EEE1024: Fundamentals of Electrical and Electronics Engineering

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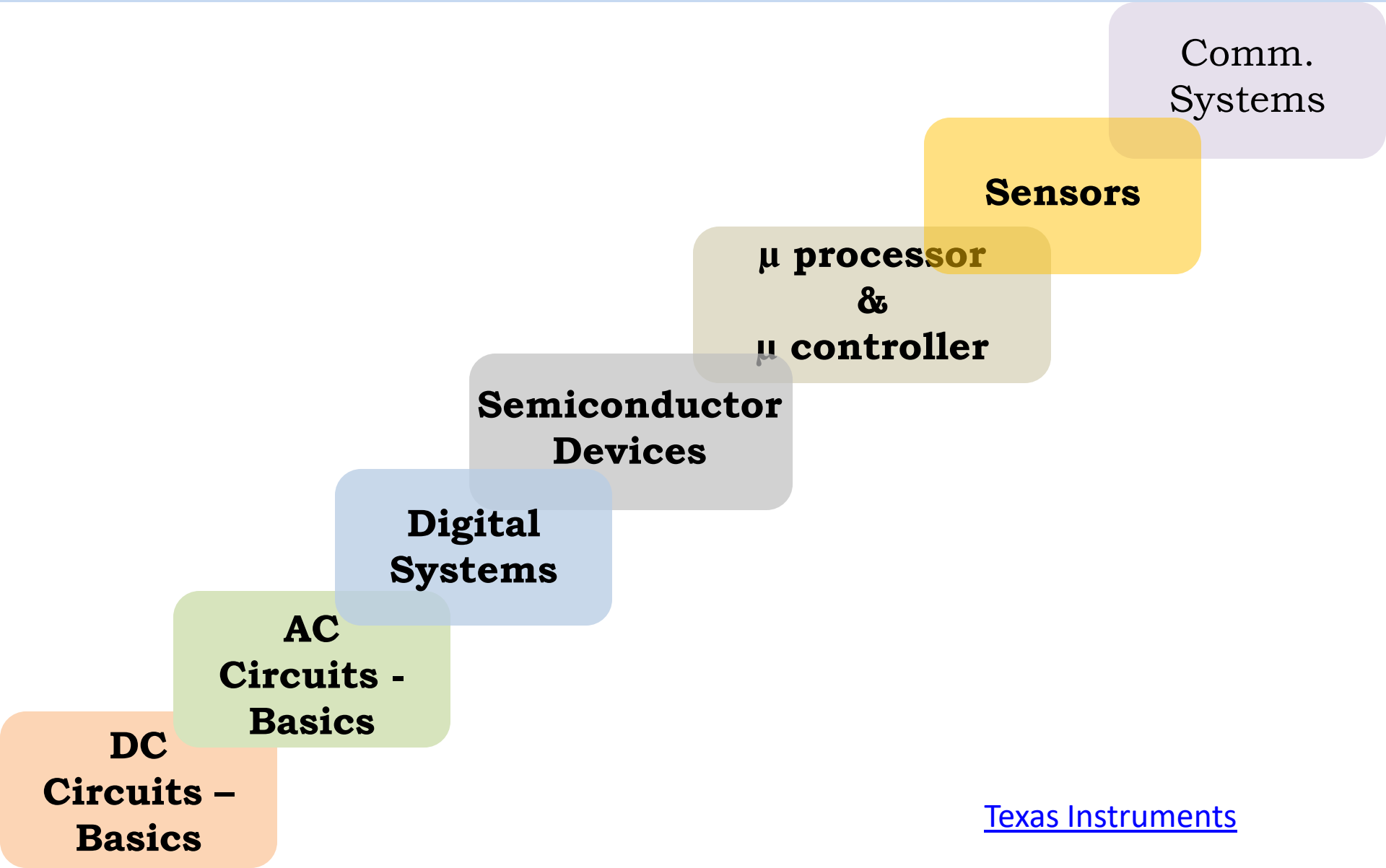
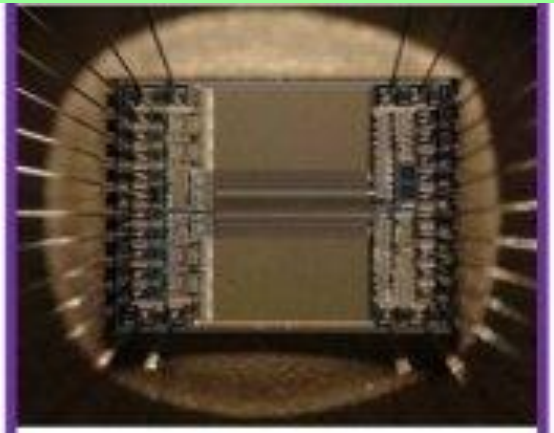
Course Outline



Texas Instruments

Types of Materials

Conductors



Semi-conductors

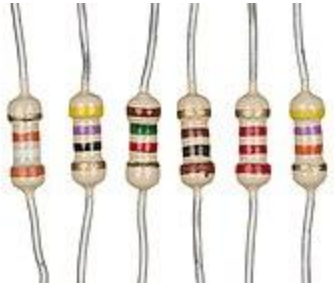
Insulators

Types of Materials (Solids)

Resistivity - ρ

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

Unit: **Ω-cm**

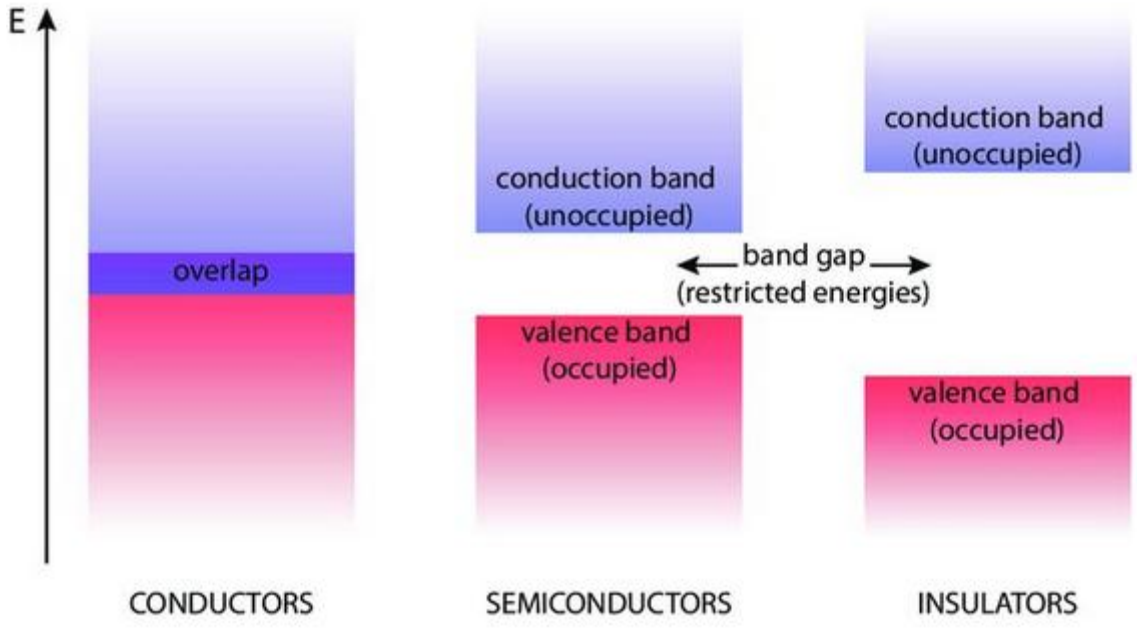


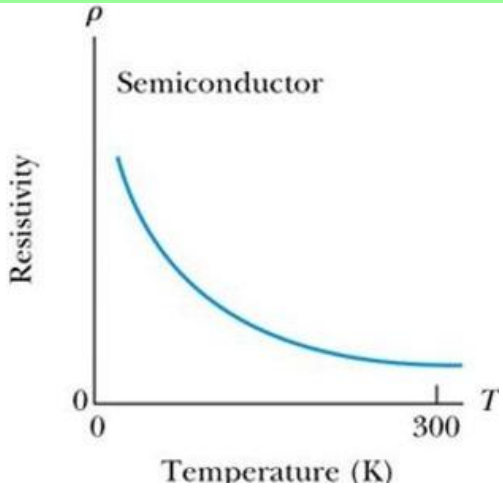
BASIS of CLASSIFICATION

Resistivity **(**Conductivity) ***Energy Band Theory***

CONDUCTORS	LESS: of the order of 10^{-8} Ω-cm	Conduction band and Valence band ⟶ Overlap
INSULATORS	MORE: > 10^{10} Ω-cm	Conduction band and Valence band ⟶ LARGE GAP
SEMICONDUCTORS	In Between: 10^{0} to 10^{3} Ω-cm	Conduction band and Valence band ⟶ SMALL GAP

Energy band theory





$$\rho = f(T)$$

Resistivity is a function of *temperature*

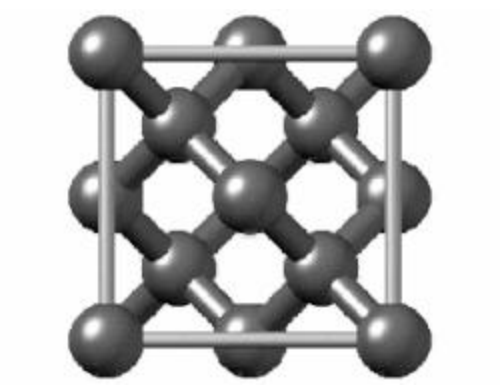
- As temperature increases, resistivity decreases
- As temperature is sufficiently raised, some semiconductors can become conductors!

Conduction in semiconductors

Examples of semiconductors

Silicon **Germanium**

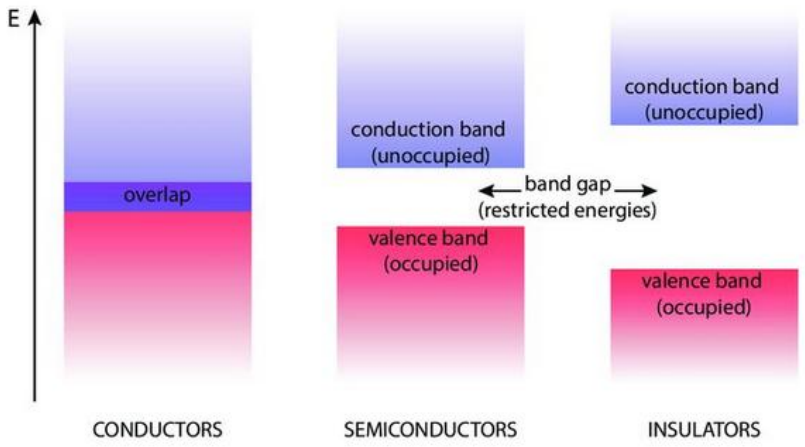
LATTICE STRUCTURE - structures composed of one or more repeating unit cells



Silicon lattice structure – diamond cubic

- For conduction to occur – ***lattice structure*** is needed
- Atoms in a lattice are held in place by ***covalent bonds***
- These bonded electrons cannot move. At room temperature, some bonds are broken and electrons get energy to move and they are called “free electrons”.
- Free electrons can move from valence band to conduction band and participate in conduction or current
- Free electrons are those which constitute current in semiconductors

Conduction in semiconductors



✓ When an electron breaks a bond and becomes *free*, it leaves behind an empty space - ***hole***

✓ Positive charge – ***hole***

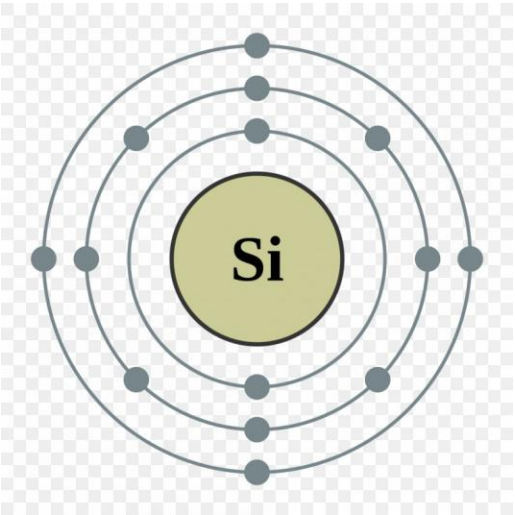
Negative charge - ***electron***

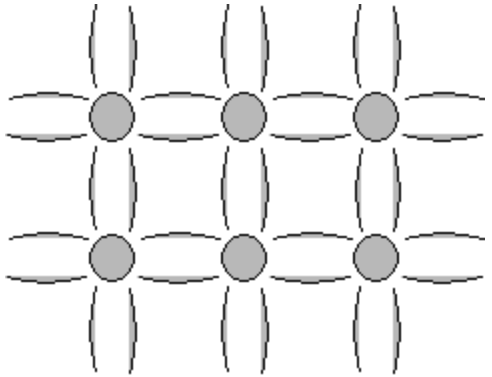
Conduction thus occurs due to the electrons that are freed by breaking of a bond and which populate the conduction band.

Silicon

Atomic number – 14

Electrons per shell – 2, 8, 4



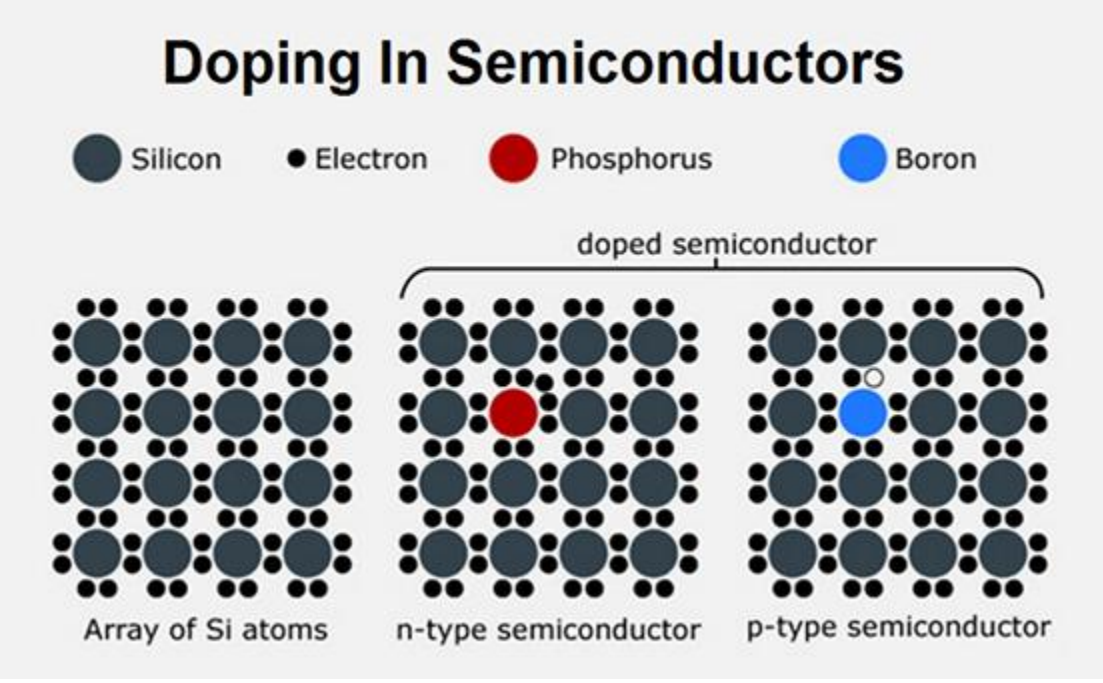


Doping of semiconductors

- *Doping* is the process of adding impurities in semiconductor with the intent of *modulating* (changing or controlling) *its electrical properties*.

If more electrons are present → ***n-type*** semiconductor

If more holes are present → ***p-type*** semiconductor



Phosphorus

Atomic number – 15

Electrons per shell – 2, 8, **5**

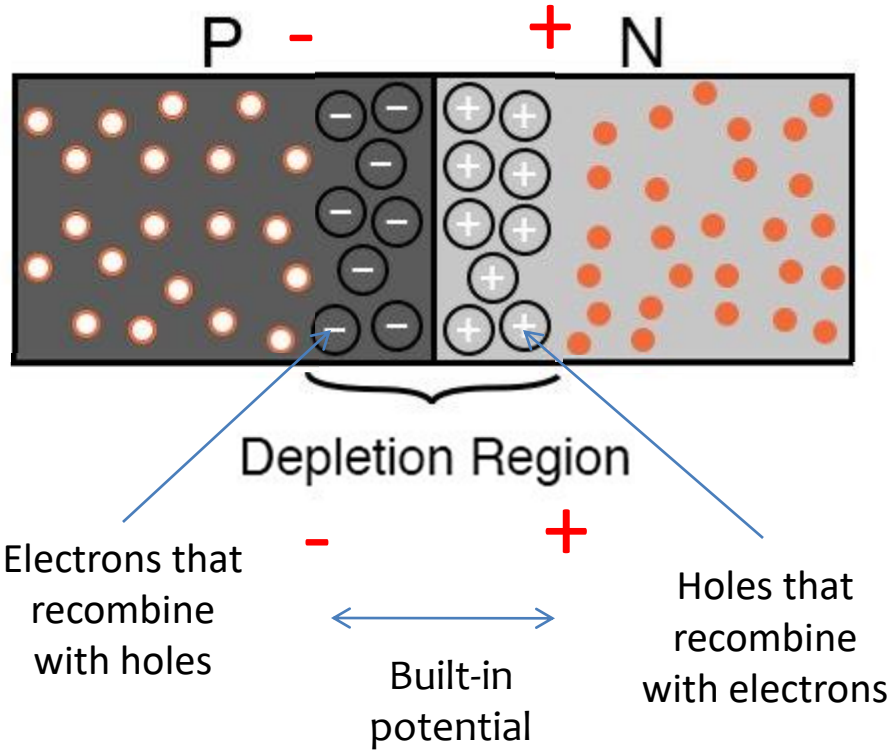
Boron

Atomic number – 5

Electrons per shell – 2, **3**

"p-n" Junction Diode

This device is formed by joining a p-type semiconductor with an n-type semiconductor



electrons

holes

Because p and n type semiconductors are joined –

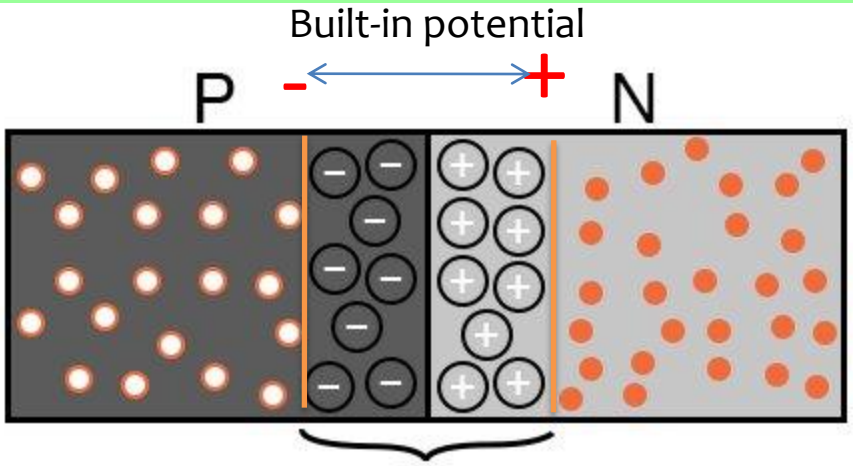
Holes from p-type can diffuse into n type

Electrons from n-type can diffuse into p-type

Built-In potential for Silicon – 0.6 to 0.7V

Will this happen till all holes come into n-type and electrons into p-type?

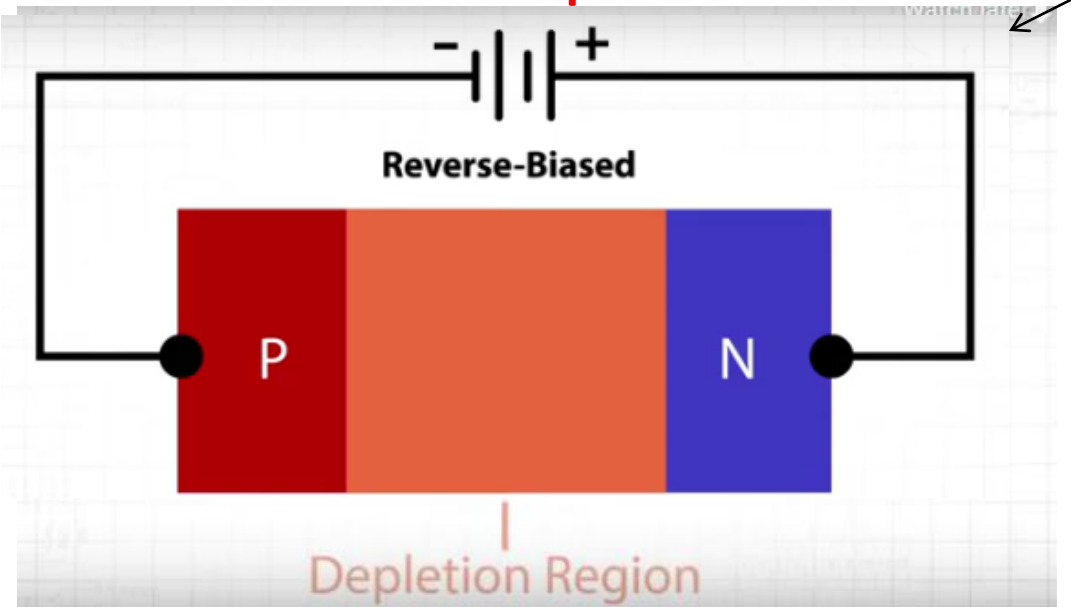
“p-n” Junction Diode – Working (RB)



The built-in potential will restrict the flow of diffusion current to either sides of the junction!

Built in potential = Barrier voltage

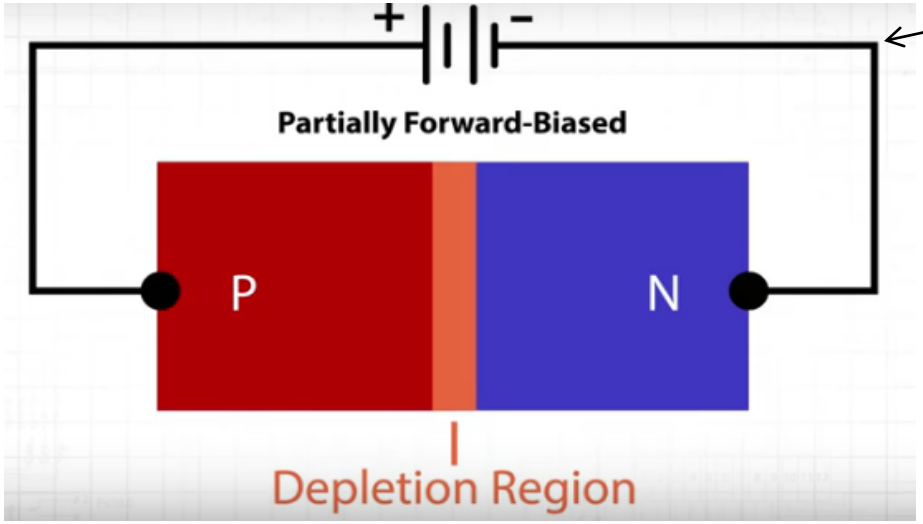
REVERSE - BIAS



- Holes in p-type: Attracted towards –ve terminal &
  Electrons in n-type: Attracted towards +ve terminal
- Depletion region increases
- Barrier voltage increases
- Diffusion current further reduced

“p-n” Junction Diode – Working (FB)

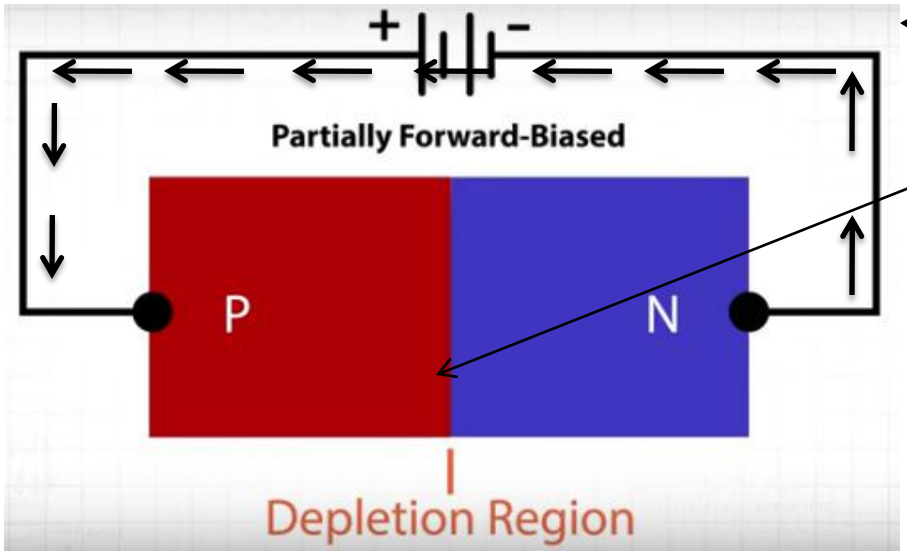
0.4V



FORWARD – BIAS(partial)

- Holes in p-type: Repelled by +ve terminal &
  Electrons in n-type: Repelled by -ve terminal
- Depletion region decreases
- Barrier voltage reduces
- Diffusion current starts to flow across the junction
- **Amount of current - low**

0.6-0.7V



FORWARD – BIAS (full)

Fully collapsed depletion region

- Applied voltage = Barrier voltage
- Barrier voltage fully overcome
- Enormous diffusion current starts to flow across the junction
- **Amount of this current – very high!**

"p-n" Junction Diode – Unique feature!

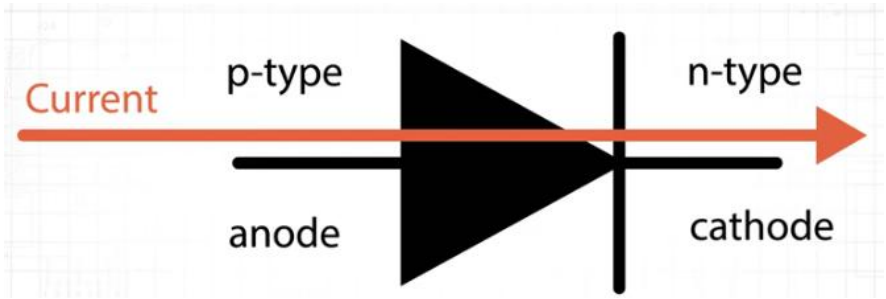
REVERSE- BIASED pn junction diode,

Resists Current flow

FORWARD- BIASED pn junction diode,

Allows Current flow

Diode ⟶ acts like a switch!!!



Circuit symbol

Acknowledgements

1. https://sites.google.com/site/puenggphysics/home/unit-5/band-theory-in-solids
2. http://semiconductordevice.net/SemiconductorDiode/semiconductors-conductors-insulator
3. https://www.researchgate.net/publication/324687441_Ab_initio_modelling_of_interfaces_in_nanocomposites_for_high_voltage_insulation/figures
4. https://en.wikipedia.org/wiki/Diamond_cubic
5. https://www.pveducation.org/pvcdrom/conduction-in-semiconductors
6. https://amitngroup.blogspot.com/2014/06/doping-in-semiconductors.html
7. https://favpng.com/png_view/purified-water-silicon-atomic-number-bohr-model-chemical-element-png/UPwi09PU
8. https://www.allaboutcircuits.com/video-tutorials/the-pn-junction-and-the-diode/