University of Anbar

College of Science – Dept. of Physics

Lectures of Semiconductors #1

for 3th level of physics students
Lecture 2 : General introduction/2
by
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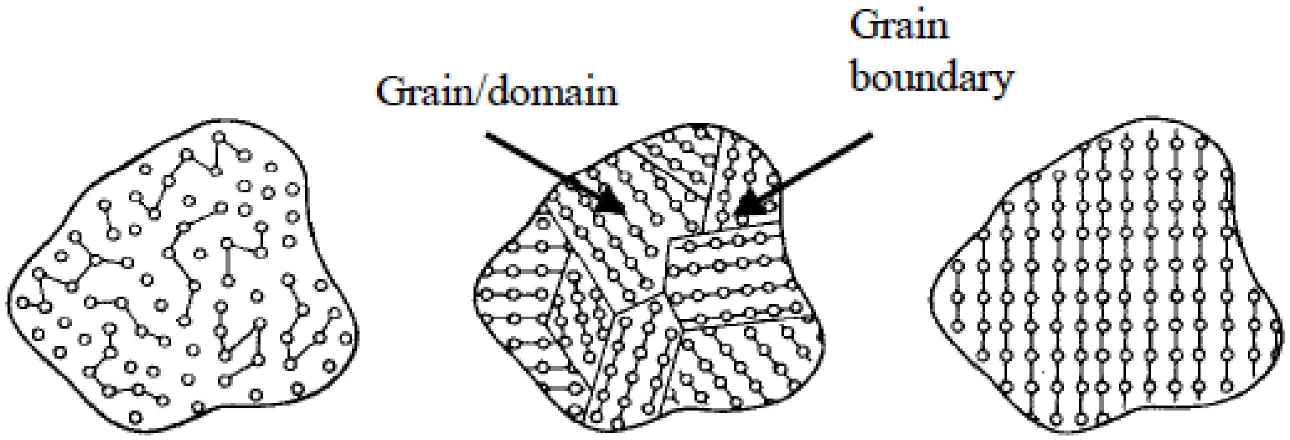
2021-2022

Types of Solids



Amorphous

No recognizable long-range order

Polycrystalline

Completely ordered In segments

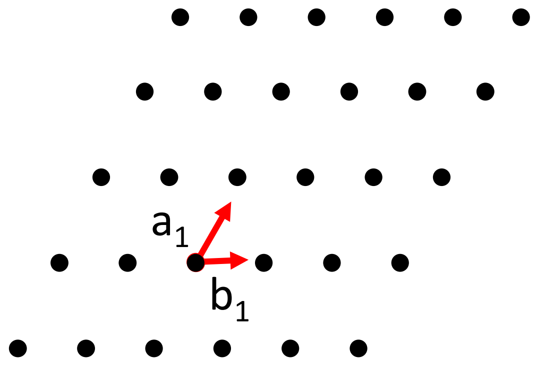
Crystal

Entire solid is made up of atoms in an orderly array

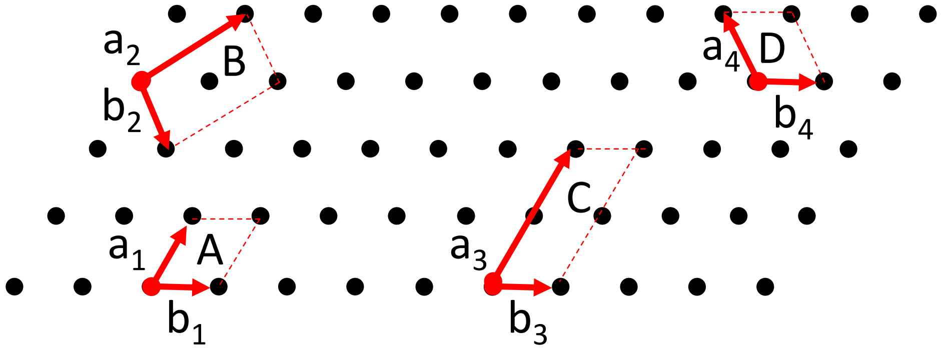
1.3 : Space Lattices

1.3.1 : Primitive and Unit Cell

The lattice is the periodic arrangement of atoms in the crystal

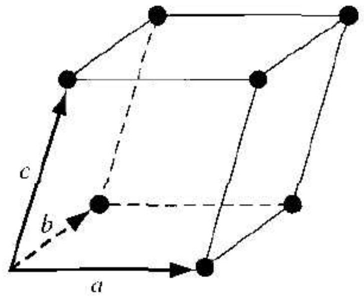


Two-dimensional representation of a single-crystal lattice



Two-dimensional representation of a single-crystal lattice showing various possible unit cells.

A primitive cell is the smallest unit cell that can be repeated to form the lattice



A generalized primitive unit cell

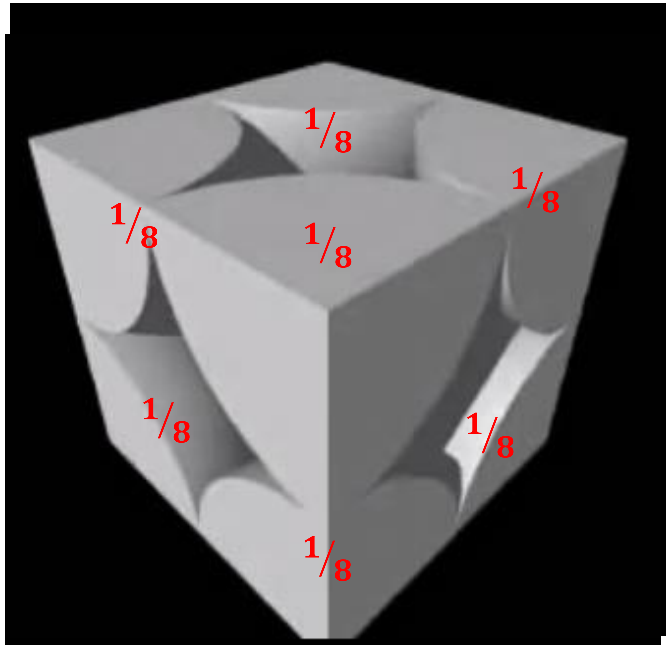
- **Every equivalent lattice point in the three- dimensional crystal can be found using the vector (r):**

$$\vec{r} = pa + qb + Sc \quad \ldots\ldots\ldots(1)$$

Where p, q, and s are integers

1.3.2 : Crystal Structures

1- The simple Cubic Lattice :



a = b = c

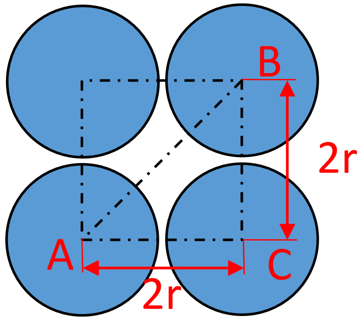
$\alpha = \beta = \gamma = 90^{o}$

This lattice consist on one atom

the nuber of atoms in the lattice is

$$1 = 8 \times [1/8]$$

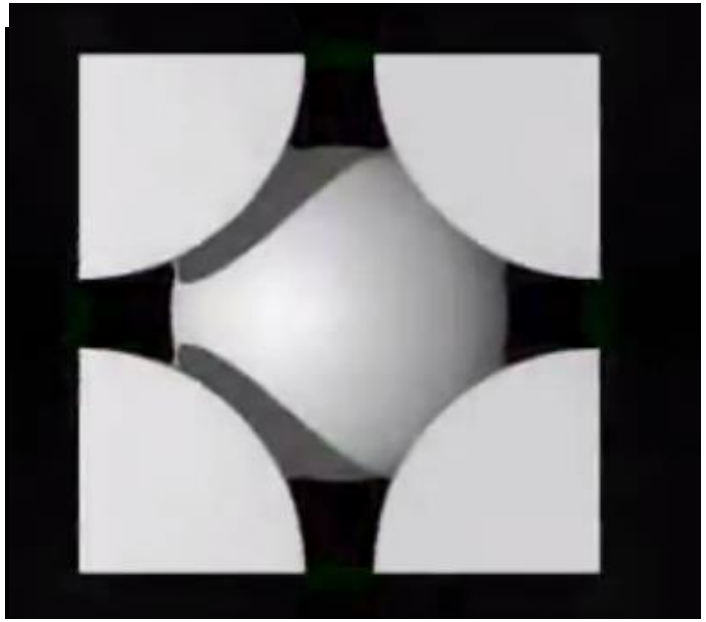
- ***the vlume of lattice is*** $V = a^3$
- ***the space's vlume of atoms is***
  $V = \frac{4}{3}\pi r^3$ ***: r is the reduce of atom***
- ***the Atomic Packing Factor (AAF) is***
  $AAF = \frac{4\pi r^3}{3a^3}$ ***: r is the reduce of atom***
- ***the relation between a and r is***
  a = 2r



$$AAF = \frac{4\pi r^3}{3(2r)^3}$$

$$AAF = \frac{\pi}{6}$$

2- *The* body-centered cubic *Lattice :*



a = b = c

$\alpha = \beta = \gamma = 90^{o}$

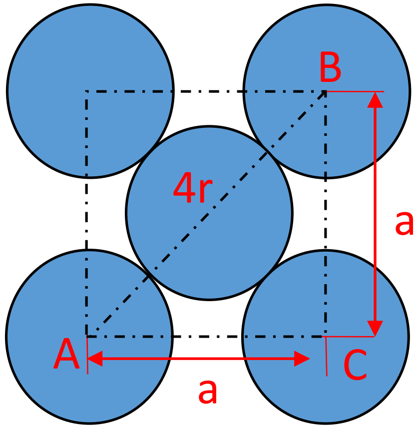
This lattice consist on two atoms

the nuber of atoms in the lattice is

$$2 = 8 \times [^{1}/_{8}] + 1$$

- ***the vlume of lattice is*** $V = a^3$
- ***the space's vlume of atoms is*** $V = \frac{4}{3} n\, \pi\, r^3$ ***: r is the reduce of atom***
- ***the Atomic Packing Factor (AAF) is*** (H.W1) $AAF = \frac{8\, \pi\, r^3}{3a^3}$ ***(prove that) :*** ***r is the reduce of atom***
- ***the relation betwee n a and r is***

$$(AB)^2 = (BC)^2 + (CA)^2$$



$$(4r)^2 = \sqrt{2}a^2 + a^2$$

$$(4r)^2 = 3a^2$$

$$(4r)^2 = 3a^2$$

$$16\, r^2 = 3a^2$$

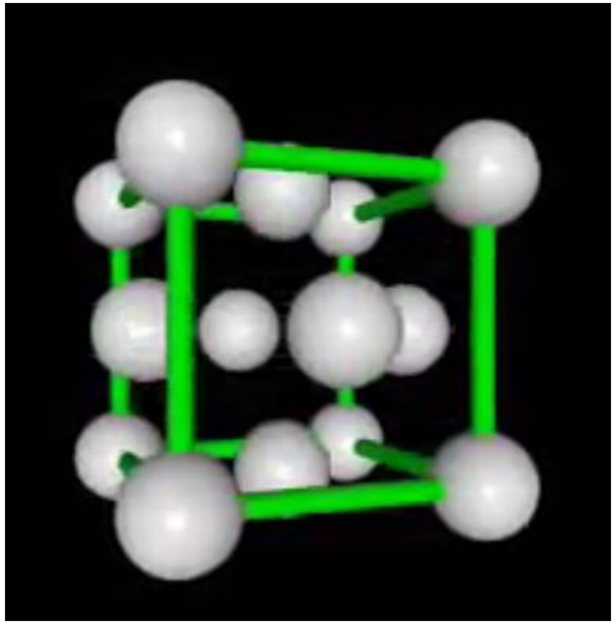
$$4\, r = a\sqrt{3}$$

$$r = a\,\frac{\sqrt{3}}{4}$$

or $a = \frac{4\, r}{\sqrt{3}}$

(H.W2) find AAF of BCC lattice

3- *The* face-centered cubic *Lattice :*



a = b = c

$\alpha = \beta = \gamma = 90^{o}$

This lattice consist on four atoms

$\boldsymbol{the\ nuber\ of\ atoms\ in\ the\ lattice\ is}$

$\mathbf{4 = 8 \times [^{1}/_{8}] + \frac{1}{2} \times 6}$

❖ $\boldsymbol{the\ vlume\ of\ lattice\ is \quad V = a^3}$

❖ $\boldsymbol{the\ space's\ \ vlume\ of\ atoms\ is}$

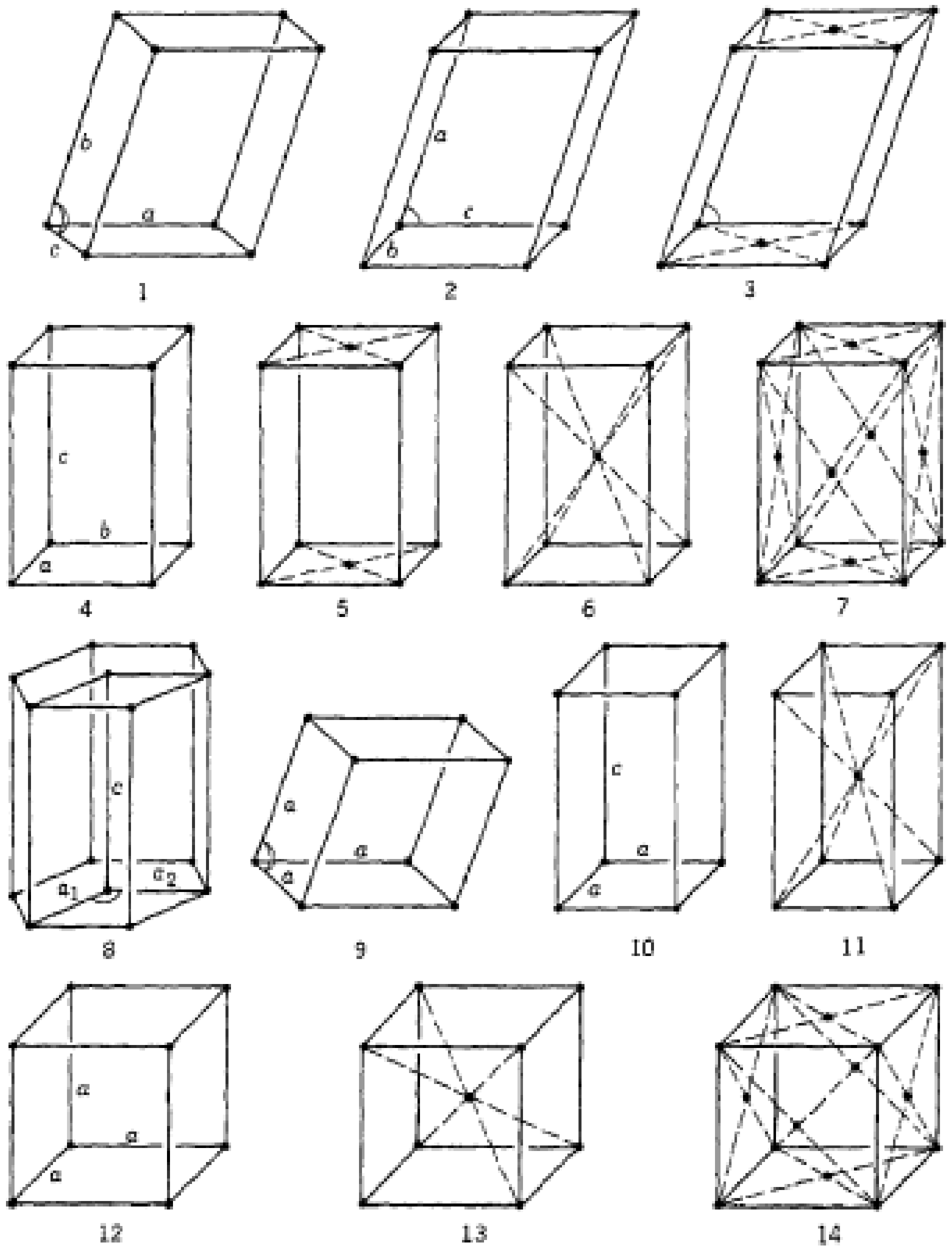
$\boldsymbol{V = \frac{4}{3} n\, \pi\, r^3}$ ***: r is the reduce of atom***

❖ $\boldsymbol{the\ Atomic\ Packing\ Factor\ (AAF)\ is}$

$\boldsymbol{(H.W3) \quad AAF = \frac{8\,\pi\, r^3}{a^3}}$ ***(prove that) :***

r is the   reduce of atom

The fourteen space lattices (Bravais lattices):



$(H.W4)$ ***write about the properties of the fourteen* Bravais lattices**

Example:

Find the volume density of atoms in a body-centered cubic crystal, if a = 5×10^{-8} cm

Solution :

$$Density = \frac{No.of\ Atoms}{Volume\ of\ lattice}$$

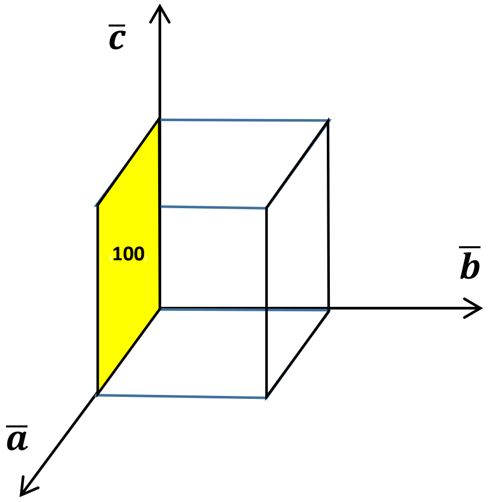
$$Density = \frac{2}{(5 \times 10^{-8})^3}$$

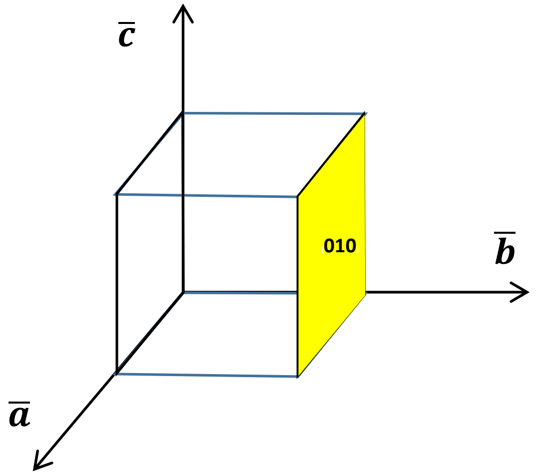
$$= 1.6 \times 10^{22} \quad atom/cm^3$$

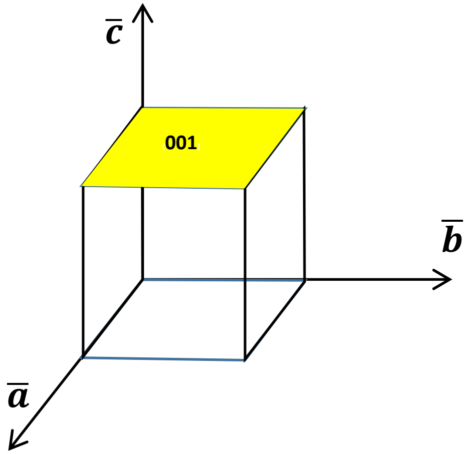
$(H.W5)$: El.1 & E1.2
in Semiconductor Physics and Devices(Donald A. Neamen) p.5

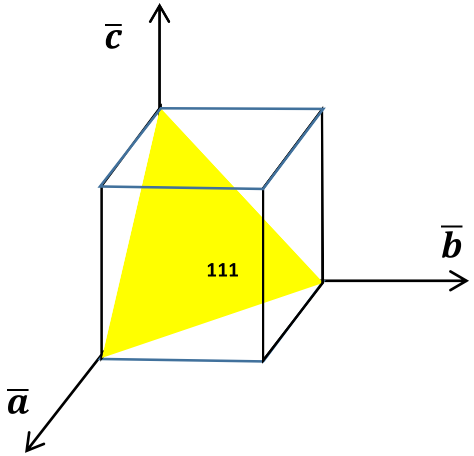
1.3.3 : The lattice's planes :

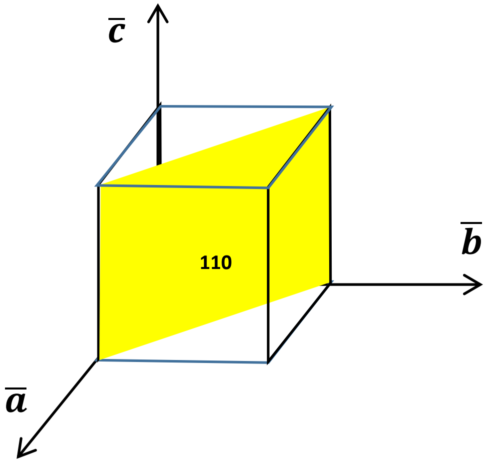
The lattice's planes are explained by Miller's indices *(hkl)* .







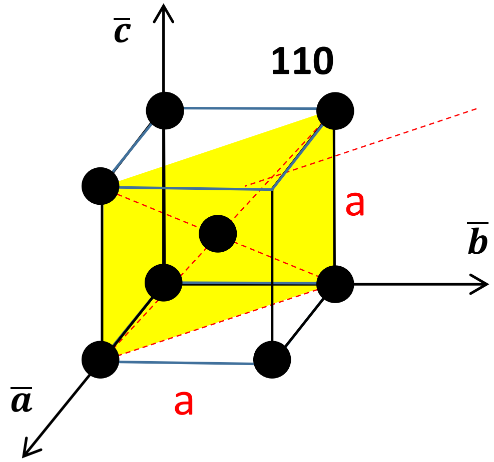




One important characteristic in semiconductor crystals is the surface concentration of atoms on the surface , number per square centimeter (atom/cm²), that are cut by a particular plane. This characteristic is called " *The surface density of atoms* ".
Again, a single-crystal semiconductor is not infinitely large and must terminate at some surface.

❖ **To calculate the surface density of atoms on a particular plane in a crystal.**

Consider the body-centered cubic structure and the (110) plane . Assume the atoms can be represented as hard spheres with the closest atoms touching each other. Assume the lattice constant is a = 5 Å



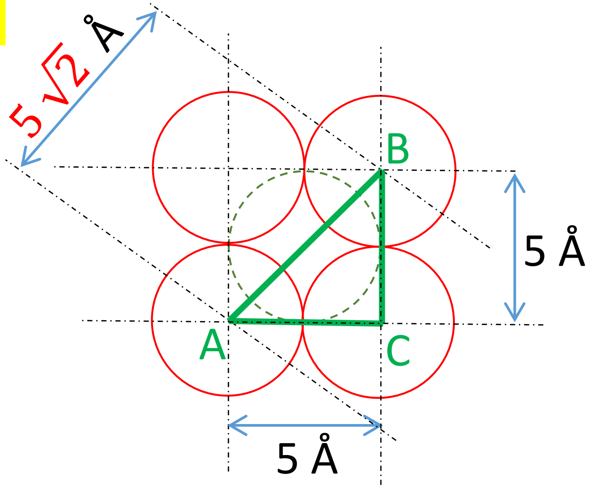
$$AB = \sqrt{BC^2 + CA^2}$$
$$= \sqrt{a^2 + a^2}$$
$$= \sqrt{2a^2}$$
$$= a\sqrt{2}$$
$$= 5\sqrt{2}\ \text{Å}$$

$$\text{The surface density} = \frac{No.\,of\ Atom}{Area\ of\ plane}$$

$$= \frac{2\ (atom)}{5 \times 5\sqrt{2}\ (\text{Å})}$$

$$= \frac{2\ (atom)}{(5 \times 10^{-8})^2 . \sqrt{2}\ (cm)^2}$$

$$= 5.66 \times 10^{14}\ Atoms\,/\,(cm)^2$$

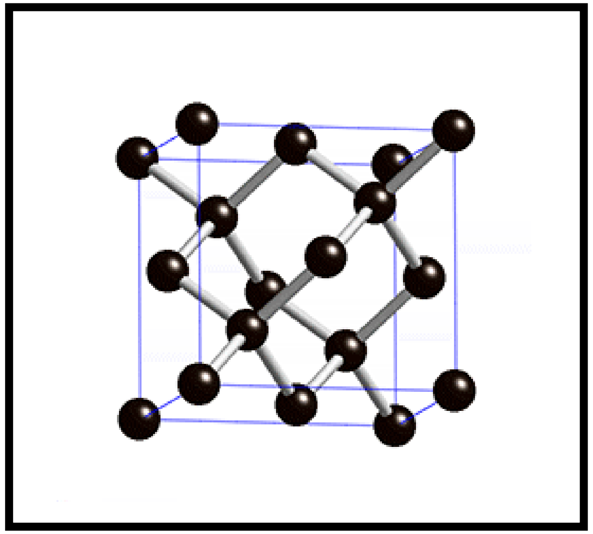


($H.W6$): E1.4 in Semiconductor Physics and Devices(Donald A. Neamen) p.9

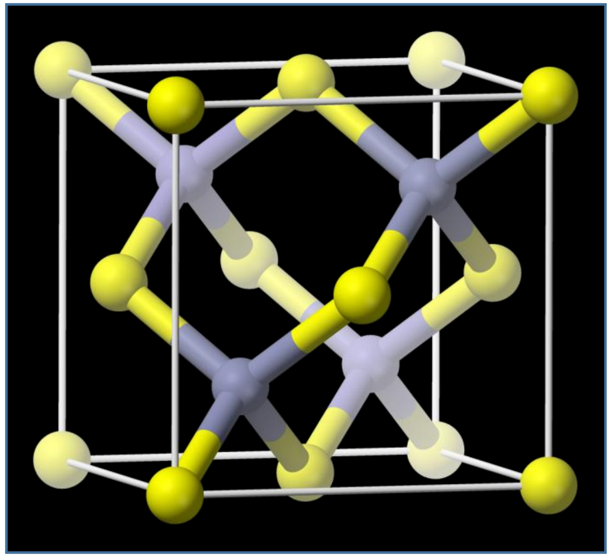
13.4: The Diamond Structure

Silicon is the most common semiconductor material. Silicon is referred to as a group IV element and has a diamond crystal structure. Germanium is also a group IV element and has the same diamond structure.

The diamond structure refers to the particular lattice in which all atoms are of the same species, such as silicon or germanium. The zinchlende (sphalerite) structure differs from the diamond structure only in that there are two different types of atoms in the lattice



A unit cell of the diamond structure.



A unit cell of the zincblende structure.

($H.W7$): E1.5 in Semiconductor Physics and Devices(Donald A. Neamen) p.11

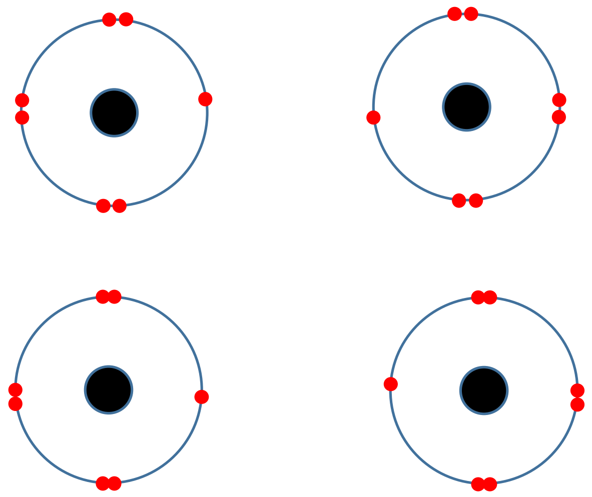
1.4 : ATOMIC BONDING

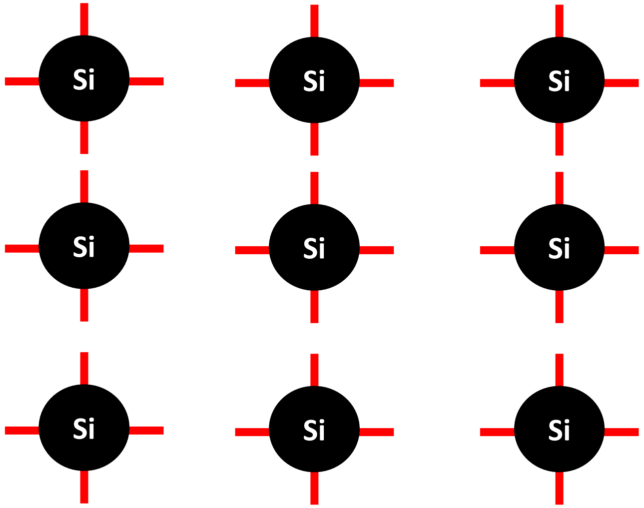
Atomic Bonding Types :

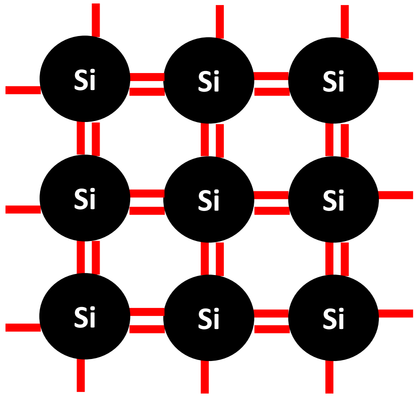
1. Ionic bonding .
2. Covalent bonding .
3. Co-ordinate (dative covalent) bonding.
4. Electronegativity.
5. Shaes of simple molecules and ions .
6. Metallic bonding .
7. Van der waals forces.
8. Hydrogen bonding
9. Bonding in organic compounds .

Covalent bonding

If we've two atoms , that are IV valency



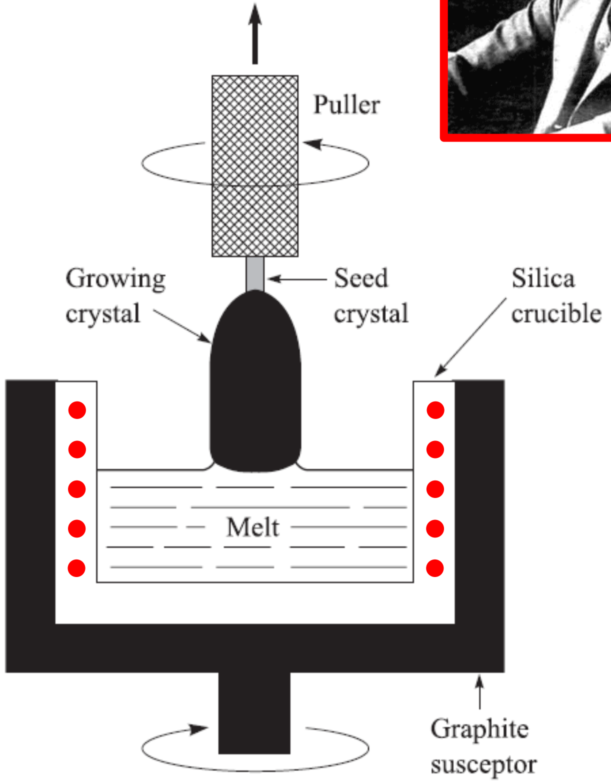




1.5 : GROWTH OF SEMICONDUCTOR MATERIALS

- Czochralski's method .

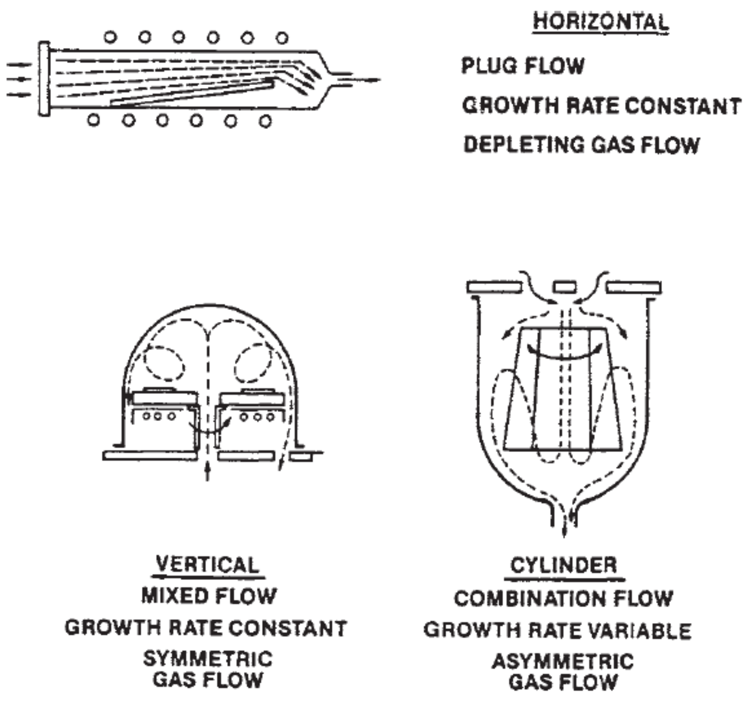
In this technique, a small piece of single-crystal material, known as a seed , is brought into contact with the surface of the same material in liquid phase, and then slowly pulled from the melt. As the seed is slowly pulled, solidification occurs along the plane between the solid-liquid interface.



Epitaxial Growth

The word ***epitaxy*** is derived from the Greek “**epi**”— upon, and “**taxis**”— to arrange.

Thus, epitaxial silicon deposition requires the ability to add and arrange silicon atoms upon a single crystal surface. Epitaxy is the regularly oriented growth of one crystalline substance upon another.



Two different kinds of epitaxy are recognized:

- Homoepitaxy growth in which the epitaxial layer is of the same material as the substrate.
- Heteroepitaxy growth in which the epitaxial layer is a different material from the substrate.

CVD (Chemical Vaporation deposition is a heterogeneous reaction involving at least the following steps:

1. Bulk transport of reactants into the process volume
2. Gaseous diffusion of reactants to the surface
3. Absorption of reactants onto the surface

Surface reaction

1. Surface reaction (reaction can also take place in the gas volume immediately above the surface)
2. Surface diffusion
3. Crystal lattice incorporation

Removal of reactant by-products

1. Reaction by-product desorption (الامدصاص , المج)
2. Gaseous transport of by - products
3. Bulk transport of by-products out of process volume