Material Science and Engineering

The physical science which deals with materials applied for engineering practice to facilitate human need is called Material Science.

Material Science and Engineering(Contd..)

In the universe there enormous materials and all of those are useful for man kind by one way or another. Here in this course, our focus is to study about those materials which can be applied for engineering practice to facilitate mankind.

Classification of Engineering Materials

1. Ceramics and glasses: Non metallic in organic substances, which are brittle and have good thermal and electrical insulating properties.
2. Metals and alloys: characterized by high thermal and electrical conductivities. They are opaque and usually they can be polished to high luster. Commonly but not always they are heavy and deformable.Alloys are combination of two metals.

Engineering Materials (contd..)

3.Organic Polymers: These are relatively inert and light and generally have high degree of plasticity.

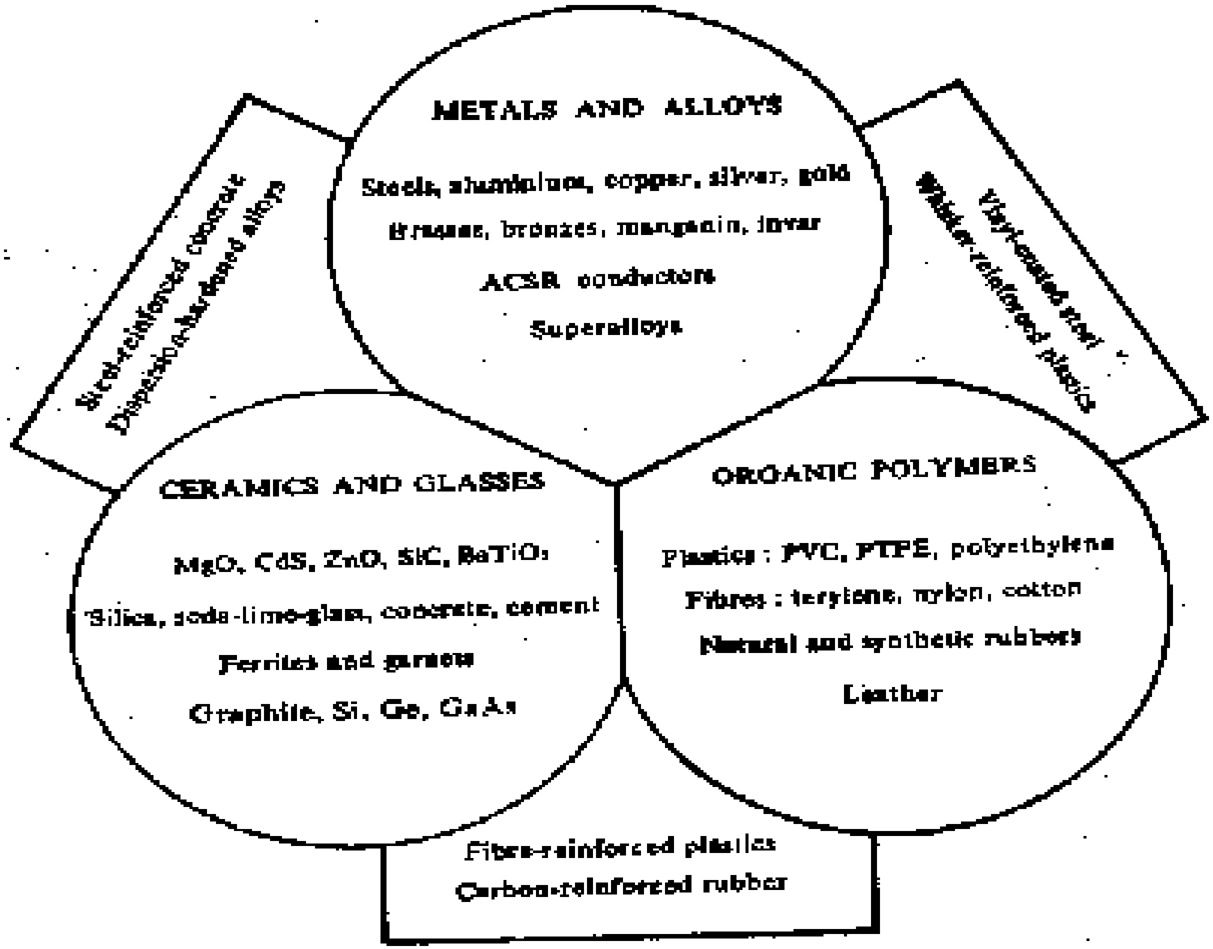
Materials can also be classified according to the major areas in which they are used.

- Structures: e.g.: Dams, Steel melting furnaces etc.
- Machines: Lathes, Milling Machines etc.
- Devices: Transistors, Photoelectric cells etc.

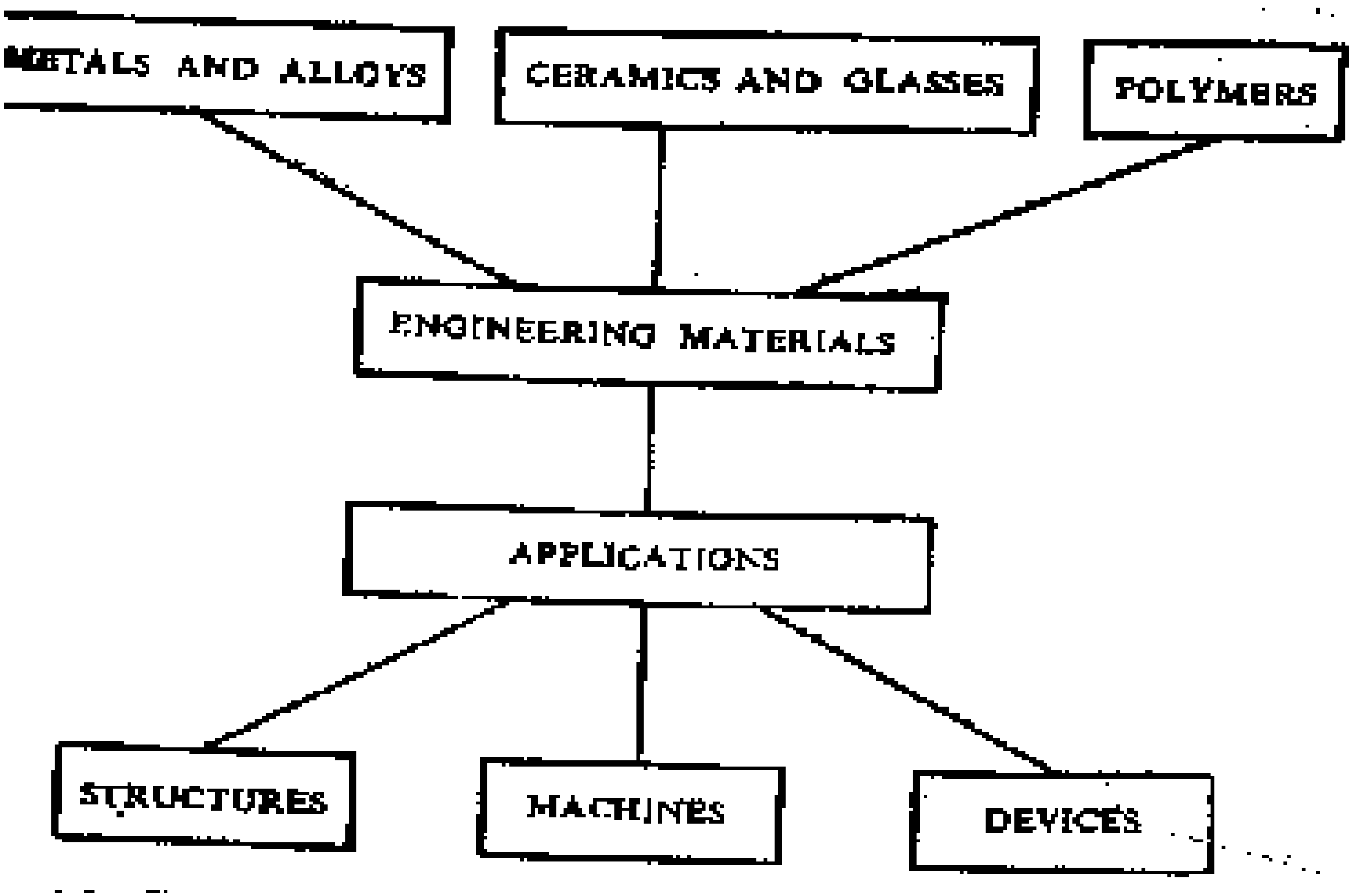
Classifications of Engineering Materials (contd..)

Each category of engineering applications require any or all of three groups.

Engineering Materials classification



Classification of Engineering Materials



Level of structure

The internal structure of materials can be studied at various levels of observations.The magnification and resolution of the physical aid used are a measure of level of observations.Depending on the level , we can classify the structure of material as

- Macrostructure
- Microstructure
- Substructure
- Crystal structure
- Electronic structure
- Nuclear structure

Level of Structure (contd..)

Macrostructure: This type of structure can be studied by naked eye or the equipment having small magnification.

Microstructure: To study microstructure of materials, we need microscope of high magnification.

Substructure: To study substructure of materials, we need equipments having very high magnification.

Crystal Structure: It tells us about the atomic arrangement within a crystal.It is sufficient to describe few atoms within unit cell.

Level of Structure (contd..)

The crystals consists of large number of unit cells forming regularly repeating patterns in space. The main technique employed to determine crystal structure is X-ray diffraction.

Electronic structure: It usually refers electrons in the outermost orbital of the individual atoms that constitute the solid.

Level of Structure (contd..)

Spectroscopic techniques are normally used for studying electronic structure of materials.

Nuclear structure: This type of structure of materials is studied by employing nuclear spectroscopic technique.

Crystal Geometry

Materials can be broadly classified as

- Crystalline solids
- Non crystalline solids

In a crystal, the arrangement of atoms is in periodically repeating manner while in non crystalline solids no such regularity is found.

Crystal Geometry (contd..)

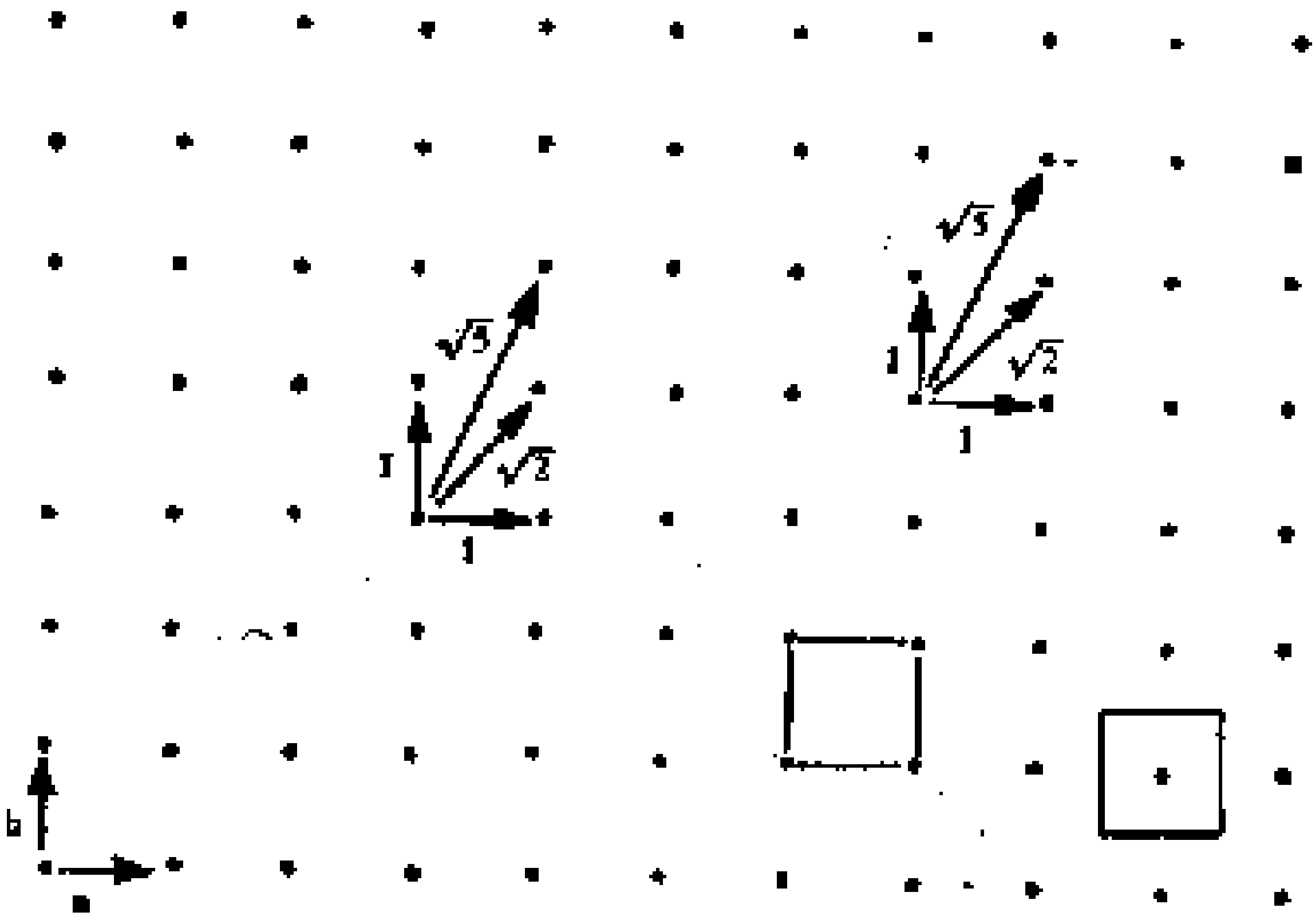
Crystalline solids can also be classified as

- Single crystalline and
- Poly crystalline solid.

Space Lattice

A space lattice is defined as an infinite array of points in 3-dimension in which every point has surrounding identical to that of every other point in the array.

Square Lattice



Space lattice (contd..)

A space lattice can be defined by referring to a unit cell. The unit cell is the smallest unit which , when repeated in space repeated in space indefinitely, will generate the space lattice. IN the example given here of square lattice, the unit cell is the square obtained by joining four neighboring lattice points.Since every corner of the square is common to four unit cells meeting at that corner, the effective number of unit cell is only one.

Space lattice (contd...)

Alternatively the unit cell can be visualized with one lattice point at the center of the square and with non at the corners.

3- D space lattice is generated by repeated translation of three non coplanar vectors, a,b, c. It so turns out that there are only 14 distinguishable way to arrange points in three dimensional space, such that each arrangements confirm to definition of space lattice.

Space Lattice (contd..)

These 14 space lattices are known as Bravais lattice. They belong to 7 crystal system.

Space Lattice (Contd...)

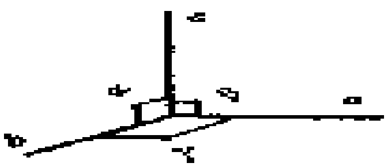
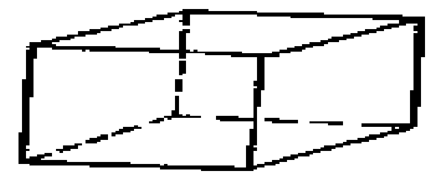
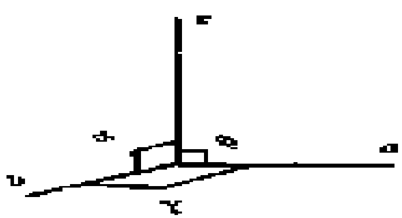
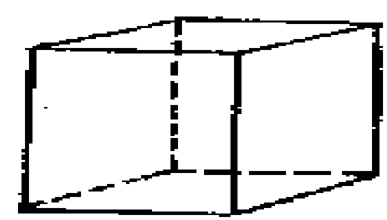
The cubic system is defined as 3 mutually perpendicular translation vectors ‘a’, ‘b’ and ‘c’ which are equal in magnitude . The angle between ‘b’ and ‘c’ is α, the angle between ‘c’ and ‘a’ is β, and that between ‘a’ and ‘b’ is γ. There 3 space lattices in cubic crystal system : The simple cubic, The body centered cubic and the Face centered cubic space lattices.

Space Lattices (Contd..)

Space lattice	*Abbreviation*	*Effective numb of lattice poin in unit cell*
Simple cubic	SC	1
Body centred cubic	BCC	2
Face centred cubic	FCC	4

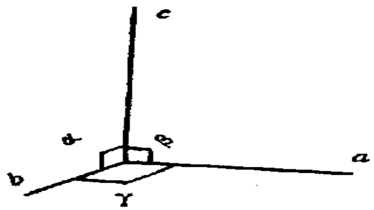
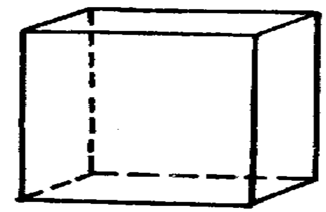
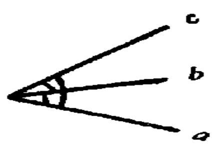
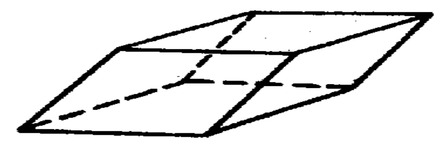
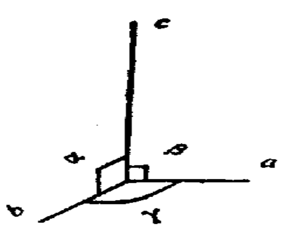
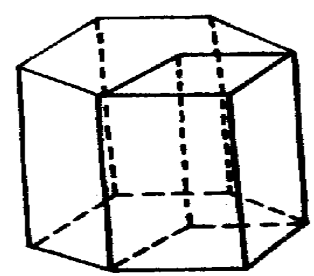
TABLE 3.1

The Bravais Lattices

Crystal system	*Space lattice*	*Unit cell*
I. Cubic $a = b = c$ $\alpha = \beta = \gamma = 90°$ 	**(1) Simple** (Lattice points at the eight corners of the unit cell) **(2) Body centred** (Points at the eight corners and at the body centre) **(3) Face centred** (Points at the eight corners and at the six face centres)	
II. Tetragonal $a = b \neq c$ $\alpha = \beta = \gamma = 90°$ 	**(4) Simple** (Points at the eight corners of the unit cell) **(5) Body centred** (Points at the eight corners and at the body centre)	

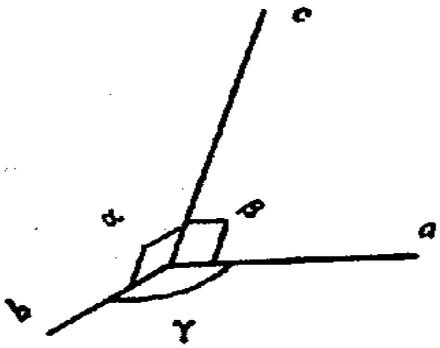
Bravais Lattices (Contd…)

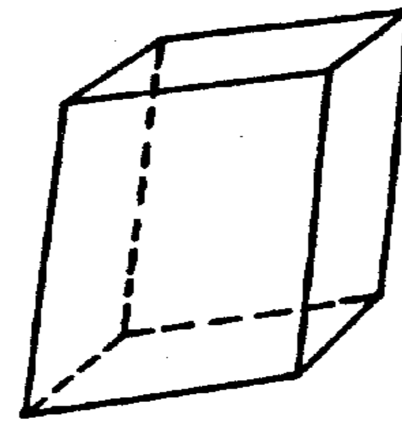
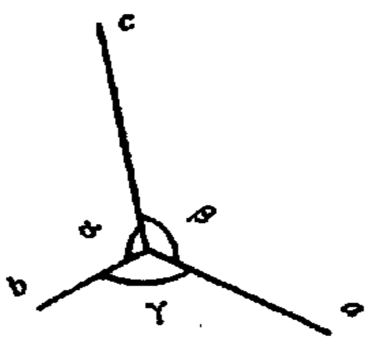
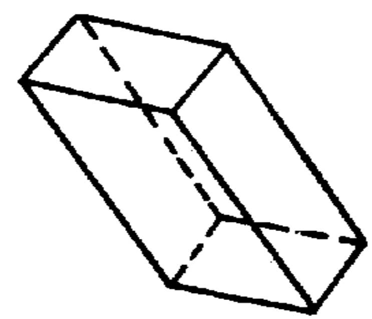
Table 3.1 Contd.

Crystal system	*Space lattice*	*Unit cell*
III. Orthorhombic $a \neq b \neq c$ $\alpha = \beta = \gamma = 90°$ 	(6) Simple (Points at the eight corners of the unit cell) (7) End centred (Also called side centred or base centred) (Points at the eight corners and at two face centres opposite to each other) (8) Body centred (Points at the eight corners and at the body centre) (9) Face centred (Points at the eight corners and at the six face centres)	
IV. Rhombohedral $a = b = c$ $\alpha = \beta = \gamma \neq 90°$ 	(10) Simple (Points at the eight corners of the unit cell)	
V. Hexagonal $a = b \neq c$ $\alpha = \beta = 90°$ $\gamma = 120°$ 	(11) Simple [(i) Points at the eight corners of the unit cell outlined by thick lines or (ii) Points at the twelve corners of the hexagonal prism and at the centres of the two hexagonal faces]	

Bravais Space Lattice

Table 3.1 Contd.

<table>
<tr><th>Crystal system</th><th>Space lattice</th><th>Unit cell</th></tr>
<tr><td>VI. Monoclinic
$a \neq b \neq c$
$\alpha = \beta = 90° \neq \gamma$

</td><td>(12) Simple
(Points at the eight corners of the unit cell)

(13) End centred
(Points at the eight corners and at two face centres opposite to each other)</td><td></td></tr>
<tr><td>VII. Triclinic
$\alpha \neq \beta \neq \gamma \neq 90°$
$a \neq b \neq c$

</td><td>(14) Simple
(Points at the eight corners of the unit cell)</td><td></td></tr>
</table>

Bravais Lattices (Contd..)

A cubic crystal is said to have a fourfold rotation symmetry about an axis passing through the centers of the two opposite faces of the unit cube. During each complete rotation about the axis, the crystal passes through identical position in space 4 times. The rotational, translational and reflection symmetry operation constitute the symmetry elements of a crystal.

Bravais Lattices (Contd..)

After the cubic system, the next less symmetric crystal system is tetragonal system. It is defined by three mutually perpendicular vectors, only two of which are equal in magnitude. There are two space lattices here.

Space Lattice	Abbreviation	*Effective No. Of Unit cell*
Simple Tetragonal	CT	1
Body centered tetragonal	BCT	2

Tetragonal space Lattice

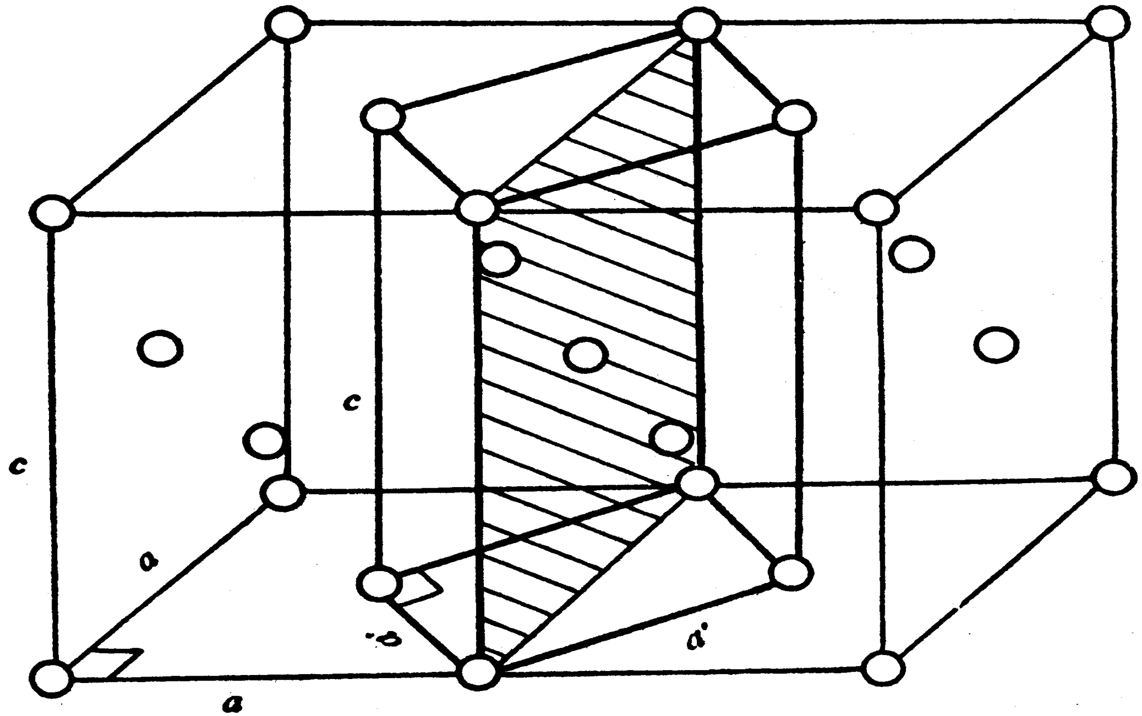


Fig. 3.2. An array of lattice points that fit in an FCT unit cell should be represented by a BCT cell (outlined by thick lines inside two adjacent FCT cells).

Orthorhombic Cell

Space lattice	*Abbreviation*	*Effective number of lattice points in unit cell*
Simple orthorhombic	SO	1
End centred orthorhombic	ECO	2
Body centred orthorhombic	BCO	2
Face centred orthorhombic	FCO	4

- Crystal System
- To be Specified
- Axes Angles
- Total no. of parameters
- Cubic
- a
- -
- 1
- Tetragonal
- a, c

Space Lattices and crystal Structure

A space lattice is combined with basis to generate crystal structure.

Space lattice+ Basis $\longrightarrow$ = Crystal Structure.

In many element crystals, the basis is simple and consists of one atom per lattice point. In such cases the crystal is generated by just positioning one atom of the element at each lattice point.

Crystal structure of Chromium and copper are generated as below.

BCC + 1 Cr atom at each lattice point = BCC crystal of
space lattice Cr

FCC + 1 Cu atom at each lattice point = FCC crystal of
Space lattice Cu

These crystals are called mono atomic crystals.