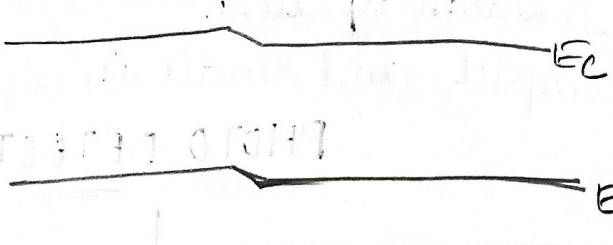
* Different regions:



1) Depletion region
2) Diffusion region
3) far away region.

When light is illuminated on the PN junction diode; EHPs are generated.

Carriers in depletion region move to respective majority charge carrier side.

When external voltage is applied, the charge carriers.

* DARK CURRENT: Reverse leakage current when no light is incident.; when no carriers are flowing.

The current flowing in the circuit is called photo current because it is generated due to the illuminated light and also due to the generated EHP.

16/03/2022

PHOTO DIODES:

⇒ WORKING

1) Carrier generation
2) Carrier transport
3) Extraction

* Anti reflecting coatings help to avoid reflecting back of the light.

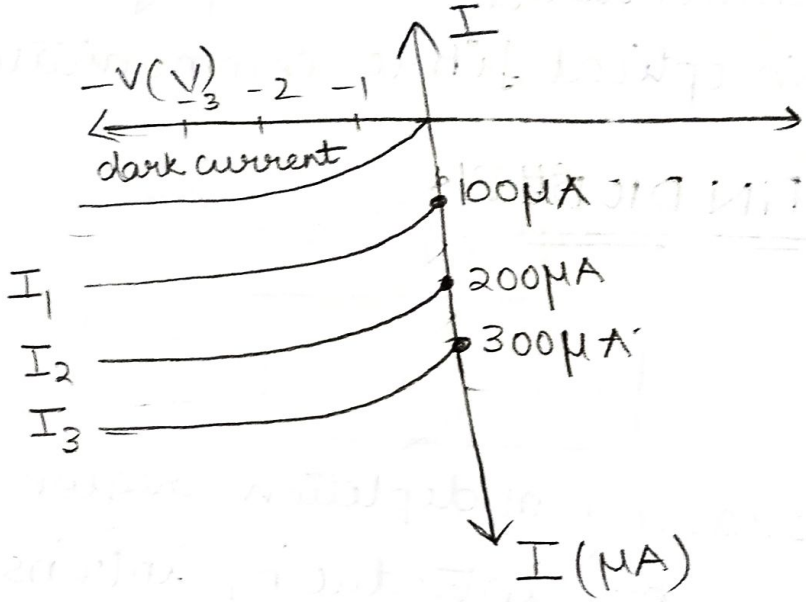
* In reverse bias; electric field is larger

~~dark current~~:

By increasing the reverse bias; we can increase the bandwidth of depletion region.

→ But ↑sing reverse bias to a greater value; breakdown occurs and large amount of current flows.

* V-I characteristics of Photodiode:



* CHARACTERISTICS OF PHOTO DIODE:

→ Quantum Efficiency: (η)

$$\eta = \frac{\text{no. of EHP generated}}{\text{no. of incident photons}}$$

$$= \frac{I/e}{(P_0/h\nu)} = \frac{I h\nu}{P_0 e} = \frac{I hc}{\lambda P_0 e}$$

$$\boxed{\eta = \frac{I}{P_0 \lambda}(1.24)}$$

→ Responsivity: (R)

Performance of device:

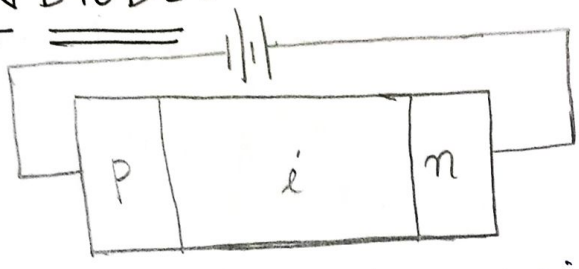
$$R = \frac{I}{P_0} \ (A/W)$$

$$R = \frac{\eta e}{h\nu} = \frac{\eta e \lambda}{hc}$$

$$\boxed{R = \frac{\eta \lambda (\mu m)}{1.24}}$$

Semiconductor made up of InGaAs is used in optical fibre communication.

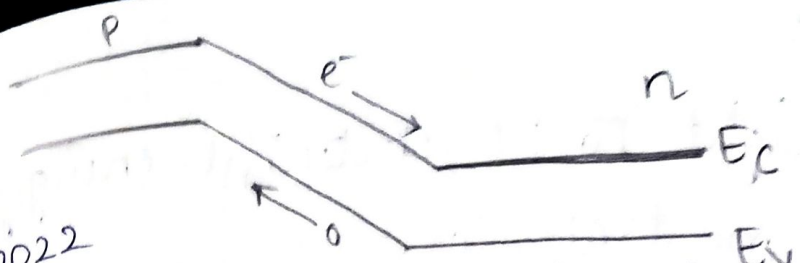
* PIN DIODE:



Increasing of depletion region is done by introducing intrinsic layer.

When we apply reverse bias to the PIN diode; intrinsic layer converts as depletion region.

* In PIN diode; intrinsic layer is sandwiched between P & N type.
* Depletion region extends well into the intrinsic region under sufficient large reverse bias and whole intrinsic region will be made free of charge carriers.



17/03/2022

→ In forward bias; barrier width is decreasing and in reverse bias; barrier width is increasing.

* Construction & working of
1) Photo diode
2) PIN diode

* ADVANTAGES:

→ Wider depletion region.
→ at low voltages
→ less dark current.

→ Advantages of Photo detectors:

* Operates at lower voltages.
* low cost for IR and visible detectors.
* Fast Response time
* Low noise
* Highly sensitive
* linear current wrto incident light.

→ Applications:

* Optical Fibre communication.
* Remote controls.
* Bar code scanner.
* Smoke detectors.
* Street lights.
* Airport security.

* SOLAR CELL:

Converts sunlight to DC electrical energy.

→ What is the need? ~~of solarcell?~~

* Coal, Petroleum resources are depleting.
* Increased population led to ↑sed utilization of current
* Technology dependent.

* → Appealing characteristics:

* Available in abundance
* Free of cost.
* clean energy / eco-friendly.

g, *

t Principle: Photovoltaic Effect

w • generation of voltage by incident
p light.

s → It was started in 1860.

*
gn

b

*
De

in

s

wi

19/03/2022

SOLAR CELL

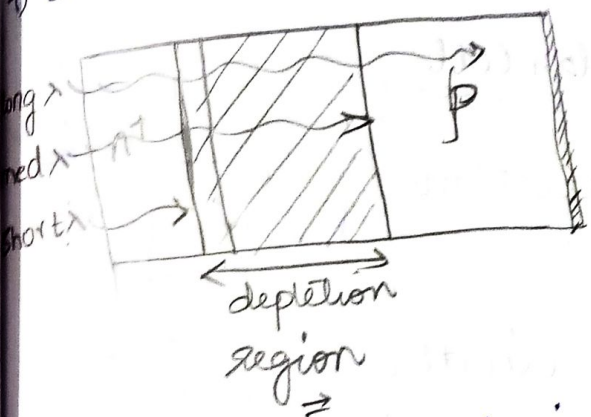
Principle: photovoltaic Effect

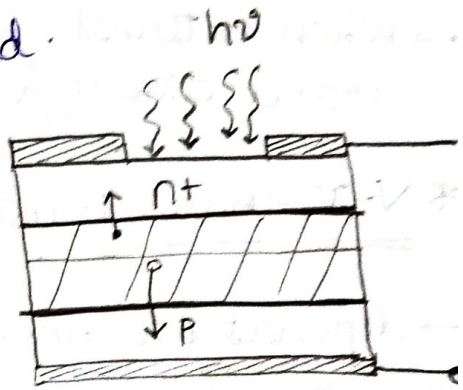
→ Works under no biasing

→ converts sunlight directly into electrical energy

BASIC STEPS:

1) generation of EHP
2) collection of EHP
3) Generation of voltage
4) Dissipation of voltage to load.





$$I = I_0\left(1 - e^{-\alpha d}\right)$$

$$\lambda \propto \frac{1}{\alpha}$$

α = absorption coefficient

Sunlight → absorbed in depletion region → produces EHP → EHP will be separated by E field.

→ Amount of absorption reduces with DEPTH.

hence, depletion region must be close to the surface to maximise absorption; this is achieved by making n region thin and heavily doped.

* n region: thin & heavily doped so that light can easily penetrate.

P-region: lightly doped

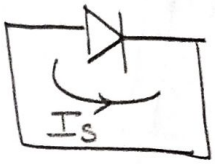
*EHP: are mainly created in depletion region due to built in $\bar{E}$ field.

e⁻s move to N side and holes move to P-side.

→ When external load is connected; excess e⁻s travel through load to combine with holes.

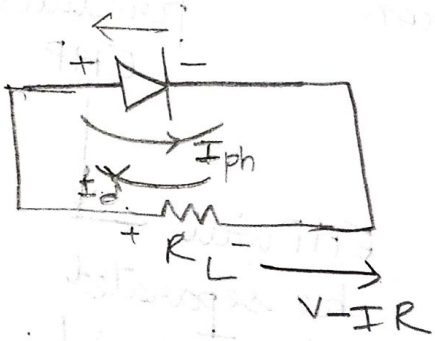
*V-I characteristics of Solar Cell:

→ depends on incident radiation
→ external load connected.



$I_{sc} = -I_{ph}$
⇒ power is generated.

I_{sc} = current flowing in the circuit when no load is connected.



with ext load

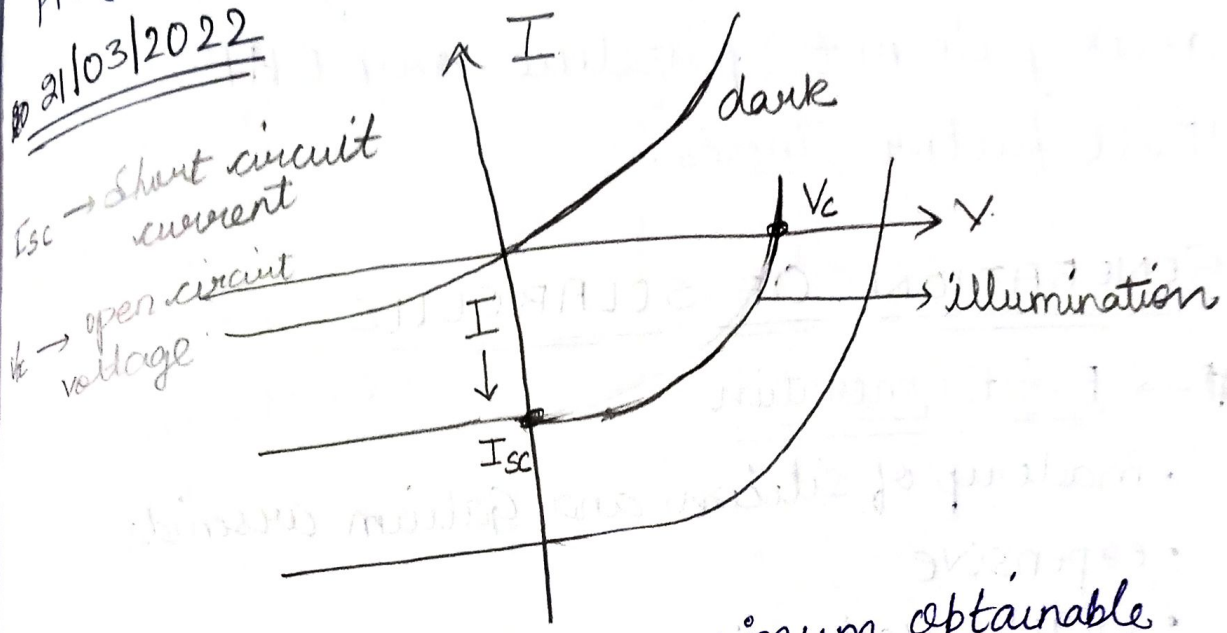
$I = I_d - I_{ph}$

Solar cell acts as in forward bias from above figure.

*If the load is short circuited; the only current flowing in the circuit is photo current also called diode current.

If load is connected; the voltage appears across PN junction diode.

21/03/2022



*FILL FACTOR: Ratio of maximum obtainable power to the ideal power.

$$F.F = \frac{P_m}{V_{oc} I_{sc}} = \frac{I_m V_m}{V_{oc} I_{sc}}$$

⇒ Conversion efficiency:

Ratio of max. obtainable power (P_m) to the incident power (P_{in}).

$$\eta = \frac{P_m}{P_{in}} \Rightarrow \frac{I_m V_m}{V_{oc} I_{sc}}$$

$$\eta = \frac{I_m V_m}{E \times A} \times 100$$

$$\eta = \frac{I_m V_m}{E \times A} \times 100$$

$$\eta = \frac{F.F \times V_{oc} I_{sc}}{P_{in}} \times 100$$

*Reasons for low efficiency of solar cell.

1) All the radiations less than Eg are wasted as they do not produce any EHP.

2) Fill factor losses.

*GENERATION OF SOLARCELLS:

→ First Generation:

- made up of silicon and Galium arsenide
- expensive
- widely used in space applications.

→ Second Generations.

- Aim was to reduce the cost.
- Thin film solar cells.
- & made up of silicon, CdTe, CIGS;
- $\eta = 10-12\%$

→ Third Generation:

- reduce the cost further
- organic solar cell.
- NO PN junction diode is used.

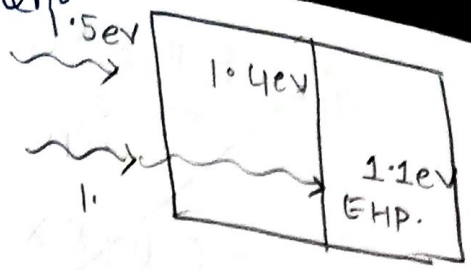
→ Fourth Generation:

- used hybrid solar cells i.e. combination of organic and other solar cells too.

*Tandem solar cells:

eg: Si $h\nu < 1.1 eV$

Stacking of different solar cells is called Tandem Solar cell.



NUMERICALS:

$V_m = 0.54V$ | $V_{oc} = 0.62V$

$I_m = 0.024\ A$ | $I_{sc} = 25\ mA$

$$F.F = \frac{I_m V_m}{V_{oc} I_{sc}}$$

$$= \frac{0.024 \times 0.54}{0.62 \times 25 \times 10^{-3}}$$

$$= 8.36 \times 10^{-1}$$

$$FF = 0.836$$

2) $A = 3cm^2$. $P = 100mW/cm^2$

$J_{SC} = 30mA/cm^2$ $V_{oc} = 0.72V$.

$P_m = 46mW$.

$F.F = ?$ $\eta = ?$

$P = 100 \times 10^{-3} \times 3.$

$= 03W$

3) $I_{sc} = 90 \times 10^{-3} = 0.09A$

$$F.F = \frac{I_m \times V_m}{E \times A} \times 100 \cdot = \frac{I_m V_m}{V_{oc} I_{sc}}$$

$$= \frac{P_m}{V_{oc} I_{sc}} = \frac{0.346}{0.72 \times 0.09} = 0.078$$

$$\eta = \frac{F.F \times V_{oc} I_{sc}}{P_{in}}$$

$$= \frac{0.078 \times 0.72 \times 0.09}{0.3}$$

$$\boxed{\eta = 0.016}$$

$$F.F = \frac{46 \times 10^{-3}}{0.72 \times 0.09}$$

$$= 0.71$$

$$\eta = \frac{F.F \times V_{oc} I_{sc}}{P_{in}} \times 100$$

$$= \frac{0.71 \times 0.72 \times 0.09}{0.3} \times 100$$

$$= 15.3\%$$