CMR

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Internal Assesment Test - II

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|---|---|---|---|---|---|---|---|---|---|
| Sub: | Electronic Devices | | | | | | | Code: | 18EC33 |
| Date: | 02/11/ 2020 | Duration: | 60 mins | Max Marks: | 50 | Sem: | 3rd | Branch: | ECE |
| Answer All Questions | | | | | | | | | |

| Instructions: Question 1 is compulsory. Attempt any three full questions out of four subjective questions. | | Marks | OBE | |
|---|---|---|---|---|
| | | | CO | RBT |
| 1. | **Q-1 Solar cell is operated in which quadrant of I-V characteristic graph of p-n junction?**<br>Ist Quadrant<br>II Quadrant<br>III Quadrant<br>IV Quadrant<br>**Answer - IV**<br>**Q-2 Photodiode is operated under**<br>Forward Bias<br>Forward Bias<br>Both a and b<br>None of the above<br>**Answer - II**<br>**Q-3 Rectifier converts**<br>AC to DC<br>AC to pulsating DC<br>DC to AC<br>None of the above<br>**Answer - II** | 2 x 10 = 20] | CO2 | L2 |

**Q-4 When transistor operates as a switch, collector current is maximum at**

Active Region

Cut off Region

Saturation Region

Triode Region

**Answer - III**

**Q-5 Which region in a transistor is most heavily doped?**

Emitter Region

Collector Region

Base Region

Gate Region

**Answer - I**

**Q-6 Calculate Maximum power delivered to the load using a Si solar Cell, given Isc=100mA, Voc=0.8V, fill factor 0.7.**

47mW

56mW

90Mw

65mW

**Answer - II**

**Q-7 A current ratio of IC/IE is usually less than one and is designated as:**

Alpha

Beta

Delta

Theta

**Answer - I**

**Q-8 Photodetector works on the principle of**

Fixed donor and acceptor ions

Majority carriers only

Minority carriers only

Mobile donor and acceptor ions

**Answer - II**

**Q-9 In PiN diode the i region is added to**

Increase the bias voltage

Increase EHP generation

Reduce power consumption

All the above

**Answer - I**

**Q-10 The Emitter region is added to BJT to**

Reduce the carrier injection

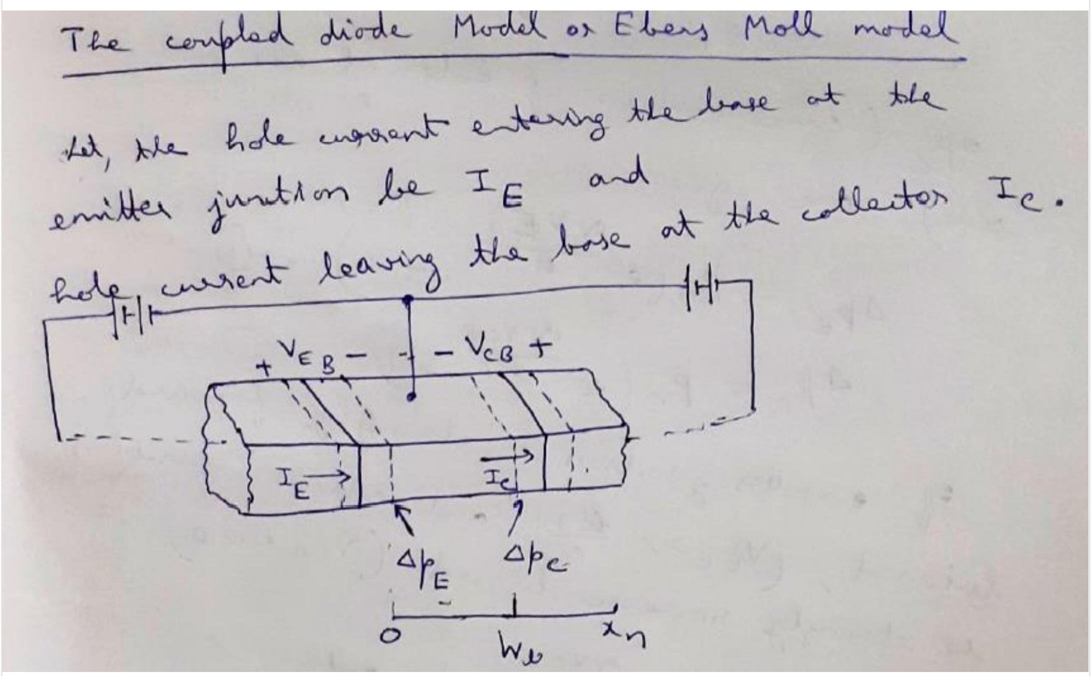
Increase forward biasing

Increase carrier injection

All the above

**Answer - III**

2. Derive and explain the Ebers Moll model and also draw the Ebers moll model


The coupled diode Model or Ebers Moll model

Let, the hole current entering the base at the emitter junction be $I_E$ and hole current leaving the base at the collector $I_C$.


[10] (8 +2) | CO2 | L3

The excess hole concentration at the edge of the emitter depletion region $\Delta p_E$ and $\Delta p_C$ (concentration of holes at the collector side) are given as,

$$\Delta p_E = p_n\left(e^{\frac{qV_{EB}}{kT}} - 1\right) \quad \text{--(1)}$$

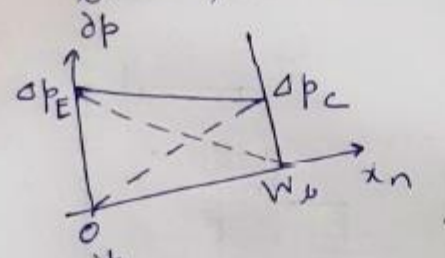
$$\Delta p_C = p_n\left(e^{\frac{qV_{CB}}{kT}} - 1\right) \quad \text{--(2)}$$

If emitter junction is strongly forward biased, $\left(V_{EB} >> \frac{kT}{q}\right)$ and collector junction is strongly reverse biased $(V_{CB} << 0)$

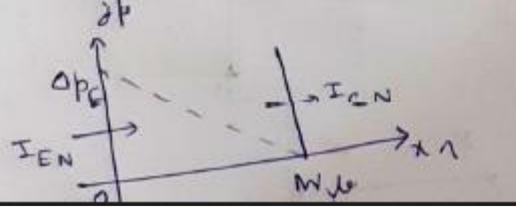
$$\Delta p_E \simeq p_n e^{\frac{qV_{EB}}{kT}} \quad \text{and}$$

$$\Delta p_C \simeq -p_n$$

If collector-base junction is also forward biased, $\Delta p_C$ is +ve. as shown below




The straight line hole distribution can be broken into two components.




One component accounts for the holes injected by emitter and collected by collector.

∴ The emitter current in the normal mode is,

$$I_{EN} = I_{ES}\left(e^{\frac{qV_{EB}}{kT}} - 1\right), \quad \Delta p_c = 0 \quad \text{--- (3)}$$

where, $I_{ES}$ is magnitude of emitter saturation current in the normal mode.

∵ $\Delta p_c = 0$, hence, $V_{CB} = 0$,

i.e. $I_{ES}$ is magnitude of emitter saturation current with collector short circuited,

Similarly, collector current in the inverted mode is,

$$I_{CI} = -I_{CS}\left(e^{\frac{qV_{CB}}{kT}} - 1\right), \quad \Delta p_E = 0 \quad \text{--- (4)}$$

where, $I_{CS}$ is magnitude of collector saturation current with $V_{EB} = 0$

- The -ve sign indicates, in inverted mode, holes are injected opposite to the defined direction of $I_c$.

The corresponding collected currents for each mode of operation,

$$I_{CN} = \alpha_N I_{EN} = \alpha_N I_{ES}\left(e^{\frac{qV_{EB}}{kT}} - 1\right) \quad \text{--- (5)}$$

$$I_{EI} = \alpha_I I_{CI} = -\alpha_I I_{CS}\left(e^{\frac{qV_{CB}}{kT}} - 1\right) \quad \text{--- (6)}$$

where, $\alpha_N$ and $\alpha_I$ are ratios of the collected current to injected current in each mode.

$\therefore$ The ~~total~~ total current can be obtained by superposition of the components,

$$I_E = I_{EN} + I_{EI}$$
$$= I_{ES}\left(e^{\frac{qV_{EB}}{kT}} - 1\right) - \alpha_I I_{CS}\left(e^{\frac{qV_{CB}}{kT}} - 1\right) \quad \cdots (7)$$

$$I_C = I_{CN} + I_{CI}$$
$$= \alpha_N I_{ES}\left(e^{\frac{qV_{EB}}{kT}} - 1\right) - I_{CS}\left(e^{\frac{qV_{CB}}{kT}} - 1\right) \quad \cdots (8)$$

Eq. (7) and (8) are derived by J.J. Ebers and J.L. Moll.

These are called as Ebers - Moll equations.

By reciprocity argument we can show that,

$\alpha_N I_{ES} = \alpha_I I_{CS}$ for non-symmetrical transistors.

Coupled-diode property

From (1), $\dfrac{\Delta p_E}{p_n} = \left(e^{\frac{qV_{EB}}{kT}} - 1\right)$ and

$$\frac{\Delta p_C}{p_n} = \left(e^{\frac{qV_{CB}}{kT}} - 1\right)$$

$\therefore$ we can write (7) and (8) as,

$$\boxed{I_E = I_{ES} \cdot \frac{\Delta p_E}{p_n} - (\alpha_I I_{CS})\frac{\Delta p_C}{\Delta p_n}} \quad \cdots (9)$$

or $$I_E = I_{ES} \cdot \frac{\Delta p_E}{p_n} - \alpha_N I_{ES} \cdot \frac{\Delta p_C}{p_N}$$

or $$\boxed{I_E = \frac{I_{ES}}{p_n}\left(\Delta p_E - \alpha_N \Delta p_C\right)} \quad \cdots (10)$$

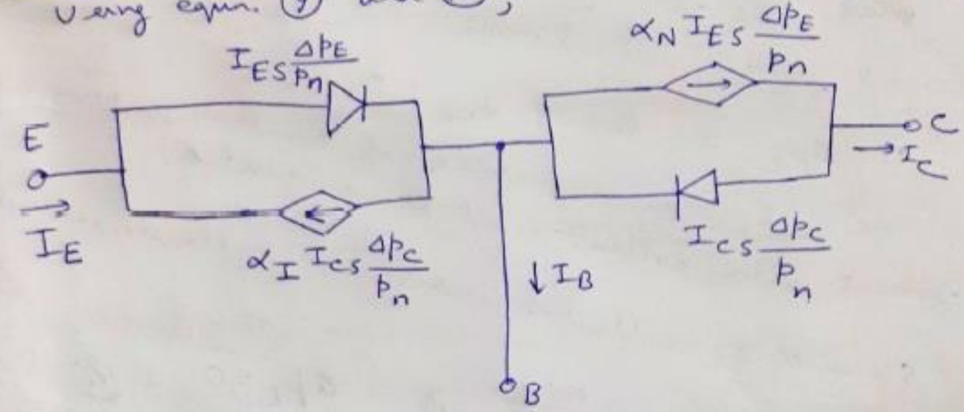
Similarly,

$$I_C = (\alpha_N I_{ES}) \cdot \frac{\Delta p_E}{p_n} - I_{CS} \frac{\Delta p_C}{p_n} \qquad (10\text{[illegible]})$$

or $$I_C = (\alpha_I I_{CS}) \frac{\Delta p_E}{p_n} - I_{CS} \frac{\Delta p_C}{p_n}$$

or $$I_C = \frac{I_{CS}}{p_n} \left( \alpha_I \Delta p_E - \Delta p_C \right) \quad \cdots (10\text{[illegible]})$$

Using eqn. (9) and (10),



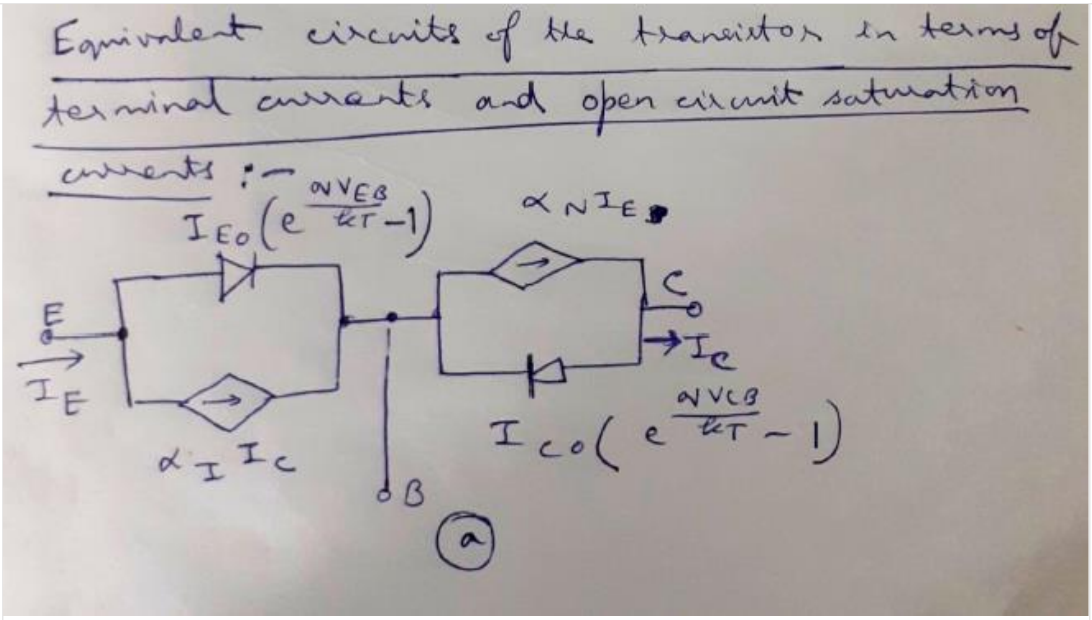

$$I_B = I_{ES}\frac{\Delta p_E}{p_n}\left(1-\alpha_N\right) + I_{cs}\frac{\Delta p_c}{p_n}\left(1-\alpha_I\right)$$

## Equivalent circuit synthesizing Ebers's Moll Equation

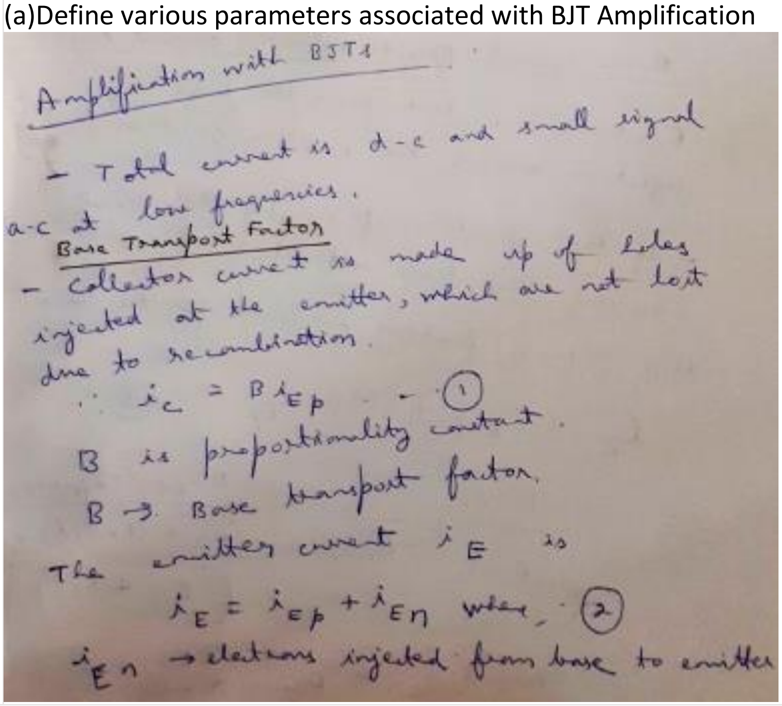
[Note: $I_B = I_E - I_C$ (using eqn (9) and (10))

$$= I_{ES}\frac{\Delta p_E}{p_n} - \left(\alpha_I I_{cs}\right)\frac{\Delta p_c}{p_n} - \alpha_N I_{ES}\frac{\Delta p_E}{p_n} + I_{cs}\frac{\Delta p_c}{p_n}$$

$$= I_{ES}\frac{\Delta p_E}{p_n}\left(1-\alpha_N\right) + I_{cs}\frac{\Delta p_c}{p_n}\left(1-\alpha_I\right)$$ ]




3. (a)Define various parameters associated with BJT Amplification



Amplification with BJTs

- Total current is d-c and small signal a-c at low frequencies.

Base Transport Factor

- Collector current is made up of holes injected at the emitter, which are not lost due to recombination.

$\therefore \; i_C = B\, i_{Ep}$ — (1)

B is proportionality constant.

B → Base transport factor.

The emitter current $i_E$ is

$i_E = i_{Ep} + i_{En}$ where — (2)

$i_{En}$ → electrons injected from base to emitter

07] (1 + 2 + 2 + 2) | CO2 | L2

Emitter Injection Efficiency :-

∴ Emitter injection efficiency.

$$\gamma = \frac{i_{Ep}}{i_{En} + i_{Ep}} \quad \text{--- (3)}$$

For efficient operation B and γ should be close to unity.

Current Transfer Ratio:-

The relation b/w ~~collector~~ collector and emitter current is,

$$\frac{i_C}{i_E} = \frac{B\, i_{EP}}{i_{En} + i_{Ep}} = B\gamma = \alpha \quad \text{--- (4)}$$

α is called current transfer ratio.

α is smaller than unity..

Base current : Base to collector current amplification Factor :-

Electrons are lost from the base by injection across the emitter junction ($i_{En}$)

- If the fraction of injected holes ~~and~~ crossing the base without recombination is B then (1 − B) fraction combined in the base.

$$\therefore i_B = i_{En} + (1-B)\, i_{Ep} \quad \text{--- (5)}$$

$$\frac{i_C}{i_B} = \frac{B\, i_{Ep}}{i_{En} + (1-B)\, i_{EP}} = \frac{B\, i_{EP} / (i_{En} + i_{Ep})}{\dfrac{i_{En} + (1-B)\, i_{EP}}{(i_{En} + i_{Ep})}}$$

$$= \frac{(B\, i_{Ep}) / (i_{En} + i_{Ep})}{1 - \dfrac{B\, i_{Ep}}{i_{En} + i_{Ep}}}$$

$$= \frac{B\gamma}{1-B\gamma} = \frac{\alpha}{1-\alpha} = \beta.$$

The factor $\beta$ is called <u>Base to collector current amplification factor.</u>

$\beta$ can be large for a good transistor and collector current is large as compared to base current.

We can also show that $\frac{i_C}{i_B} = \beta = \frac{\tau_p}{\tau_t}$

for $\gamma = 1$ and negligible collector saturation current.

3. (b) Write the mechanisms for generation of base current.

<u>Mechanisms for $I_B$ :-</u>

1) $W_b \ll L_p$. But then also electrons lost to recombination to be supplied through base contact.

(2) Some electrons will be injected from n to p in the forward-biased emitter junction. These electrons must be supplied by $I_B$

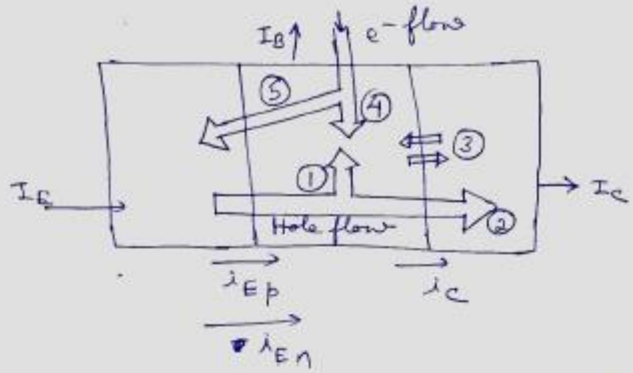
(3) Some electrons are swept into base at reverse-biased collector junction due to thermal generation in the collector. This current reduces $I_B$ by supplying electrons to the base.

[03] (3 x 1) | CO2 | L2

4. (a) Discuss the hole and electron flow in p-n-p transistor with proper biasing using suitable diagram.

[05] ( 5 x1 ) | CO2 | L2

Hole and electron flow in p-n-p transistor with proper Biasing :-

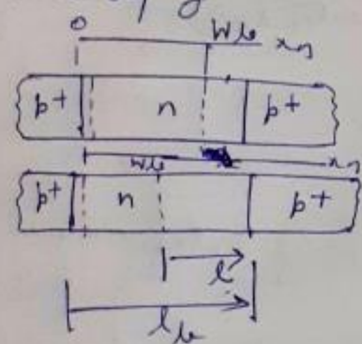
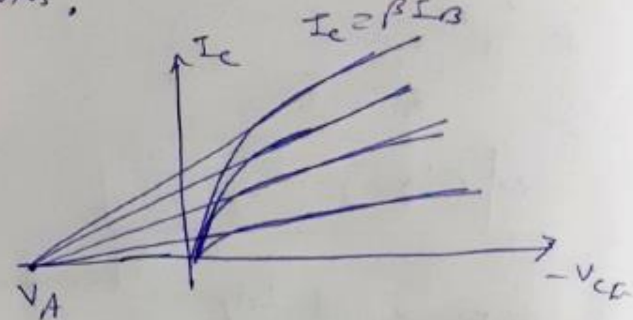



1. Injected holes lost to recombination in the base.
2. Holes reaching the reverse-biased collector junction.
3. Thermally generated electrons and holes making up the reverse saturation current in the collector ~~region~~ junction.
4. Electrons ~~supp~~ supplied by the base contact for recombination with holes.
5. Electrons injected across forward biased emitter junction.

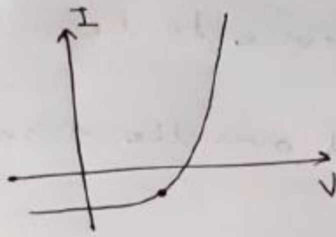
| | | | | |
|---|---|---|---|---|
| 4. | (b)Explain Early Effect in BJT with suitable diagram. | [05] | CO2 | L2 |

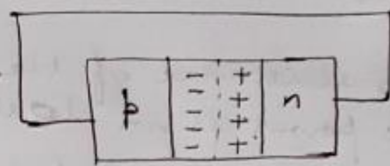
## Base - Narrowing

- If the base-region is lightly doped, the depletion region at the reverse biased collector junction can extend into the n-type base region.
- Because of this $W_b$ (effective base width) reduces.
- This effect is called base narrowing, base-width modulation, Early effect.
- Decrease of $W_b$ causes $\beta$ to increase.
- As a result $I_c$ increases with collector voltage instead of staying constant.
- The slope introduced is almost linear with $I_c$.

<table>
<tr><td></td><td>The length l of the collector junction depletion region,<br><br>$l = \left(\frac{2 \epsilon V_{BC}}{q N_d}\right)^{1/2}$<br><br>- If $-V_{CE}$ is goes more -ve, punch-through can happen i.e. depletion region can fill entire base<br><br>- Base-narrowing is less prominent in graded base doping transistors.<br><br><br><br><br>$W_b = l_b - l$<br>$l \propto \sqrt{V_{BC}}$<br><br><br><br><br>Common-emitter characteristics (increase in $I_C$ with increased collector voltage).</td><td></td><td></td><td></td></tr>
<tr><td>5.</td><td>Explain the operation of a typical solar cell with a neat diagram. Define fill factor with diagram for a solar cell. Explain the significance of fill factor.</td><td>[10]<br><br>(1+<br>6+2+1)</td><td>CO2</td><td>L2</td></tr>
</table>

## Solar cell



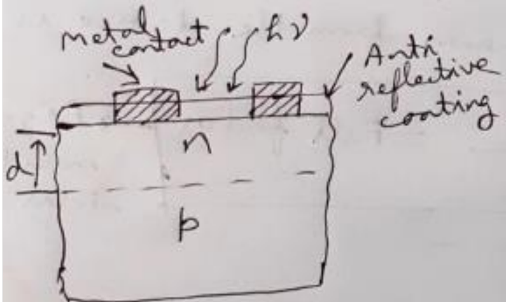




- Power can be delivered to an external circuit by an illuminated junction.
- The open ckt. voltage across a p-n junction is,

$$V_{oc} = \frac{kT}{q} \ln\left(\frac{I_{op}}{I_{th}} + 1\right)$$

Here, $V_{oc} < 1\,V$

$I_{oc}$ in the range 10 - 100 mA for an area of $1\ cm^2$.




configuration of a solar cell

Working: EHP are generated in depletion region. The electric field in depletion region drives the electrons in n-region and holes in p-region, thereby creating potential diff. across p-n junction.

Requirements :-

— (a) For max. usage of available optical energy, solar cell has large area.

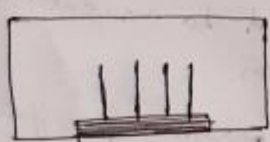
(b) Surface of the cell is coated with anti-reflective coating.

(c) Junction depth d to be less than $L_p$.

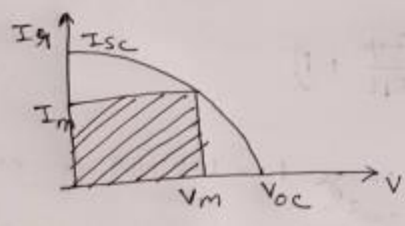
(d) The thickness of the p-region must be such that electrons generated in this region can diffuse to junction.

(e) Series resistance of the device to be small so that power is not lost.

(f) contact can be distributed over the n-surface.



metal contact fingers




maximum power is delivered when $V_R$ and $I_R$ are maximum,

i.e. $P_{max} = V_{oc} I_{sc}$

The actual power drawn from the device is, $V_m I_m$

The ratio, $\frac{I_m V_m}{I_{sc} V_{oc}}$ = Fill factor → Figure of merit of solar cell.