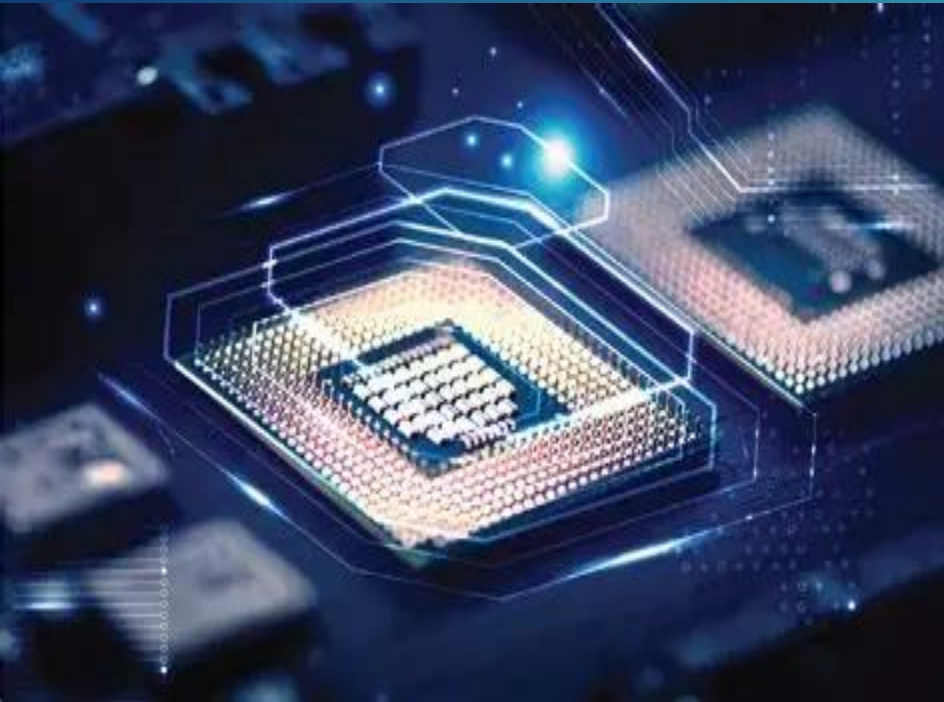


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Semiconductor and PN Junction

L1 COMPUTER ENGINEERING
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01 Introduction to
Semiconductors

02 Extrinsic
Semiconductors

03 PN Junction

04 Semiconductors
fabrication processes

05 Conclusion



Part 01

Introduction to Semiconductors

What are Semiconductors

Defintion

Semiconductors are materials with electrical conductivity between conductors and insulators, their conductivity can be controlled by various factors like temperature, impurities, and electric fields, which makes them essential in modern electronics.

Examples of common semiconductors

Silicon (Si) and Germanium (Ge) are widely used semiconductors in various electronic devices, Silicon is particularly dominant due to its abundance, cost-effectiveness, and well-established fabrication process.

Intrinsic Semiconductors

Definition

Intrinsic semiconductors are pure semiconductors with no impurities or dopants added, electrical properties are determined by the material itself

Electron-Hole pair generation

Thermal excitation causes electrons to jump from the valence band to the conduction band, creating free electrons and leaving behind hole in the valence band, this generates electron-hole pairs

Intrinsic carrier concentration

Intrinsic carrier concentration (n_i) represents the number of electrons and holes in an intrinsic semiconductor, it increases with temperature and varies with the material's properties



Part 02

Extrinsic Semiconductors

Doping semiconductors

What is doping

Doping is intentionally adding impurities to a semiconductor to modify its electrical properties by increasing either the electron or hole concentration, common dopants include Group III and Group V elements

Types of doping

N-type doping introduces donor impurities that contribute a free electrons to the conduction band, increasing electron concentration

P-type doping introduces acceptor impurities that create holes in the valence band increasing hole concentration

N-type Semiconductors

Donor impurities' introduction

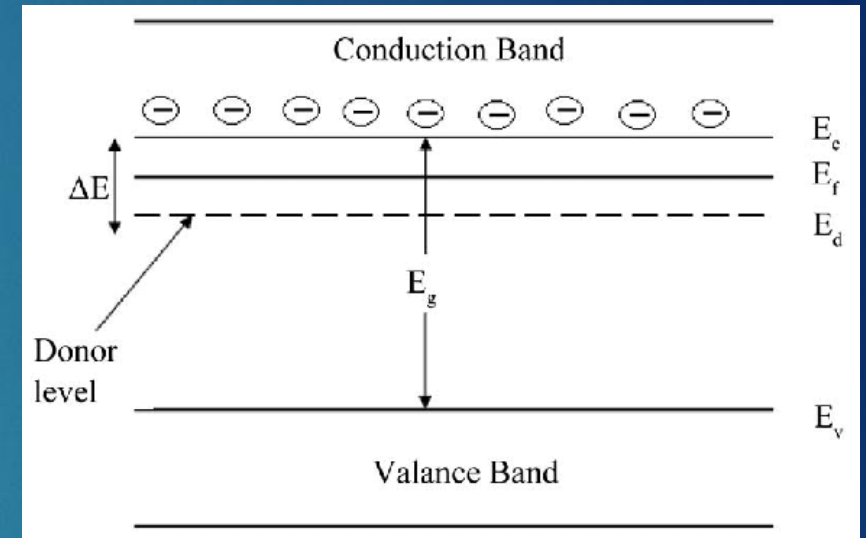
Donor impurities like Phosphorus, Arsenic, and Antimony (posses five valence electrons) contribute extra electrons to the conduction band when added to Silicon or Germanium

N-type energy band diagram

The doner energy level is just below the conduction band, easily exciting electrons and boosting electron concentration

N-type carrier concentration

Electrons are the majority carries with significantly higher concentration than holes ($n \gg p$)



P-type Semiconductors

Acceptor impurities' introduction

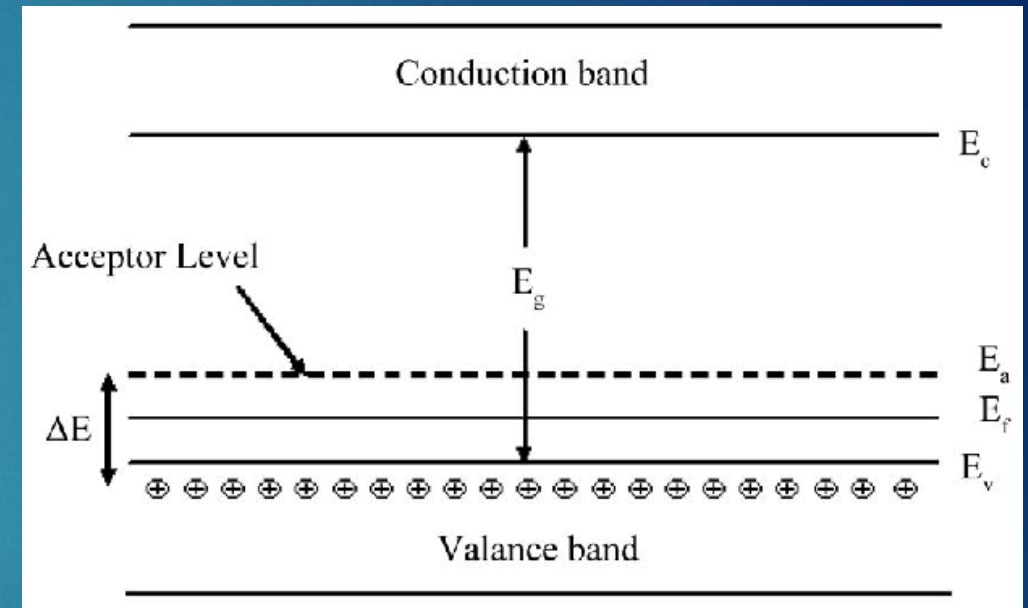
Acceptor impurities like Boron, Aluminum, and Gallium have three valence electrons. When added to Silicon or Germanium, they create holes

P-type energy band diagram

The acceptor energy level is just above the valence band, allowing electrons to jump and create free holes

P-type carrier concentration

Holes are the majority carriers with significantly higher concentration than electrons ($p \gg n$)





Part 03

PN Junction

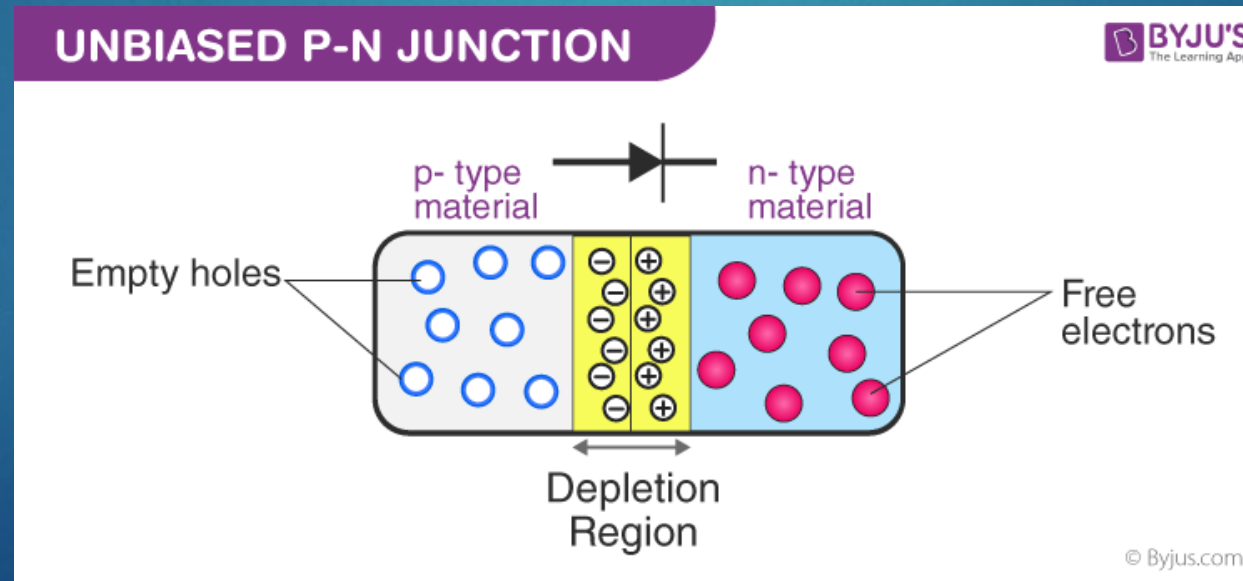
Formation of a PN Junction

Definition

A PN junction is formed by joining a P-type semiconductor with an N-type semiconductor, the interface creates unique electrical properties.

Diffusion of carries

Electrons from the N-side diffuse into the P-side, and holes from the P-side diffuse into the N-side due to concentration gradients, this diffusion leads to the creation of a depletion region.



Depletion region

Formation of depletion region

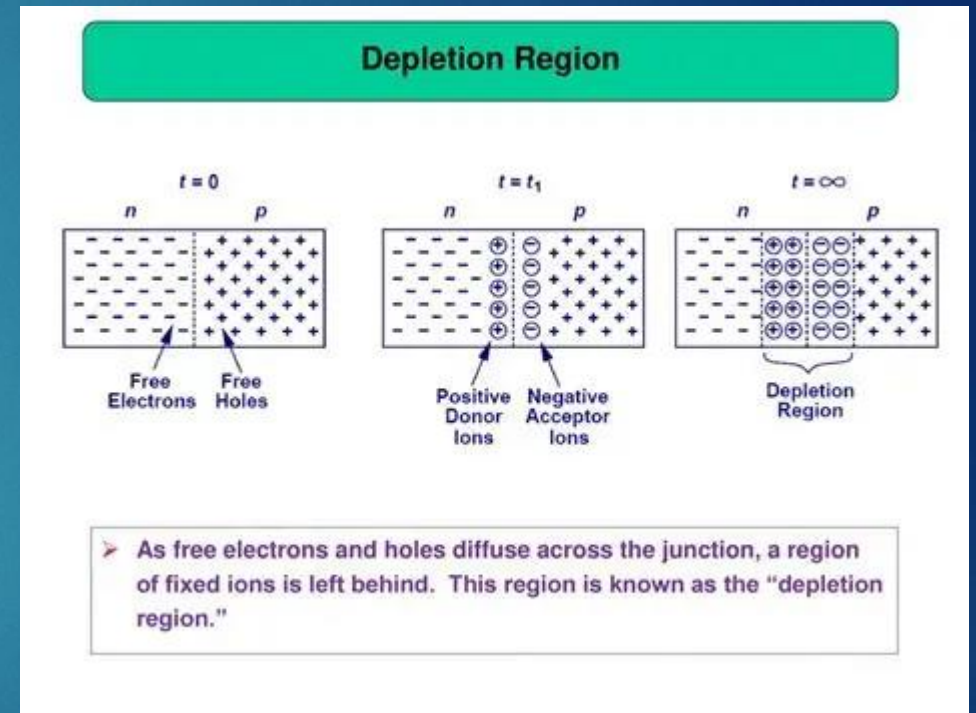
As electrons and holes diffuse, they recombine near the junction, creating a region depleted of mobile carriers, this region contains only fixed ionized impurities

Space charge and electric field

The ionized donor atoms on the N-side and ionized acceptor atoms on the P-side create a space charge region, this space charge generates an electric field that opposes further diffusion of carriers

Barrier potential

The electric field across the depletion region creates a barrier potential that prevents further diffusion of carriers at equilibrium, this potential depends on the material properties, doping concentrations, and temperature





Part 04

Semiconductors fabrication processes

Wafer Fabrication

The fabrication of semiconductor devices begins with the production of silicon or other semiconductor wafers, which undergo a series of complex processes like crystal growth, slicing, and polishing to create the foundation for device creation.

Doping and Thin-Film Deposition

Doping and thin-film deposition techniques, such as chemical vapor deposition and sputtering, are used to selectively introduce impurities and deposit various materials onto the wafer to create the desired semiconductor structures and devices.

Lithography

Lithography is a critical step in semiconductor manufacturing, where patterns are transferred onto the wafer using light, electron beams, or other forms of radiation to define the microscopic features of the individual devices.

Etching and Packaging

Etching and packaging are the final steps in semiconductor fabrication, where the individual devices are separated, encased in protective packages, and prepared for integration into larger electronic systems.



Part 05

Conclusion

Key takeaways

Understating of semiconductors

Semiconductors are essential materials with tunable electrical conductivity, foundational to modern electronics, doping allows for manipulation through N-type and P-type materials

Role of PN junction

PN junctions enable devices like diodes and transistors, their I-V characteristics make applications like rectification, switching, and amplification realizable

Future trends in semiconductor technology

Miniaturization advances

Miniaturization through nanoscale devices and nanotechnology enhances performance and integration density.

Semiconductor innovation

Research focuses on new materials and architectures to improve semiconductor performance

Sustainable electronics focus

Sustainable electronics emphasis eco-friendly materials, processes, recycling, and waste reduction