# PHOTONIC DESIGN FOR PHOTOVOLTAIC CELL

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## ABSTRACT

*In solar cell most important thing is its efficiency there for new technological continuously introduce different type of solar cell such as polymer solar cell, quantum dot solar cell, hybrid solar cell, organic solar cell, nanocrystal solar cell, plasmonic solar cell etc. so, approach of the research to increase the efficiency of solar cell and decrease the cost per watt, the photovoltaic technology is very popular to convert sun light into electricity, the conversion efficiency for single-crystal commercial modules ranges between 15-20% due to the thermodynamic limits, in photovoltaic technology recoded efficiency of single junction silicon cell is 28.3%, we will try to increase efficiency of photovoltaic cell by changing the surface structure that provide better light trapping and control emission of sunlight, it help to decrease the losses of sunlight.*

**Keywords : -** *Photovoltaic cell, Solar cell, Solar*

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## 1. Introduction

The solar energy is most important than other energy sources such as petroleum product, coal, and wood, agricultural west, wind energy, geothermal energy, hydraulic energy etc. because:

- There is a no moving parts to wear out during utilization of solar energy,
- It convert directly in electrical energy by using photovoltaic cell,
- There is no consumption of fuel for conversion of solar energy,
- It does not create pollution,
- Easy to install and required less maintenance compare to other sources,
- It give high power handling capacity from microwatt to megawatt,
- It is use full for home application as well as business and centralize power generation

Capacity of U.S. utilities. This energy fills the solar system, bathing the earth's atmosphere with a near Constant supply of 1.37 kilowatts per square meter (kW/m 2). This large amount energy is wastage due to low efficiency of solar cell, from invention to present the solar cell continuously developed, efficiency of solar cell is increase by using different technologies and the cost of solar cell per watt is decrease. This study is related to design of photovoltaic cell, and to understand effect of different phenomena on the solar cell, the main focus is high efficiency and low cost. A more efficient module by definition yields more power per unit area. A significant fraction of a solar cell's cost scales proportional to the installation area, including the cost of the glass, inverter costs (actually directly proportional to the power), and installation costs, among others. Such costs are fixed relative to the module technology, thereby providing a lower bound on the total costs for a given efficiency. For example, even if the module cost is zero, a 10% efficient module cannot produce electricity at cheaper than about $0:06=kWh. By comparison, a 25% efficient module can cost about 300$=m2 and yet produce electricity for the same cost. The path to cost-parity is through high-efficiency cells.

### 1.1 The Internal Photoelectric Effect in Solar cell

The solar cells made of semiconductor materials the internal photoelectric effect comes into play. A photon that carries sufficient energy, E= h.v, can liberate an electron from the crystal lattice or lift it out of the valence band into the conduction band. In semiconductors, electrons are normally bonded to the outermost shell in the crystal lattice; these are known as valence electrons. In order for an electron to be liberated from its lattice, a minimum amount of additional energy is needed; this is known as band gap energyE_G.

When semiconductor temperature rises, the crystal-lattice atoms begin oscillating around their respective steady positions, with the result that some of the valence bonds are broken and the electrons thus liberated migrate to the conduction band; this phenomenon is known as intrinsic conductivity. The stronger the band gap energy, the fewer electrons migrate to the conduction band, i.e. the lower the electrical conductivity of the material at a given temperature. On the other hand, the higher the temperature of a given semiconductor material, the more electrons migrate to the conduction band and electrical conductivity increases accordingly.

Liberation of an electron from a valence bond creates a hole in the crystal lattice. An electron from an adjoining atom's valence bond can fall into a crystal-lattice hole, in which case the original hole disappears but a new one is created elsewhere. Hence, like a free electron, a hole can move freely within a semiconductor and can promote conductivity. If a free electron happens to collide with a hole, it will fall into it, i.e. the electron and completely recombine. In the case of radiation onto semiconductor materials, photons with sufficient energy, h.v> E_G can lift an electron out of the valence band into the conduction band, whereupon the photon is absorbed. This processes as shown in "fig.1 (a)"

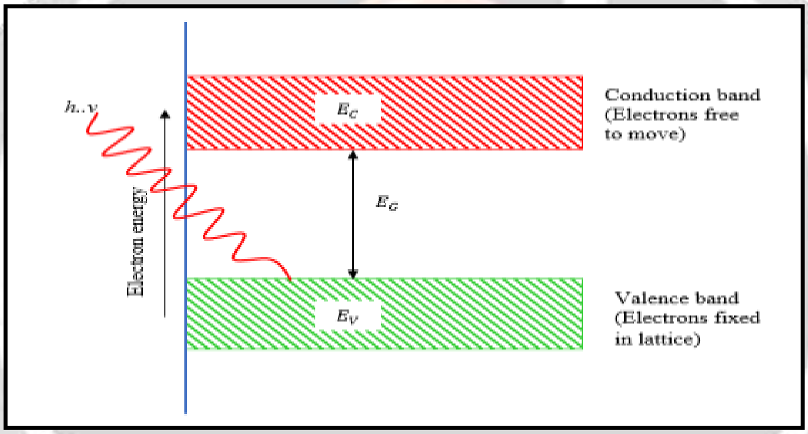


**Fig. 1 (a) band gap energy**

### 1.2 Semiconductor

Semiconductors are materials whose electrical conductivity is lower than that of conductors but higher than that of non-conductors. Silicon (Si), which is the most widely used semiconductor material today, is abundantly available around the globe and ecologically friendly. The other semiconductor materials that can be used for technical applications are germanium (Ge), selenium (Se), gallium arsenide (GaAs), gallium phosphide (GaP), indium phosphide (InP), cadmium sulphide (CdS), cadmium telluride (CdTe) and copper indium diselenide (CuInSe2 or CIS, sometimes with a small amount of gallium added to form copper indium gallium diselenide, Cu(In,Ga)Se2, or CIGS).

Silicon has four valence electrons in its outermost shell. In order to establish a stable electron configuration (rare-gas configuration with eight electrons), each silicon atom along with four adjacent atoms form a covalent bond, where each atom controls an electron at each bond; thus a bond consists of two electrons. In a silicon crystal, eight electrons are arrayed around each silicon atom, which means that the desired electron configuration has been attained.

## 2. Literature Survey

### 2.1 Silicon Wafer Processing

Crystal Growth and Wafer Slicing Process

The first step in the wafer manufacturing process is the formation of a large, perfect silicon crystal. The crystal is grown from a ‘seed crystal’ that is a perfect crystal. The silicon is supplied in granular powder form, and then melted in a crucible. The seed is immersed carefully into the crucible of molten silicon, then slowly withdrawn

In order to achieve full absorption of all photons where , h.v> E_G, the crystalline silicon solar cells must allow for at least a 100 mm path of light through the silicon. For reasons of mechanical stability (a key factor during the manufacturing process in particular), material thicknesses ranging from 150 to 300 mm are often used, to ensure that the condition for full radiation absorption is met.

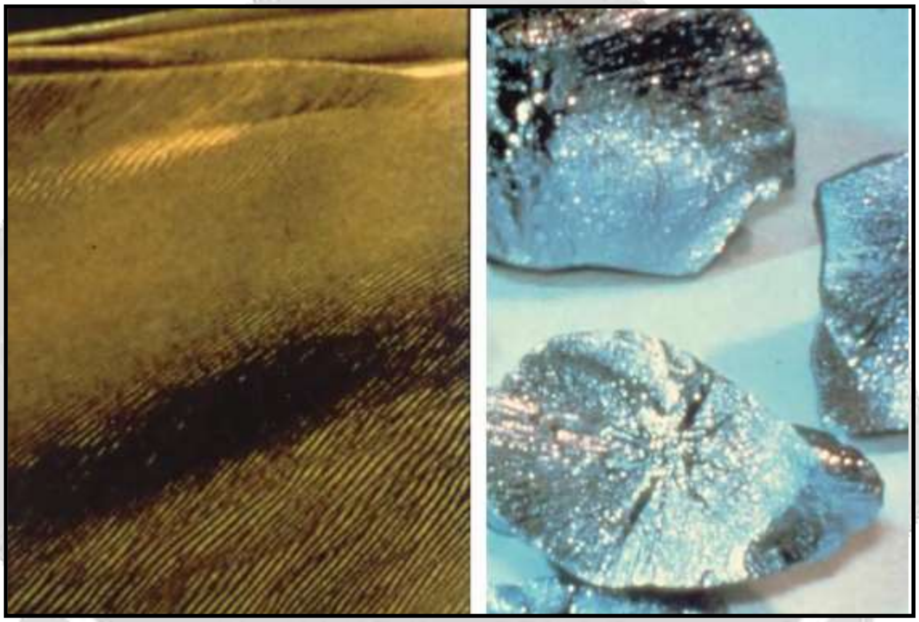


**Fig. 2 (a), Left: base material for silicon manufacturing, quartz sand**

**Step 1: Obtaining the Sand**

The sand used to grow the wafers has to be a very clean and good form of silicon. For this reason not just any sand scraped off the beach will do. Most of the sand used for these processes is shipped from the beaches of Australia

**Step 2: Preparing the Molten Silicon Bath**

The sand ($SiO2$) is taken and put into a crucible and is heated to about 1600 degrees C – just above its melting point. The molten sand will become the source of the silicon that will be the wafer. “Fig. 2 (b)” show the silicon road during processes.

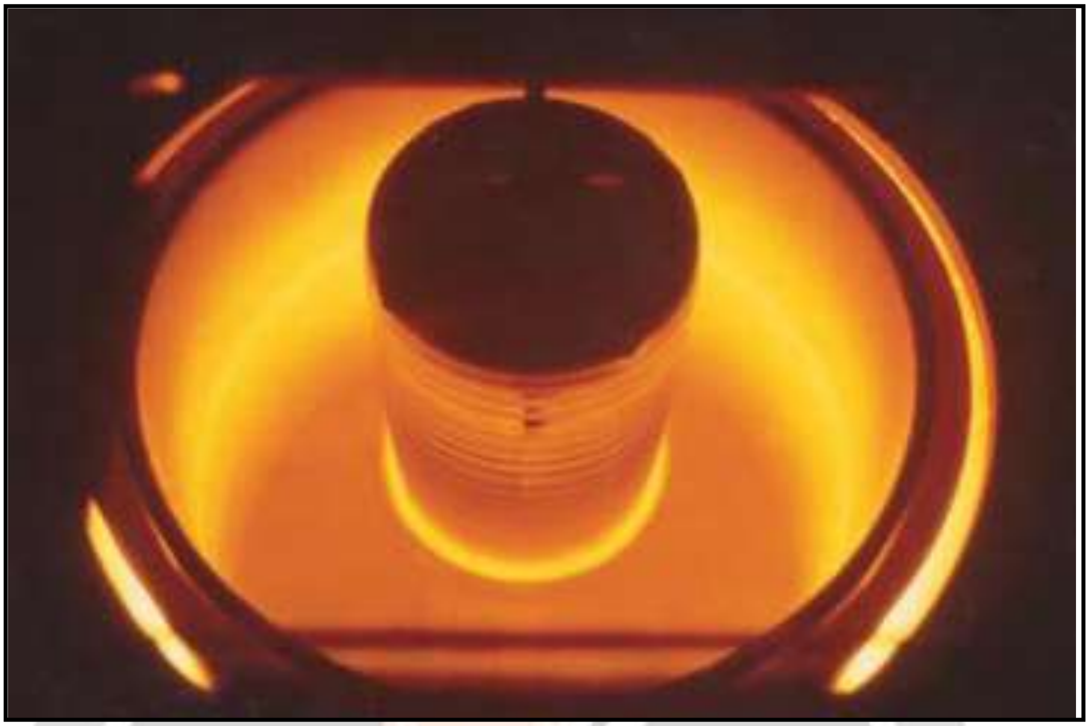


**Fig. 2 (b) Pulling a silicon nanocrystal (sc-Si) using the Czochralski (CZ) method for Monocrystalline solar cell manufacturing**

## Step 3: Making the Ingot

A pure silicon seed crystal is now placed into the molten sand bath. This crystal will be pulled out slowly as it is rotated. The dominant technique is known as the Czochralski (CZ) method. The result is a pure silicon cylinder that is called an ingot. The Czochralski method this step is done to provide a good clean surface for later processing. If a layer of Silicon is grown onto the top of the wafer using chemical methods then that layer is of a much better quality then the slightly damaged or unclean layer of silicon in the wafer. The epitaxial layer is where the actual processing will be done. The diameter of the silicon ingot is determined by the temperature variables as well as the rate at which the ingot is withdrawn. When the ingot is the correct length, it is removed, then ground to a uniform external surface and diameter. Each of the wafers is given either a notch or a flat edge that will be used later in orienting the wafer into the exact position for later procedures. In below “fig. 2 (c)” you can see the work flow.

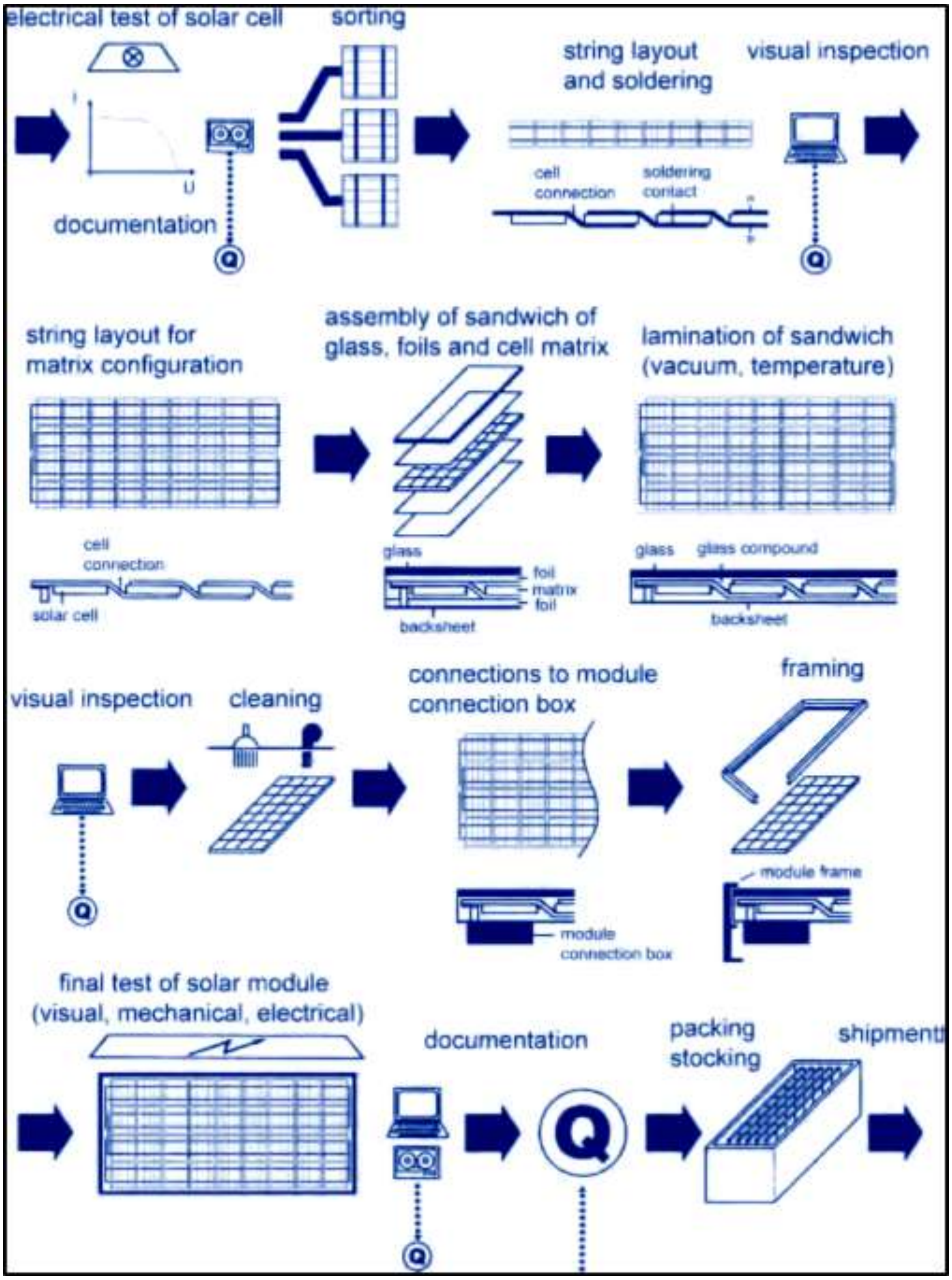


**Fig. 2 (c), the manufacturing process for crystalline silicon solar cells**

**Step 4: Preparing the Wafers**

After the ingot is ground into the correct diameter for the wafers, the silicon ingot is sliced into very thin wafers. This is usually done with a diamond saw. Each of these wafers will then go through polishing until they are very smooth and just the right thickness.

## 3 - PV cell /solar cell design

### 3.1 Solar cell design parameters

Solar cell design main focused on maximize efficiency according to working environment, where the cost is priority required at there the price of solar cell is low and the cost of fabrication also consider. The efficiency is most important in reach environment. It is main consideration. The theoretical efficiency is 86.8%. However, the 86.8% figure uses detailed balance calculations and does not describe device implementation. For silicon solar cells, a more realistic efficiency under one sun operation is about 29%. The maximum efficiency measured for a silicon solar cell is currently 24.7%

The difference between the high theoretical efficiencies and the efficiencies measured from terrestrial solar cells is due mainly to two factors. The first is that the theoretical maximum efficiency predictions assume that energy from each photon is optimally used, that there are no unabsorbed photons and that each photon is absorbed in a material which has a band gap equal to the photon energy. This is achieved in theory by modeling an infinite stack of solar cells of different band gap materials, each absorbing only the photons, which correspond exactly to its band gap.

The second factor is that the high theoretical efficiency predictions assume a high concentration ratio. Assuming that temperature and resistive effects do not dominate in a concentrator solar cell, increasing the light intensity proportionally increases the short-circuit current. Since the open-circuit voltage (Voc) also depends on the short-circuit current, Voc increases logarithmically with light level. Furthermore, since the maximum fill factor (FF) increases with Voc, the maximum possible FF also increases with concentration. The extra Voc and FF increases with concentration, which allows concentrators to achieve higher efficiencies.

In designing such single junction solar cells, the principles for maximizing cell efficiency are:

- increasing the amount of light collected by the cell that is turned into carriers;
- increasing the collection of light-generated carriers by the p-n junction;
- minimizing the forward bias dark current;
- Extracting the current from the cell without resistive losses.

### 3.2 Anti-Reflection Coatings

Silicon has a high surface reflection over 30%. This surface reflection is decrease by anti-reflection coating or surface texturing. Anti-reflection coating is similar to the optical lenses. The thickness of the anti-reflection coating is chosen so that the wavelength in the dielectric material is one quarter the wavelength of the incoming wave. For a quarter wavelength anti-reflection coating of a transparent material with a refractive index $n_1$ and light incident on the coating with a free-space wavelength $\lambda_0$, the thickness $d_1$, which causes minimum reflection, is calculated by:

$$d_1 = \frac{\lambda_0}{4n_1}$$

Some anti-reflection structure of solar cell is shown in “Fig. 3 (a)”

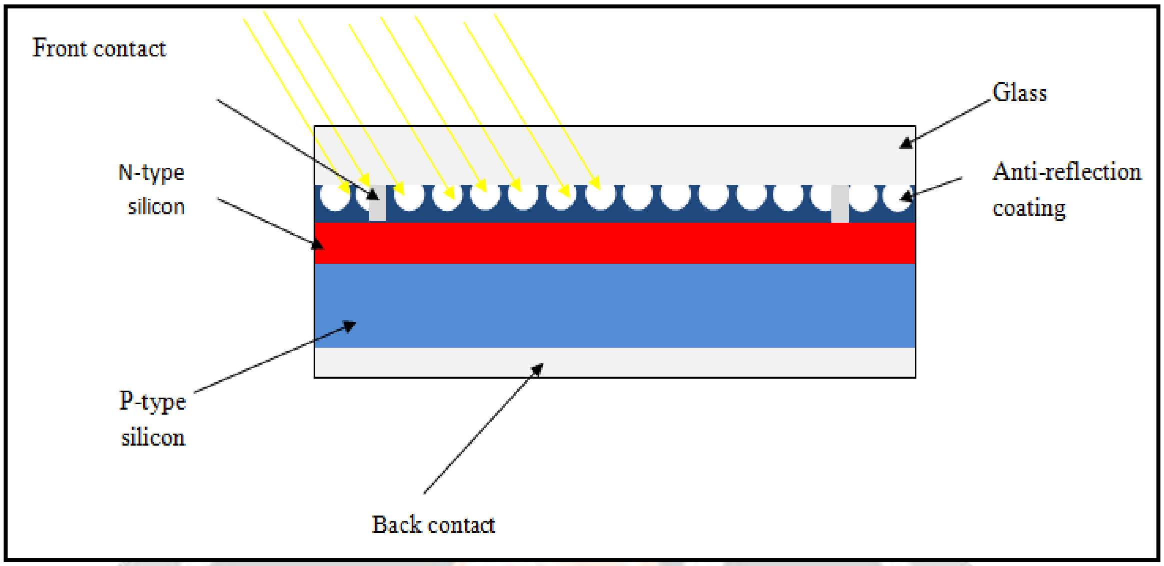


**Fig. 3 (a) Idea of anti-reflection surface texture**

Reflection is further minimized if the refractive index of the anti-reflection coating is the geometric mean of that of the materials on either side; that is, glass or air and the semiconductor. This is expressed by;

$$n_1 = \sqrt{n_0 n_2}$$

For the reflectance at normal incidence we define a series of parameters: $r_1$, $r_2$, and θ. the surrounding region has a refractive index of $n_0$, the ARC has a refractive index of $n_1$ and a thickness of $t_1$, and the silicon has a refractive index of $n_2$.

$$r_1 = \frac{n_0 - n_1}{n_0 + n_1}$$

$$r_2 = \frac{n_1 - n_2}{n_1 + n_2}$$

$$\theta = \frac{2\pi n_1 t_1}{\lambda}$$

For a single layer ARC on a substrate the reflectivity is:

$$R = \left|r^2\right| = \frac{r_1^2 + r_2^2 + 2r_1 r_2 \cos 2\theta}{1 + r_1^2 r_2^2 + 2r_1 r_2 \cos 2\theta}$$

The graph shows the effect of a single layer anti-reflection coating on silicon. Use the sliders to adjust the refractive index and thickness of the layer. For simplicity this simulation assumes a constant refractive index for silicon at 3.5. And the coating is a function of wavelength.

According to antireflection film thickness and reflective index the color of the film is affected, and different color of solar cell obtained. Due this effect solar cell get different colors generally green wafer is very thick and brown color wafer is very thin near about 0.07 micrometer Color of silicon nitride films with a refractive index of ~2.05 as a function of film thickness under fluorescent lighting for normal incident.

The graph shows the effect of a single layer anti-reflection coating on silicon. Use the sliders to adjust the refractive index and thickness of the layer. For simplicity this simulation assumes a constant refractive index for silicon and the coating is a function of wavelength.

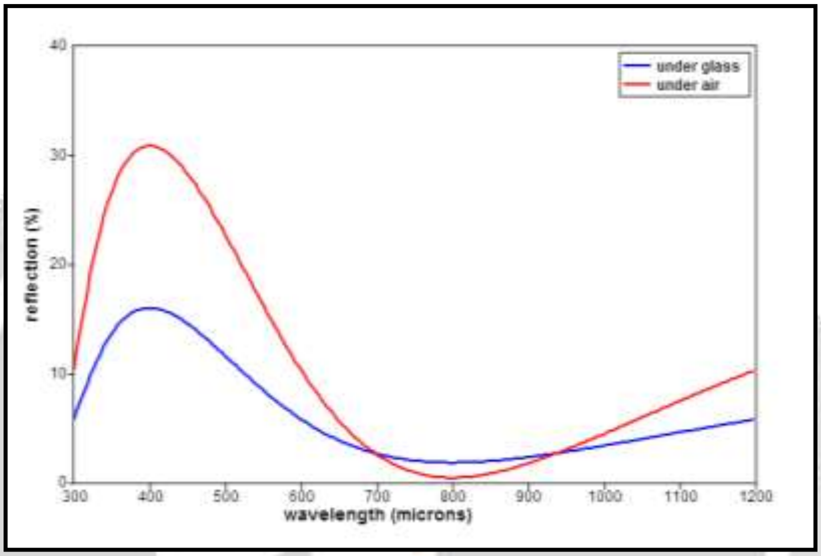


**Fig. 3 (b) Reflection Vs. wavelength curve according to texture**

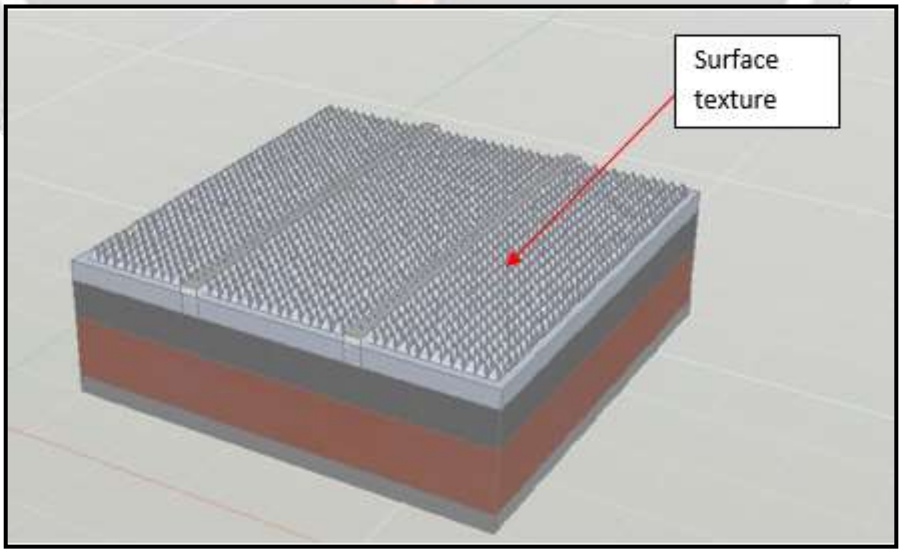


**Fig. 3 (c) 3D model of c-Si cell with triangular texture**

### 3.3 Surface Texturing

Surface texturing, either in combination with an anti-reflection coating or by itself, can also be used to minimize reflection. Any "roughening" of the surface reduces reflection by increasing the chances of reflected light bouncing back onto the surface, rather than out to the surrounding air. Surface texturing can be accomplished in a number of ways. A single crystalline substrate cans be textured by etching along the faces of the crystal planes. The crystalline structure of silicon results in a surface made up of pyramids if the surface is appropriately aligned with respect to the internal atoms. One such pyramid is illustrated in the drawing below. An electron microscope photograph of a textured silicon surface is shown in the photograph below. This type of texturing is called "random pyramid" texture and is commonly used in industry for single crystalline wafers.

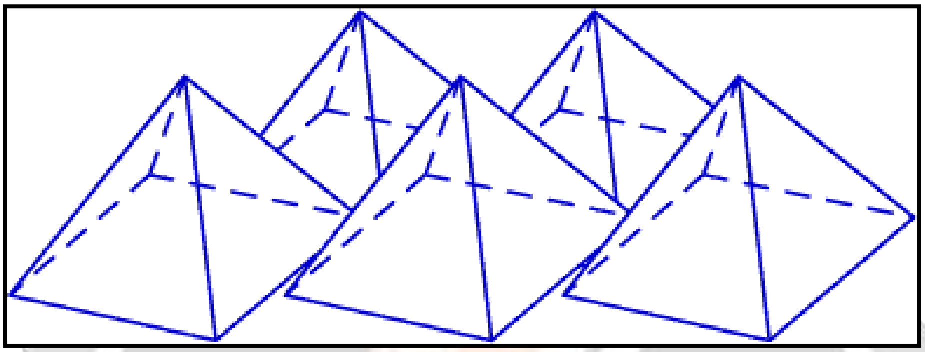


**Fig. 5 (d) Triangular texture**

The spherical surface texture has more decreasing the light reflection because it has a curve surface and it help to reflect all direction light rays.

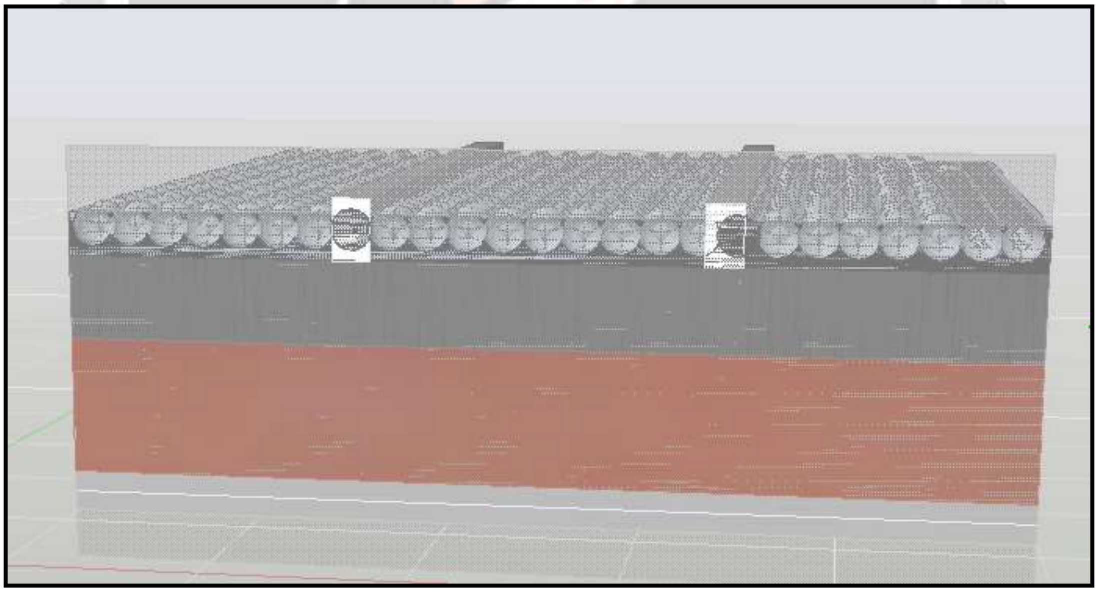


**Fig. 3 (e) Cross section of spherical texture solar cell**

### 3.4 Light trapping

Light trapping is usually achieved by changing the angle at which light travels in the solar cell by having it be incident on an angled surface. A textured surface will not only reduce reflection as previously described but will also couple light obliquely into the silicon, thus giving a longer optical path length than the physical device thickness. The angle at which light is refracted into the semiconductor material is, according to Snell's Law, as follows;

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Where $\theta_1$ and $\theta_2$ are the angles for the light incident on the interface relative to the normal plane of the interface within the mediums with refractive indices $n_1$ and $n_2$ respectively. By rearranging Snell's law above, the angle at which light enters the solar cell (the angle of refracted light) can be calculated;

$$\theta_2 = \sin^{-1}\left(\frac{n_2}{n_1}\sin\theta_1\right)$$

If light passes from a high refractive index medium to a low refractive index medium, there is the possibility of total internal reflection (TIR). The angle at which this occurs is the critical angle and is found by setting $\theta_2$ in the above equation to 0. Also internal reflection makes more effective light trapping.

$$\theta_1 = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

### 3.5 Effect of Temperature

The temperature effect on solar cell is most considerable factor. In solar cell, the temperature increase efficiency is decrease because of Increases in temperature reduce the band gap of a semiconductor, thereby effecting most of the semiconductor material parameters. The decrease in the band gap of a semiconductor with increasing temperature can be viewed as increasing the energy of the electrons in the material. Lower energy is therefore needed to break the bond. In the bond model of a semiconductor band gap, reduction in the bond energy also reduces the band gap. In the solar cell effect of temperature is shown in graph

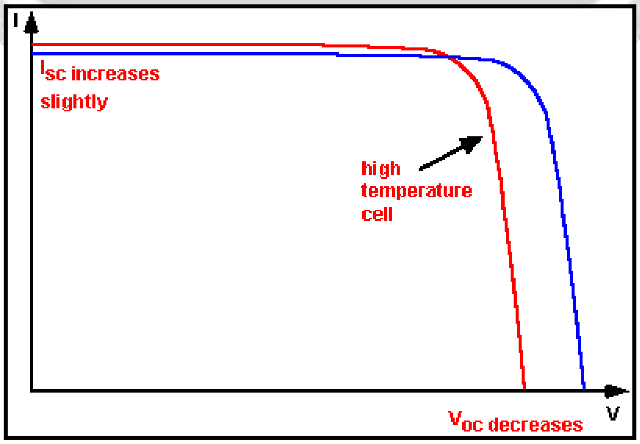


**Fig.3 (f) Effect of temperature on the IV characteristics of a solar cell**

The open-circuit voltage decreases with temperature because of the temperature dependence of $I_0$. The equation for $I_0$ from one side of a *p-n* junction is given by;

$$I_0 = qA\frac{Dn_i^2}{LN_D}$$

Where:
q is the electronic charge given in the constants;
D is the diffusivity of the minority carrier given for silicon as a function of doping in the Silicon Material Parameters;
L is the diffusion length of the minority carrier;
$N_D$ is the doping; and
$n_i$ Is the intrinsic carrier concentration.

From above parameter the intrinsic carrier is more important compare to other parameter. $n_i$ The intrinsic carrier concentration depends on the band gap energy (with lower band gaps giving a higher intrinsic carrier concentration), and on the energy which the carriers have (with higher temperatures giving higher intrinsic carrier concentrations). The equation for the intrinsic carrier concentration is;

$$n_i^2 = 4\left(\frac{2\pi kT}{h^2}\right)^3 (m_e^* m_h^*)^{3/2} \exp\left(-\frac{E_{G0}}{kT}\right) = BT^3 \exp\left(-\frac{E_{G0}}{kT}\right)$$

Where:
T is the temperature;
h and k are constants;
$m_e$ and $m_h$ are the effective masses of electrons and holes respectively;
$E_{GO}$ is the band gap linearly extrapolated to absolute zero; and
B is a constant, which is essentially independent of temperature.

Substituting these equations back into the expression for $I_0$, and assuming that the temperature dependencies of the other parameters can be neglected, gives;

$$I_0 = qA\frac{D}{LN_D}BT^3 \exp\left(-\frac{E_{G0}}{kT}\right) \approx B'T^\gamma \exp\left(-\frac{E_{G0}}{kT}\right)$$

Where

B' is temperature independent constant.

A constant,

γ, is used instead of the number 3 to incorporate the possible temperature dependencies of the other material parameters.

For silicon solar cells near room temperature,

$I_0$ approximately doubles for every 10 °C increase in temperature

Now open circuit voltage can be calculate as bellow

$$V_{OC}=\frac{kT}{q}\ln\left(\frac{I_{SC}}{I_0}\right)=\frac{kT}{q}\left[\ln I_{SC}-\ln I_0\right]=\frac{kT}{q}\ln I_{SC}-\frac{kT}{q}\ln\left[B'T^{\gamma}exp\left(-\frac{qV_{G0}}{kT}\right)\right]$$
$$=\frac{kT}{q}\left(\ln I_{SC}-\ln B'-\gamma\ln T+\frac{qV_{G0}}{kT}\right)$$

Where

$E_{G0} = qV_{G0}$. Assuming that $dV_{oc}/dT$ does not depend on $dI_{sc}/dT$, $dV_{oc}/dT$ can be found as;

$$\frac{dV_{OC}}{dT}=\frac{V_{OC}-V_{G0}}{T}-\gamma\frac{k}{q}$$

The above equation shows that the temperature sensitivity of a solar cell depends on the open circuit voltage of the solar cell, with higher voltage solar cells being less affected by temperature. For silicon, $E_{G0}$ is 1.2, and using $\gamma$ as 3 gives a reduction in the open-circuit voltage of about 2.2 mV/°C;

$$\frac{dV_{OC}}{dT}=-\frac{V_{G0}-V_{OC}+\gamma\frac{kT}{q}}{T}\approx -2.2mV\ per\ {}^{\circ}C\ for\ Si$$

The short-circuit current, $I_{sc}$, increases slightly with temperature, since the band gap energy, $E_G$, decreases and more photons have enough energy to create e-h pairs. However, this is a small effect and the temperature dependence of the short-circuit current from a silicon solar cell is;

$$\frac{1}{I_{SC}}\frac{dI_{SC}}{dT}\approx 0.0006\ per\ \ {}^{\circ}C\ for\ Si$$

The temperature dependency FF for silicon is approximated by the following equation;

$$\frac{1}{FF}\frac{dFF}{dT}\approx\left(\frac{1}{V_{OC}}\frac{dV_{OC}}{dT}-\frac{1}{T}\right)\approx -0.0015\ per\ \ {}^{\circ}C\ for\ Si$$

The effect of temperature on the maximum power output, $P_m$, is;

$$P_{Mvar}=\frac{1}{P_M}\frac{dP_M}{dT}=\frac{1}{V_{OC}}\frac{dV_{OC}}{dT}+\frac{1}{FF}\frac{dFF}{dT}+\frac{1}{I_{SC}}\frac{dI_{SC}}{dT}$$

$$\frac{1}{P_M}\frac{dP_M}{dT}\approx -(0.004\ to\ 0.005)per\ \ {}^{\circ}C\ for\ Si$$

### 3.6 Effect of Light Intensity

Changing the light intensity incident on a solar cell changes all solar cell parameters, including the short-circuit current, the open-circuit voltage, the FF, the efficiency and the impact of series and shunt resistances. The light intensity on a solar cell is called the number of suns, where 1 sun corresponds to standard illumination at AM1.5, or 1 kW/m$^2$. For example, a system with 10 kW/m$^2$ incident on the solar cell would be operating at 10 suns, or at 10X. A PV module designed to operate under 1-sun conditions is called a "flat plate" module while those using concentrated sunlight are called "concentrators"

A concentrator is a solar cell designed to operate under illumination greater than 1 sun. The incident sunlight is focused or guided by optical elements such that a high intensity light beam shines on a small solar cell. Concentrators have several potential advantages, including a higher efficiency potential than a one-sun solar cell and the possibility of lower cost. The short-circuit current from a solar cell depends linearly on light intensity, such that a device operating under 10 suns would have 10 times the short-circuit current as the same device under one sun operation. However, this effect does not provide an efficiency increase, since the incident power also increases linearly with concentration. Instead, the efficiency benefits arise from the logarithmic dependence of the open-circuit voltage on short circuit. Therefore, under concentration, $V_{oc}$ increases logarithmically with light intensity, as shown in the equation below;

$$V'_{OC} = \frac{nkT}{q}\ln\left(\frac{XI_{SC}}{I_0}\right) = \frac{nkT}{q}\left[\ln\left(\frac{I_{SC}}{I_0}\right) + \ln X\right] = V_{OC} + \frac{nkT}{q}\ln X$$

Where

X is the concentration of sunlight.

From the equation above, a doubling of the light intensity (X=2) causes a 18 mV rise in $V_{OC}$. The cost of a concentrating PV system may be lower than a corresponding flat-plate PV system since only a small area of solar cells is needed. The efficiency benefits of concentration may be reduced by increased losses in series resistance as the short circuit current increases and also by the increased temperature operation of the solar cell. As losses due to short-circuit current depend on the square of the current, power loss due to series resistance increases as the square of the concentration.

When the light intensity is low the incident power from the sun varying between 0 and 1 kW/m$^2$. At low light levels, the effect of the shunt resistance becomes increasingly important. As the light intensity decreases, the bias point and current through the solar cell also decreases and the equivalent resistance of the solar cell may begin to approach the shunt resistance. When these two resistances are similar, the fraction of the total current flowing through the shunt resistance increases, thereby increasing the fractional power loss due to shunt resistance. Consequently, under cloudy conditions, a solar cell with a high shunt resistance retains a greater fraction of its original power than a solar cell with a low shunt resistance.

### 3.7 Metallic contact design

In addition to maximizing absorption and minimizing recombination, the final condition necessary to design a high efficiency solar cell is to minimize parasitic resistive losses. Both shunt and series resistance losses decrease the fill factor and efficiency of a solar cell. A detrimentally low shunt resistance is a processing defect rather than a design parameter. However, the series resistance, controlled by the top contact design and emitter resistance, needs to be carefully designed for each type and size of solar cell structure in order to optimize solar cell efficiency.

The series resistance of a solar cell consists of several components as shown in the diagram below. Of these components, the emitter and top grid (consisting of the finger and busbar resistance) dominate the overall series resistance and are therefore most heavily optimized in solar cell design.

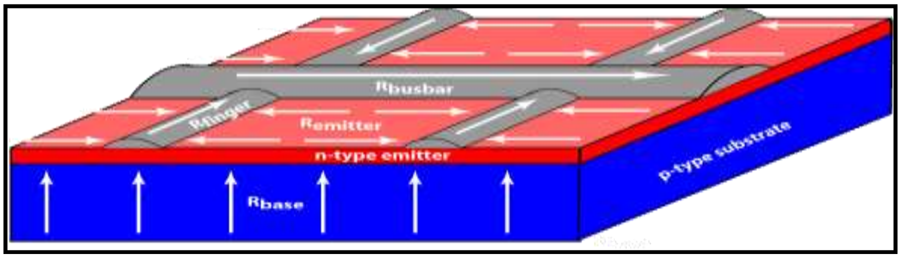


**Fig. 5 (g) Resistive components and current flows in a solar cell**

The metallic top contacts are necessary to collect the current generated by a solar cell. "Busbars" are connected directly to the external leads, while "fingers" are finer areas of metallization, which collect current for delivery to the busbars. The key design trade-off in top contact design is the balance between the increased resistive losses associated with a widely spaced grid and the increased reflection caused by a high fraction of metal coverage of the top surface.

The resistance and current of the base is assumed to be constant. The resistance to the current of the bulk component of the cell, or the "bulk resistance", $R_b$, is defined as:

$$R_b = \frac{\rho l}{A} = \frac{\rho_b W}{A}$$

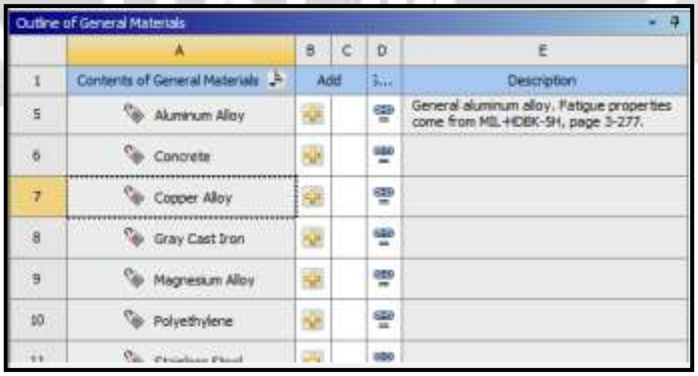
Where:

l = length of conducting (resistive) path
$\rho_b$= "bulk resistivity" (inverse of conductivity) of the bulk cell material (0.5 - 5.0 Ω cm for a typical silicon solar cell)
*A* = cell area, and
w = width of bulk region of cell.

### 3.8 Analysis processes

Taking analysis with help of software, the steps for it is as follow.

- open ANSYS workbench and in toolbox open thermal electric project and give title as solar cell



Outline of General Materials

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Contents of General Materials | Add | | 3... | Description |
| 5 | Aluminum Alloy | | | | General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277. |
| 6 | Concrete | | | | |
| 7 | Copper Alloy | | | | |
| 8 | Gray Cast Iron | | | | |
| 9 | Magnesium Alloy | | | | |
| 10 | Polyethylene | | | | |

**Fig. 5 (h) General material box in ANSYS**

- Save this project
- Now apply the material property, for this bellow, some table is given for silicon and silicon dioxide different properties, to apply the property double click on engineering data. Here structure steel is default added, by right click open engineering data and open general material, we have to add three material n-type semiconductor, p-type semiconductor and copper alloy.
- add copper alloy, it is seen in engineering data list,

- Now for adding two more material, click on structural steel and rename as p type and add following property

  Isotropic Thermal Conductivity: **1.46** W/ m K

  Isotropic Resistivity: **1.64e-5** Ω m

  Isotropic See beck Coefficient: **187e-6** V /K

- now create second material n-type by duplicating of p-type and add following property

  Isotropic Thermal Conductivity: **1.46** W /m K

  Isotropic Resistivity: **1.64e-5** Ω m

  Isotropic Seebeck Coefficient: **–187e-6** V/ K

- Click on the icon "return to the Project" in the menu bar to return to the Project. And save the project
- Now click on geometry to add geometry of solar cell for taking thermal analyses.

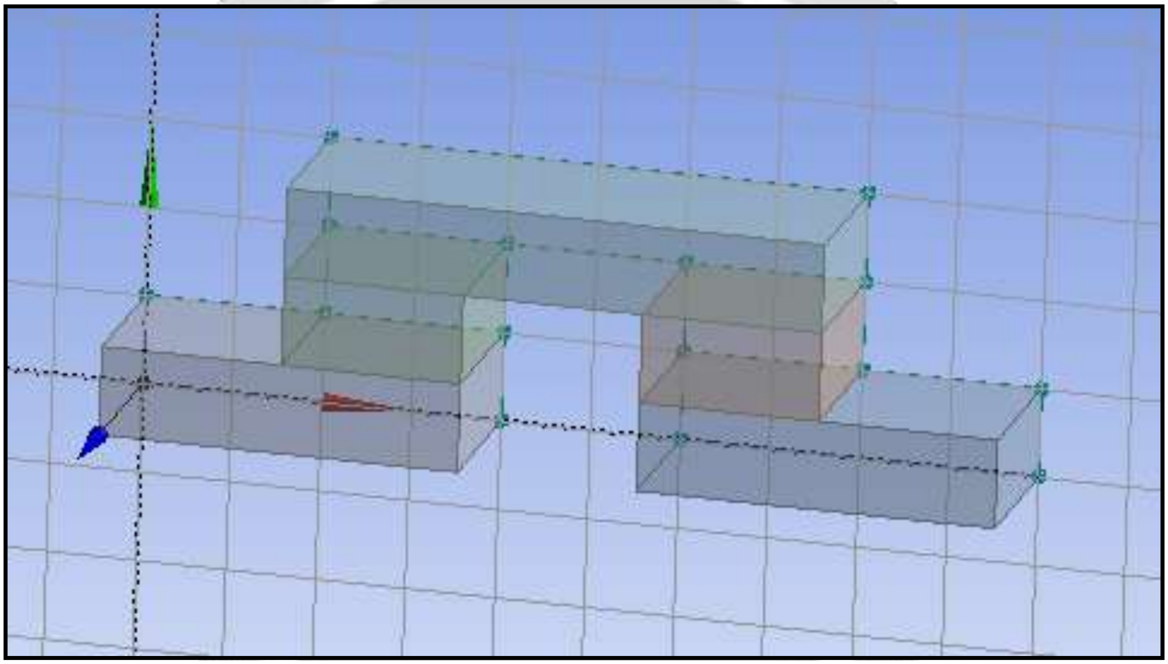


**Fig. 3 (i) Geometry view of P-N junction**

- Now click on model for setting of model and launch to solve in model window solar cell or p n junction model is shown as bellow

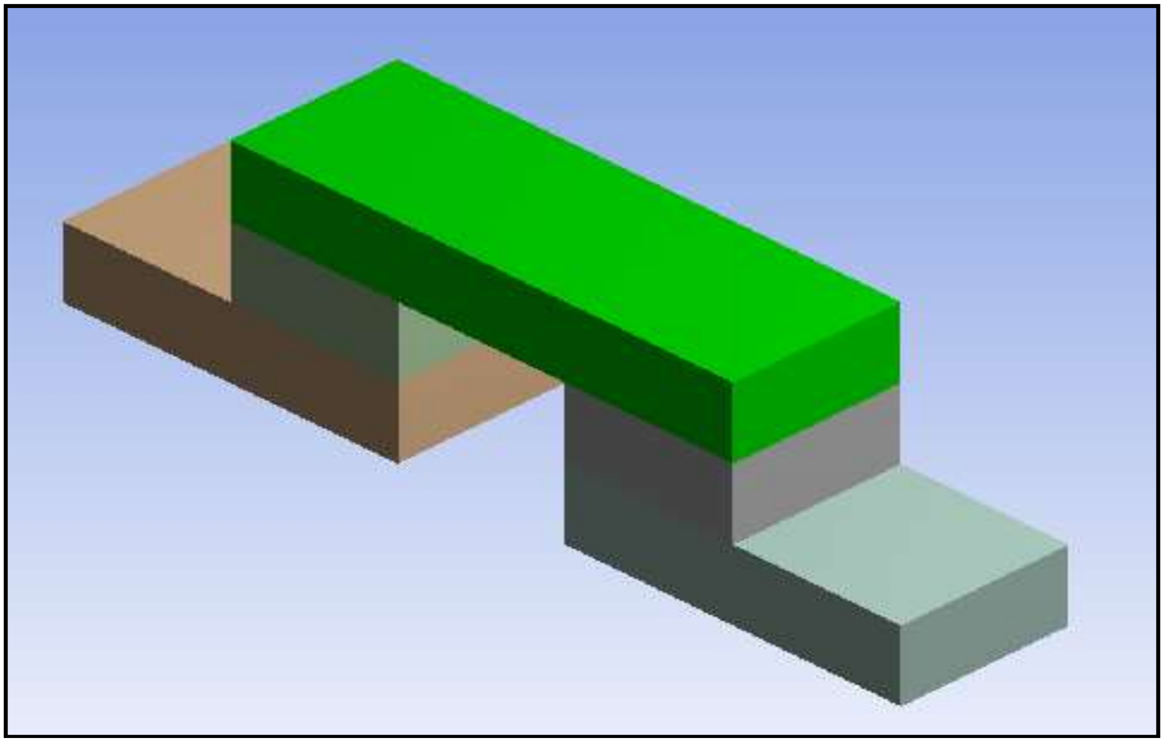


**Fig. 3 (j) model of solar cell with different property**

- The result is display by clicking solve as shown in “Fig. 3(k)” and “Fig. 3(l)”.

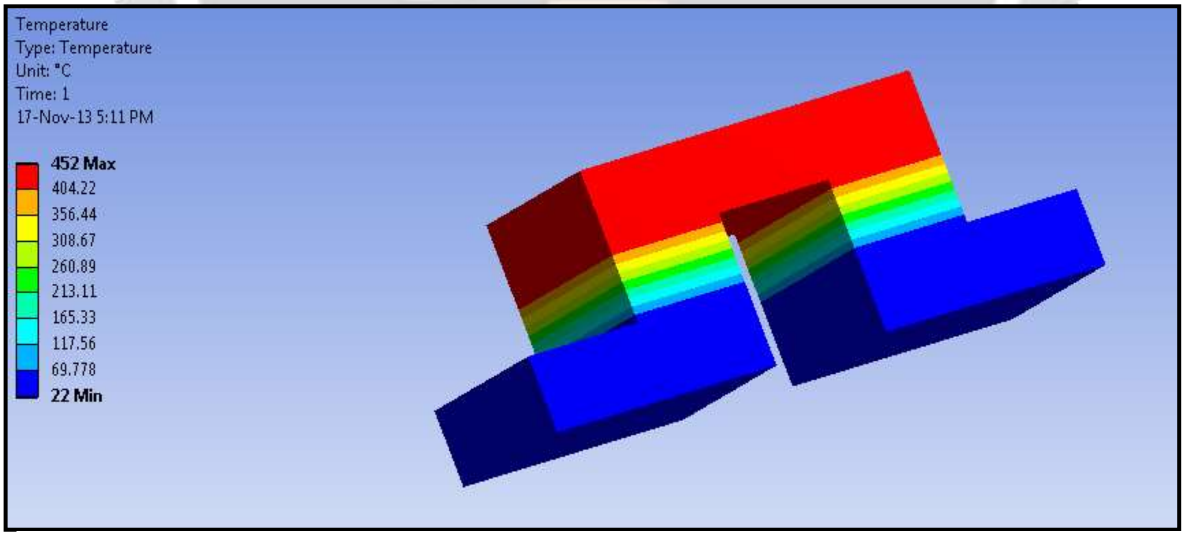


**Fig. 3 (k) temperature effect in solar cell**

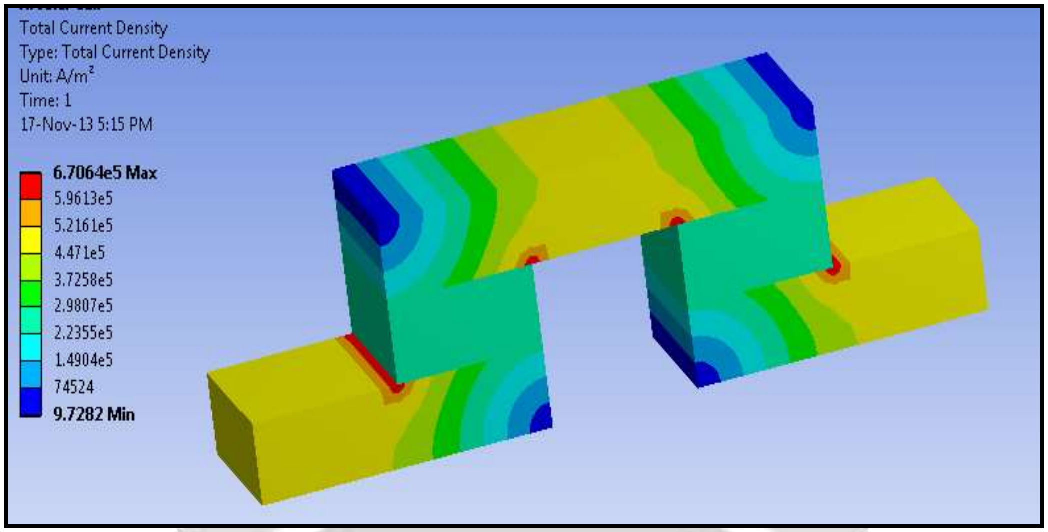


**Fig. 3 (l) analytic view of total current density**

## 4. CONCLUSIONS

- Increase efficiency by using light management, controlling radiative emission, effective use of solar spectrum and by decreasing losses.
- Reduce the manufacturing defect to improve the efficiency of solar cell, this done by the investigation of different manufacturing process of solar cell.
- To provide the crystalline solar cell, to reduce the requirement of different types of layer which create difficulty to manufacturing of solar cell.
- Create a design, which give batter light trapping structure, working long time in desirable efficiency and increase possibility to reuse of silicon material.

- Increase the stability of solar cell at high temperature for providing reliability of solar cell during the working life of solar cell.

- To increase the power generation per unite area of solar cell to full fill demand of energy according to present requirement by this the use of fossil fuel is decrease and create batter economy of solar energy or solar electricity.

## 6. REFERENCES

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