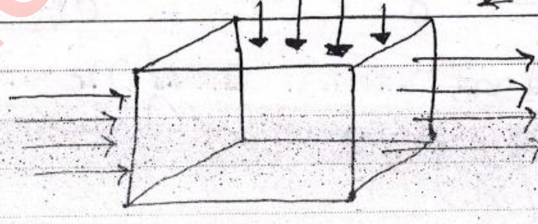
PHOTOCONDUCTIVITY

Defination

Photoconductivity is optical and electrical phenomenon in which the material becomes more conductive when incident beam of radiation falls over it. If the energy of the incident beam is greater than energy gap that exists in valence and conduction band, electron and hole changes and give rise to electrical conductivity. All the photoconductors are not intrinsic but imperfaction plays a important role. The role of impurities is to understand the experimental facts of photoconductivity. The presence of impurities produces discrete energy levels in forbidden gap and often known as traps.

Sample Model of photoconductor



When the incident beam of light is allowed to fall on crystal specimen then electron hole pairs are produced which moves throughout volume of crystal. The electron and hole recombines due to amilation of electron and hole. We further supposed that when one electron moves from either side of the crystal then from other side another electron enters. This model is very hypothetical one.

Current Density:

The production of electron and hole pairs is

$$\frac{dn}{dt} = L - A n_e n_h$$

where L is no of photons absorb n_e – no of electron and n_h is no of holes and term $A n_e n_h$ represents the recombination rate which is directly proportional to production of electron and holes.

In steady state $\frac{dn}{dt} = 0$

$$L = A n_0^2 \qquad (n_e = n_h = n_0)$$

$$n_0 = \left(\frac{L}{A}\right)^{1/2}$$

photo conductivity is : $\sigma = n_0 e\mu$

$$\sigma = \left(\frac{L}{A}\right)^{1/2} e\mu .$$

photocurrent density : $J = \sigma E$

$$J = \left(\frac{L}{A}\right)^{1/2} \cdot e\mu \cdot \frac{V}{d} \quad -(1)$$

Decay of photocurrent

When light is switched off suddenly then $L = 0$

$$\frac{dn}{dt} = -An^2$$

$$\frac{dn}{n^2} = -A\,dt$$

$$\frac{1}{n} = \frac{1}{1/c} + At$$

At $t = 0$, $n = n_0$

$$c = \frac{1}{n_0}$$

$$\frac{1}{n} = \frac{1}{n_0} + \frac{1}{(At)^{-1}}$$

$$n = \frac{n_0}{n_0 At + 1} \quad -(2)$$

Notes

Response time

T_0 called response time, when the

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Concentration of electron will be reduce by half. $\left(\frac{n_0 t_0}{2}\right)$. At that time $L = 0$, no illumination of light.

$$\frac{1}{n} = \frac{1}{n_0} + At_0$$ [using this equation]

$$\frac{1}{n_0/2} = \frac{1}{n_0} + At_0$$

$$\frac{1}{n_0} = At_0 \Rightarrow t_0 = \frac{1}{An_0} = \frac{1}{(AL)^{1/2}}$$

$$t_0 = \frac{1}{(AL)^{1/2}} \cdot \frac{L}{L} = \frac{n_0}{L}$$

And photoconductivity, $\sigma = n_0 e \mu$

$$\frac{\sigma}{\mu e} = n_0$$

$$\therefore t_0 = \frac{\sigma}{\mu e L}$$

Response time (t_0) is directly proportional to photo conductivity.

Gain factor or Photo Sensitivity

It can be defined as number of charge carrier passing through specimen to the no of photons absorbed by specimen.

If d is thickness of specimen per unit crossectional area then no of photons absorbed will be

$$G = \frac{n}{L \cdot d}$$

$J = I = ne$ [in case of unit cross-sectional area]

$$n = \frac{J}{e} = \frac{n_o \mu v}{d}$$

$$G = \left(\frac{L}{A}\right)^{1/2} \cdot \frac{\mu v}{L d^2} = \frac{\mu v}{(AL)^{1/2} d^2}$$

(2) It can also be defined as ratio of response time (t_o) to the transit time (t_d).

$$G = \frac{t_o}{t_d}$$

$$G = \frac{1}{(AL)^{1/2}} \cdot \frac{\text{velocity}}{\text{distance}} = \frac{\mu E}{(AL)^{1/2} \cdot d}$$

$$= \frac{\mu v}{(AL)^{1/2} \cdot d^2}$$

Effect of trap:

Trap is the energy level in forbidden energy gap which is capable of capturing either electron or hole. The captured electron or hole may be re-emitted at any time

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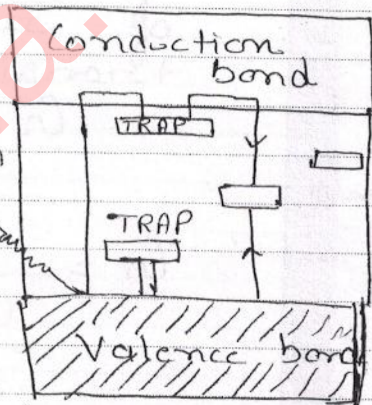
and move to further traps. There are two types of traps one is that which contribute directly to recombination process of electron and holes so that equilibrium (thermal) will achieve. other one is that which contributes indirectly to the recombination process.

Suppose there are N electron trap level and illumination is L.
The production of electron & hole pair

$$\frac{dn}{dt} = L - An(n+N)$$



The term Bn_t is added because of the thermal ionisation of charge carrier from traps back into the conduction bond.

In Steady State

$$\frac{dn}{dt} = 0 \quad , \quad n = n_0$$

$$L = An_0(n_0 + N)$$

Notes

$$\frac{L}{A} = n_0(n_0+N) \quad (1)$$

* At low illumination (L) : In this case
$N >>> n_0$

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SEP 09			1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30			

$\therefore$ eq (1) becomes

$$\frac{L}{A} = n_0 (N)$$

$$n_0 = \frac{L}{AN} \quad -(i)$$

$$\sigma = n_0 e \mu$$

$$\sigma = \frac{L}{AN} e \mu$$

and $$J = \frac{L e \mu v}{AN \cdot d}$$

[At high illumination $n_0 \gg N$ $\therefore J = \frac{n_0 e \mu v}{d}$]

This equation shows that $J \propto L$ but inversly proportional to N (electron trap levels).

Decay of photocurrent

At $t = 0$, $n = n_0$ and light is switched off then $L = 0$

$$\frac{dn}{dt} = -n_0 A (n_0 + N)$$

$$\frac{dn}{n_0(n_0 + N)} = -A dt$$

Notes

$$\frac{1}{N}\left[\log n_0 - \log(n_0 + N)\right] = -At + C$$

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$$\log n_0 - \log (n_0 + N) = -ANt_0 + C$$

At $t = 0$, $n = n_0$

$$C = \log n_0 - \log (n_0 + N)$$

and $N >> n_0$

$$\log \frac{n}{N} - \log \frac{n_0}{N} = -ANt$$

$$\log \frac{n}{n_0} = -ANt$$

$$n = n_0 e^{-ANt}$$

Response Time

Response time is the time at which the concentration of electron/hole is reduced to $\frac{1}{e}$ of it's orignal value

$$\frac{n_0}{e} = n_0 e^{-ANt_0}$$

$$1 = ANt_0$$

$$t_0 = \frac{1}{AN}$$

Notes

Response time (t_0) decreases with increase in electron trap levels N and vice versa.

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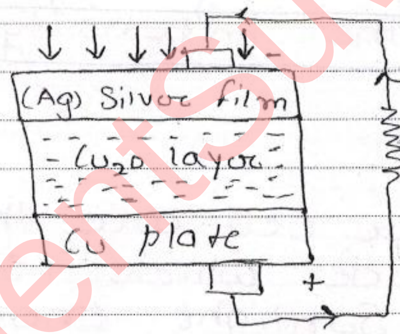
Photovoltaic Cell

Principle: when pair of electrodes is dip into an electrolyte Solution and incident beam of light is allowed to fall on any one of the electrode then potential difference will developed between the electrodes. This phenomenon is called photovoltaic and devices based on this is called photovoltaic devices/cell. The potential difference developed is directly proportional to intensity and frequency of incident beam.

Construction: Photovoltaic cell is based on photovoltaic effect. It consists of a Copper plate (Cu).



Copper plate (Cu) is Surrounded by thick film of cuprous oxide layer (Cu_2O) Above this layer Silver film is deposited Resistor of resistance R is

Connected to the appratus. Incident beam of light is allowed to fall on Silver film.

Working: when Sunlight is allowed to fall on Silver film (Ag) that acts as a transparent flim and light will passes through it to Cuprous oxide layer. This is the place where the electron hole recombination takes place. Electrons moves towards Silver film thus made it negetively charged and hole moves towards positively charged thus making (Cu) plate (+) charged and potential difference will set up between copper and Silver plate. Thus current will flow in the circuit and strength of current depends upon the intensity of light.

Solar Cell

Principle: Solar Cell are the p-n Junction diode which is used to convert Sunlight energy into electrical energy. They are called energy Convertor and Simply a photodiode that operates at zero bias voltage.

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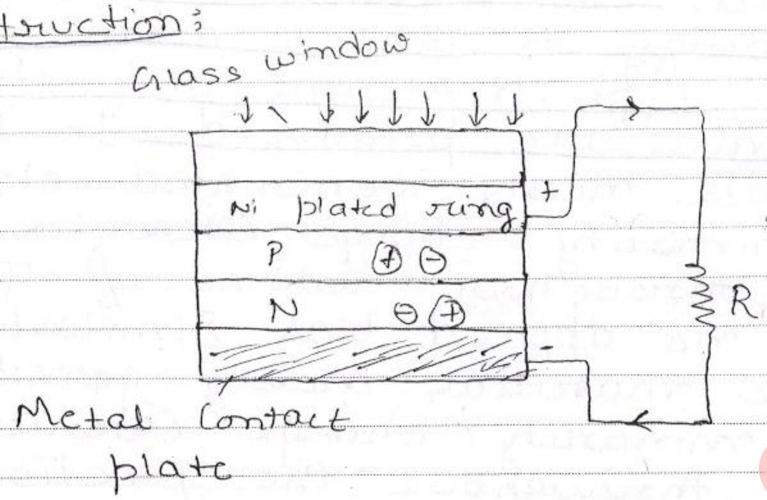
Construction:



Solar Cell Can be made from PN Junction diode that is Si or Ge. It Can be constructed with other PN Junction diode as Gallium arsenide indium arsenide, Cadmium arsenide. PN diode is packed in Can over which there is a glass window (at top), So that light will fall on both p and N type materials. p type material is Surrounded by Ni plated ring and N type material is Surrounded by metal Contact plate that acts as positively and negetively charged.

Notes

Working: When incident beam of light is allowed to fall on cell, it will interact with both p and N type

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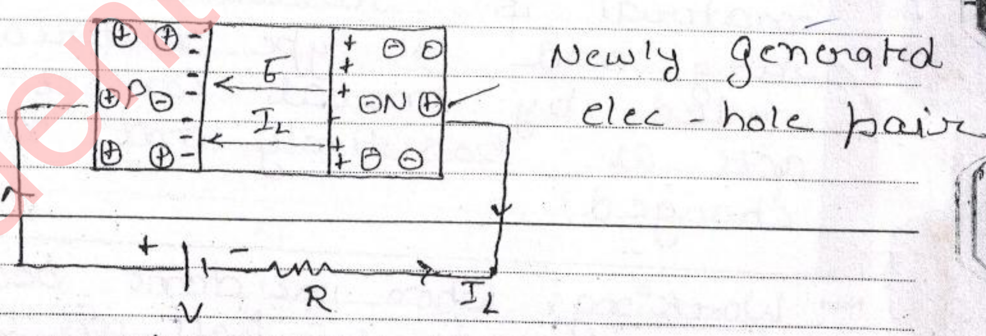
materials. These radiation provide sufficient energy to ionize atoms of p and N type material and electron holes pair are produced. In p-type materials newly generated electrons are minority charge carrier which moves throughout volume of Junction with no applied bias. Similarly In N type material newly generated holes are minority charge carrier which moves throughout the Junction with no applied Bias.

Therefore a electrostatic feild is generated which causes current to flow in reverse direction. This is called photocurrent (I_L). This current causes a voltage drop in the resistance and forward current flows in opposite direction to I_L. Thus, strength of electric feild is reduced.



The main charactestics are:

Since, total current

$$I = I_L - I_F$$
$$= I_L - I_s(e^{eV/kT} - 1)$$

(i) Short circuit conditions occur when $R = 0$, $V = IR = 0$

$$I_{sc} = I_L - I_s(1-1) = I_L$$

Thus, a photocurrent will flow in the circuit.

(ii) open circuit conditions occur when $R = \infty$, $V = IR$ and $I = \frac{V}{R} = 0$

$$\therefore 0 = I_L - I_F$$
and $I_L = I_F$

Forward current = Photo current.

Applications:

1) They are used in controlling street lights.
2) They are used for relay control.
3) They are used in exposure meter for cameras.
4) They are used as a voltage regulators.

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
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25	26	27	28	29	30	31

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5). They are used in large burglur alarms.

6) They are used in moving object counter.

7). They are used to control the temprecture in chemical reactions.

8). They are used in finding out opacity of solid and liquid.

9). The main application is the reproduction of sound in televisions, cinemas etc.

10). They are used to measure the intensity of light.

Notes

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