SOLID STATE DETECTOR

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NUCLEAR DETECTORS

- An instrument responsible for detection of ionizing radiations by interacting with matter or to measure radiation or to do both.

Solid state detector

This consists of the solid materials with semiconducting properties.

- Semiconductor Detectors are example of solid state detectors.

Solid State Detectors

Insulator, Conductor and Semiconductor Difference

In case the conduction band is filled the crystal is a conductor.

In case the conduction band is empty and ‘far away’ from the valence band, the crystal is an insulator.

In case the conduction band is empty but the distance to the valence band is small, the crystal is a semiconductor.

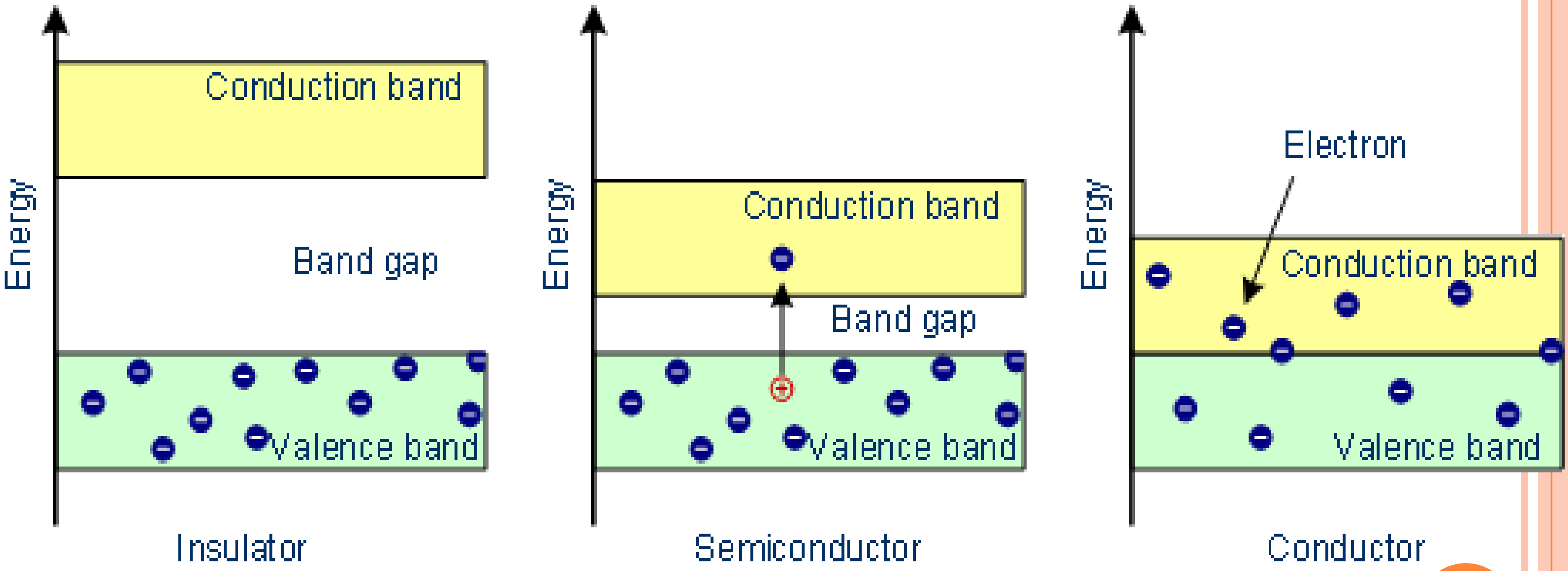
The energy gap between the last filled band – the valence band – and the conduction band is called band gap E_g.

The band gap of Diamond/Silicon/Germanium is 5.5, 1.12, 0.66 eV.

The average energy to produce an electron/hole pair for Diamond/Silicon/Germanium is 13, 3.6, 2.9eV.

In case an electron in the valence band gains energy by some process, it can be excited into the conduction band and a hole in the valence band is left behind.

The number of electrons in the conduction band is therefore increasing with temperature i.e. the conductivity of a semiconductor increases with temperature.

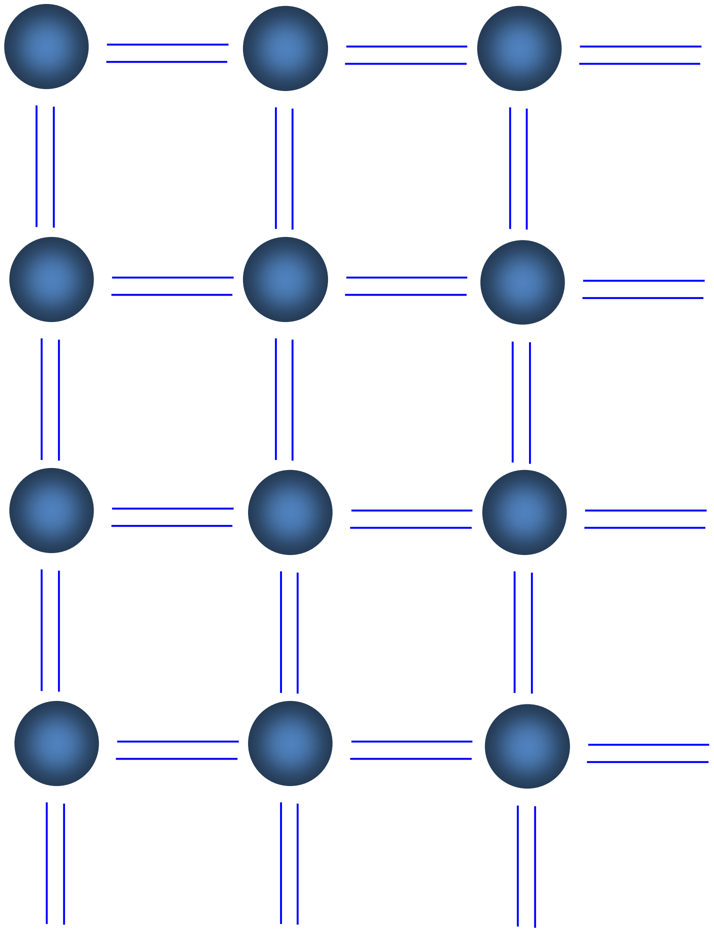


- Common materials of choice
  Silicon and Geranium
- Generally, used for the detection of alpha and beta particles.
- Electron-hole production at few eV compare with 30eV in gas
- Light radiation can be detected in semiconductors through release of charges across the band gap
- Higher energy radiation can be expected to do so at much higher efficiencies.
- Use as vivo dosimeter in rectum and urinary bladder

Silicon

Properties of Si

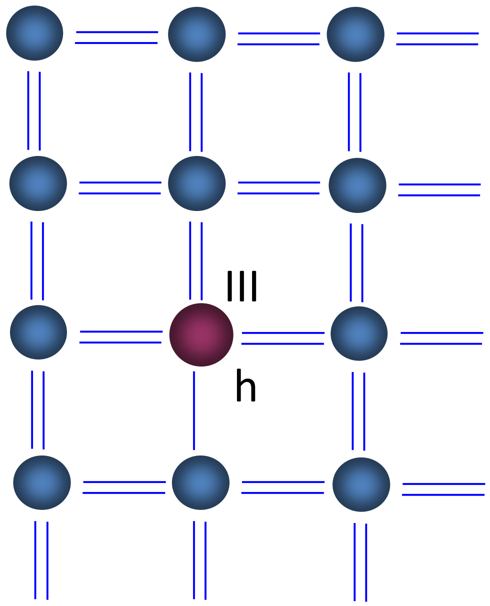
- Crystal structure
- Group IV
- 4 electrons in valence shell

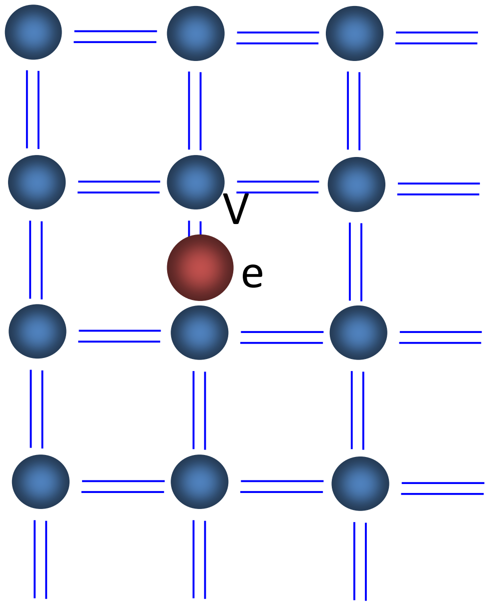


Impurities

Group III (e.g. B)

- acceptor type atoms
- majority carriers=holes
- p-type

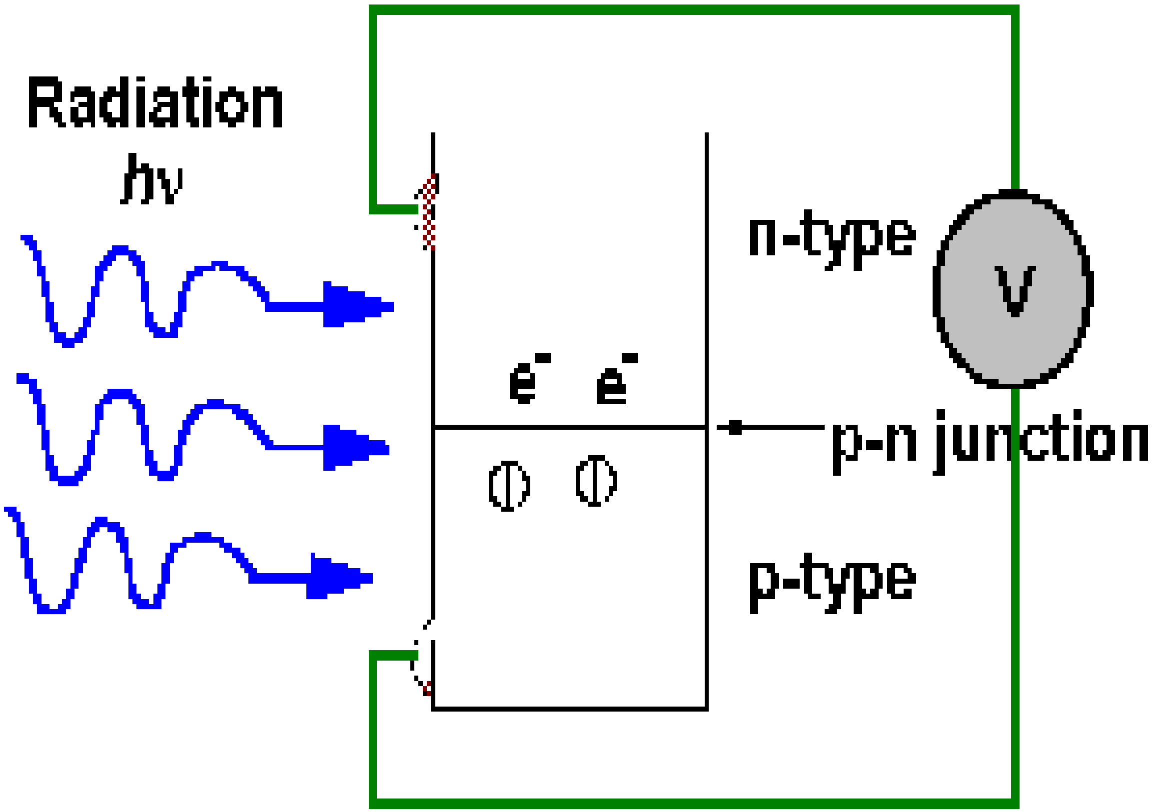




Group V (e.g. P)

- donor type atoms
- majority carrier=e’s
- n-type

- Act as a solid state ionization chamber.
- Operation depends on having either an excess of electrons or an excess of holes



Working Principle

In solids (crystals), the electron energy levels are in ‘bands’.

Inner shell electrons, in the lower energy bands, are closely bound to the individual atoms and always stay with ‘their’ atoms.

In a crystal there are however energy bands that are still bound states of the crystal, but they belong to the entire crystal. Electrons in this bands and the holes in the lower band can freely move around the crystal, if an electric field is applied.

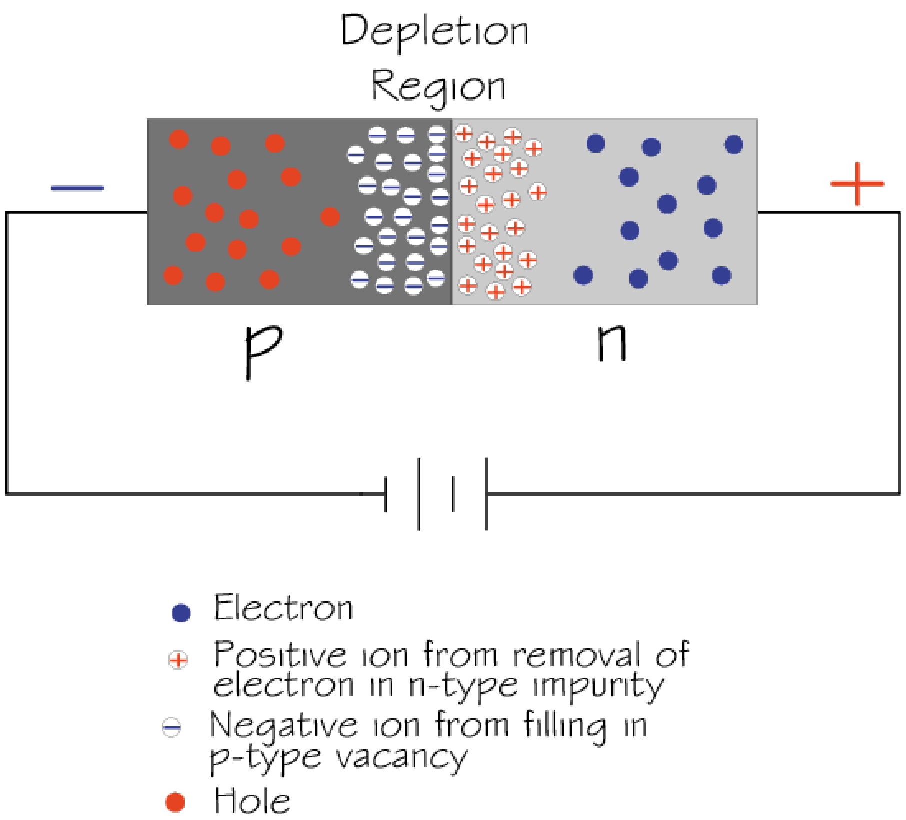
At the p-n junction the charges are depleted and a zone free of charge carriers is established.

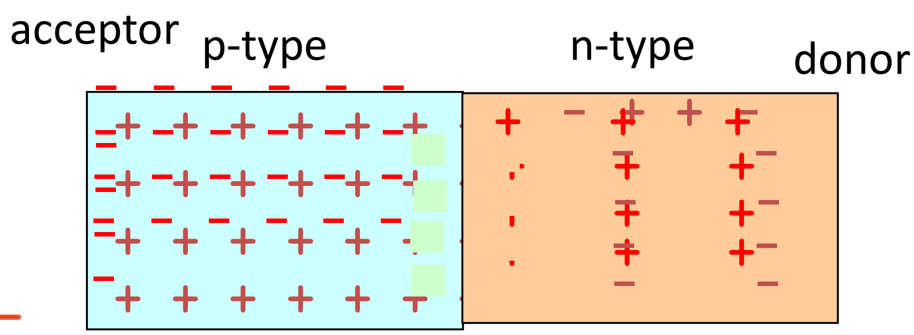
By applying a voltage, the depletion zone can be extended to the entire diode highly insulating layer.

An ionizing particle produces free charge carriers in the diode, which drift in the electric field and induce an electrical signal on the metal electrodes.

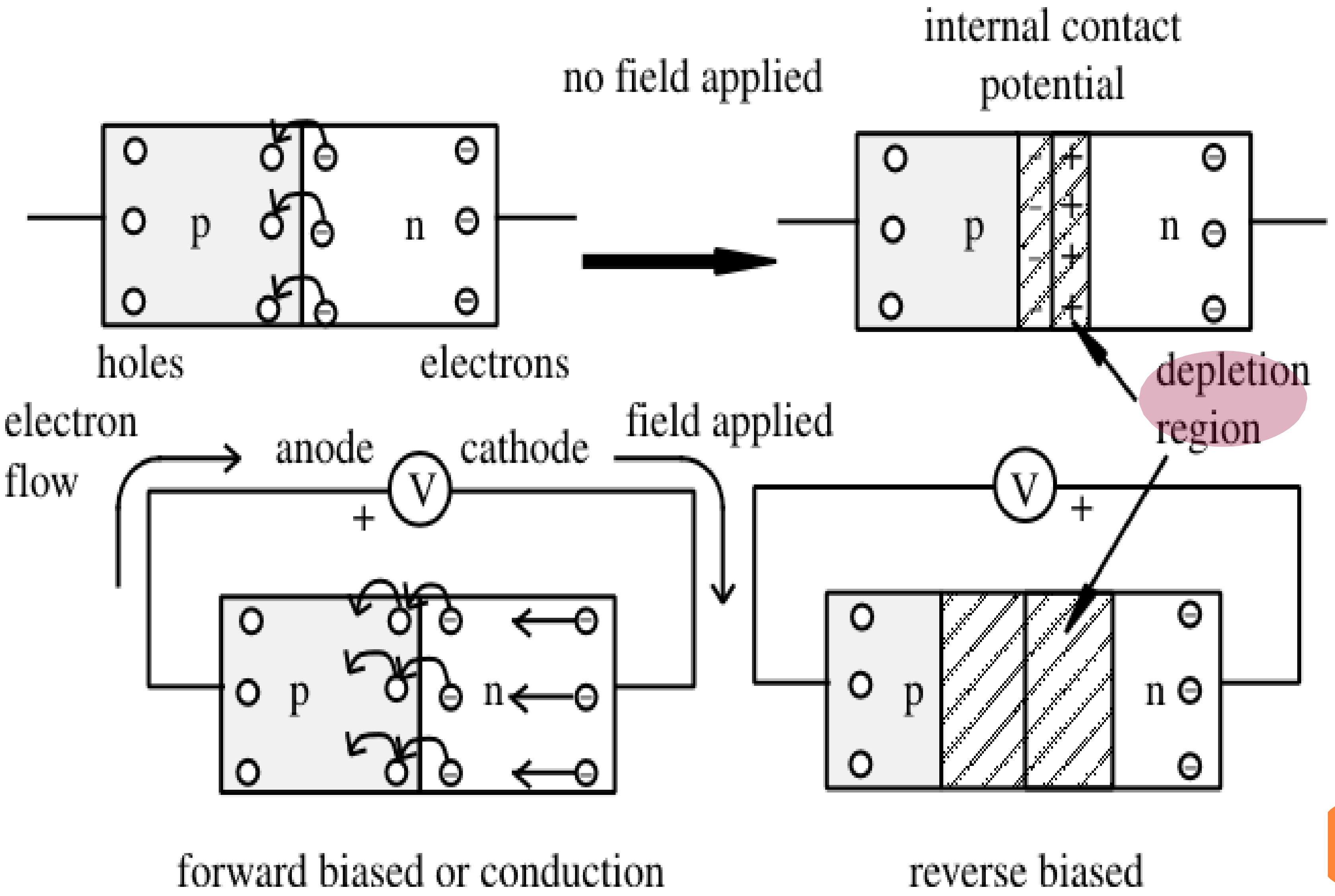
As silicon is the most commonly used material in the electronics industry, it has one big advantage with respect to other materials, namely highly developed technology.

Si-Diode used as a Particle Detector !





Semiconductor Detectors



SEMICONDUCTOR DETECTOR MERITS

- Detector of choice of very high resolution energy measurement
- Response that varies linearly with the energy deposited in the detector and doesn't depend upon the type of radiation that deposits the energy
- High efficiency and low dead time
- Negligible absorption of energy
- Small size detector
- They are also able to withstand a much higher amount of radiation over their lifetime than other detectors types such as G-M Tubes, meaning that they are also useful for instruments operating in areas with particularly strong radiation fields.

Thank you!