IZO, as a possibility of luxurious indium tin oxide, ITO. Replacement of silver used in the series electrodes thru manner of copper is each other way, and is presently extraordinarily investigated to lower SHJ charge.

Another method to type SHJ cell more carefully attractive is based on the discount of silicon wafers thicknesses. The functionality of HIT shapes to used silicon wafers of low thickness and to accumulates high usual performance at the identically time becames examine already in 2009, even as the SHJ HIT sun cells with a conversion efficiency of twenty-two.8% prepared on a ninety eight µm thick n-kind silicon wafer became added thru former employer Sanyo (currently Panasonic) .

Nowadays, new boom ideas are growing based totally mostly on the substitute of the amorphous emitter thru metallic oxides. Such a idea has the potential to offer every an increase of standard performance further to a decrease of fabrication fee. Metal oxides offer benefits of huge band gaps, consequently lower parasitic absorption within the emitter, less difficult deposition with the aid of way of thermal evaporations and no requirements of toxic dopant gases in the path of fabrication. Moreover, the deposition of such oxides may be accomplished at low temperatures leading to a similarly decrease of the thermal fee variety and consequently fabrication price. Metal oxides are extensively used as a hole shipping layers in herbal solar cells. Current tries to replace them into the SHJn technology display very promising effects with achieved overall performance of η = 22. Five% for molybdenum oxide hole collector MoOx-based truely SHJ solar mobile. The development inside the development of electron selective contacts based totally totally mostly on lithium fluoride (LiFx) allows fabrication of dopant-loose uneven heterocontacts cellular (DASH) with conversion overall performance coming close to 20%.

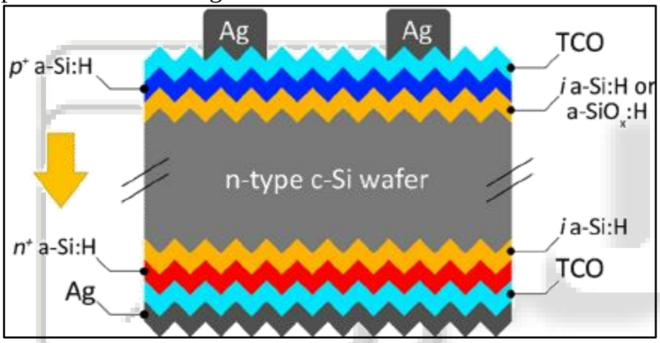


Fig. 1: Sketch of Diffused Junction Solar Cell

a-Si	Gas flow rate (sccm)				Substrate temp. (℃)	Pressure (Pa)	RF power (mW/cm^2)
	SiH_4	B_2H_6 (1%)	PH_3 (1%)	H_2			
p-type	5-20	2-40	—	20-100	80-180	10-40	5-90
n-type	5-40	—	5-40	5-200	80-180	10-40	10-60
i-type	5-40	—	—	0-100	80-180	5-40	5-90

(B_2H_6, PH_3 : H_2 Balanced)

Table 1: Deposition Conditions of a-Si Films

III. IDEAL MODEL

A. *Hetrojunction Concept*

Key to the fulfillment of SHJ devices are the separation of expressly recombination-active (ohmic) contacts from the crystalline floor thru insertion of a passivating, semiconducting film with a miles wider bandgap. For SHJ devices. The interface country density on the wafer surfaces must be minimum, else the buffer layers will enhance in place of inhibit recombination. The SHJ idea shows a splendid affinity in principle with metal insulator-semiconductor (MIS) sun cells, which rely on quantum-mechanical tunneling of vendors via an insulating buffer layer. However, such tunneling does not constantly stand up in SHJ gadgets, and diffusive transport of carriers can be at the least as vital. For SHJ devices, hydrogenated amorphous silicon (a-Si:H) films some nanometers thick are attractive applicants for buffer layers: their bandgap is barely wider than that of c-Si and they will be doped mainly without trouble, each n- orp-type, allowing the fabrication of electronic heterojunctions.

The basis of the concept for calculating the restricting efficiency of homo-junction unmarried hole sun cells—or single-hollow sun cells for quick—modified into hooked up with the resource of Shockley and Queisser (S&Q) in 1961 This concept establishes, on the excellent hand, that photons with energy underneath the bandgap of the semiconductor cannot be absorbed; this devices a limit to the maximum image present day that the cell can offer. On the opportunity hand,aftersome refinements to be considered for stimulated emission , the principle furthermore establishes that the open-circuit voltage of the solar cellular cannot exceed the gap of the semiconductor (divided with the useful aid of the electron charge) that the cell is fabricated from. However, a heterojunction sun cellular, fabricated from the junction of a high-bandgap semiconductor and alow-bandgap semiconductor should plausibly providea image-contemporary-day limit edby the semiconductor with the lowest bandgap and a voltage constrained by means of the semiconductor with the very first-rate bandgap having, therefore, the ability to conquer S&Q efficiency restriction of unmarried-hole solar cells. Whilst a unmarried-gap sun cellular with gap EG seems, we will discuss with the S&Q restricting efficiency of this cellular due to the fact the “EG sun cell S&Q efficiency restriction.” We may even clarify whether or not or no longer a once more reflector has been placed within the back of the cell or a medium of refraction index nr because the limiting efficiencies, for the equal bandgap, are unique.

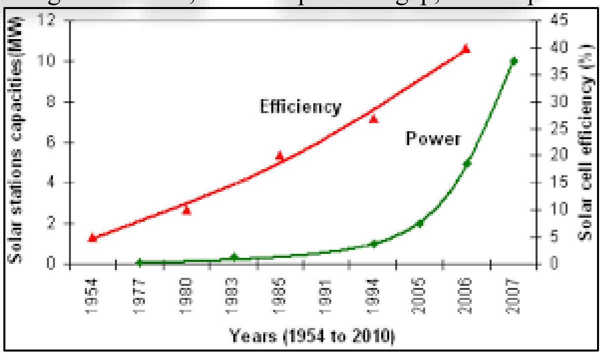


Fig. 2: Progress of Silicon Solar Cell Technology

B. *Finite Mobility Case*

- The situation modifications if we do away with the situation of infinite provider mobility. In this recognize. Information the electricity band diagram and quasi-Fermi degree distribution foracase in which we count on that hole mobility is finite in a transition location on the interface a number of the immoderate- and occasional-bandgap semiconductors (we maintain the belief of infinity electron mobility for simplicity).
- The transition layer might be the distance fee regionor a bigger vicinity. In our talk, we are able to leave out the generation and recombination of company staking region on this transition layer as it is also assumed in

Shockley's best diode model. The statistics of the version for the contemporary–voltage function of the heterojunction sun cellular.

– The diode DL and the modern generator JL constitute a excellent S&Q sun mobile (with lower all over again reflector) characterised with the useful aid of manner of the distance EL. The resistor Rh debts for a voltage loss in the route of the transition layer due to our assumption off initeholemobilit

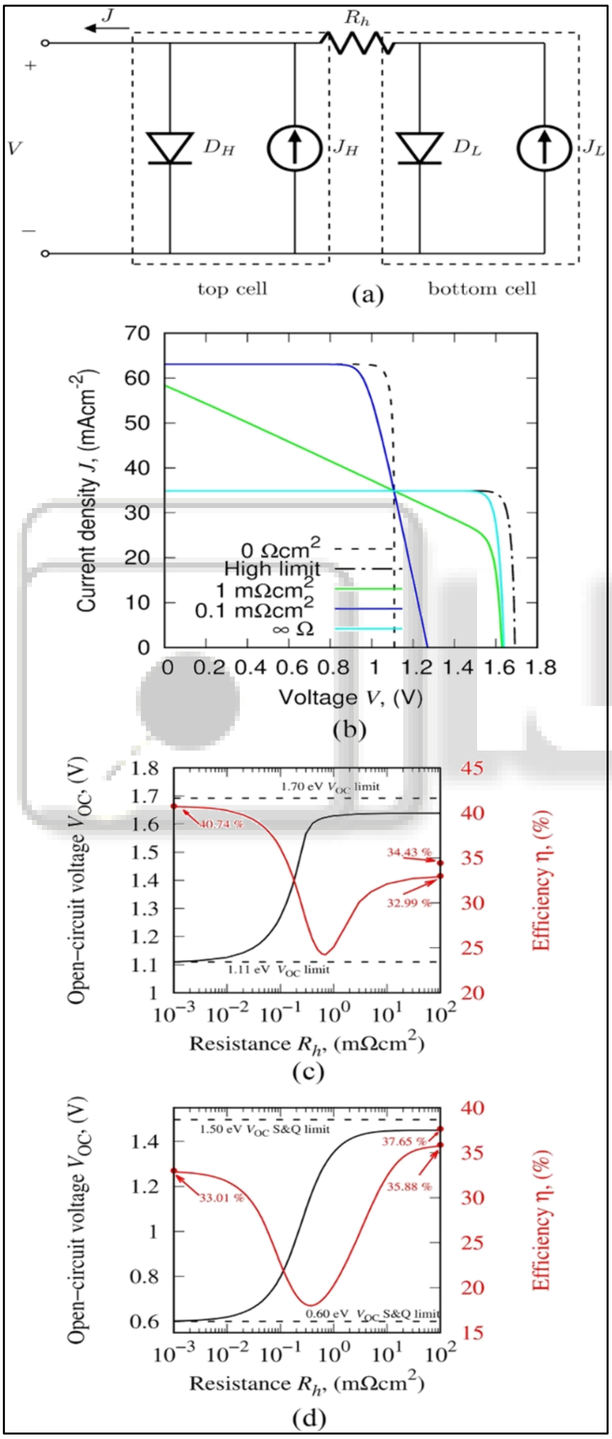
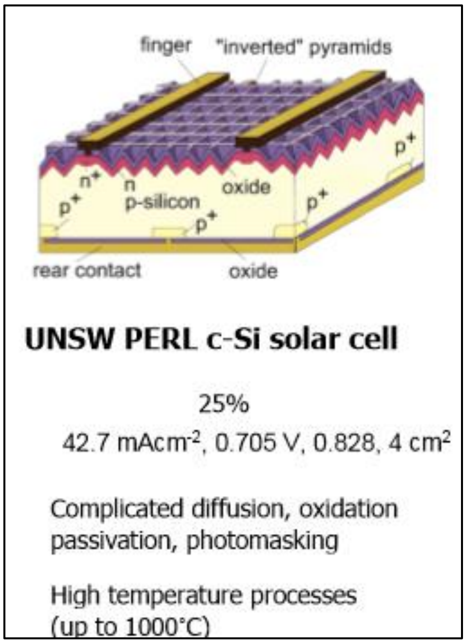
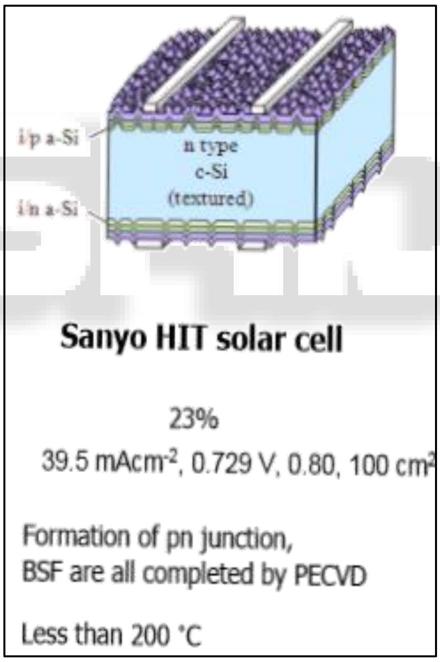


Fig. 3: Simplified Equivalent Circuit of a Heterojunction Solar Cell

C. Homojunction c-Si Solar Cell



D. HETROJUNCTION Si SOLAR CELL



E. Open Circuit Voltage and Carrier Inversion

The output ordinary performances of the solar cells may be defined through the use of v o c, jsc and ff. All such parameter are associate with the η and define the overall outputs universal overall performance of sun cell. While the precept purposes of this bankruptcy is to explains the functions of heterointerface and inversion on the a-si:h/c-si, we are capable of reputation on voc that is strongly suffering from recombination's residences and provider transport within the solars cellular. The voc for shjp solar cells may be expressed via the logical models.

$$V_{OC} = \frac{E_{g-Si} - \delta_{Si(p)}}{q} - \frac{kT}{q} \ln\left(\frac{N_C}{\Delta n} \cdot \frac{\frac{D_p}{L_p} + S_p}{\frac{D_p}{L_p}}\right)$$

Similarly for shj, the voc is expressed

$$V_{OC} = \frac{E_{g-Si} - \delta_{Si(n)}}{q} - \frac{kT}{q}\ln\left(\frac{N_V}{\Delta p}\cdot\frac{\frac{D_n}{L_n}+S_n}{\frac{D_n}{L_n}}\right)$$

S symbols in the above equation denoted: t is the temperature, q is the standards charge, okay is the boltzmann regular, eg-si is the band gap of c-si, nc and nv are the controlling densities of states in the conveyance band of c-si, δsi(p) and δsi(n) are the dopant beginning energy of c-si substrate with p-type and n-type doping, individually, lp and ln are diffusion distances for holes and electrons, individually, and dp and dn are dispersal coefficients for holes and electrons.

From the above equation it is clear that voc relies upon on δn, it is decided with the resource of τeff and g. G is related to the illumination intensity. Teff is decided with the resource of the recombination velocities sp and sn and consequently via the defect nation density at the a-si:h/c-si hetero interface, dit recombinations at the rear ground and recombination within the c-si substrate. The recombination within the c-si substrate isn't always the priority of this financial disaster, in preferences to this, we consciousness our interest to the a-si:h/c-si

Affiliation	η (%)	V_{oc} (mV)
Sanyo [39], Japan	23.7	745
Kaneka [121], Japan	22.1	729
RRS [116], Switzerland	21.9	735
EPFL [127], Switzerland	21.8	726
HHI [128], Korea	21.1	721
CEA-INES [129], France	21	732
CIC [112], Japan	20	685
HZB [130], Germany	19.8	639
NTUST [131], Taiwan	19.6	690
Univ. Hagen [132], Germany	19.3	675
FhG-ISE [133], Germany	18.7	~705
IEC [69], USA	18.3	694
LG [134], Korea	18.2	687
NREL [135], USA	18.2	694
Titech [136], Japan	17.9	671
AIST [137]#, Japan	17.5	656
Sungkyunkwan Univ. [138], Korea	17.4	631
LPICM [139], France	17.2	701
Utrecht Univ. [140], the Netherlands	16.7	681
CNR-IMM [141], Italy	16.2	573
Delft Univ. [142], the Netherlands	15.8	646
Univ. Toronto [143], Canada	15.5	679
Kyung Hee Univ. [144], Korea	14	575
ECN [145], the Netherlands	13.2	635
KIER [146], Korea	12.8	<600

Table 2: Device results on n-type c-Si wafers

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REFERENCES

[1] M. A. Green et al., “Solar cell efficiency tables (version 52),” Prog. Photovolt. Res. Appl., vol. 26, no. 7, pp. 427–436, 2018.
[2] T. Kato, J.-L. Wu, Y. Hirai, H. Sugimoto, and V. Bermudez, “Record efficiency for thin-film polycrystalline solar cells up to 22.9% achieved by Cs-treated Cu(In,Ga)(Se,S)2,” IEEE J. Photovolt., vol. 9, no. 1, pp. 325–330, Jan. 2019.
[3] S. Krum, “First solar achieves yet another cell conversion efficiency world record | business wire,” Business Wire, Feb. 2016. [Online]. Available: https://www.businesswire.com/news/home/20160223005315/en/. Accessed on: Jan 25, 2019.
[4] T. Lauinger, J. Schmidt, A. G. Aberle and R. Hezel, Appl. Phys. Lett. 86, 1232 (1996).
[5] Z. Chen, P. Sana, J. Salami and A. Rohatgi, IEEE Trans. Electron. Dev. 40, 1161 (1993).
[6] R. Hezel and K. Jaeger, J. Electrochem Soc. 136, 518 (1989).
[7] G.Agostinelli,A.Delabie,P.Vitanov,Z.Alexieva,H.F.W. Dekkers, S. De Wolf and G. Beaucarne, Sol. Energy Mater. Sol. Cells 90, 3438 (2006).
[8] B. Hoex, S. B. S. Heil, E. Langereis, M. C. M. van de SandenandW.M.M.Kessels,Appl.Phys.Lett.89,042112 (2006).
[9] J. Szlufcik, F. Duerinckx, J. Horzel, E. Van Kerschaver, H. Dekkers, S. De Wolf, C. Allebe and J. Nijs, Sol. Energy Mater. Sol. Cells 74, 155 (2002).
[10] C. Ballif, D. M. Huljic, G. Willeke and A. Hessler-Wyser, Appl. Phys. Lett. 82, 1878 (2003).
[11] T. Saga, NPG Asia Mater. 2, 96 (2010).
[12] E. Schneiderlochner, R. Preu, R. Ludemann and S. W. Glunz, Prog. Photovoltaics 10, 29 (2002).
[13] G. Agostinelli, P. Choulat, H. F. W. Dekkers, S. De WolfandG.Beaucarne,Proc.31stIEEEPhotovoltaicSpecialists Conference, Lake Buena Vista, Florida, 2005, p. 1149.
[14] E. Yablonovitch, T. Gmitter, R. M. Swanson, and Y. H. Kwark,. Appl. Phys. Lett. 47, 1211 (1986).
[15] P. Würfel, Physics of Solar Cells: From Principles to New Concepts, Wiley-WCH, Weinheim, 2005.

