Chapter no. 18
Electrical Conduction.

(obeys at a const T & P)
Ohm's law

$V = IR$.

$\rho = \frac{RA}{l}$

Conductivity: material ability to conduct electricity

$\sigma = \frac{1}{\rho}$

Resistivity: Property of a material to resist the flow of $\bar{e}$s in a passing current. Independant of sample size and geometry

Q. which phenomena change will result in greater resistance?
$l = 2l$ or $D = 2D$

1 Siemen (S) = A/V
1 Weber (Wb) = V.s
1 Tesla (T) = Wb/m²
1 Henry (H) = Wb/A.

$R_1 = \frac{\rho l}{A}$

$R_2 = \frac{\rho l}{\pi D^2}$

$R_1 = \frac{\rho l}{\pi R^2}$

$R_1 = \frac{\rho 2l}{\pi (\frac{D}{2})^2} \Rightarrow 8 \frac{\rho l}{\pi D^2}$

$\therefore R_2 = \frac{R_1}{8}$

$[R_1 > R_2]$ Ans

Resistance does depend upon sample size and geometry.

Electric flux :- $J = \sigma (V I l)$

conductivity, voltage, current, length

Electric field intensity ; $E = \frac{F}{q}$; also $\Delta V = \frac{\text{Energy}}{\text{charge}} = \frac{E}{q}$

$\Delta V \Rightarrow \frac{Fd}{q} \Rightarrow \frac{W}{q}$

Q. What is the minimum diameter (D) of the wire that $V < 1.5V$.

$Cu = 6.07 \times 10^{7}\ Ohm.m^{-1}$ (conductivity.

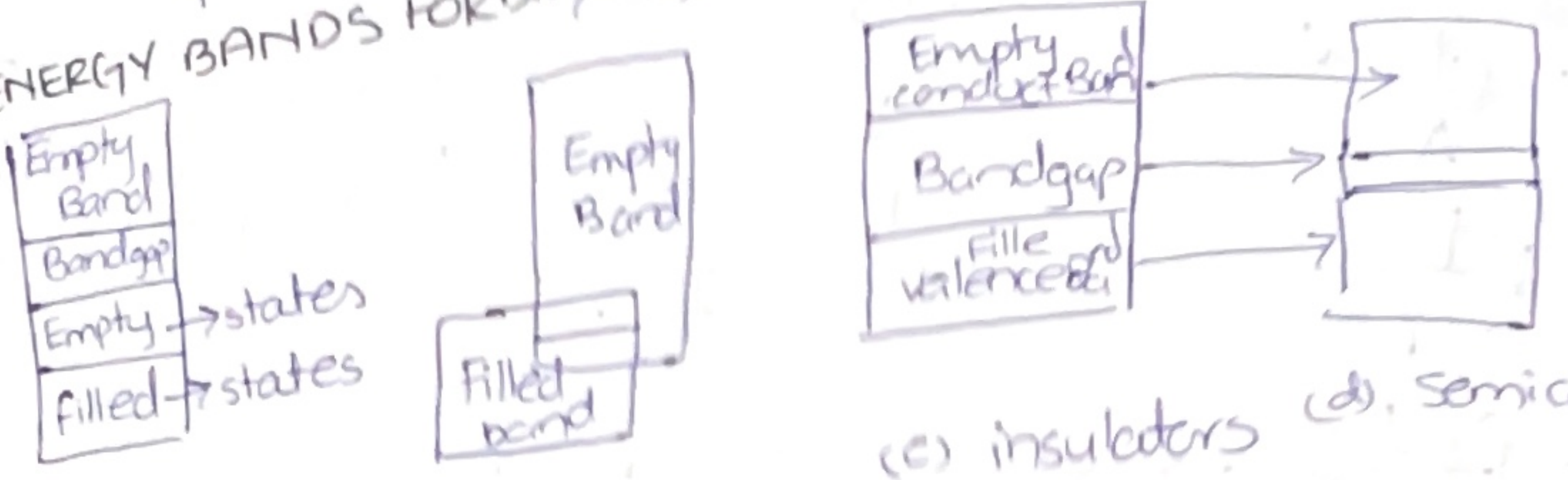
$l = 100m$
$I = 25$

$R = \frac{V}{I}$ also $R = \frac{l}{A\sigma}$

$\frac{V}{I} = \frac{l}{A\sigma} \rightarrow \frac{V}{I} = \frac{l}{\frac{\pi D^2}{4}\sigma}$

$D = \sqrt{\frac{lI}{\frac{\pi}{4}\sigma V}}$ apply values the $D > 1.87mm$ Ans!

Q. ENERGY BANDS FOR DIFF SOLIDS.



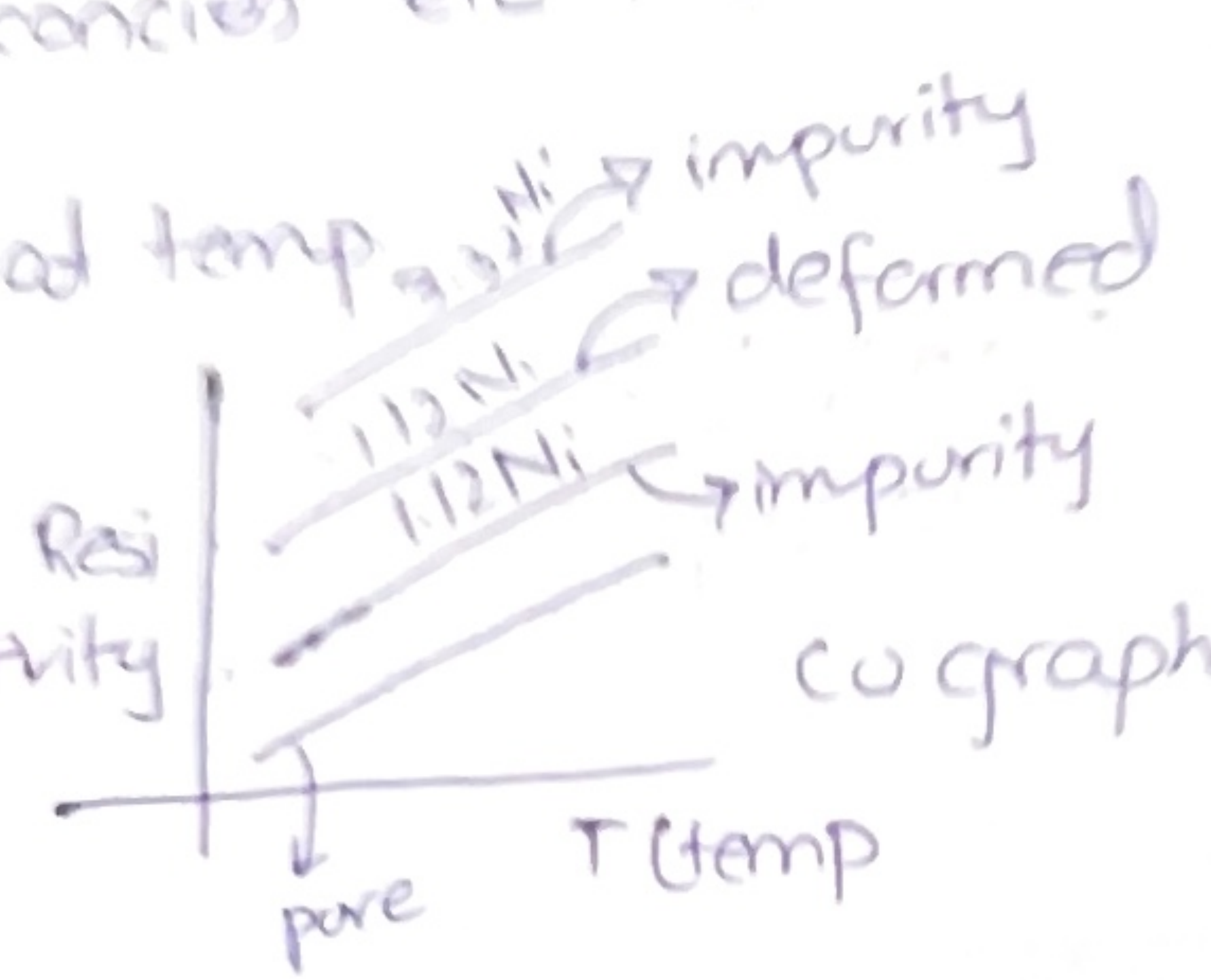
(a) copper (b) Magnesium. (c) insulators (d). Semiconductors

* Diamonds Bandgap is greater $\Rightarrow 5.5eV$
SiC $\Rightarrow$ 3.26eV.

Q. Resistivity in relation with temp & impurity (Cu-graph)

* impurities, grain dislocations, vacancies etc increase resistivity.
* Resistivity increases with increase of temp.

$V = \mu_e E$
drift velocity
electric field.



$\uparrow \Delta E$ = wider energy gap.

Q.

Semi Conductor!

- **Intrinsic** (pure-semiconductor)
  - Pure Semi-C of
  - Ge, Si
- **Extrinsic** doped semiconductor.
  - N-type: Pentavalent impurity
  - P-Type.: Trivalent impurity

Electrical Conductivity:-

Relation b/w σ and intrinsic carrier conc.

$$\sigma = n|e|\mu_e + p|e|\mu_h$$

n → electrons/m³

μ_e → electron mobility.

p → hole/m³

μ_h → hole mobility.

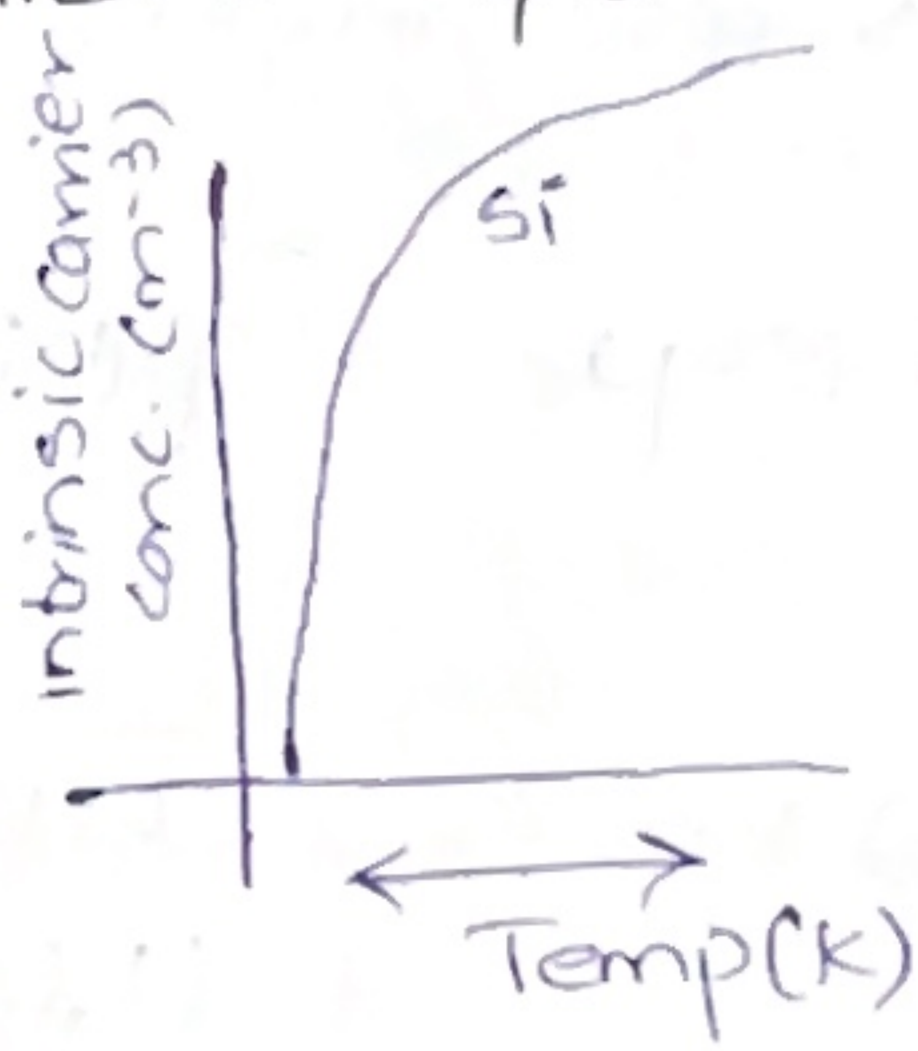
$$\sigma = n_i|e|(\mu_e + \mu_h)$$

$$n_i = \frac{\sigma}{|e|(\mu_e + \mu_h)} \quad \text{—— (a)}$$

n_i → intrinsic carrier conc.

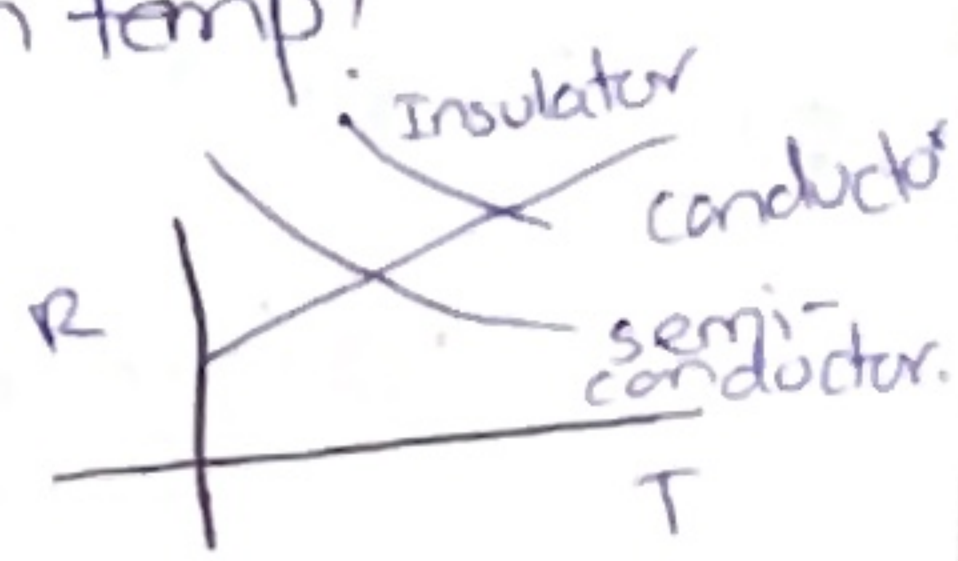
$|e|$ → $(1.6 \times 10^{-19} C)$

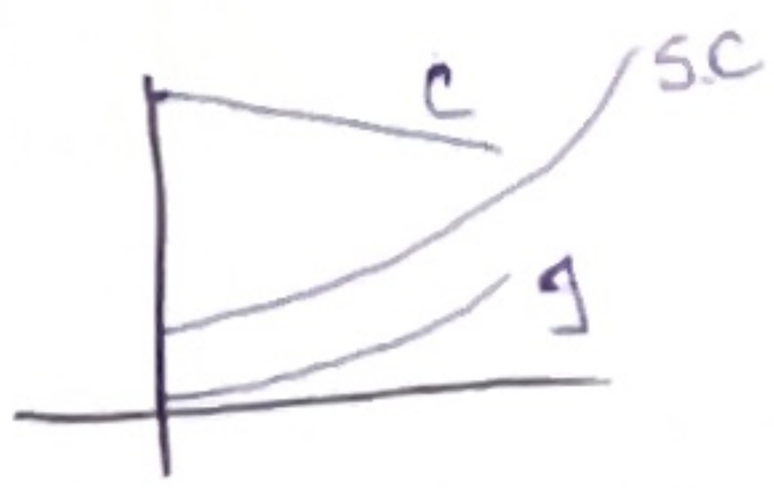
Q. Explain Temp effect at silicons n_i & σ.



in pure silicon. n_i & σ increases with temp!

Q explain the relation of temp with metals, semiconducters & insulaters.





Increase in temperature of metals causes to increase the resistance in it due to atomic vibrations, electron-photon scattering and increased impurities / defect while it is the opposite in semiconducters / non conductors i.e insulaters due to the structure of band & energy levels.

NUMERICAL.

$D = 5.1 mm$

$l = 51 mm$

$I = 0.1 A$

$V = 12.5 V$

(a)

$R = \rho \frac{L}{A}$

$R = \frac{L}{\sigma A}$

$V = IR$

$R = \frac{V}{I}$

$R = 125 \Omega$

$\sigma = \frac{38 \times 10^{-3}}{125 (\pi) \left(\frac{5.1}{2}\right)^2}$

$\Rightarrow 14.9 \Omega$

NUMERICAL:-

As per (a) part

$n_i = \frac{\sigma}{|e| |\mu_e + \mu_h|}$

this also implies as

$n_i |e| \mu_e + p(n_i) \mu_h = \sigma$

(b)

$R = \frac{l}{\sigma A} \Rightarrow \frac{50.8 \times 10^{-3}}{(14.9) \left(\frac{5.1 \times 10^{-3}}{2}\right)^2}$

$\Rightarrow 166.9 \Omega$

① $2.5 \times 10^{-6} = (3.0 \times 10^{13})(1.6 \times 10^{-19}) \mu_e + (1.6 \times 10^{-19})(3 \times 10^{3}) \mu_h$

$0.52 = \mu_e + \mu_h$ —(a)

② $3.6 \times 10^{-5} = 4.5 \times 10^{14} (1.6 \times 10^{-19}) + (2 \times 10^{12})(1.6 \times 10^{-19})$

$112.4 = 225 \mu_e + \mu_h$ —(b)

solve a & b simultaneously for exact values of μ_e & μ_h.

Describe Intrinsic Conduction & extrinsic conduction.

Intrinsic: determined in pure material e.g pure silicon

measured by / have #holes = #$\bar{e}$s
(p) (n)

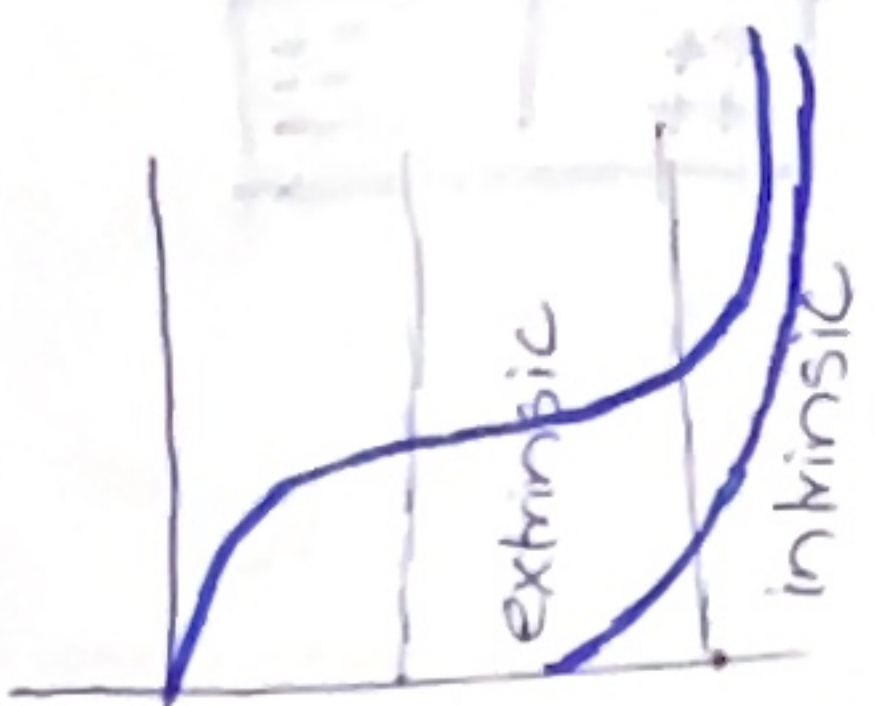
Extrinsic: determined by the impurity type present in a material

#holes ≠ #$\bar{e}$s

n type	p-type
$(n >> p)$	$(n << p)$
no. of $\bar{e}$s >> no. of holes	no. of $\bar{e}$s are less than no. of holes
it is done by dopping P-atom	it is done dopping a Baron atom
$\sigma \approx n\lvert e \rvert \mu_e$	$\sigma \approx p\lvert e \rvert \mu_h$

Q. Explain how conductivity increases with doping by graph.

The doping mechanism allows the imperfection sites to lower the activation energy and to produce more mobile $\bar{e}$s ∴ conductivity increases

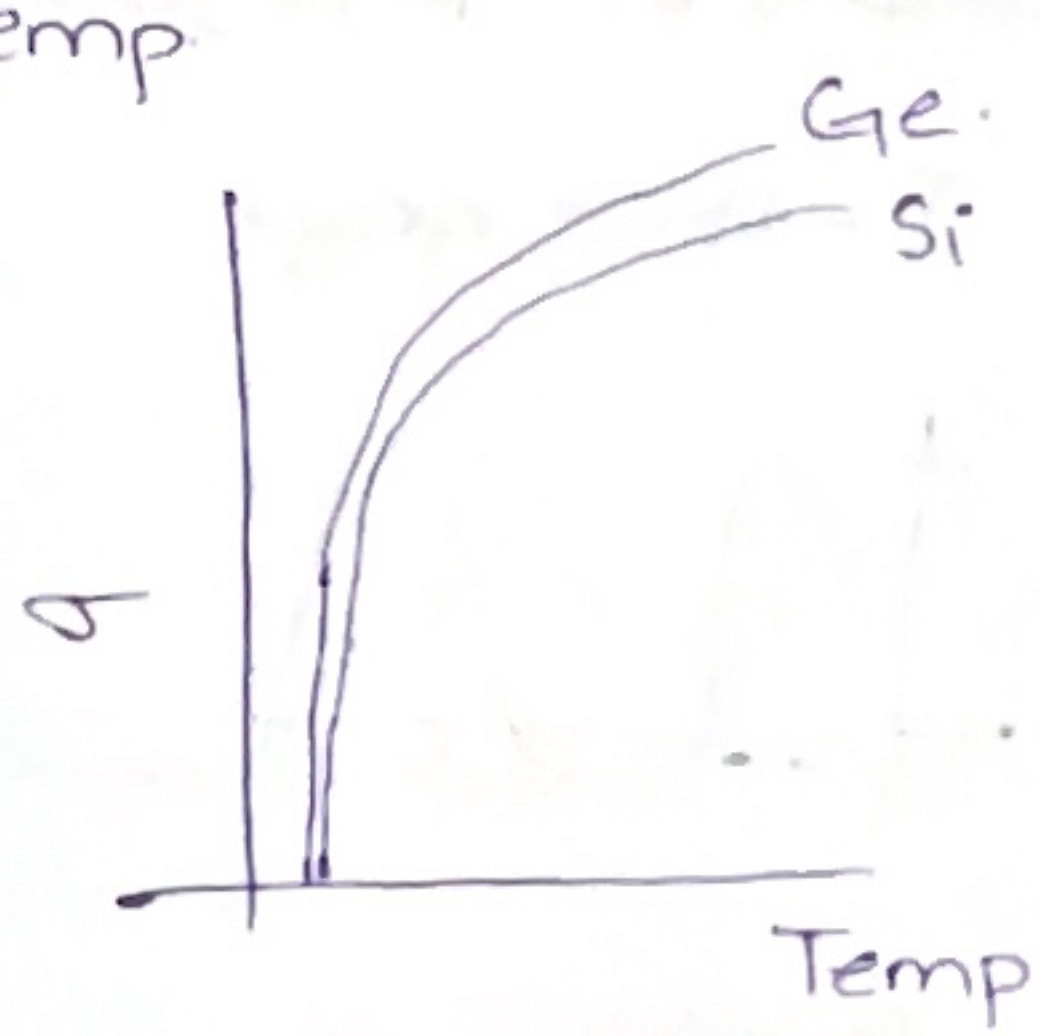


150k — freez-out
"insufficient energy to excite electrons.

450k — extrinsic

>>450k — Intrinsic

Germanium is more conductive than silicon over the same temp



Q. Describe P-N rectifying juction.

A rectifier or a diode, enables the motion of $\bar{e}s$ only at one direction. ∴ converting alternating current into direct current.

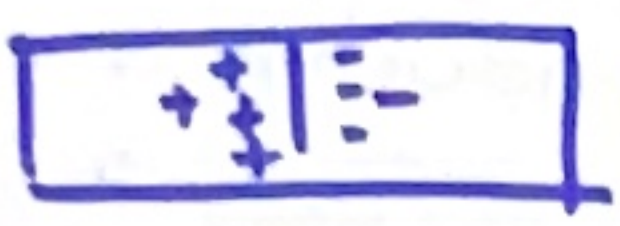
(a) PN juction with no potential.

In P-N rectifying juction a single piece of semi-conductor is doped so that it has n-type on one side and p-type on the other. It has two types of connection.

Low Resitivity **FORWARD BIAS**

P side → positive terminal
N side → negative "

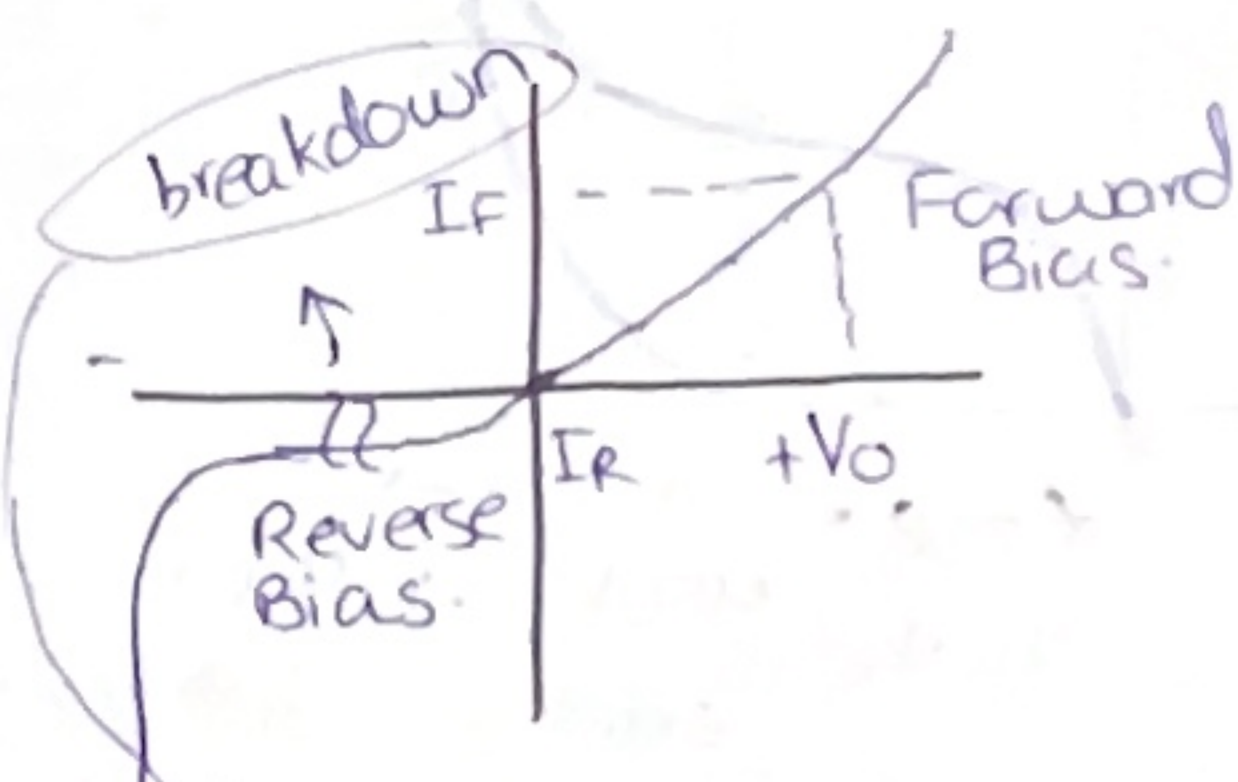
where then holes of p and n of $\bar{e}s$ are attracted to one another. At the point of juction they recombine & anilate each other.



REVERSE BIAS. high resitivity.

N side - Positive.
P-side - negative

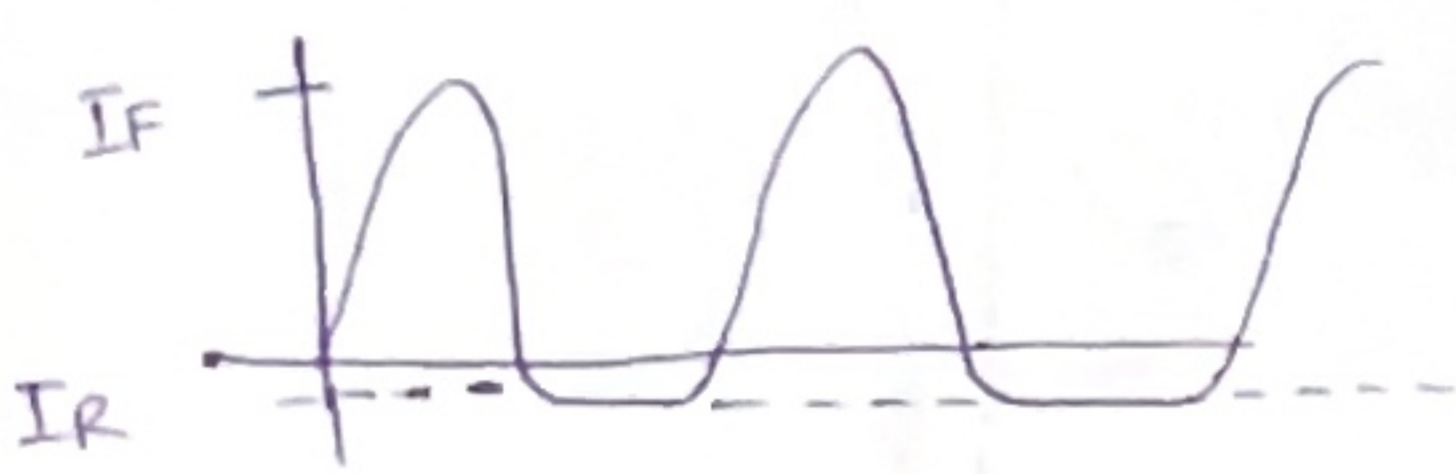
n of $\bar{e}s$ & p of holes move away from one another



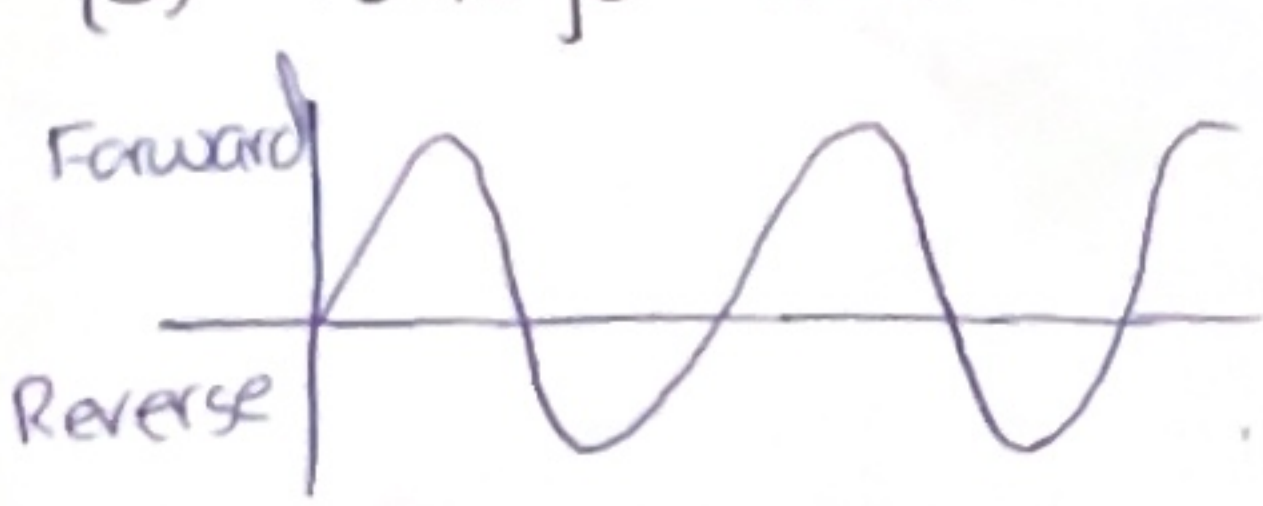
a high reverse voltage giving rise to increasing current.

Q. Graphs of P-N juction.

(a) I-time graph.

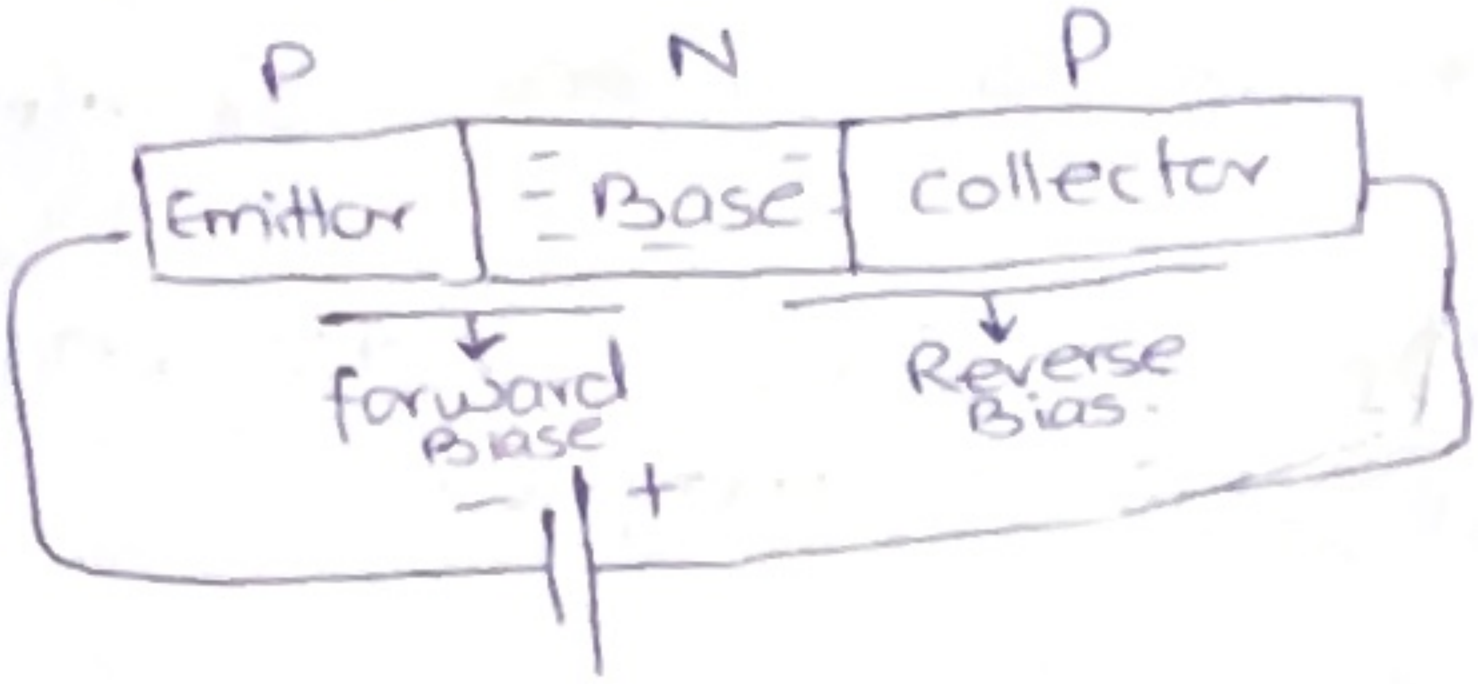


(b) Voltage-Time.



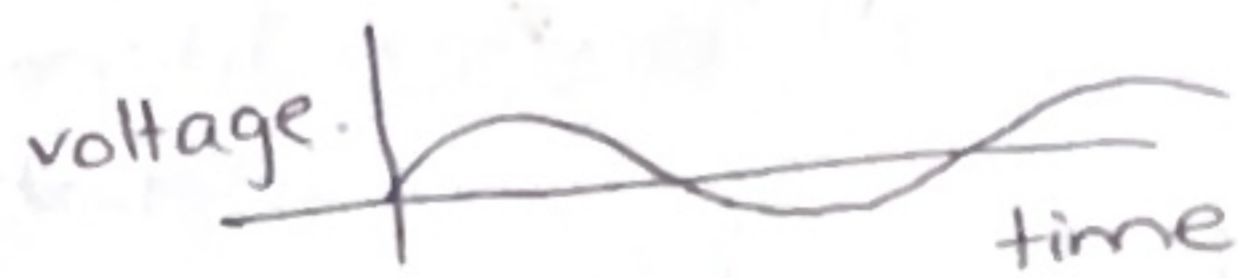
Junction Transistors.

composes of two PN juctions back to back either npn or pnp.



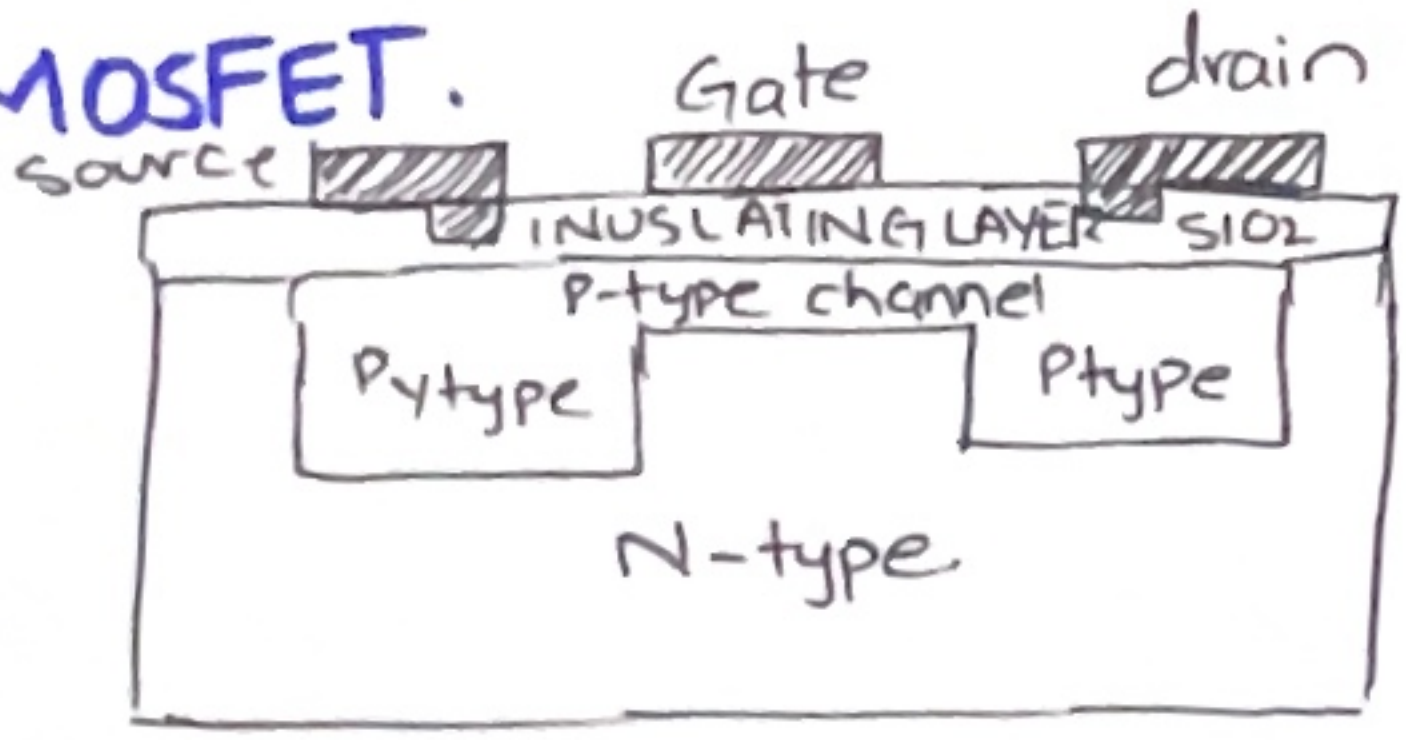
Basically in this setup when voltage is provided to the forward Bias E-B regions, holes from its P-type tend to pass through the base into the collector P-type. If the base is narrow and with appropiate material no hole is anilated by the base es and easily swips through. These holes being minority charge carriers if reach collector region successfully it would result in ↑ increase current (from a small input V) Which is illustrated again by a increased voltage graph as $V \propto I$.

(a) Low input voltage



(b) high output voltage

Q. MOSFET.



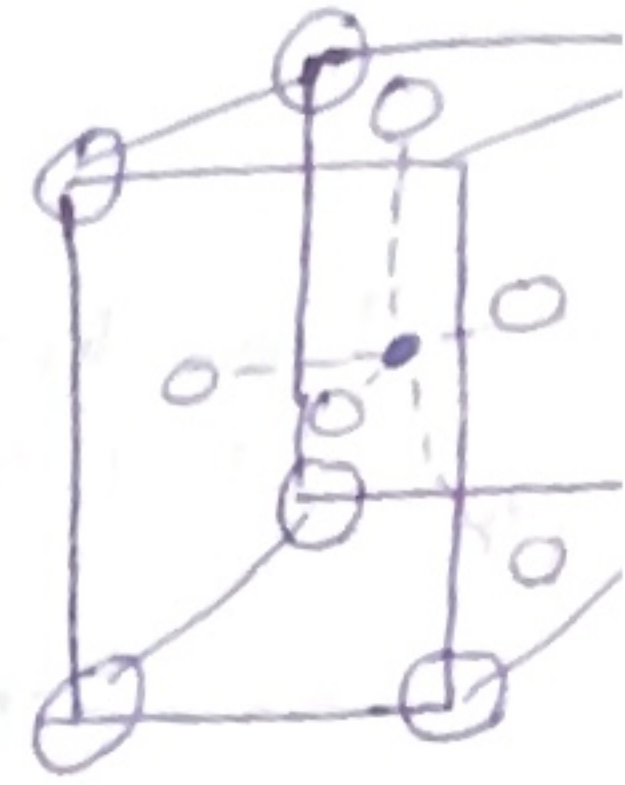
in MosFet imposition of the positive field on the gate drives electric charges out of the channel i.e increasing resistivity.

∴ the field at the gate controls the working of a MOSFET.

Ferroelectric S/Ceramics:- (ferroelectrics

- Materials that exhibit spontaneous polarization (i-e polarization in the absence of electric field)

- They are analogue of ferromagnetic materials that are usually permanent magnet.



- The phenomena occurs due to their specific geometry. Example:

  i) Barium Titanate

  (Tetragonal symmetry)

Piezoelectric Materials ($\bar{P} \rightarrow$ Electricity by strain or stress) (sign reverses from tension to compression)

1. used as transducers b/w electric & mechanical energies
2. used in sonar systemer.

   (Electricity $\rightarrow$ mechanical vibrations) and vice versa.