ME4152 Nanomaterials for Energy Engineering

Monocrystalline Si Solar Cells

Optimization of Si-solar cell design

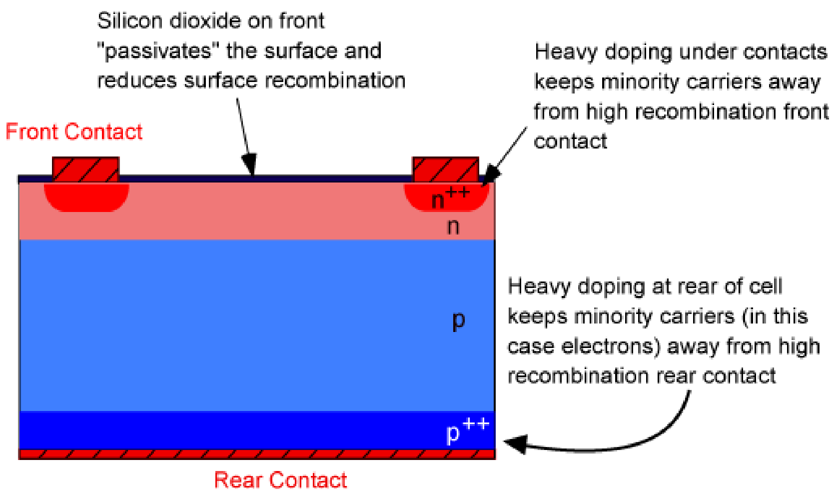
1

6.2 Silicon Solar Cell

2

Surface Recombination

Techniques for reducing the impact of surface recombination



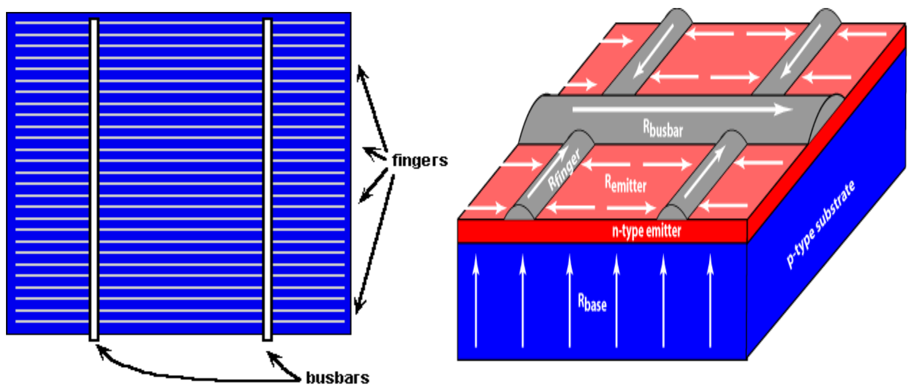
Effects of Back Surface Field:

Rare surface passivation

- A p^+ layer is added to *p* layer at the bottom of a silicon solar cell to reduce electron-hole recombination at the cell's rear surface
- The interface between the high and low doped region behaves like a *p-n* junction and an electric field known as "**Back Surface Field (BSF)**" is formed which introduces a barrier to minority carrier flow to the rear surface
- The BSF reflects electrons back toward the *p-n* junction, where they are sent into the n-type side of the cell, there by enhancing the carrier collection efficiency
- The BSF has a net effect of passivating the rear surface

Top contact design considerations

The emitter and top grid (consisting of the finger and busbar resistance) contributes to the overall series resistance



Typical Top contact design in a solar cell

Optimization of Si-solar cell design

Three major challenges in crystalline Si - solar cell deign are:
1. Maximize absorption
2. Minimize rear surface recombination
3. Minimize series resistance

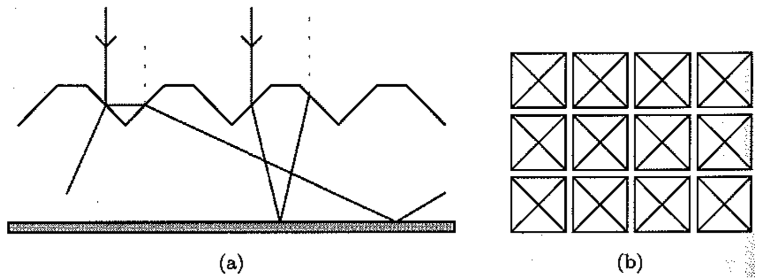
Strategies to enhance absorption

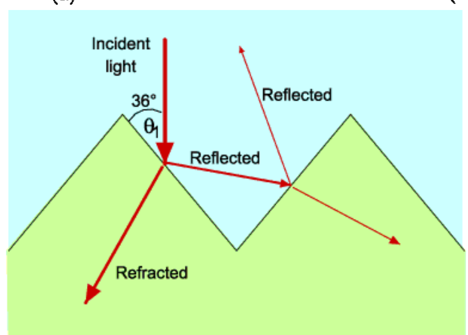
i. Texturing of front surface: reduces net refection of light, increases optical depth of the cell.

   How to achieve texturing: treat the surface with anisotropic chemicals which acts preferentially along (111) crystal planes and hence forming a pattern of pyramids on the surface.

   Regular pyramids can be produced on a single crystal of Si by photolithographic definition.

6.3 Surface texturing

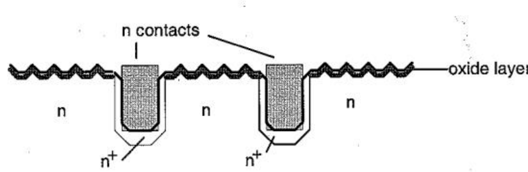




Optimization of Si-solar cell design

ii. Improving the light trapping: using inverted pyramids, which improves total internal reflection of light reflected from the back surface by asymmetric pyramids or by texturing the rear surface.

iii. Optimization of contacts: shading reduces surface area available by about 10%. Reducing the contact area- increases the series resistance. Optimum arrangement is a grid of narrow dense and highly conducting grids. Embedding the contact in the semiconductor, one could increase the contact area.



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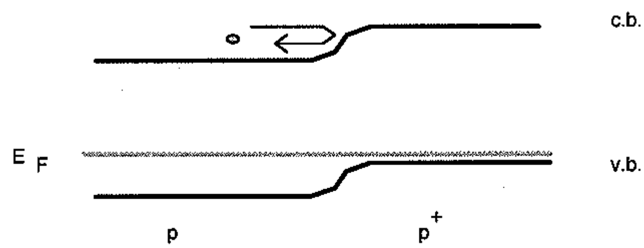
Strategies to reduce surface recombination

i. Back surface field (BSF): a more heavily doped layer formed at the back of p-layer; Forming p+ - p junction, provides a potential barrier for minority electrons.

Rear surface recombination velocity is reduced

Extra p+ - p junction also increases built-in bias of the cell and hence enhance V_{oc}.



Optimization of Si-solar cell design

ii. Passivation of front surface:

High surface recombination at surface creates a dead layer – no photo-generated carrier could be formed.

Oxidizing the surface creates a thin layer of SiO_2, which prevents the carriers reaching the surface – thus suprresing effective surface recombination velocity.

This reduces loss of carriers in the emitter by surface recombination – improves the response to blue light.

Optimization of Si-solar cell design

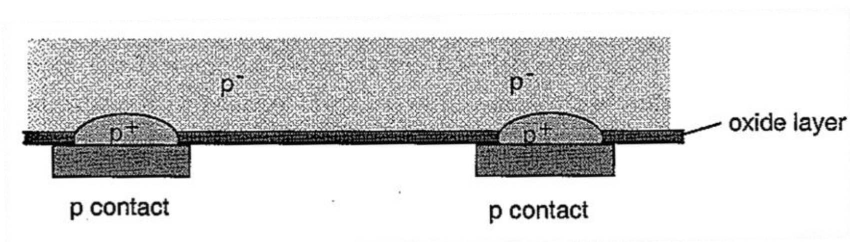
iii. Use of point contact at rear:

Silicon-metal contact is more defective than Si-SiO_2 contact.

Point contact of metal with Si is beneficial.

Rest of the surface is passivated with oxide.

In order to avoid problem of series resistance due to point contact, region of semiconductor close to point contact is differentially doped p+. See figure:

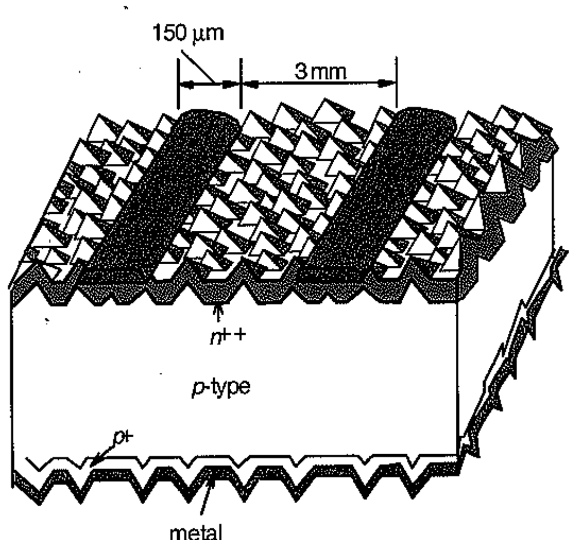


Optimization of Si-solar cell design

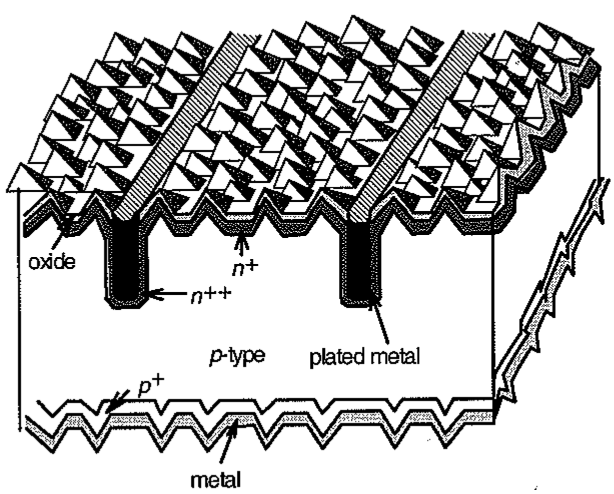
Strategies to reduce series resistance

- Optimization of n-region doping
- Reduced doping improves collection from the n-region but increases series resistance.
- Increased n-doping increases V_{bi}, and reduce series resistance
- Very high n-doping is not useful for increasing V_{oc}, because of Auger recombination and band gap narrowing.
- Differential doping of the area around the contacts: For point and grid contacts the current density through the materials close the contacted area will be high; doping heavily reduces the losses due to series resistance.
- Narrow but deep fingers in front contact: relatively high contact area reduces the current density at the contact.

Screen printed crystalline si-solar cells (Green, 1995)



Buried-contact Si solar cell (Green, 1995)



Output characteristics of buried contact cell and screen printed cell