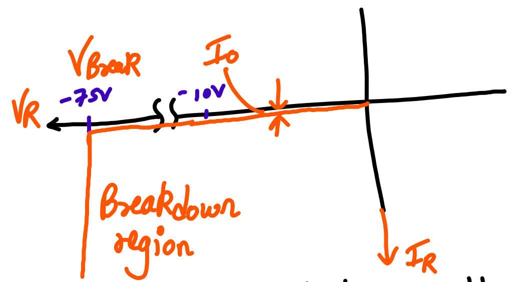
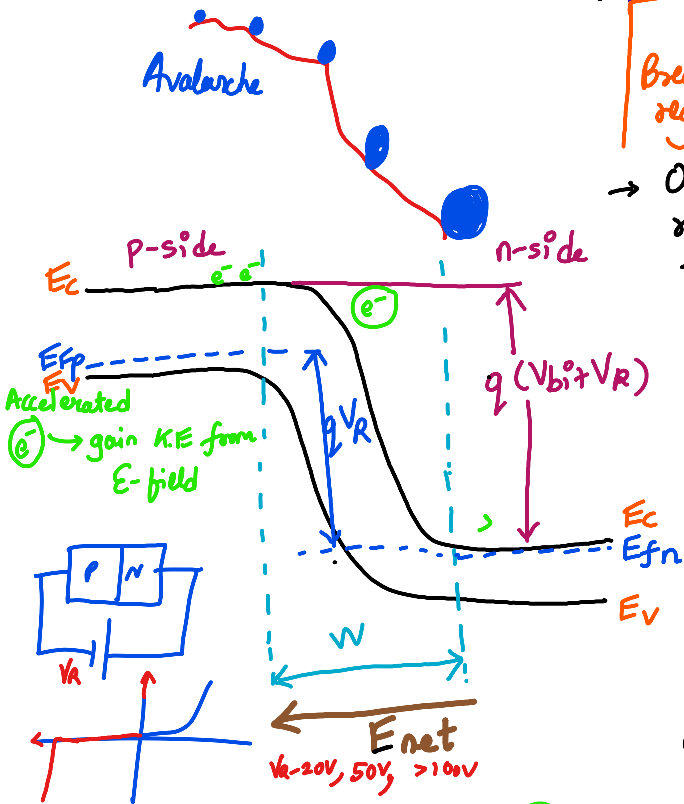
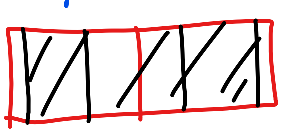
EEEE lec 35a

→ Avalanche breakdown:

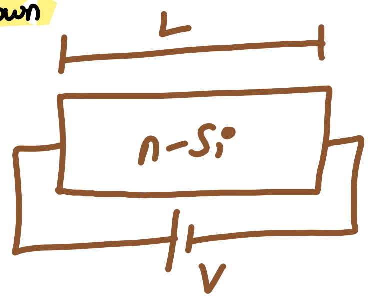


→ Once breakdown voltage (~75 to 100V) is reached for diode → current flowing through ↑ses sharply due to Avalanche breakdown





V_R↑ W↑



$E = \frac{V}{L}$ V/cm V/m

E ↑ → V ↑↑ ✓ or L ↓↓

{ e^- move more quickly through Depletion region }

e^- accelerated electron's → traverse through depletion region (within which immobile ions are present) → e^- accelerated electrons collides with Si atom

K.E – Kinetic energy

a) accelerated e^- collides with Si atom & knocks off it's bound e's with enough K.E → b) Now, we have 2 free e's, these again K.E from E-field & knocks Si atom's which gives rise to more free e's.

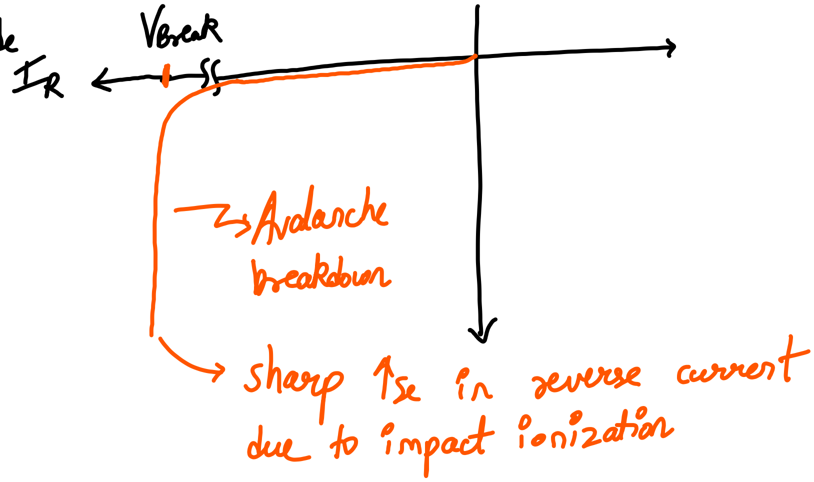
c) Due to these collision's, number of free carrier concentration increases rapidly i.e there is a sudden jump in reverse saturation current

d) This breakdown is caused by impact ionization { high energy charge carriers can knock-out bound e^- from Si atom }

e) This is Avalanche breakdown effect

f) Avalanche breakdown happen at much high breakdown voltage for PN Junction diode

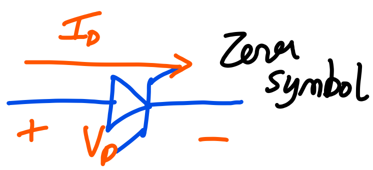
V_{Break} : Breakdown voltage

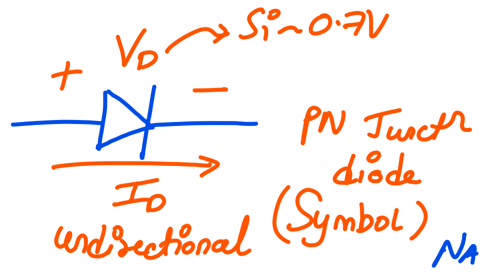


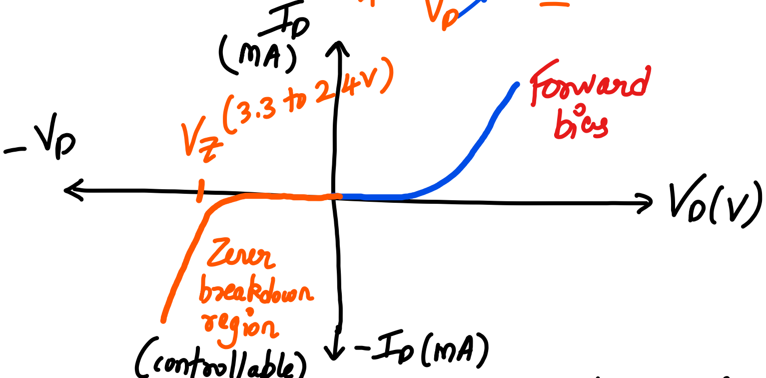
Construction of zener diode →

① Zener diode is similar to pn junction diode → except it is very heavily doped i.e N_A & N_D are about $10^{18}/cm^3$

* Zener diode:

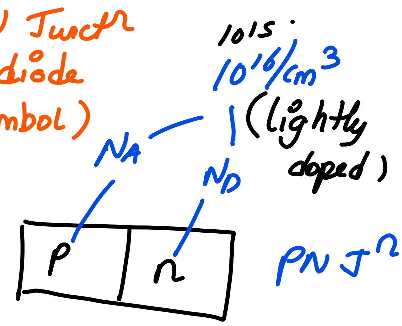


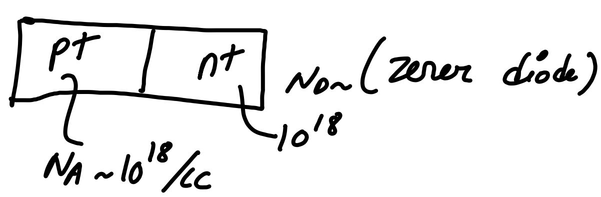


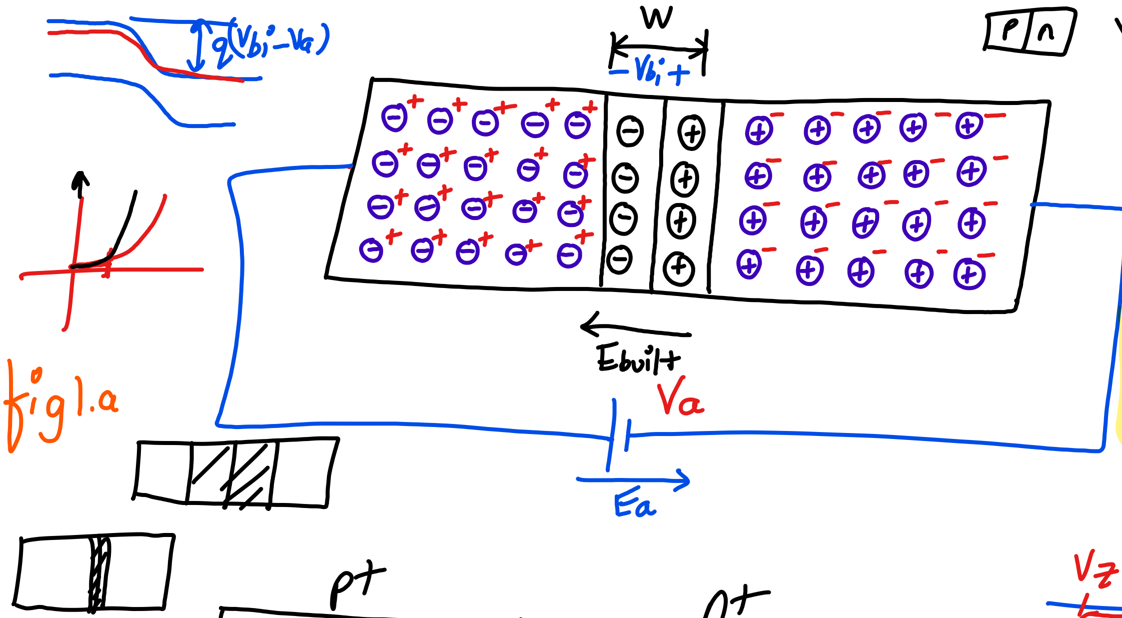


− Zener as a voltage regulator (Application)

Zener:
− heavily doped





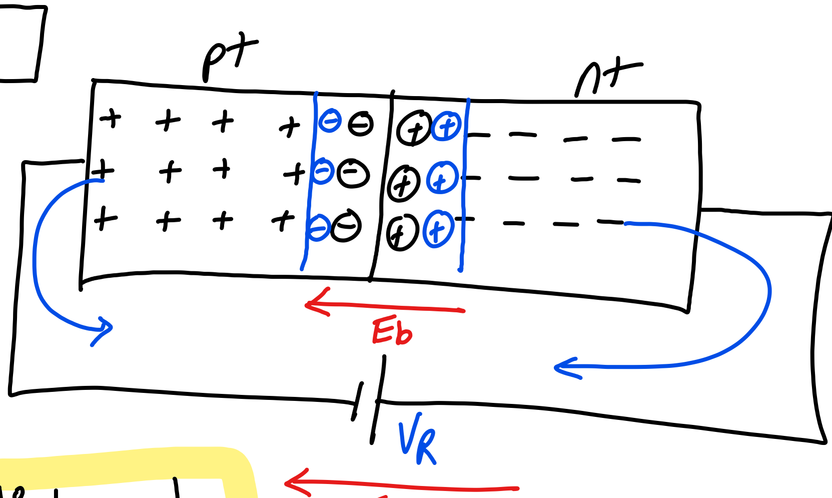


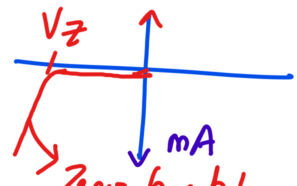
p | n W reduces as in comparison to pn jn

$E = \frac{V}{W\downarrow}$

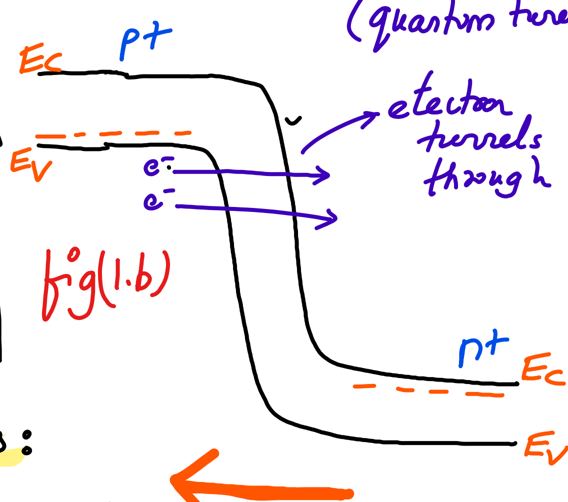
$E\uparrow$

Zener under forward-bias





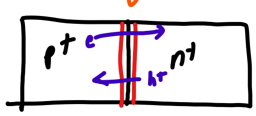
(quantum tunelling)



fig(1.b)

Zener diode under reverse bias

Ea → applied electric field



Events for zener diode under forward bias:

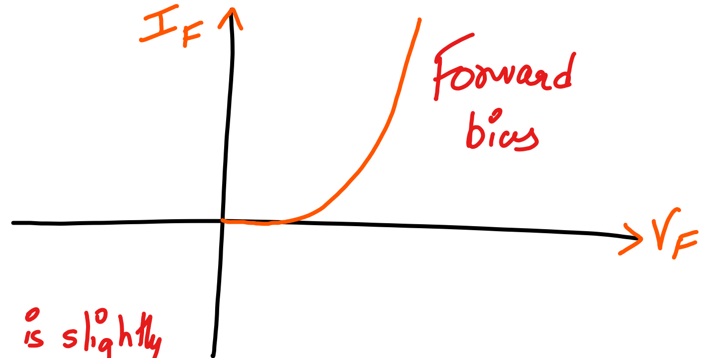
① In forward bias i.e when p^+ side is connected to +ve side of supply Va & n^+ side is connected to -ve side of supply voltage Va, the operation of zener diode is similar to that of pN Junction diode

② Only difference being → depletion region width 'W' is much narrower than p-N Junction diode → due to very heavy doping ie p^+–n^+ junction → Due to this built-in electric field in the depletion region is much stronger too

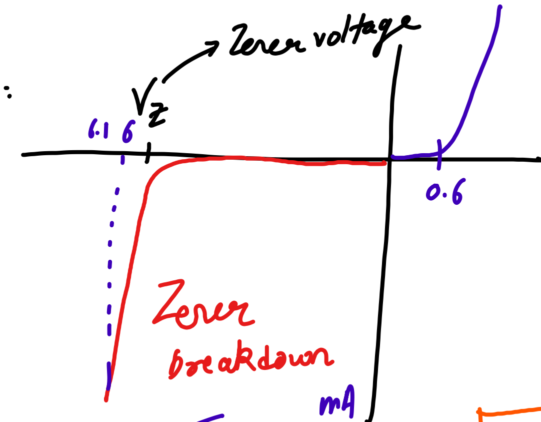
(Refer 1.a)

③ So, for zener diode, the forward I-V characteristics are exactly similar to pn Junction diode ie after barrier potential, current I_F ↑ses exponentially with voltage V_F

is slightly less than pN Junction



Event for Zener diode under Reverse-bias:

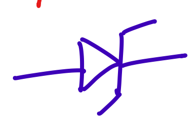


① In reverse bias, due to applied voltage V_R (refer fig 1.c), E-field is directed as shown in the same direction of built-in electric field

← E_b

← E_a

← E_{net}



$$\boxed{E \propto \frac{V}{L} \quad L\downarrow \quad E\uparrow}$$

② Thus, the net electric field in reverse bias in zener diode is extremely powerful (due to narrow w)

③ There is absolutely no possibility of electron & hole diffusion since barrier is very high (refer fig 1.d)

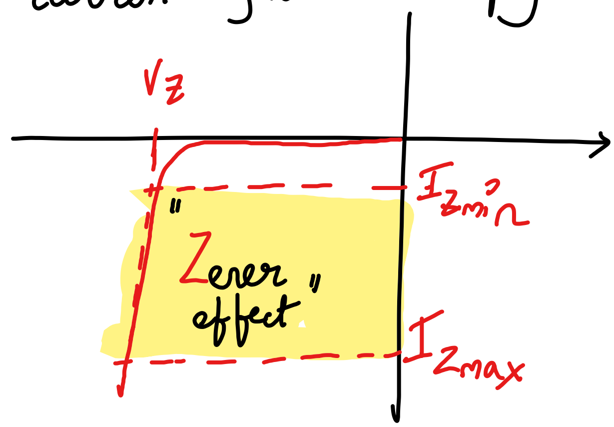
④ So, minority carriers (electron's in p^+ side near the junction & holes in n^+ side near the junction) come under the influence of very powerful E-field → E-field is so powerful that ~~it~~ knocks out bound e^-s of many Si atom at once (since free carrier gain tremendous K.E from electric field & they collide with nearby Si atom in depletion region)

⑤ The result is that e^- funnels through the narrow depletion region & reach other side → This process is called as "Zener breakdown" or "Zener effect" (Quantum tunneling)

⑥ Good news is that at a zener voltage V_Z when zener breakdown takes over → it reversible i.e we can use zener diode as many time we want to

⑦ Wide range of V_Z are available right from 2.2V to 18V commercially

⑧ Due to zener effect, reverse current flows sharply but within safe limits ($I_Z < I_{Zmax}$)



⑨ Since the voltage V_Z is almost constant for wide range of zener current 'I_Z' it main application is "voltage regulation"

* Avalanche breakdown

1. It occurs in lightly doped diodes
2. It occurs due | impact ionization process
3. It's effect is s at higher breakdown vol-ages
4. ith increase in temperature, breakdown voltage ↑ses

Zener breakdown

1. It occurs in heavily doped diodes
2. It occurs due to strong electric field (quantum tunneling)
3. It's effect is seen at low breakdown voltages
4. With increase in temperal, breakdown voltage redu