

Electronic Patent Application Fee Transmittal

Application Number:				
Filing Date:				
Title of Invention:	Buried Insulator Isolation for Solar Cell Contacts			
First Named Inventor/Applicant Name:	Peter G. Borden			
Filer:	Mark J. Danielson/Bobbie Jutras			
Attorney Docket Number:	013085/NBNP/KCHANG			
Filed as Large Entity				
Provisional Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Provisional application filing	1005	1	210	210
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				HANWHA 1011

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				210

Electronic Acknowledgement Receipt

EFS ID:	2764174
Application Number:	61023354
International Application Number:	
Confirmation Number:	1135
Title of Invention:	Buried Insulator Isolation for Solar Cell Contacts
First Named Inventor/Applicant Name:	Peter G. Borden
Customer Number:	71728
Filer:	Mark J. Danielson/Bobbie Jutras
Filer Authorized By:	Mark J. Danielson
Attorney Docket Number:	013085/NBNP/KCHANG
Receipt Date:	24-JAN-2008
Filing Date:	
Time Stamp:	18:19:35
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$210
RAM confirmation Number	3337
Deposit Account	033975
Authorized User	

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1		AMAT_13085.pdf	1901235	yes	18
			8d39922a2bc8d23f27ace49dc2875cb261dbc70d		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Provisional Cover Sheet (SB16)		1	2	
	Specification		3	10	
	Claims		11	11	
	Abstract		12	12	
	Drawings-only black and white line drawings		13	14	
	Appendix to the Specification		15	18	
Warnings:					
Information:					
2	Fee Worksheet (PTO-06)	fee-info.pdf	8130	no	2
			6a35ce226481e70ffa19ca369a39d84be9038076		
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Total Files Size (in bytes):			1909365		

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PTO/SB/16 (10-07)

Approved for use through 06/30/2010. OMB 0651-0032

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. _____

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Peter G.	Borden	San Mateo, California
Li	Xu	Santa Clara, California

Additional inventors are being named on the _____ separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max):

BURIED INSULATOR ISOLATION FOR SOLAR CELL CONTACTS

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☒ The address corresponding to Customer Number: 27,498

OR

☐ Firm or Individual Name

Address

City	State	Zip
Country	Telephone	Email

ENCLOSED APPLICATION PARTS (check all that apply)

☐ Application Data Sheet. See 37 CFR 1.76 ☐ CD(s), Number of CDs _____

☒ Drawing(s) Number of Sheets 2 ☒ Other (specify) Appendix, 4 sheets

☒ Specification (e.g. description of the invention) Number of Pages 10

Fees Due: Filing Fee of \$210 (\$105 for small entity). If the specification and drawings exceed 100 sheets of paper, an application size fee is also due, which is \$260 (\$130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

METHOD OF PAYMENT OF THE FILING FEE AND APPLICATION SIZE FEE FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27. 210.00

☐ A check or money order is enclosed to cover the filing fee and application size fee (if applicable).

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PROVISIONAL APPLICATION COVER SHEET
Page 2 of 2

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No.

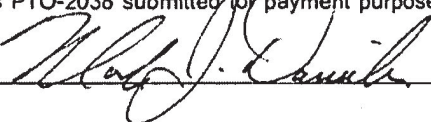


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SIGNATURE _____

Date January 24, 2008TYPED or PRINTED NAME Mark J. DanielsonREGISTRATION NO. 40,580
(if appropriate)TELEPHONE (650) 233-4777Docket Number: 013085 /NBNP/SOLAR-OTH/KCHANG

BURIED INSULATOR ISOLATION FOR SOLAR CELL CONTACTS

FIELD OF THE INVENTION

[0001] The present invention relates to forming contacts in a semiconductor device, and more particularly to methods and apparatuses for providing a buried insulator isolation for solar cell contacts.

BACKGROUND

[0002] To obtain high efficiency in silicon solar cells, it is considered advantageous to eliminate surface recombination. Such recombination comes from both unpassivated surfaces and from metal contacts. A measure of recombination is the surface recombination velocity (SRV), which is the rate of minority carrier recombination at the surface. For a reference value, <100 cm/sec provides a well passivated surface needed for a high efficiency cells. By contrast, a metal contact will have an SRV of 10^7 cm/sec, five orders of magnitude higher. If the metal covers 3% of the surface, then the effective surface recombination velocity is 3×10^5 cm/sec, more than 3 orders of magnitude larger than desired. Therefore, contact passivation is essential.

[0003] A well known method to isolate the contacts from the bulk is to use a selective emitter, shown in FIG. 1. The area away from the contacts has a shallow emitter diffusion (n-type, typically with Phosphorous doping, on a p-type substrate). The shallow emitter provides good blue response, as blue photons are absorbed near the surface. This emitter might be 0.3 to 0.5 μm thick. Deep diffusions – 2-3 μm thick – are placed under the contacts. These provide isolation so that the high recombination contact surfaces do not affect the cell performance. However, such structures are difficult to form as they require aligned patterning of the contact

holes and the metal lines, as well as a several hour diffusion to obtain such a deep junction.

Therefore, selective emitters are rarely used in commercial solar cells.

[0004] Another method to passivate contacts is to place a thin tunnel oxide – typically 15Å thick – under the metal contacts. Such contacts are also well known, and have been used commercially by Schott solar to manufacture MIS solar cells. Groups at the University of New South Wales and the Institute for Solar Forschung Hameln have also demonstrated this method. Martin Green, in his book on Silicon Solar Cells, describes use of a thin tunnel oxide under a layer of polysilicon to form a high efficiency solar cell. Such solar cells have not been commercially introduced, possibly because of the difficulty of reliably forming a thin tunnel oxide.

[0005] Therefore, there remains a need in the art for a commercially feasible method and apparatus for providing contact passivation in a solar cell.

SUMMARY

[0006] The present invention relates to methods and apparatuses for providing a buried insulator isolation for solar cell contacts. According to certain aspects, the invention places a buried oxide under the emitter of a polysilicon emitter solar cell. The oxide provides an excellent passivation layer over most of the surface. Holes in the oxide provide contact areas, increasing the current density to enhance efficiency. The oxide isolates the contacts from the substrate, achieving the advantage of a selective emitter structure without requiring deep diffusions. The oxide further enables use of screen printing on advanced shallow emitter cells. Positioning of the grid lines close to the openings also enables use of a very thin emitter to maximize blue response.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures, wherein:

[0008] Figure 1 shows a prior art selective emitter cell.

[0009] Figure 2 shows the buried oxide cell structure.

[0010] Figure 3 shows the buried oxide cell with an offset contact structure.

[0011] Figure 4 shows key elements of the buried oxide cell process flow.

DETAILED DESCRIPTION

[0012] The present invention will now be described in detail with reference to the drawings, which are provided as illustrative examples of the invention so as to enable those skilled in the art to practice the invention. Notably, the figures and examples below are not meant to limit the scope of the present invention to a single embodiment, but other embodiments are possible by way of interchange of some or all of the described or illustrated elements. Moreover, where certain elements of the present invention can be partially or fully implemented using known components, only those portions of such known components that are necessary for an understanding of the present invention will be described, and detailed descriptions of other portions of such known components will be omitted so as not to obscure the invention. In the present specification, an embodiment showing a singular component should not be considered limiting; rather, the invention is intended to encompass other embodiments including a plurality of the same component, and vice-versa, unless explicitly stated otherwise herein. Moreover, applicants do not intend for any term in the specification or claims to be ascribed an uncommon or special meaning unless explicitly set forth as such. Further, the present invention

encompasses present and future known equivalents to the known components referred to herein by way of illustration.

[0013] In general, the invention provides a buried oxide under the emitter of a polysilicon emitter solar cell. The oxide provides an excellent passivation layer over most of the surface. Holes in the oxide provide contact areas, increasing the current density to enhance efficiency. The oxide isolates the contacts from the substrate, achieving the advantage of a selective emitter structure without requiring deep diffusions.

[0014] The present inventors recognize that a point contact solar cell provides improved efficiency. This is because the current flow is concentrated into a small region, providing a higher current density. The open circuit voltage is given by the equation:

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[0015] where k is Boltzmann's constant, T the temperature, q the electron charge, J_L the short circuit current density, and J_0 the diode saturation current. Therefore, an increase in short circuit current density provides an increase in voltage and, hence, efficiency.

[0016] FIG. 2 shows the new cell structure of this invention. As shown in FIG. 2, the cell structure includes an insulating layer under the doped region and the contact. This insulating layer isolates the contact from the substrate. If the insulating layer is made using a material that passivates silicon, such as thermal SiO_2 , then the solar cell surface has very good passivation and a low surface recombination velocity, both in the field region and under the contacts.

[0017] Photocurrent flows through contact holes patterned in the oxide layer. This concentrates the current flow, providing an increased current density at the junction. The collected current then flows laterally to the contacts. Typical dimensions of the openings can be 20 to 200 μm and spacing between openings can be 1-5 mm. The ratio of the spacing to opening

width provides the concentration, which is limited by series resistance due to current crowding at the contact holes. Concentration ratios on the order of 5 to 20 are typical. The openings can be lines parallel to the contact grid lines, or holes of shape such as rectangles or circles. Larger openings can be patterned without lithography, using screen printing. Laser ablation can also be used.

[0018] The doped region is formed using polysilicon, which may be deposited at a temperature on the order of 630°C and is in-situ doped. A short anneal at 1050°C for 30 seconds after deposition activates the dopants. A thin tunnel oxide may be included between the substrate and the polysilicon in the contact holes. This oxide – typically 8 to 15Å thick – provides passivation between the substrate and the polysilicon, as described in the prior art.

[0019] In another embodiment, the contact lines are not centered with respect to the holes, but offset, as shown in FIG. 3. Now the current path from the contact holes to the contact grid lines is shortened. This path may be typically 50 to 200 μm long, so that the metal grid lines are well isolated from the contact holes, but the series resistance between the contact and the hole is low because of the short path length. This enables use of a thinner emitter layer – on the order of 500 to 1000Å thick – reducing absorption of blue light in the emitter and improving blue response.

[0020] Note that the contact metal is blocked from reaching the substrate by the buried oxide. This enables contacting to the thin emitter without use of a sophisticated contact process.

[0021] The buried oxide is preferably relatively thin so that it does not provide an optical element that reduces light transmission into the cell. A thickness of 100 to 150Å is adequate, although thinner layers may be used. A thickness >20Å is desirable, as thinner layers may support leakage through tunnel currents. This thickness provides some contrast, so that the

contact hole position can be identified for alignment of the grid lines, but has a negligible affect on light transmission into the cell.

[0022] FIG. 4 shows an example embodiment of the process flow for this cell. First, the wafer is cleaned and the buried oxide formed, using a process such as thermal oxidation or RadOx® from Applied Materials. The contact holes are then formed. An etch mask layer is screen printed on the cell and the buried oxide is etched in HF. The resist is then removed. The wafer is then cleaned and, in one embodiment, a tunnel oxide is grown in the contact holes using a process such as ISSG or Radox. Another embodiment does not use the tunnel oxide. The doped polysilicon is then deposited. On p-type substrates, this is 500 to 1000Å of n-type poly, doped with either As or P. On n-type substrates, the layer is doped with B. The antireflection coating is also deposited, which may be a 750Å layer of silicon nitride. In the preferred embodiment, the wafer is then annealed at 450°C for 30 minutes in forming gas to provide hydrogen passivation.

[0023] Holes are then patterned in the AR coating using screen printing and etching. Plating may be used to form Ni/Ag contacts, which are then annealed. In another embodiment, silver paste is screen printed on the AR coating and fired in, with the buried oxide blocking the fired paste from reaching the substrate.

[0024] The described structure may be formed on the front of the cell. In an alternate embodiment, it is formed on the back of the cell. This is advantageous if the front of the cell has a texture, as the structure can be made on a planar surface. The textured surface exposes the $\langle 111 \rangle$ plane which has a higher atom density than the $\langle 100 \rangle$ plane and also has 1.7 times of the area of planar surface. The textured surface has a higher SRV than planar surface and is more

difficult to passivate. It is desirable to form such structures on the planar surface on the back of the cell.

[0025] The opposite side of the cell also requires a contact structure. In one embodiment, aluminum is deposited on the back and fired in using a laser to form laser fired contacts, which are well known in the prior art. In another embodiment, the front structure is repeated on the back, using polysilicon with the same doping type as the substrate.

[0026] It should be noted that the cell operates in forward bias. For example, if the poly layer is p-type and the substrate is n-type, then the poly layer is positive with respect to the substrate. Therefore, the surface will be accumulated (high electron concentration). This provides a means to passivate the surface, as holes will not be present, and both holes and electrons are needed to recombine at interface traps.

[0027] To operate in inversion, it is necessary to form the dielectric with a fixed charge that provides a threshold voltage shift greater than the cell operating voltage.

[0028] Note, also, that the buried layer can be made of more than one material. For example, one can form a thin oxide to passivate the surface, followed by a thicker silicon nitride. The nitride can provide charge and hydrogen, and can be an improved barrier to block metal atoms from diffusing from the contacts into the substrate when the contacts are annealed.

[0029] The attached Appendix forms part of the present disclosure and is incorporated herein by reference.

[0030] Although the present invention has been particularly described with reference to the preferred embodiments thereof, it should be readily apparent to those of ordinary skill in the art that changes and modifications in the form and details may be made without departing from

the spirit and scope of the invention. It is intended that the appended claims encompass such changes and modifications.

WHAT IS CLAIMED IS:

1. A solar cell structure that includes an insulating layer under the emitter, said insulating layer being patterned to provide contact holes.
2. A solar cell as in claim 1 in which the insulating layer is silicon dioxide.
3. A solar cell as in claim 2 in which the silicon dioxide is thermally grown.
4. A solar cell as in claim 3 in which the insulator is $>20\text{\AA}$ thick.
5. A solar cell as in claim 1 in which the emitter is made of polysilicon.
6. A solar cell as in claim 1 in which said contact holes have a tunnel insulator between the emitter and the underlying semiconductor.
7. A solar cell as in claim 6 that includes a contact structure, said contact structure being offset from said contact holes.

ABSTRACT

The present invention relates to methods and apparatuses for providing a buried insulator isolation for solar cell contacts. According to certain aspects, the invention places a buried oxide under the emitter of a polysilicon emitter solar cell. The oxide provides an excellent passivation layer over most of the surface. Holes in the oxide provide contact areas, increasing the current density to enhance efficiency. The oxide isolates the contacts from the substrate, achieving the advantage of a selective emitter structure without requiring deep diffusions. The oxide further enables use of screen printing on advanced shallow emitter cells. Positioning of the grid lines close to the openings also enables use of a very thin emitter to maximize blue response.

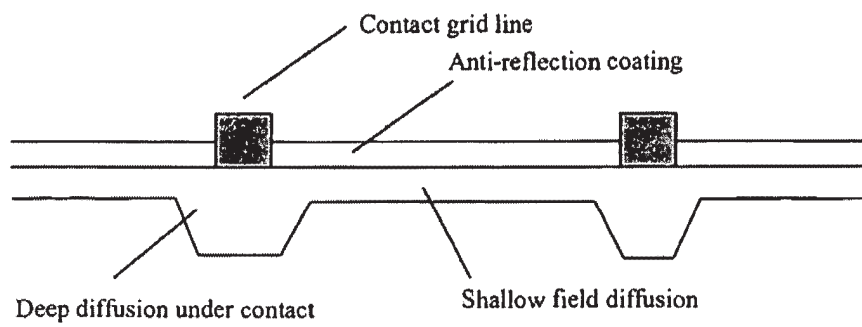


FIG. 1

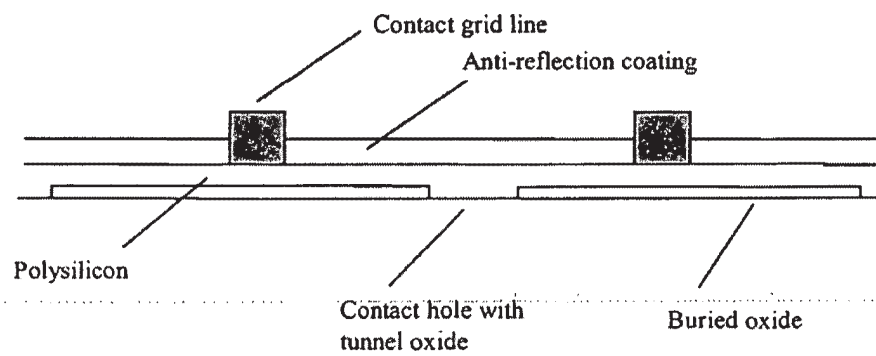
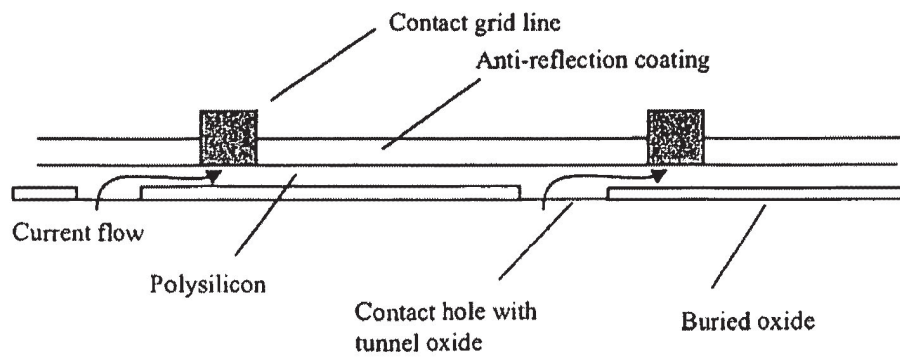
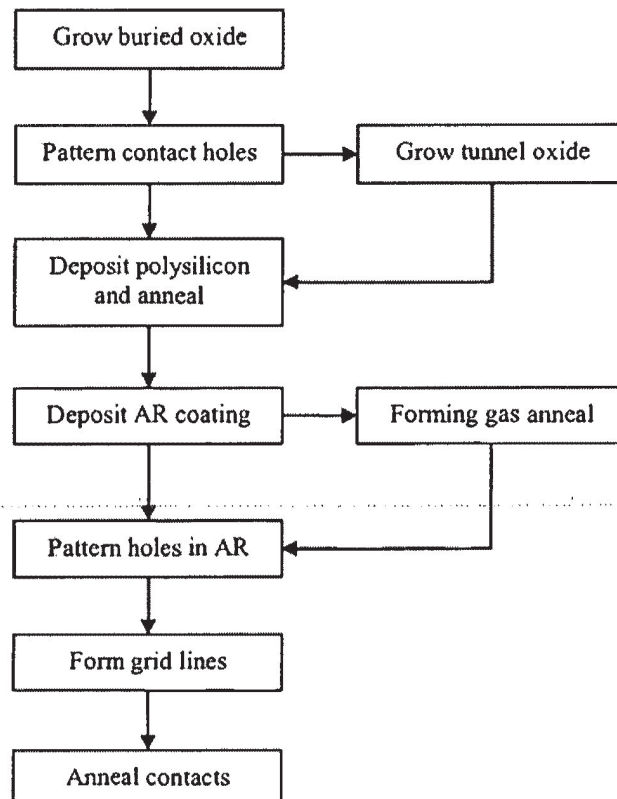
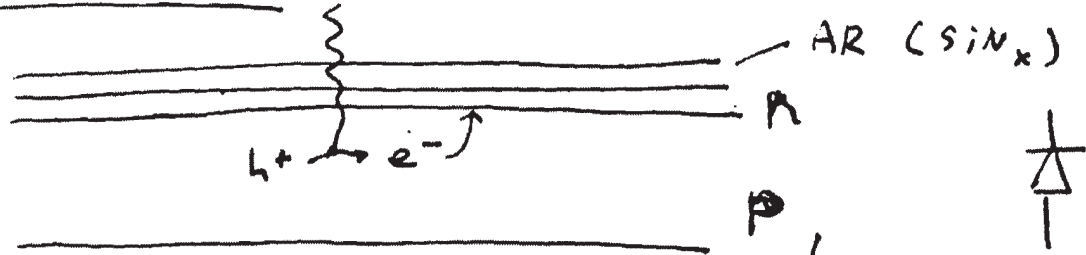


FIG. 2

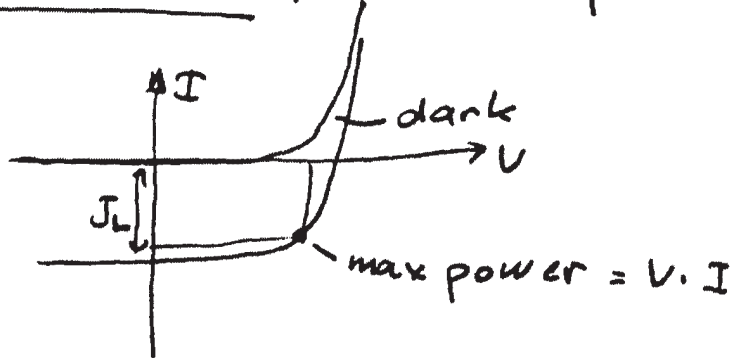
**FIG. 3****FIG. 4**

APPENDIX

Atty. Dkt. 013085 / NBNP/SOLAR-OTH
/KCHANG

Buried oxide photon

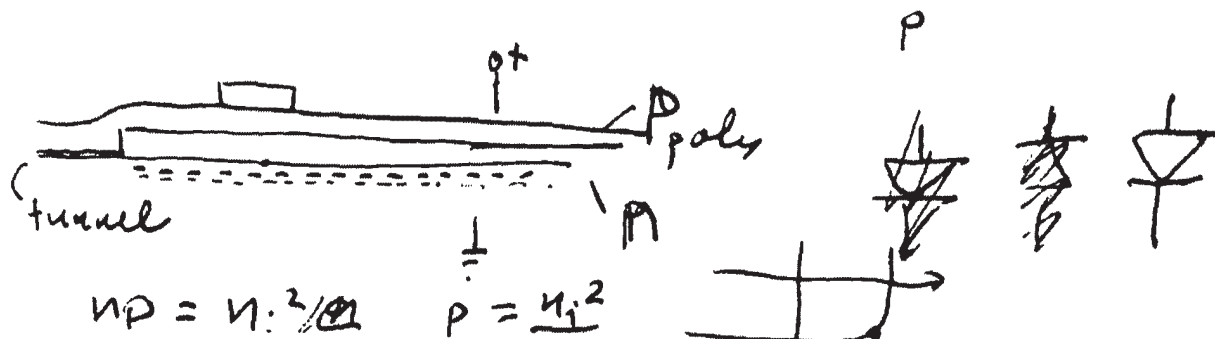
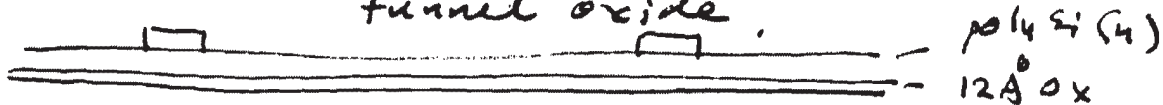
$$J = J_0 (e^{\frac{qV}{kT}} - 1) - J_L$$

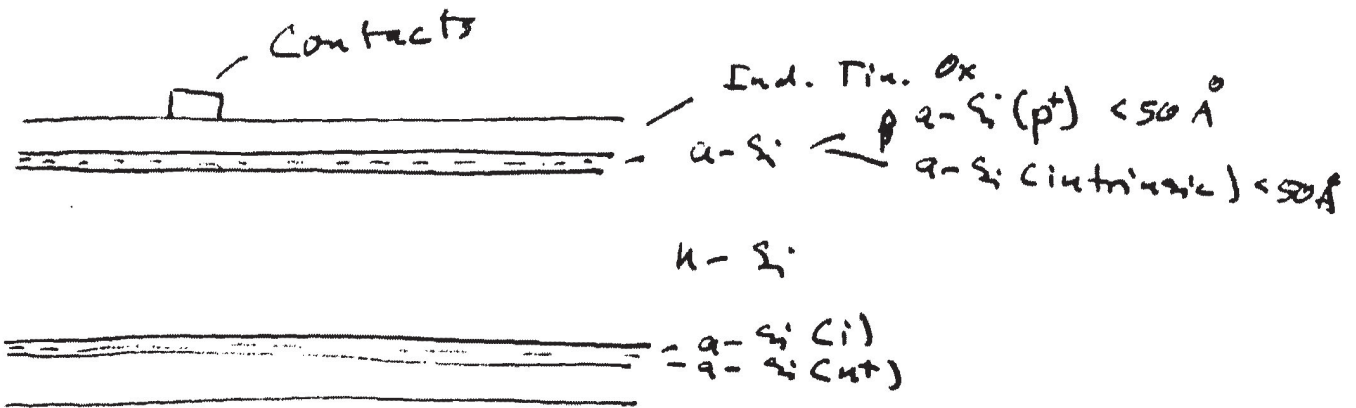


Key: collect before carriers recombine

- long bulk lifetime ✓
- passivate the surfaces ✓
- minimize contact area ✓
esp. metal contacts.
- thin surface doped layer. ✓

Note: w/ p-type poly. → B dopant, diffuses thru oxide ∴ may want to nitride the tunnel oxide.



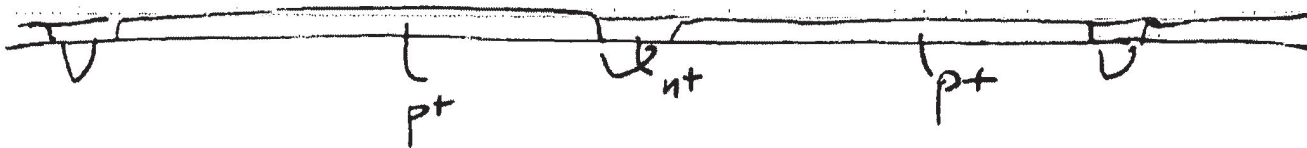
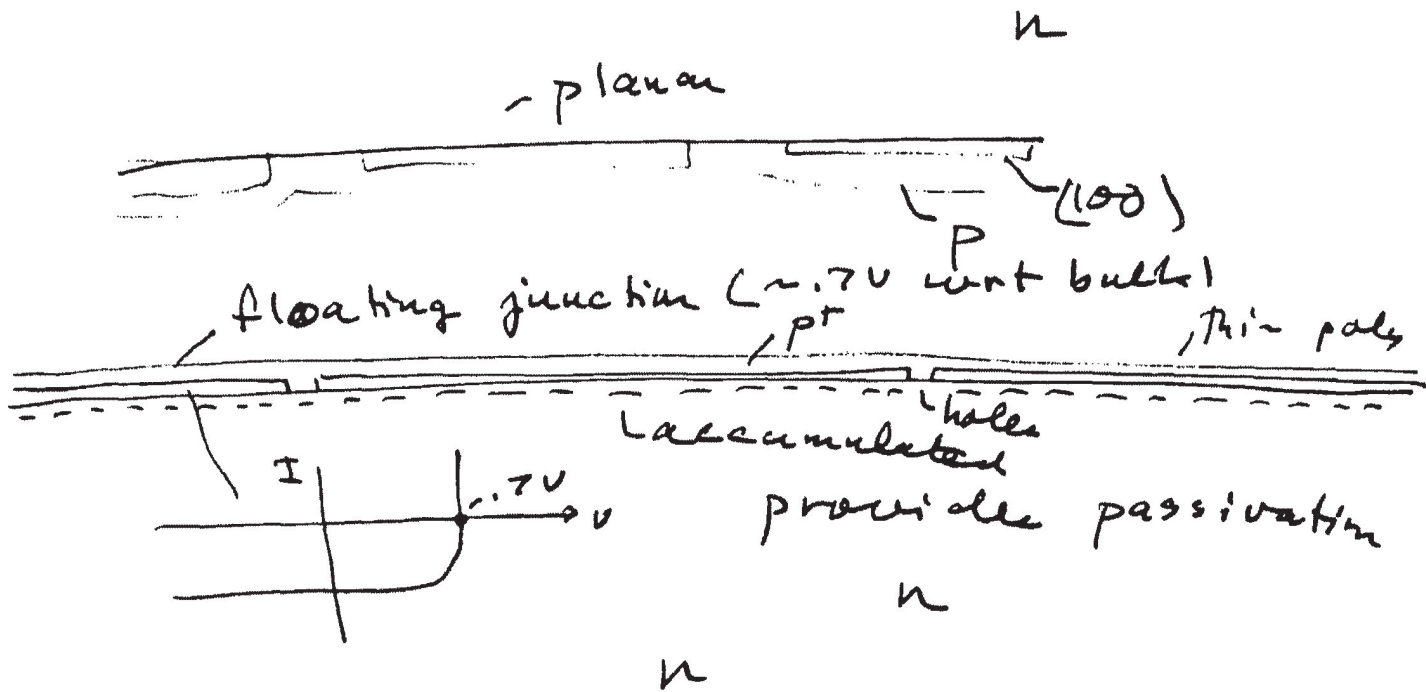
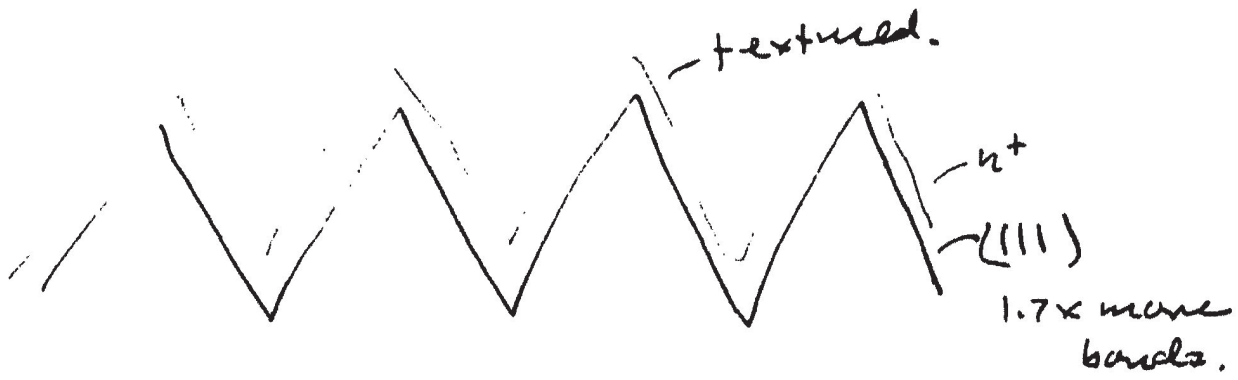
HIT

- + low temp planar process
- no diffusions
- good efficiency
- Sanyo has ~ 20% cells in mfg.

- interface very tricky
 - ✓ $a-Si$ can epitaxially regrow
 - ✓ plasma damage in deposition
 - ✓ requires special prep (unknown)
- low temp - limits usable processes.

thin oxide overcomes limitations.

- + know how to prepare surface,
 - cstd. IC process
 - protects from damage
 - isolates to prevent epi seeding





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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
61/023,354	01/24/2008		210	013085 /NBNP/SOLAR-OTH/KC		

CONFIRMATION NO. 1135

27498
 PILLSBURY WINTHROP SHAW PITTMAN LLP
 P.O. BOX 10500
 MCLEAN, VA 22102

FILING RECEIPT



OC000000028468199

Date Mailed: 02/26/2008

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please write to the Office of Initial Patent Examination's Filing Receipt Corrections. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Peter G. Borden, San Mateo, CA;
 Li Xu, Santa Clara, CA;

Power of Attorney:

Mark Danielson--40580

If Required, Foreign Filing License Granted: 02/25/2008

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 61/023,354**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No

Title

Buried Insulator Isolation for Solar Cell Contacts

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Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

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Title 37, Code of Federal Regulations, 5.11 & 5.15

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