# Fundamental of Electronics

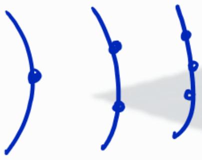
# Lecture 2-semiconductor

# Part 1

# EE1224 Fundamentals of Electronic Devices

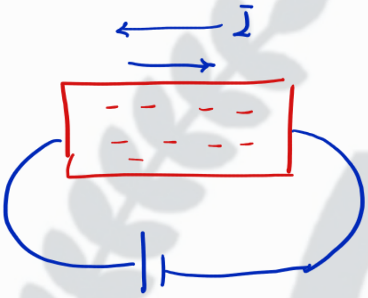
Material

Conductors



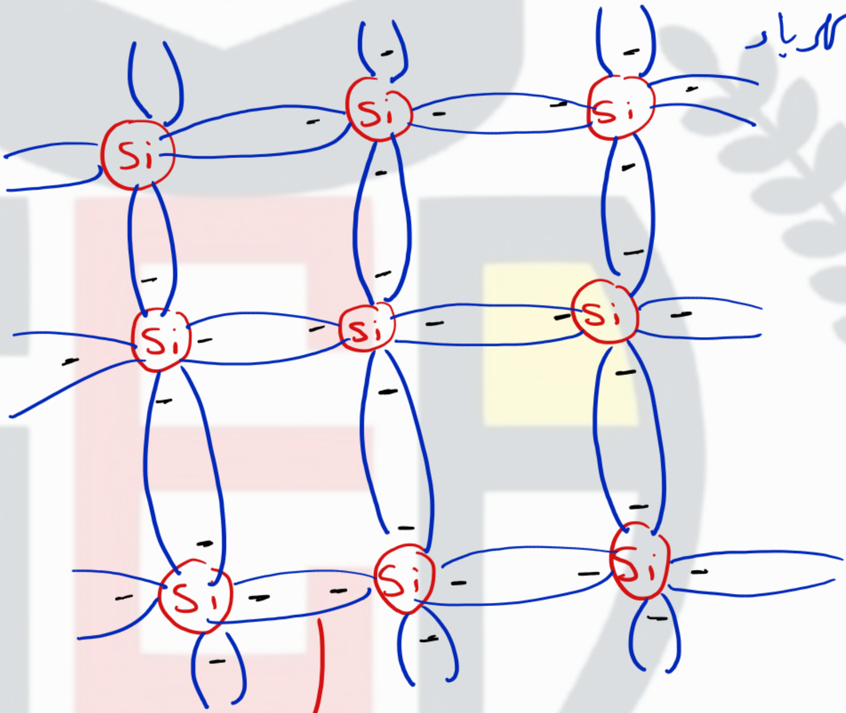
بيفقد الالكترونات

توصيل كهربي




Semiconductor

Si => 14 electron




Covalent bond

الروابط التساهمية

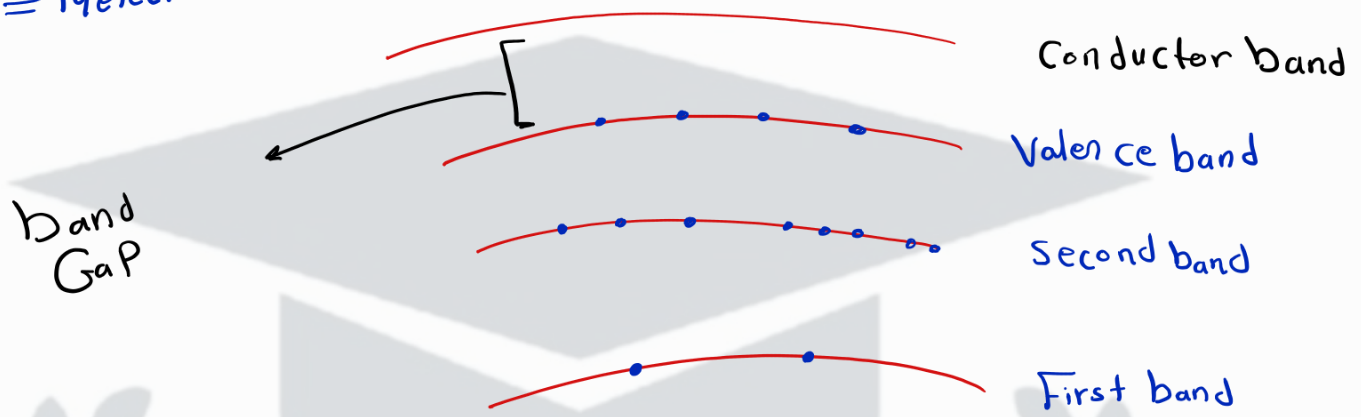
Insulators

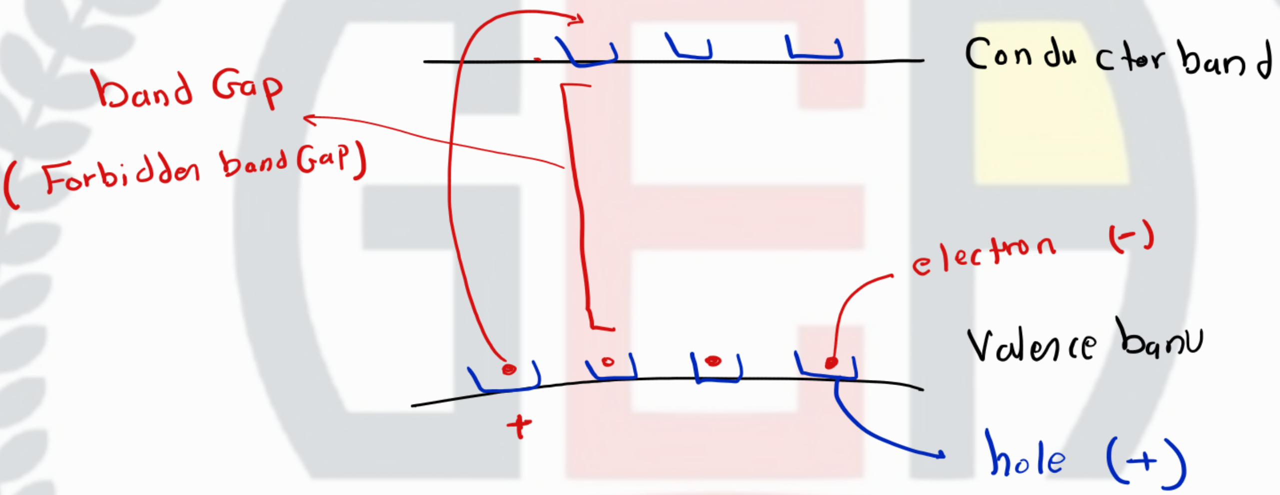
لا يفقد الكترونات

لا يوجد الكترونات حرة

لا يوصل كهرباء

$\boxed{Si}$ = 14 electron




Conductor

Conduction band

overlapping

Valence band

Semiconductor

Conduction band

$E_g = 1ev$

Valence band

Insulator

conduction band

$E_g = 5ev$

Valence band

# Semi Conductors

## Intrinsic

١. اشباه الموصلات نقية مثل Si, Ge

. ذرات رباعية التكافؤ وبالتالي كل electron يرتبط بـ electron مجاور له

- No free electron

$n = p = n_i$

$n$: تركيز electron

$p$: تركيز الـ hole

$n_i$: intrinsic concentration التركيز الكلي

## Extrinsic

. تحوي بإضافة شوائب وهي عبارة عن ذرات خماسية التكافؤ او ثلاثية التكافؤ ولذلك يوجد اما Free electron او Free hole

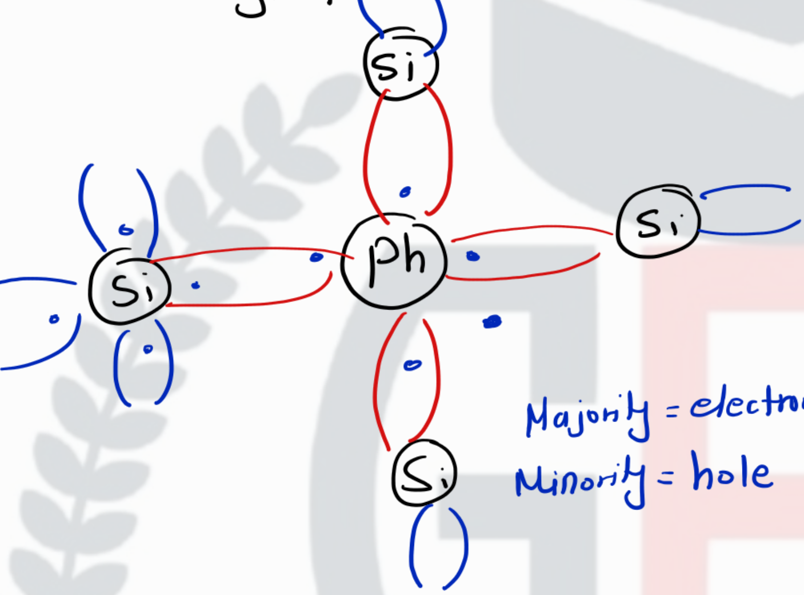
N-Type — P-Type

عن طريق Doping التطعيم

# Extrinsic Semi conductor

## N-Type

• is Doped with 5th group electron

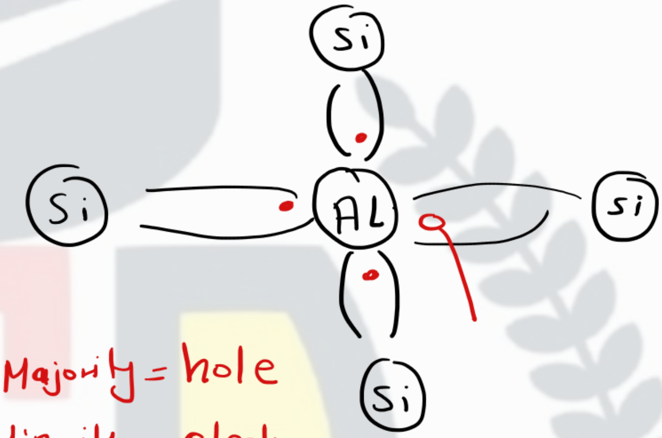



Majority = electron
Minority = hole

Ph ⇒ Donor

## P-Type

is Doped with 3th

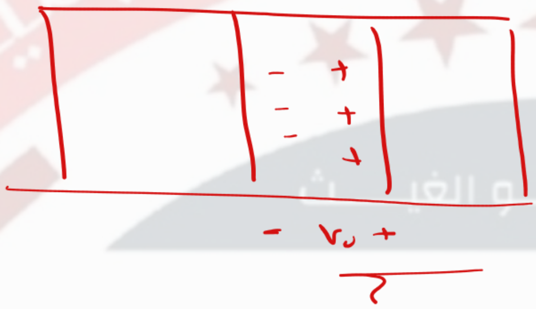



Majority = hole
Minority = electron

AL ⇒ Accepter

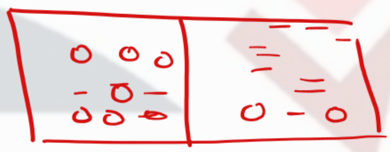
## current in Semi Conductor

### Drift Current




### Diffusion Current

نتيجة اختلاف "Con centration"
يحدث انتشار "Diffusion"



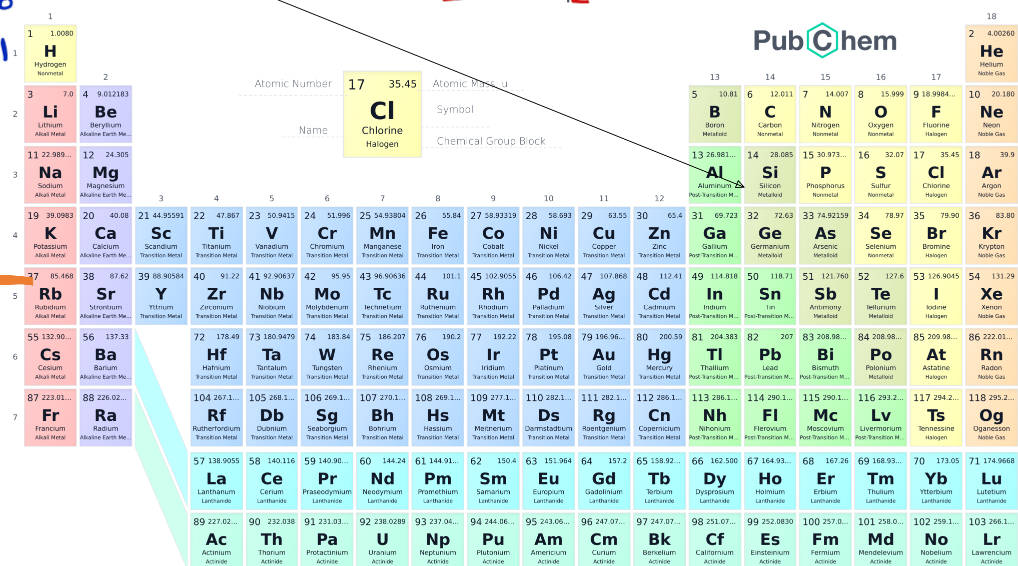
# Semiconductor Materials and Properties

Conductors | Semiconductors | Insulators
Copper, Gold, and Silver | | Glass, Plastics, and Paper

مادة موجودة في الطبيعة وفي الجدول الدوري

- Two kinds of semiconductors:
  1. ➢ single-element semiconductors, such as germanium and silicon, group IV in the periodic table.
  2. ➢ compound semiconductors, such as gallium-arsenide, which are formed by combining elements from groups III and V or groups II and VI.

اكثر من مادة مع بعض




A. S. Sedra and K. C. Smi, *Microelectronic Circuit*, 7th ed. 2016, pp. 44.
"Periodic Table," Lam Research. [Online]. Available: https://blog.lamresearch.com

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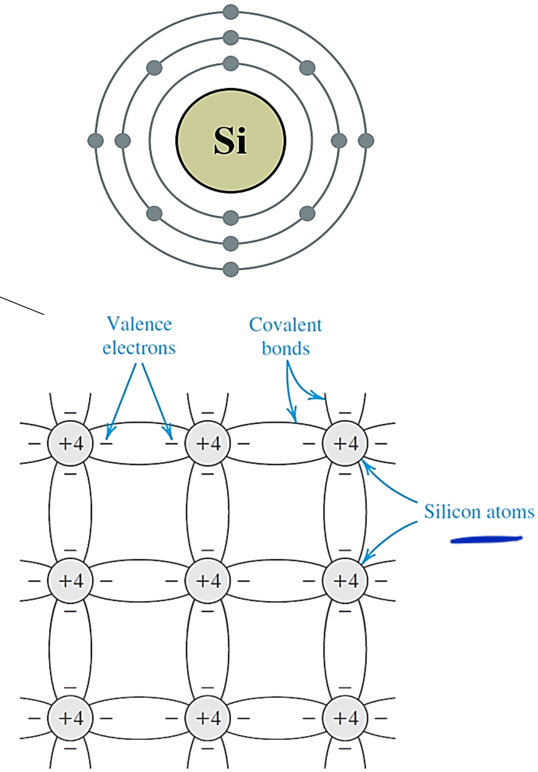


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“Popular science homepage,” Popular Science, 06-Jul-2021. [Online]. Available: http://www.popsci.com/.

# Semiconductor Materials and Properties

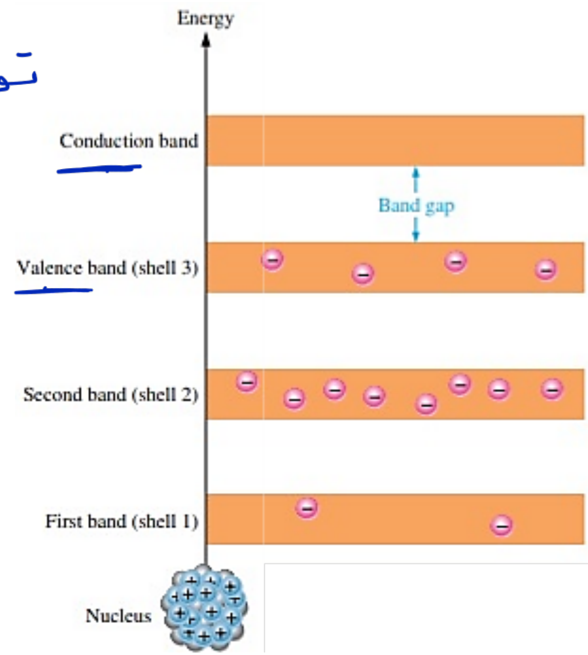
توزيع الالكترونات للمادة في الحالة الطبيعية (دون إثارة)

- Energy band diagram for unexcited atom in a pure intrinsic silicon crystal.

- At sufficiently low temperatures, approaching absolute zero (0 K), all the covalent bonds are intact, and no electrons are available to conduct electric current.
- Thus, at such low temperatures, the intrinsic silicon crystal behaves as an insulator.

في درجات الحرارة المنخفضة المادة شبه الموصل تتصرف

كأنها مادة عازلة اي لا توصل كهرباء





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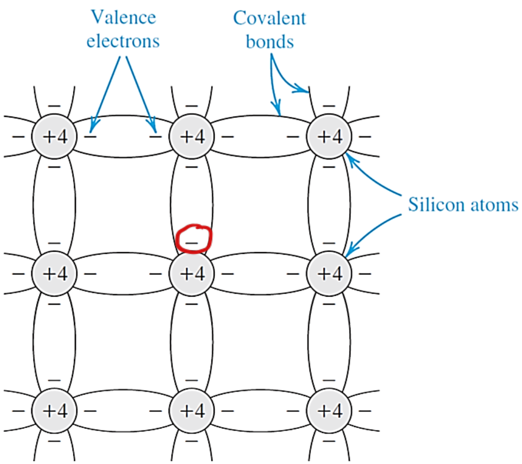
Henry, "Knowledge for all engineers," The Engineering Knowledge. [Online]. Available: http://www.theengineeringknowledge.com/.

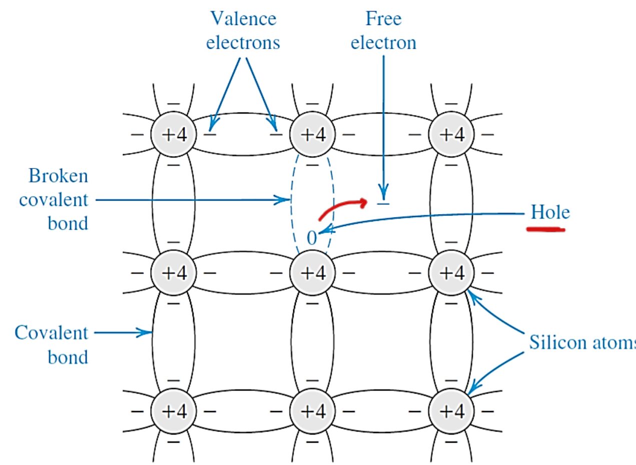
# Semiconductor Materials and Properties

- Room Temperature effect:




At T = 0 K

Increasing Temperature




At T > 0 K

when a covalent bond is broken, an electron is freed, and hole is created (current can flow)

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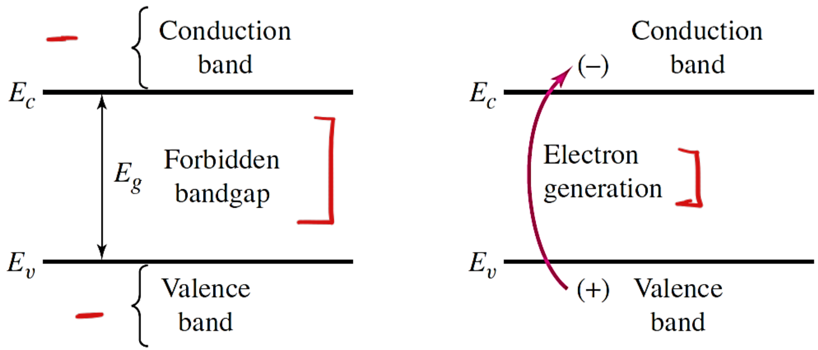
# Semiconductor Materials and Properties





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# Semiconductor Materials and Properties

- Insulator: large bandgap energies, in the range of 3 to 6 electron–volts (eV).
- Conductors: contain very large numbers of free electrons at room temperature.
- Semiconductor: the bandgap energy is on the order of 1 eV

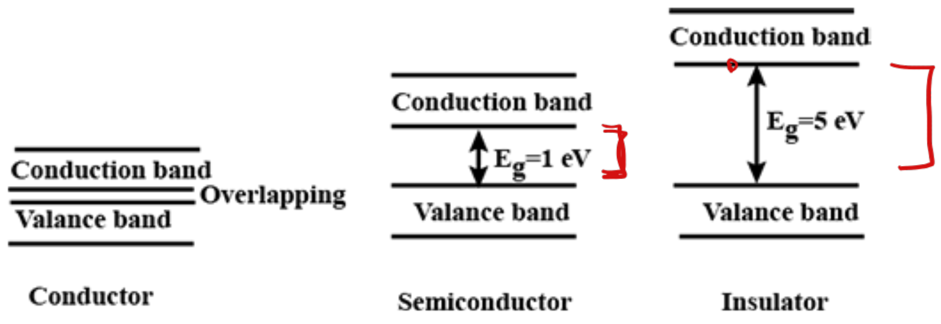


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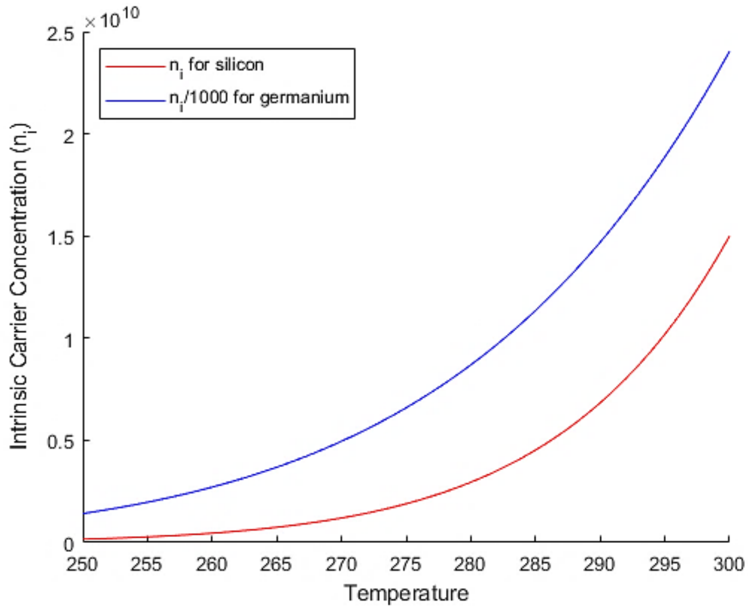
**Table 1.3** Semiconductor constants

| Material | $Eg$ (eV) | $B$ ($cm^{-3}\ K^{-3/2}$) |
|---|---|---|
| Silicon (Si) | 1.1 | $5.23 \times 10^{15}$ |
| Gallium arsenide (GaAs) | 1.4 | $2.10 \times 10^{14}$ |
| Germanium (Ge) | 0.66 | $1.66 \times 10^{15}$ |

# Semiconductor Materials and Properties





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# Semiconductor Materials and Properties

## Extrinsic Semiconductor

- **Intrinsic semiconductor**: has equal concentrations of free electrons and holes, generated by thermal generation.
- These concentrations are far too small for silicon to conduct appreciable current at room temperature.

توزيع الشحنات

- To solve the issue: a method was developed to change the carrier concentration in a semiconductor crystal.
- This process is known as **doping**, and the resulting silicon is referred to as doped silicon.
- **Doping:** introducing impurity atoms into the silicon crystal to increase the concentration of either free electrons or holes.

اضيف ذرات

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# Semiconductor Materials and Properties

Conductors
Copper, Gold, and Silver

Semiconductors

Insulators
Glass, Plastics, and Paper

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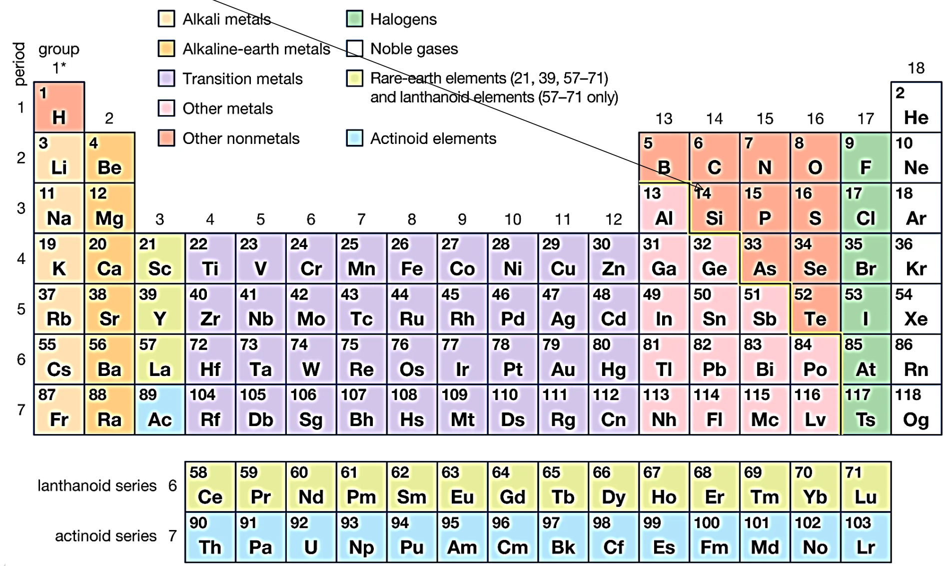



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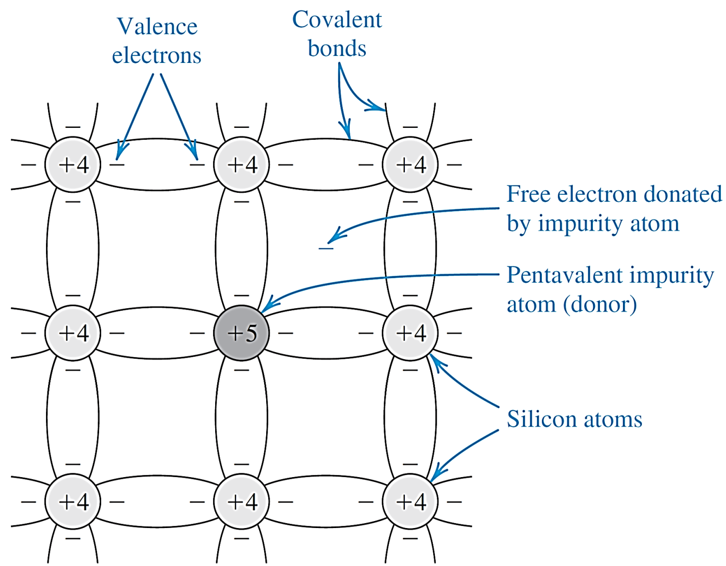
# Semiconductor Materials and Properties

## Extrinsic Semiconductor

- Increasing the concentration of free electrons (n) Doping with an element with a valence of 5 such as phosphorus

  **silicon is n type**

- Four of phosphorus's electrons form covalent bonds.
- The fifth electron becomes a free electron.
- Each phosphorus atom donates a free electron
- Phosphorus impurity is called a **donor**.
- **No holes are generated by this process**.
- Electrons: majority carrier while holes: minority carrier





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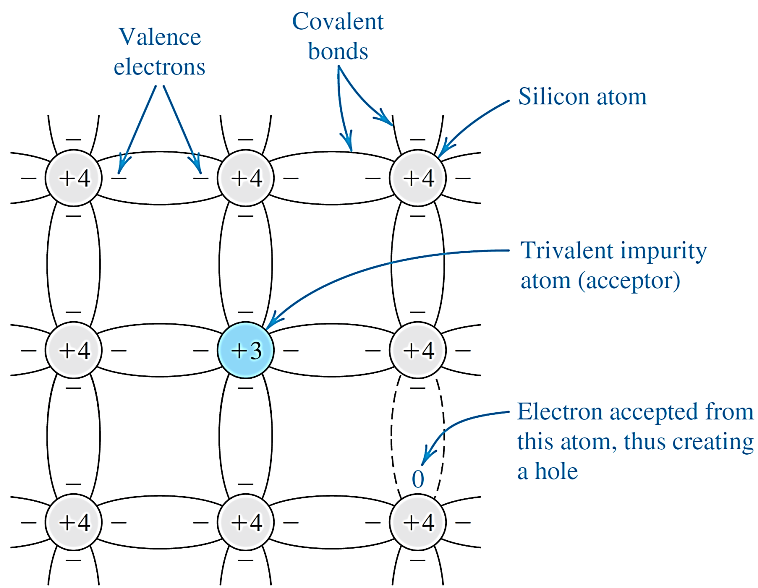
# Semiconductor Materials and Properties

## Extrinsic Semiconductor

- Increasing the concentration of holes (p) → Doping with an element having a valence of 3 such as boron

**silicon is p-type**

- Boron atom has three electrons in its outer shell.
- Accepting an electron from a neighboring atom
- The result is a hole in the neighboring atom
- Boron impurity is called an **acceptor**.
- **Generating holes without electrons being generated**.
- Holes: majority carrier while electrons: minority carrier





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# Semiconductor Materials and Properties

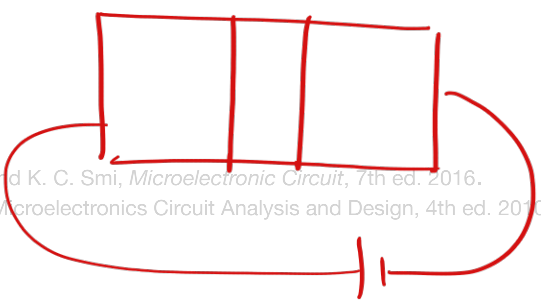
## Current Flow in Semiconductors

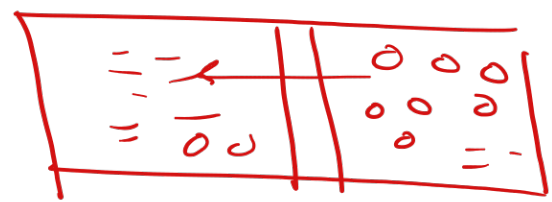
- Two different mechanisms for the movement of charge carriers (current flow in semiconductors):

Drift and Diffusion

Movement caused by electric fields | Flow caused by variations in the concentration

المجال الكهربي





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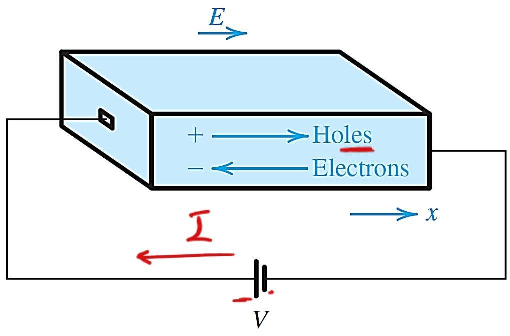


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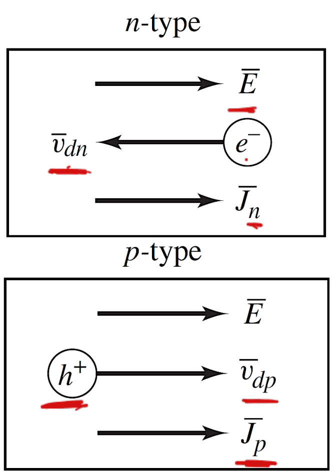


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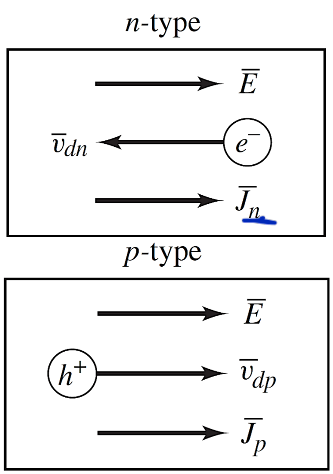



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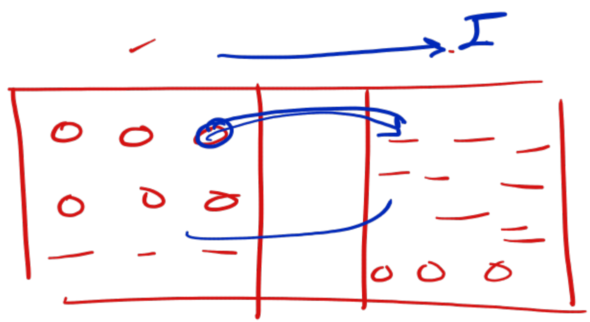
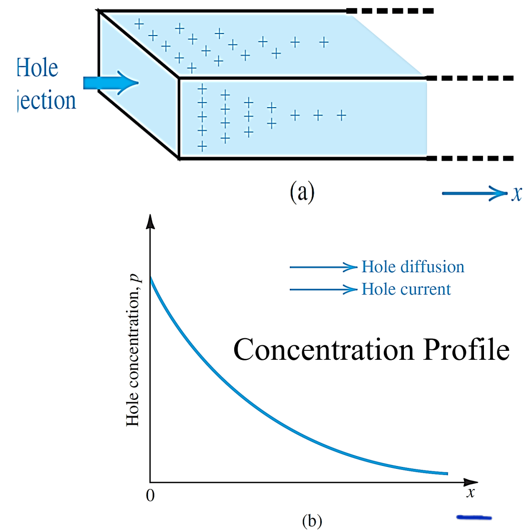
# Semiconductor Materials and Properties

## Diffusion Current

- Carrier diffusion occurs when the density of charge carriers in a piece of semiconductor is not uniform.

- Ex: hole concentration is made higher in one part of a piece of silicon than in another, then holes will diffuse from the region of high concentration to the region of low concentration.



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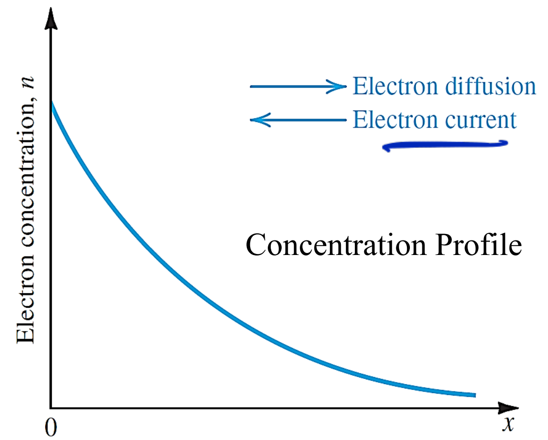


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