SUPERCONDUCTORS

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Contents

Semiconductor

- ***Semiconductors are materials whose electronic properties are intermediate between those of Metals and Insulators.***

- ***They have conductivities in the range of 10^{-4} to 10^{+4} S/m.***

- ***The interesting feature about semiconductors is that they are bipolar and current is transported by two charge carriers of opposite sign.***

- ***These intermediate properties are determined by 1.Crystal Structure bonding Characteristics. 2.Electronic Energy bands.***

- ***Silicon*** *and* ***Germanium*** *are elemental semiconductors and they have* ***four valence electrons*** *which are distributed among the outermost* ***S and p*** *orbital's.*

- *These outer most* ***S and p*** *orbital's of Semiconductors involve in* ***Sp³ hybridanisation****.*

- *These* ***Sp³ orbital's*** *form* ***four covalent*** *bonds of equal angular separation leading to a* ***tetrahedral*** *arrangement of atoms in space results* ***tetrahedron*** *shape, resulting crystal structure is known as D****iamond c***

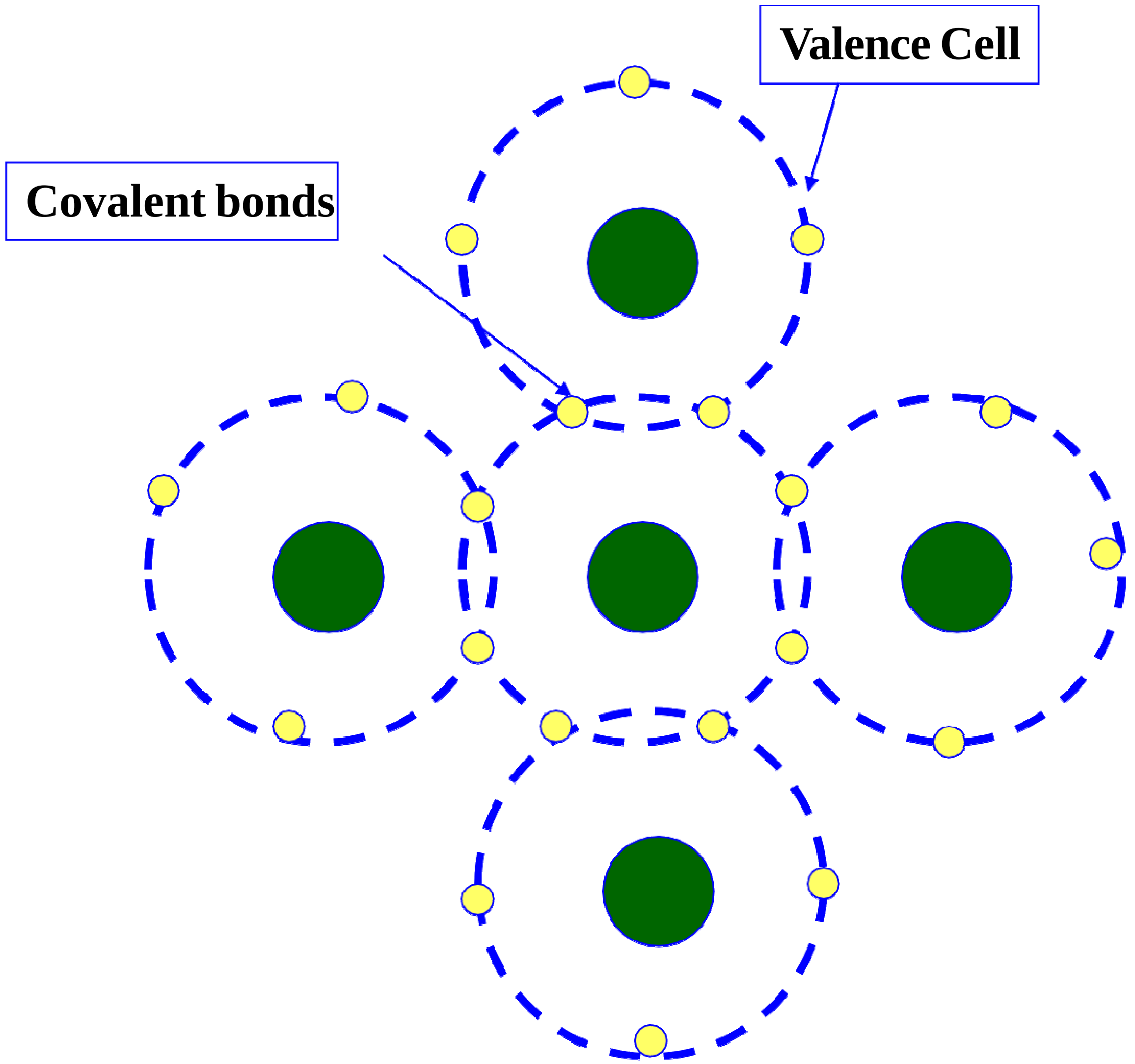
Semiconductors are mainly two types

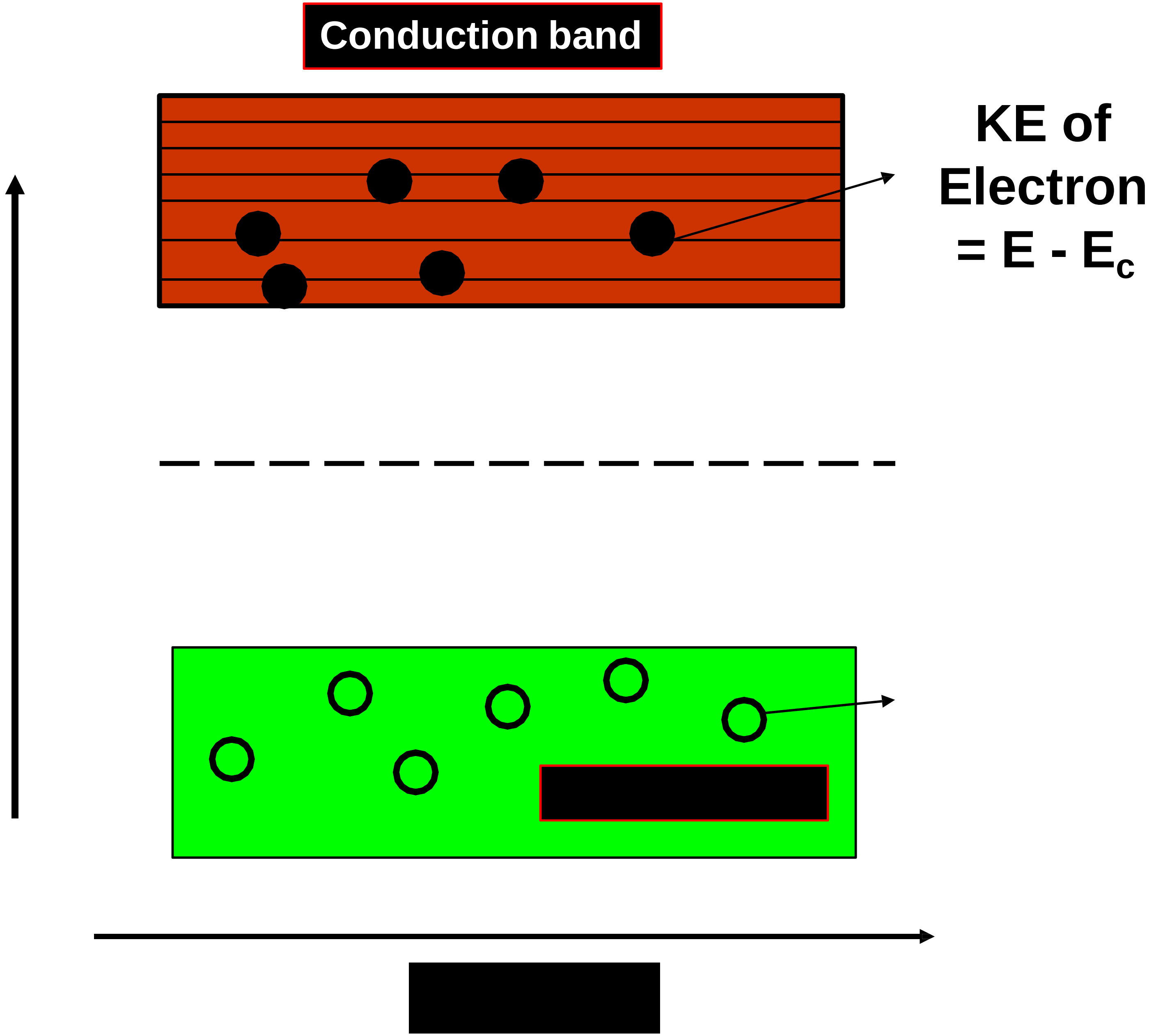
1. ***Intrinsic (Pure) Semiconductors***
2. ***Extrinsic (Impure) Semiconductors***

- ***A Semiconductor which does not have any kind of impurities, behaves as an Insulator at 0k and behaves as a Conductor at higher temperature is known as Intrinsic Semiconductor or Pure Semiconductors.***

- ***Germanium and Silicon (4th group elements) are the best examples of intrinsic semiconductors and they possess diamond cubic crystalline structure.***

Intrinsic Semiconductor




Conduction band
KE of Electron = E - E_c
[redacted]
[redacted]

Carrier Concentration in Intrinsic Semiconductor

When a suitable form of Energy is supplied to a Semiconductor then electrons take transition from Valence band to Conduction band.

Hence a free electron in Conduction band and simultaneously free hole in Valence band is formed. This phenomenon is known as Electron - Hole pair generation.

In Intrinsic Semiconductor the Number of Conduction electrons will be equal to the Number of Vacant sites or holes in the valence band.

- The Extrinsic Semiconductors are those in which impurities of large quantity are present. Usually, the impurities can be either 3rd group elements or 5th group elements.

- Based on the impurities present in the Extrinsic Semiconductors, they are classified into two categories.

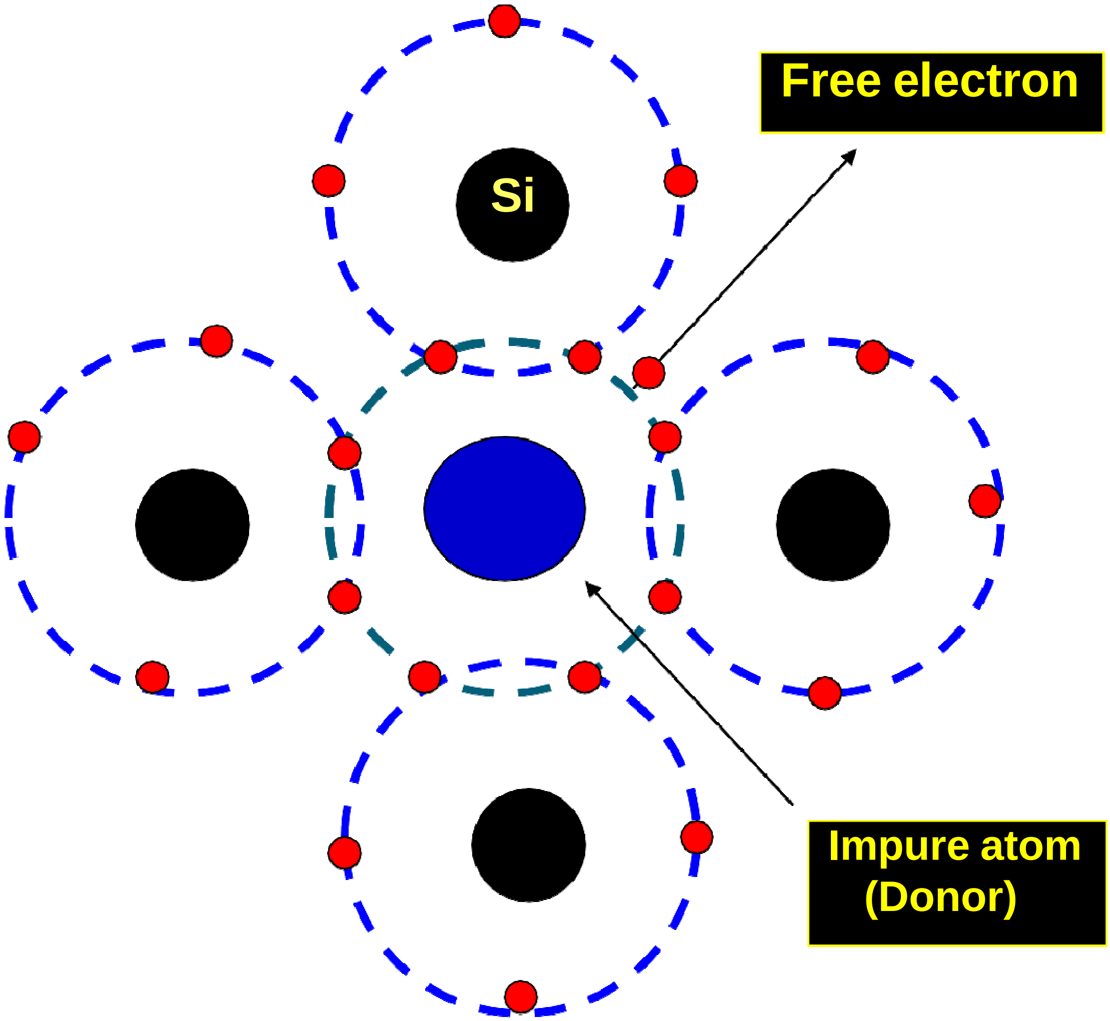
  1. N-**type** semiconductors
  2. **P-type** semiconductors

N - type Semiconductors

When any pentavalent element such as Phosphorous, Arsenic or Antimony is added to the intrinsic Semiconductor , four electrons are involved in covalent bonding with four neighboring pure Semiconductor atoms.

The fifth electron is weakly bound to the parent atom. And even for lesser thermal energy it is released Leaving the parent atom positively

N-type Semiconductor

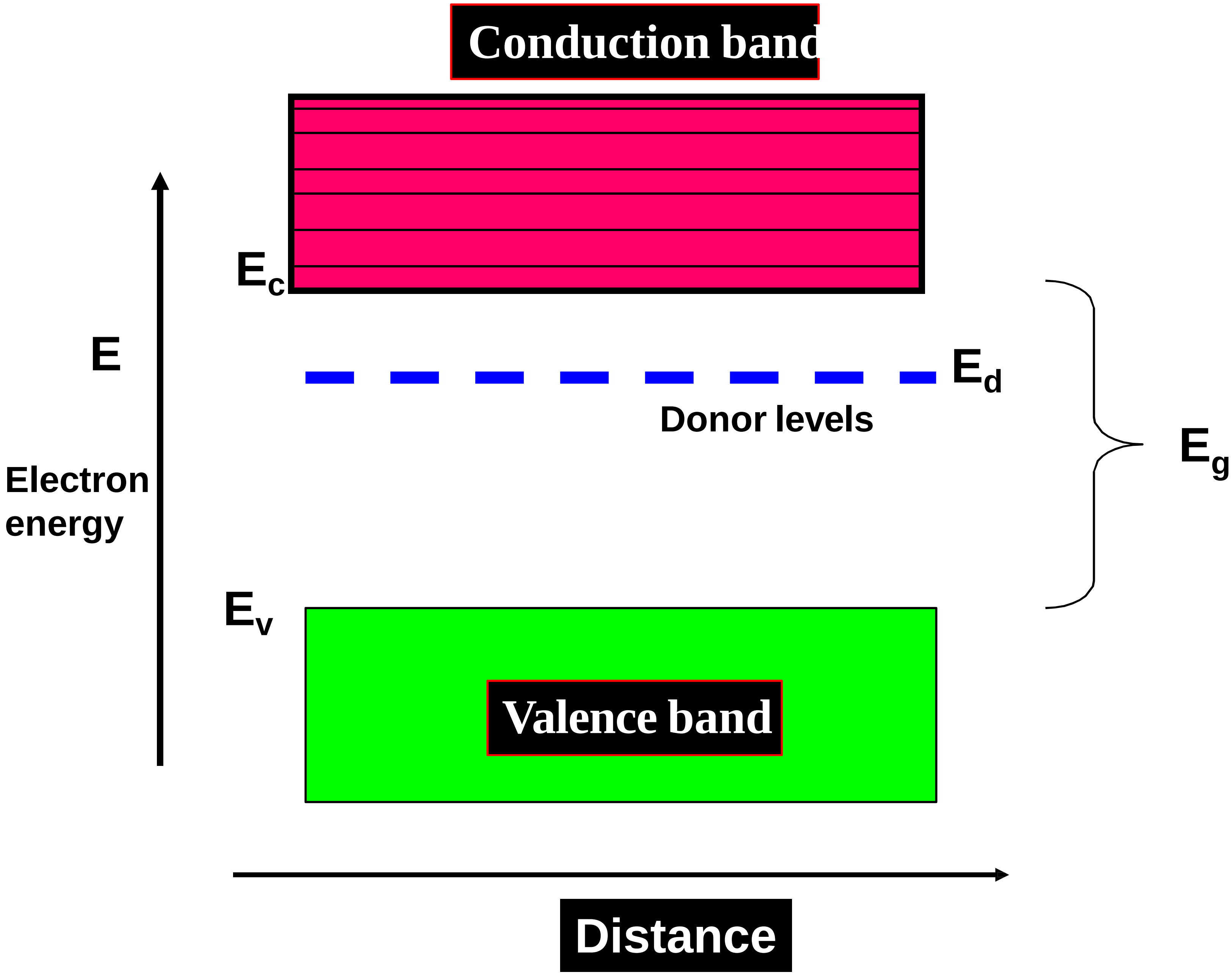


The Intrinsic Semiconductors doped with pentavalent impurities are called N-type Semiconductors.

The energy level of fifth electron is called donor level.

The donor level is close to the bottom of the conduction band most of the donor level electrons are excited in to the conduction band at room temperature and become the Majority charge carriers.

Hence in N-type Semiconductors electrons are Majority carriers and holes are Minority carriers.



Conduction band
E
Electron
energy
Ec
Ed
Donor levels
Eg
Ev
Valence band
Distance

Carrier Concentration in N-type Semiconductor

- **Consider N_d is the donor Concentration i.e., the number of donor atoms per unit volume of the material and E_d is the donor energy level.**

- **At very low temperatures all donor levels are filled with electrons.**

- **With increase of temperature more and more donor atoms get ionized and the density of electrons in the conduction band increases.**

Variation of Fermi level with temperature

To start with ,with increase of temperature E_f increases slightly.

As the temperature is increased more and more donor atoms are ionized.

Further increase in temperature results in generation of Electron - hole pairs due to breading of covalent bonds and the material tends to behave in intrinsic manner.

The Fermi level gradually moves towards the intrinsic Fermi level E_i.

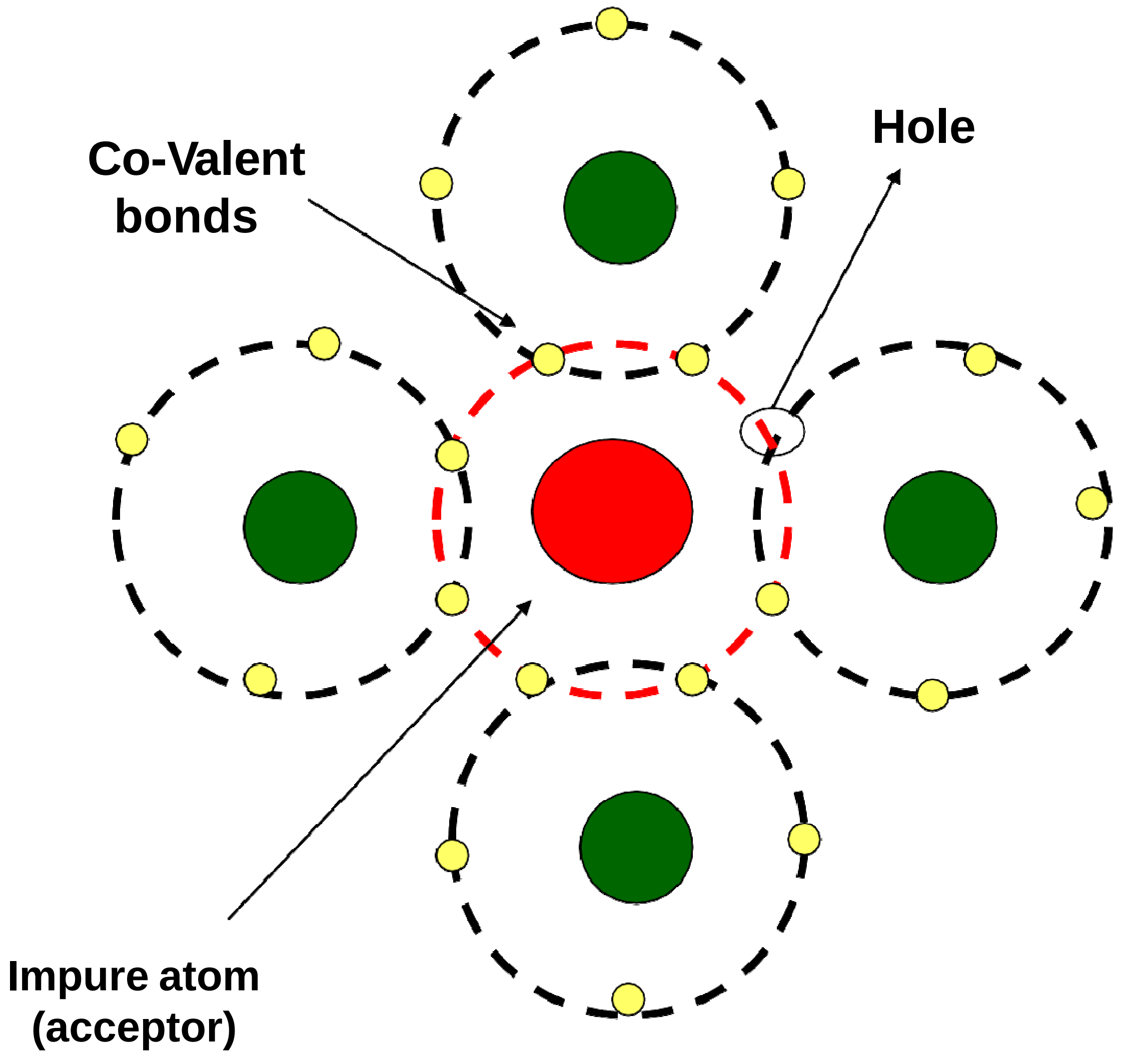
- When a trivalent elements such as **Al, Ga or Indium** have three electrons in their outer most orbits , added to the intrinsic semiconductor all the three electrons of Indium are engaged in covalent bonding with the three neighboring Si atoms.

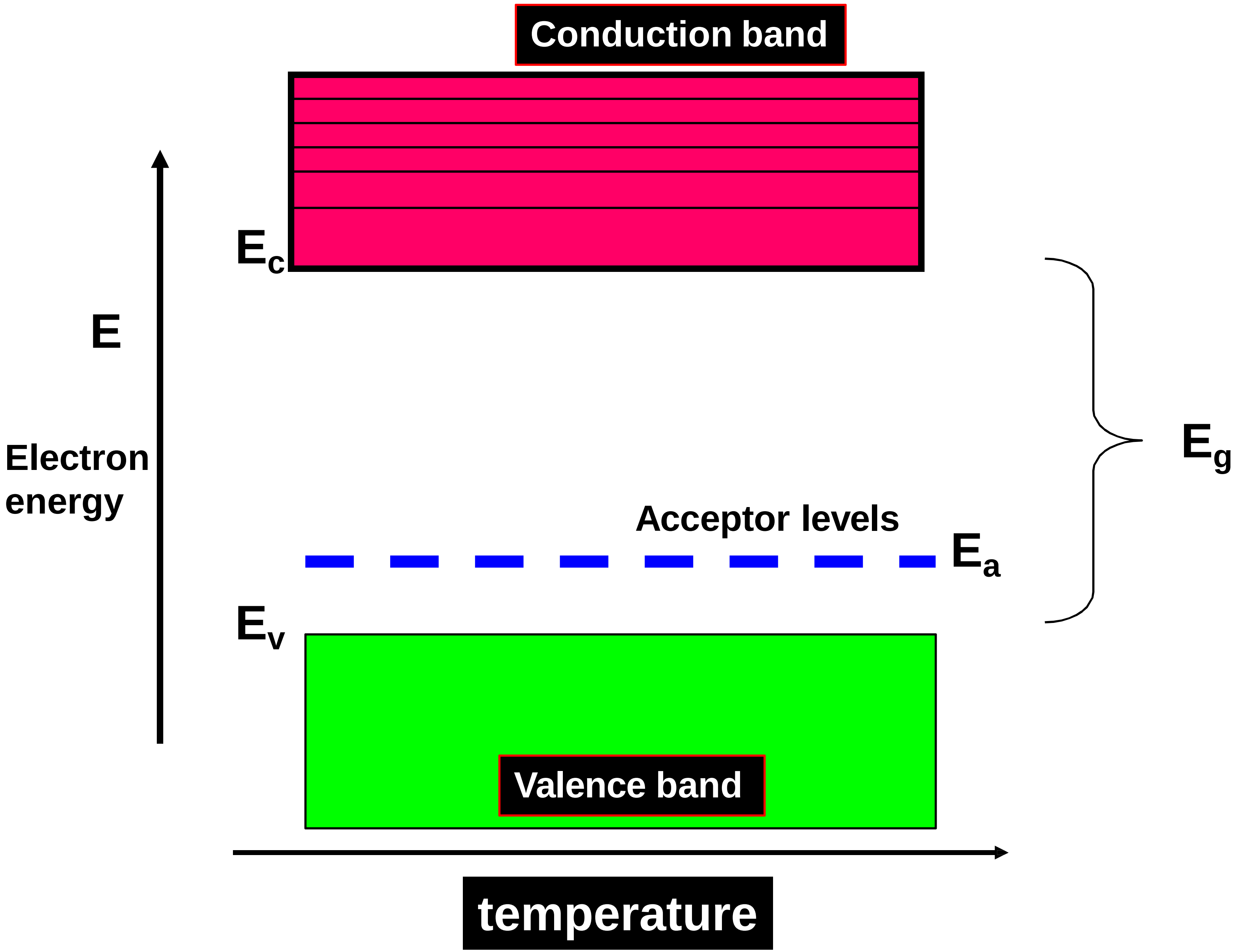
- Indium needs one more electron to complete its bond. this electron maybe supplied by Silicon , there by creating a vacant electron site or hole on the semiconductor atom.

- Indium accepts one extra electron, the energy level of this impurity atom is called **acceptor level** and this acceptor level lies just above the valence band.

- These type of trivalent impurities are called **acceptor impurities** and the semiconductors doped the acceptor impurities are called **P-type semiconductors**

P-type Semiconductor




Conduction band
E
Electron
energy
E_c
E_g
Acceptor levels
E_a
E_v
Valence band
temperature

- **Even at relatively low temperatures, these acceptor atoms get ionized taking electrons from valence band and thus giving rise to holes in valence band for conduction.**

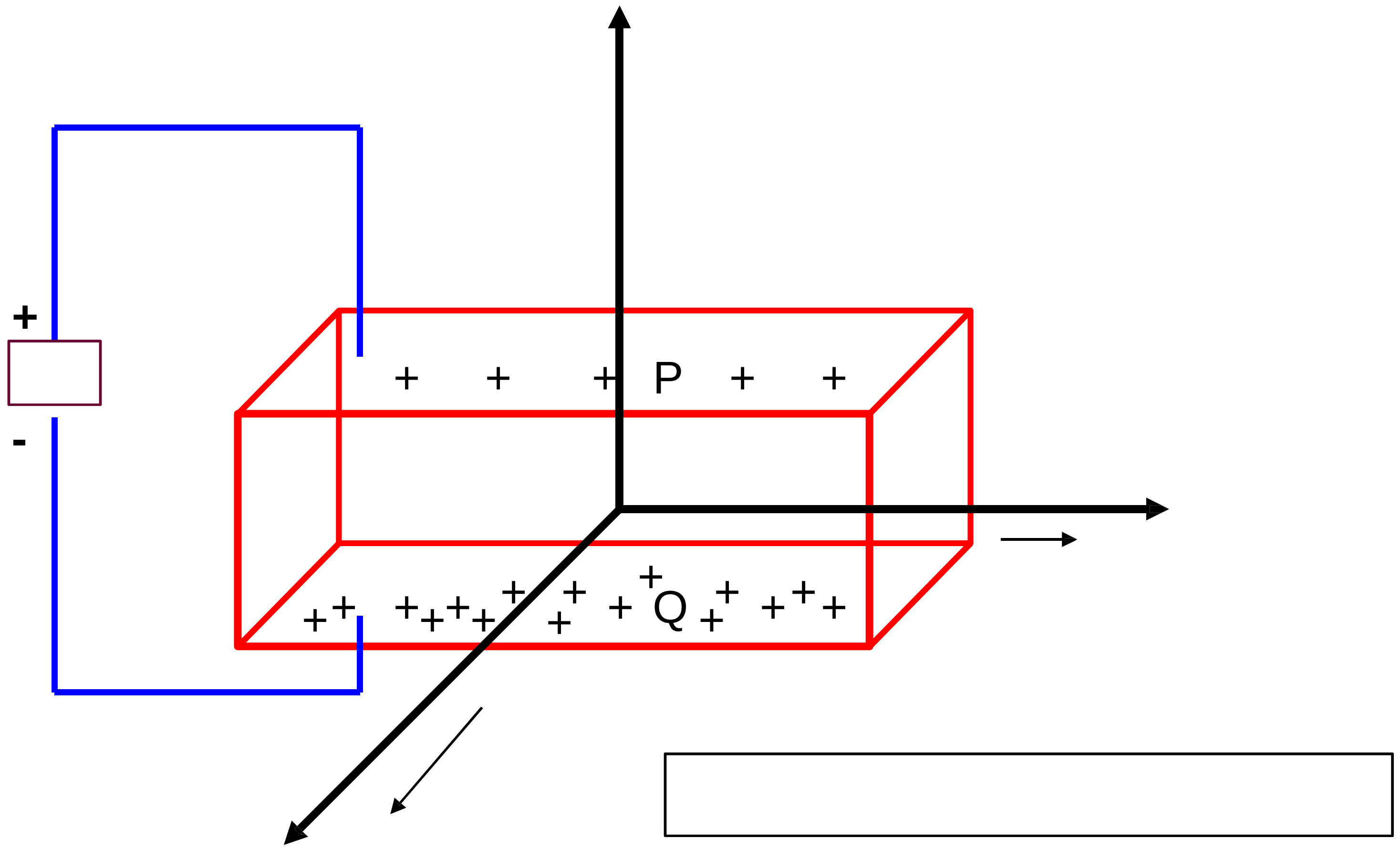
- **Due to ionization of acceptor atoms only holes and no electrons are created.**

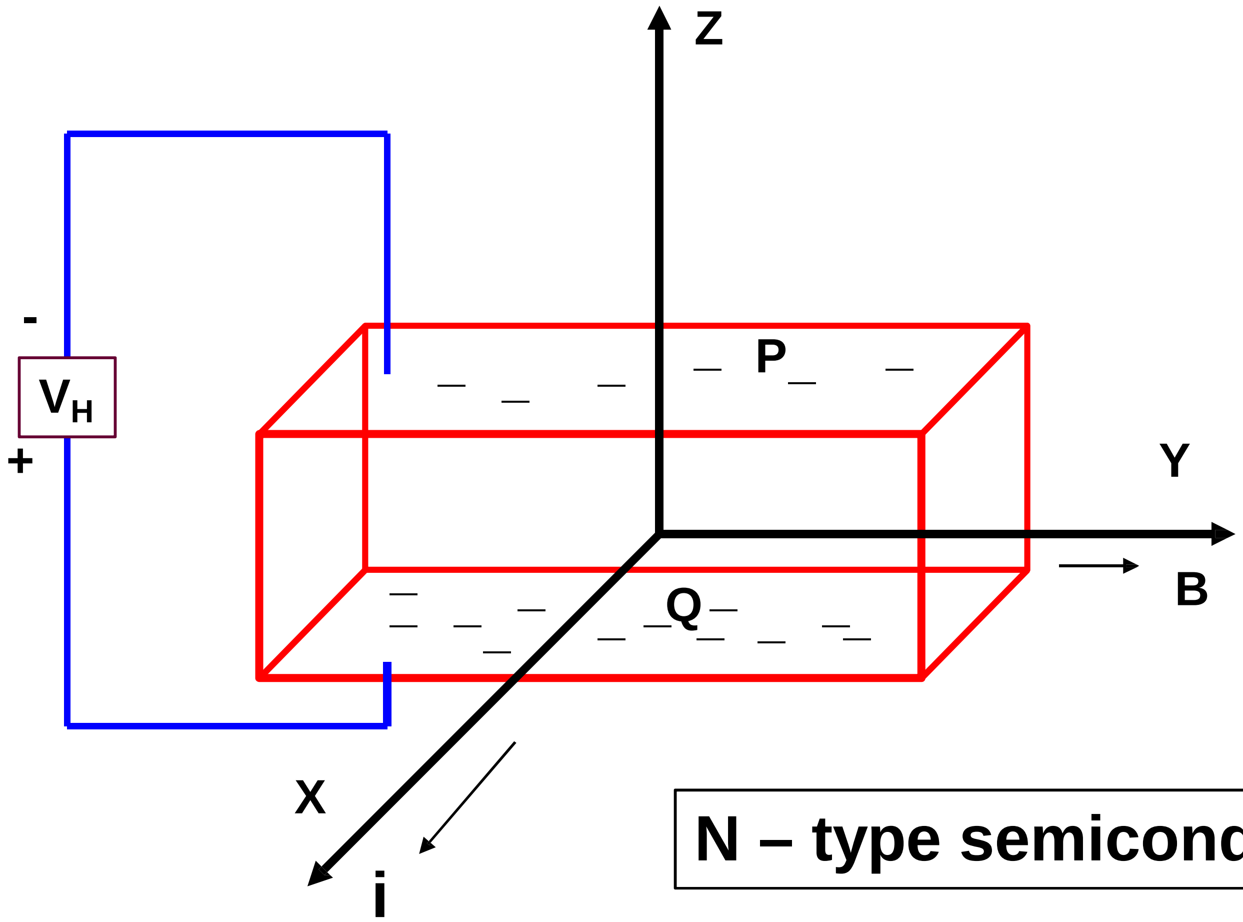
- **Thus holes are more in number than electrons and hence holes are majority carriers and electros are minority carriers in P-type semiconductors.**

Hall effect

When a **magnetic field** is applied perpendicular to a current carrying conductor or semiconductor, **voltage** is developed across the specimen in a direction perpendicular to both the current and the magnetic field. This phenomenon is called the **Hall effect** and voltage so developed is called the **Hall voltage**.

Let us consider, a thin rectangular slab carrying current (i) in the x-direction.
If we place it in a magnetic field B which is in the y-direction.
Potential difference Vpq will develop between the faces p and q which are perpendicular to the z-direction.


+
-
P
Q

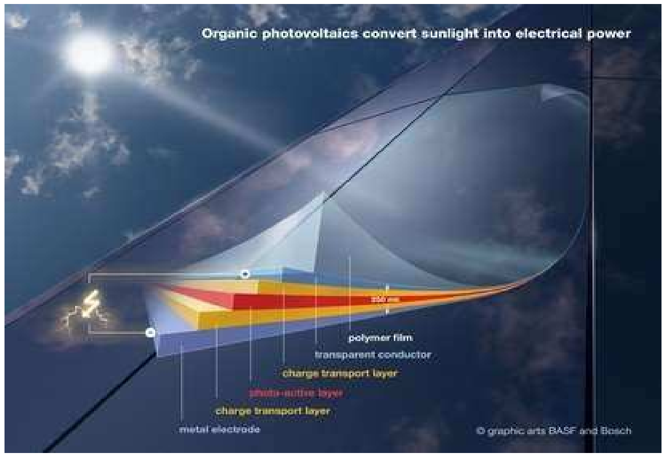


N – type semiconductor

Applications

- Displays:
  - (OLED) Organic Light Emitting Diodes

- RFID :
  - Organic Nano-Radio Frequency Identification Devices
- Solar cells



Displays (OLED)

- One of the biggest applications of organic transistors right now.

  Organic TFTs may be used to drive LCDs and potentially even OLEDs, allowing integration of entire displays on plastic.

- Brighter displays
- Thinner displays
- More flexible

RFID

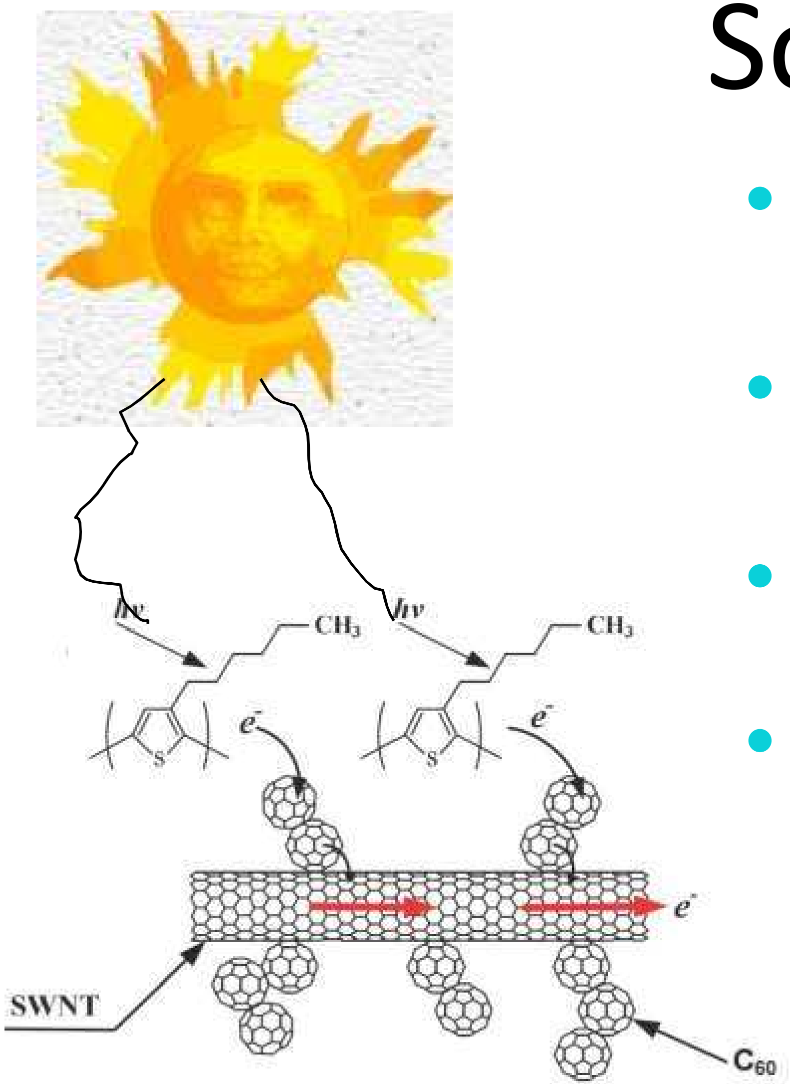
- Passive RF Devices that talk to the outsideworld … so there will be no need for scanners.


RFID benefits

- Quicker Checkout
- Improved Inventory Control

- Reduced Waste
- Efficient flow of goods from manufacturer to consumer

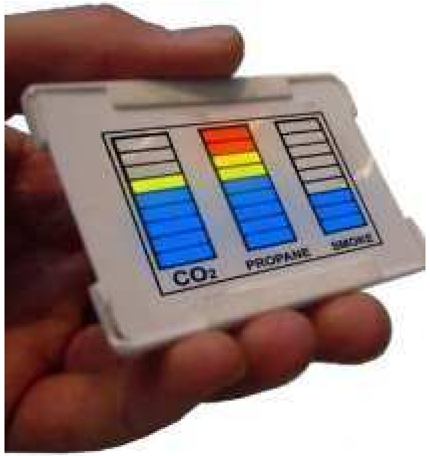
Solar Cells

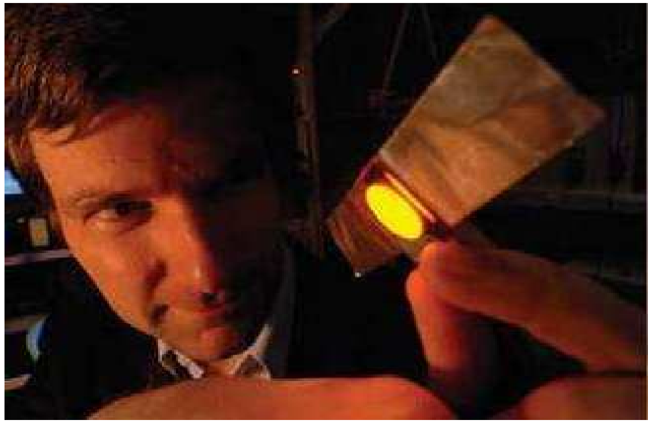


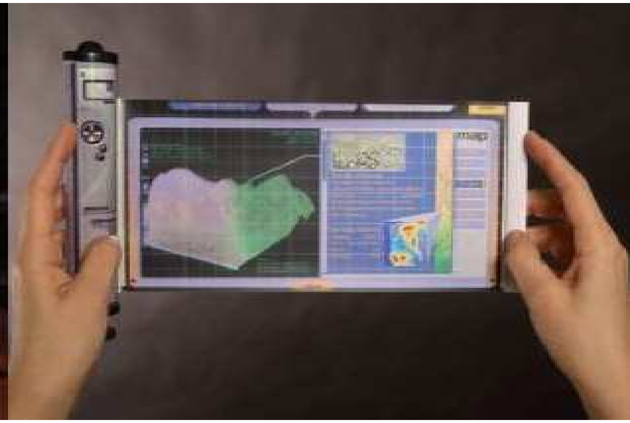
- The light falls on thepolymer
- Electron/hole is generated
- The electron is captured C60
- The electricity is passed bythe nanotube

Future of Organic Semiconductor

- Smart Textiles
- Lab on achip
- Portable compact screens
- Skin Cancer treatment

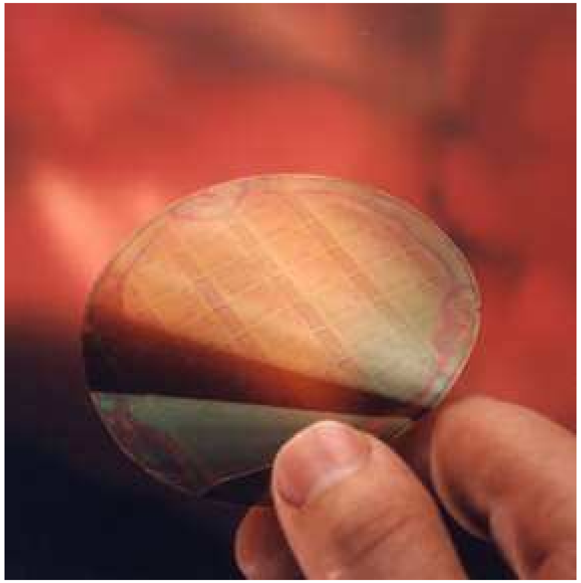






Organic Semiconductors

- Primary interest: Organic LEDs and displays.
- Low cost plastic electronics.
- Modification of semiconductor devices.



Polymers

Long molecular chains, „Spin-Coating“.

Monomers

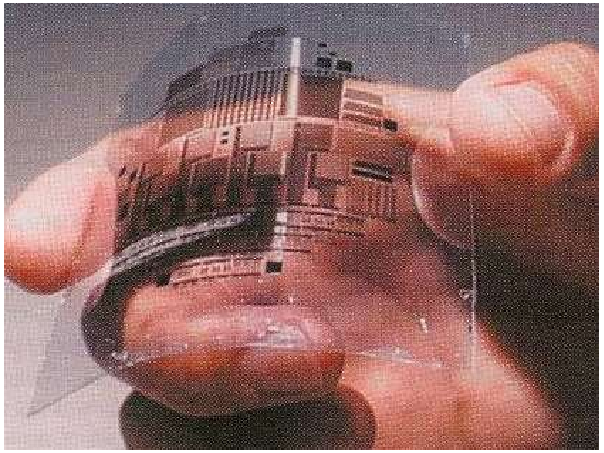
Extended and conjugated π-electron system.

Phthalocyanines, perylene derivatives.

Organic Molecular Beam Deposition (OMBD).

(S. R. Forrest, Chem. Rev. **97** (1997) 1793)

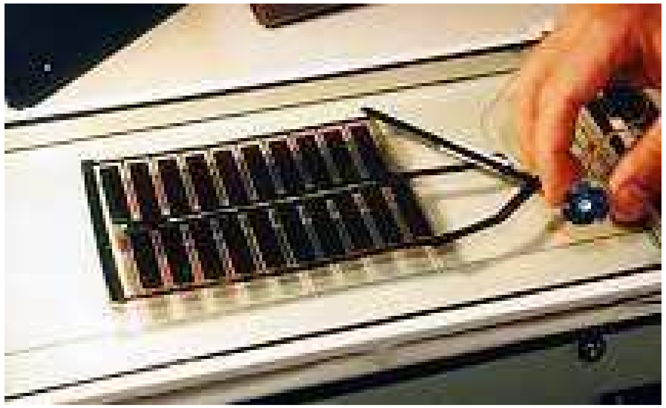
Organic field-effect transistors



Displays (Kodak)

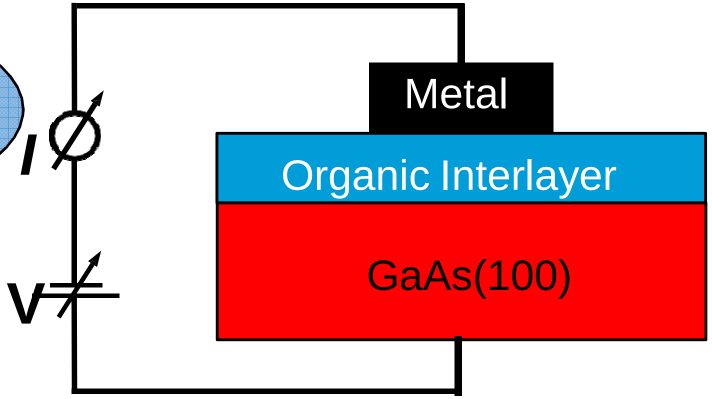
Electrically driven organic lasers

Organic semiconductors



Plastic solar cells

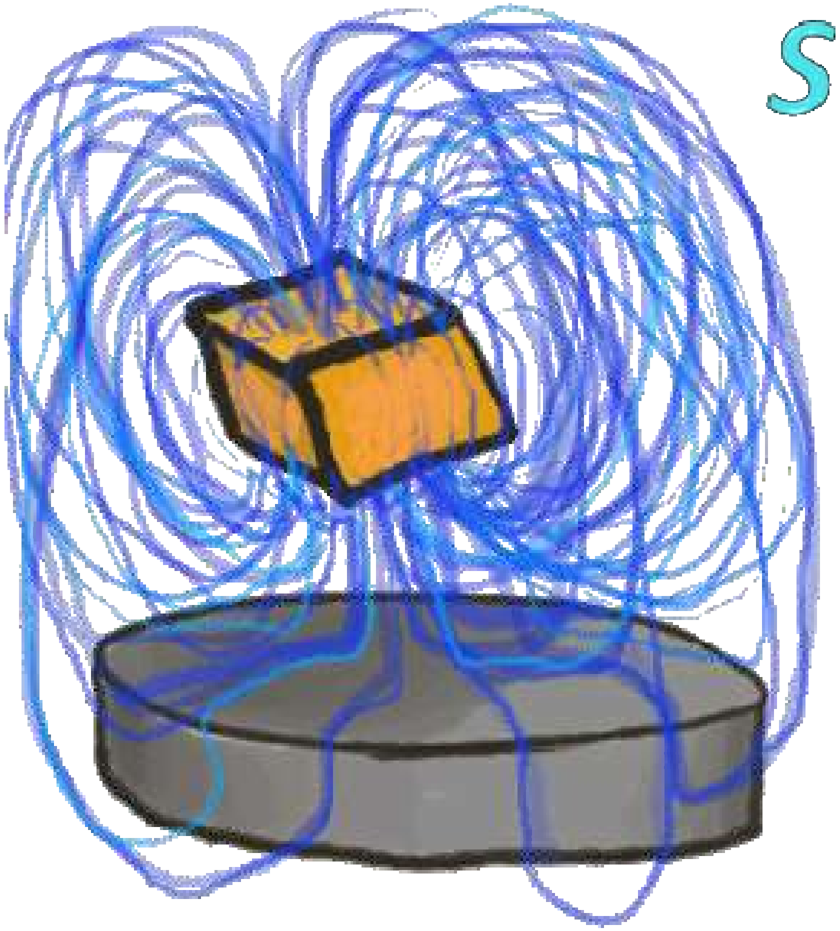
Organic/Inorganic Microwave Diodes



Organic-modified Schottky Diodes

IHP Research Training Network

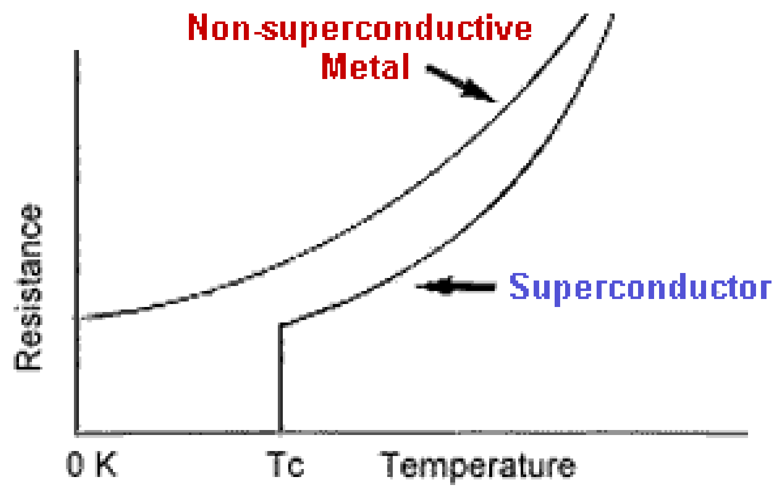
G. Salvan,
TU Chemnitz



Superconductors

Superconductors

- **T_c:** This is the critical temperature at which the resistivity of a superconductor goes to zero. Above this temperature the material is non- superconducting, while below it, the material becomes superconducting.
- **B_c:** The scientific notation representing the "critical field" or maximum magnetic field that a superconductor can endure before it is "quenched" and returns to a non-superconducting state. Usually a higher Tc also brings a higher Bc. Type II superconductors



- J_c: The scientific notation representing the "critical current density" or maximum current that a superconductor can carry without becoming non-superconductive.
- **Meissner Effect:** Exhibiting diamagnetic properties to the *total* exclusion of all magnetic fields. (Named for Walter Meissner.) This is a classic hallmark of superconductivity and can actually be used to levitate a strong

Superconductor Types

- Type I

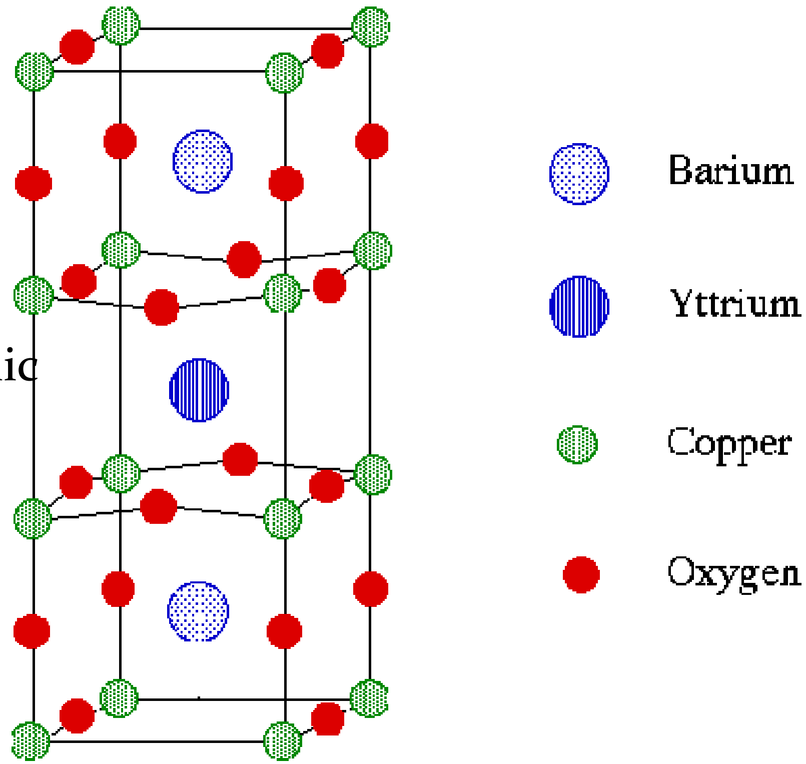
  Exhibits perfect diamagnetism below transition temperature T_c and has only one critical magnetic field B_c.

- Type II

  Totally expels and excludes magnetic flux below lower critical field B_{c1} and partially does so between B_{c1} and upper critical field B_{c2}; all superconductors except elements are Type II. This type has a larger T_c than that of a Type I superconductor.

$YBa_2Cu_3O_7$

- Discovered: 1987 by Paul Chu
- T_c: 90-95K
- B_{c2}: 100 Tesla at 77 K
- J_c: 1.0×10^9 A/m^2 at 77 K
- Referred to as "1-2-3" superconductor because of the ratio of the three metallic elements
- Type: Type II Ceramic



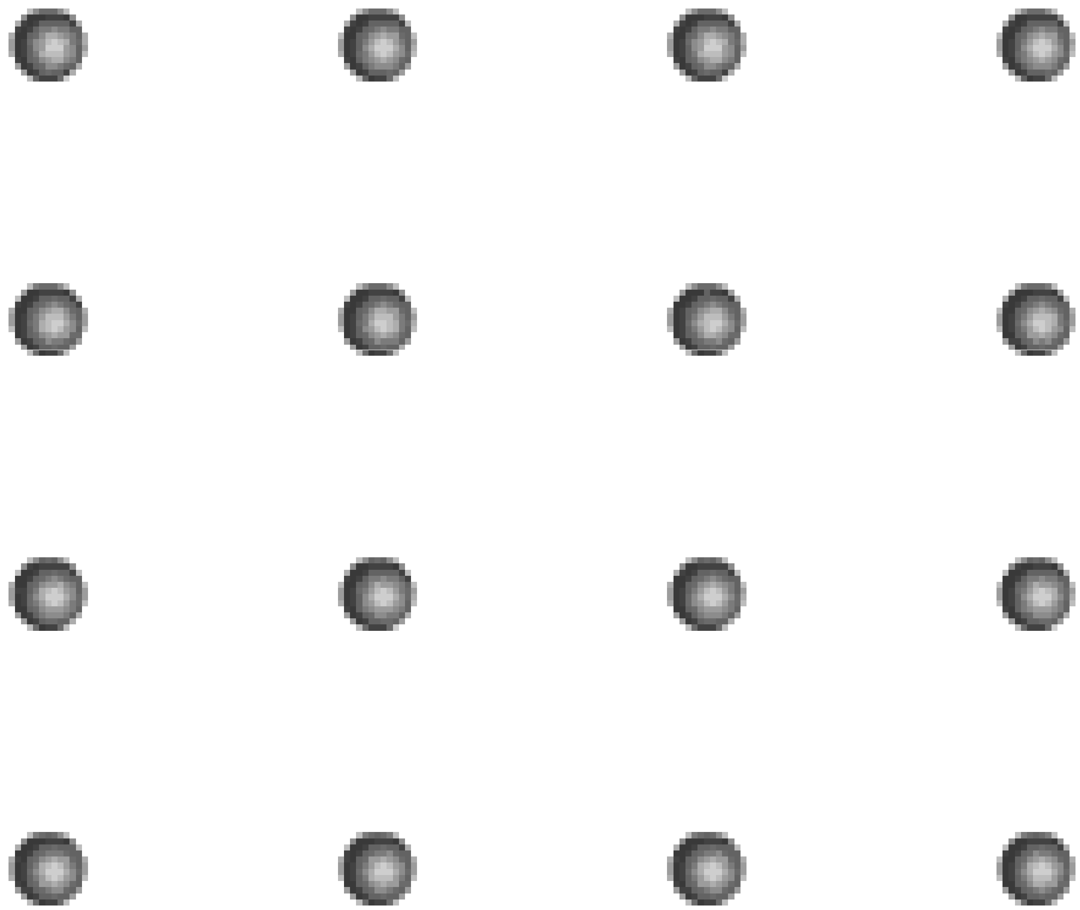
The Meissner Effect

- Levitation of a magnet above a cooled superconductor, the **Meissner Effect**, has been well known for many years. If a superconductor is cooled below its critical temperature while in a magnetic field, the magnetic field surrounds but does not penetrate the superconductor. The magnet induces current in the superconductor which creates a counter-magnetic force that causes the two materials to repel. This can be seen as the magnet is levitated above the superconductor.

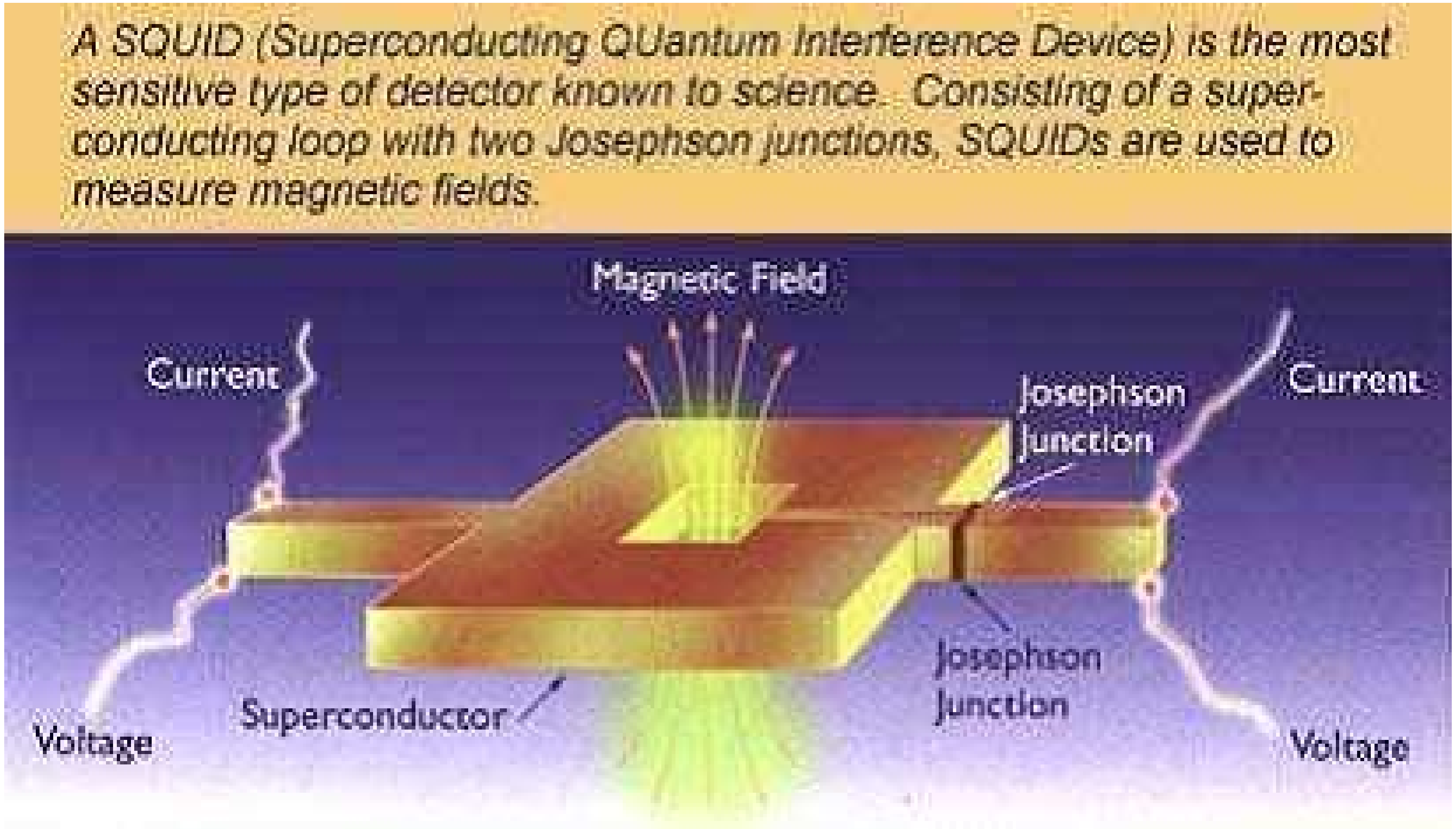
Cooper Pair:

- Two electrons that appear to "team up" in accordance with theory - BCS or other - despite the fact that they both have a negative charge and normally repel each other. Below the superconducting transition temperature, paired electrons form a condensate - a macroscopically occupied single quantum state - which flows without resistance

Cooper pairs:



SQUIDS

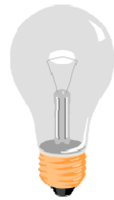

A SQUID (Superconducting QUantum Interference Device) is the most sensitive type of detector known to science. Consisting of a superconducting loop with two Josephson junctions, SQUIDs are used to measure magnetic fields.
Magnetic Field
Current
Current
Josephson Junction
Josephson Junction
Superconductor
Voltage
Voltage

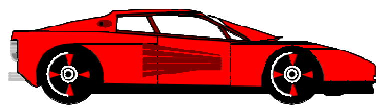
Economic Impact of Superconducting Equipment

- Utilities
  - Higher density transmission uses & higher economic productivity
  - Reduced environmental impact
- Industrial

  More cost effective industrial processes:
  - Manufacturing & energy production
  - Electrical storage, transmission and expansion
- Transportation

  More cost effective electrical transportation:
  - High Speed Rail & MAGLEV technologies
  - Electric car / bus
  - Ship

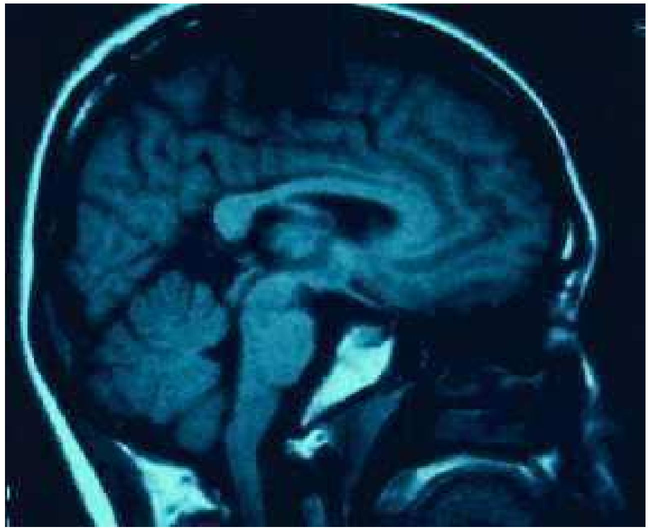




Application of Superconductors

- Particle Accelerators
- Generators
- Transportation
- Power Transmission
- Electric Motors
- Military
- Computing
- Medical
- B Field Detection (S

The Yamanashi MLX01 MagLev train



Advantages of Semiconductors & Superconductors

Semiconductors

a semiconductor device on changing temperature can be used as a conductor as well as an insulator. This is the main advantage of a semiconductor device.it is also light weight, small, cheap and finds many applications in modern devices like computers, electrical appliances.

Superconductors

Can carry large quanities of energy without heat loss and are able to generate strong magnetic fields. Superconductors beneficial applications in medical imaging techniques. New superconductive films may result in miniaturization and increased speed in computer chips.