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IFTM University, Moradabad, Uttar Pradesh

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FORMATION OF METALS

HOW METALS ARE BEING FORMED FROM RAW MATERIALS TO USABLE FORM

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FORMATION OF METALS

Introduction:

Since the development of civilization, men are using different vital materials for day to day life. Initially,humans were dependent on the materials available in natural form. This age of civilization was called as Stone Age. With the development of science and technology, a wide variety of materials have been developed and the civilization moved towards Bronze Age and Iron Age. Based on the materials we are using today, the civilization is called as Tailor Made Materials Age. In the modern era the materials can be defined as, the substances whose constituent atoms or molecules are arranged in a systematic pattern. Till date, the materials available are said to be made from 118 types of elements (atoms) and their arrangement to form a particular structure. As per the available scientific literature the human body has been made from 25-27 types of elements in which oxygen atom alone is present 65% by weight. It is very much important to note that 90% mass of human body is made from oxygen, carbon, nitrogen, hydrogen, calcium and phosphorus. So it is the era in which the scientists and engineers are able to create or develop the materials by playing withNano size particles.

There are three basic state of materials at atmospheric conditions i.e.,solid, liquid and gas. The state of a material can be changed by changing their surrounding atmospheric conditions. Materials in solid state may be termed as metals and nonmetals.On the basis of crystalline structure, the metals (solid materials)may be crystalline or non-crystalline (amorphous). In case of solid materials, there may be solids having single crystal structure or an aggregate of all crystals to form polycrystalline structure. In every crystal, atoms are arranged in similar pattern. The boundary where this pattern changed is called crystal boundary and the metal is non as polycrystalline metal. So, the metals can be crystalline or polycrystalline.Atoms are the main constituents to form a material. A metal may be made from single atom orit may have more than one atom. Metals with more than one atom are called alloys (such as steel).

Arrangement of Atoms:

The metals such as steel, aluminum, copper etc., which are being used in our daily life, are extracted from their raw materials available in the crust of our Earth. Initially, these metals are in liquid state at the time of extracting process. During extraction process, the metal in liquid statehas to be cooledfollowing some cooling rate. This process of transformation from liquid to solid phase is called solidification.The type of atom and its atomic structure plays a very significant role in the development of any crystal structure of metals. In the process of solidification, the atoms of liquid metal reach to static position (equilibrium) to from solid and they get freeze at lattice point. As per the bonding theory such as metallic bond in metals;the atoms freeze at some distance from each other in space lattice and this way a unit cell is formed. On the base of parameters of this unit cell,the lattice structure can be anyone of the proposed Bravais lattices; such as cubic in case of copper, iron and aluminum.

Role of Unit Cell:

A unit cell is the building block of any crystal in a metal (crystalline or polycrystalline). When the atoms of a liquid starts to get arranged in a unit cell; the transformation starts toform solid. Now, if unit cell is considered to be cubic as in case of gold (Au), it will be having its dimensions in all three coordinates (X, Y and Z) and thesedimensions have to be at some angles (α, β and γ). These dimensions and angles are called parameters of a unit cell. As per Bravais, there are fourteen (14) possible space lattices and maximum materials existing in our surrounding are based on them.

The atoms are regarded as rigid sphere and are identical in size for a particular metal. In case of metals the most common types of unit cell are given below.

i) Body centered cubic (BCC) unit cell (Mo, Va, Mn, Nb, Cr, α-Fe etc.)
ii) Face centered cubic (FCC) unit cell (Al, Cu, Au, Ag, Pb, γ -Fe, etc.)
iii) Hexagonal closed packed (HCP) unit cell (Be, Ca, Mg, Zn, Cd, Ti, etc.)

In the development of unit cell the atoms are supposed to be at the lattice points. These lattice points in a unit cell are shown for FCC structure in figure 1.

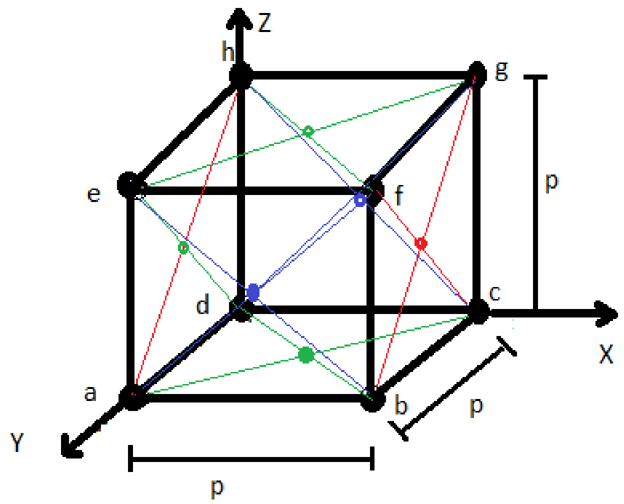

Figure-1

The FCC unit cell is shown in the diagram in Cartesian coordinates.
The side of the cube is shown by “p” equal for all sides.
In the figure letters a, b, c, d, e, f, g and h are the lattice points, where the atoms are supposed to occupy these sites.
There are six sites, at the diagonal of faces and atoms will occupy these sites also.
Total Number of atoms: 04
APF: 0.74

Arrangement of Atoms in Unit Cell:

In a unit cell at room temperature the arrangement of atoms can be in such way as shown in Figure-2 & Figure-3

i) In case of every cubic unit cell there is one atom at each corner of it.

ii) In case of BCC unit cell, one atom at the center of it.

iii) In case of FCC unit cell, one atom at the center of every face of it.

iv) In case of HCP unit cell, one atom at each corner and one atom at the center of upper and bottom face three atoms at the center plane; parallel to the bottom and upper face.

Sharing of Atoms in Unit Cell:

Sharing of atoms of in a unit cell is explained below in different possible ways. So the number of atoms in unit cell can be calculated by following it.

i) In every cubic unit cell, the atom at every corner shares with eight adjoining unit cells

ii) In case of BCC unit cell, the atom at center of the body shares all atoms at corner

iii) In case of FCC unit cell, the atom at the face shares half of it and half to the adjoining unit cell

iv) In case of HCP unit cell; each corner atom shares six adjoining unit cell. The atom at the top face and bottom faces, shares half to adjoining unit cell. There are three atoms in the center plane of a unit cell

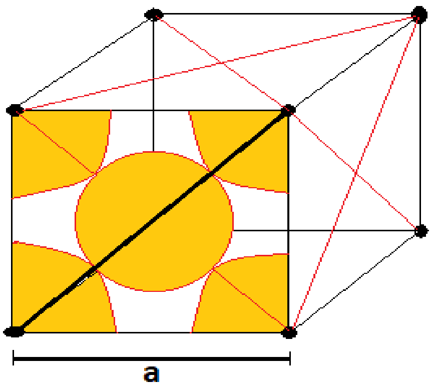

Figure-2

A FCC unit cell, showing atomic arrangement on one face and touching corner atoms. At other faces the atoms will be arranged in same way.

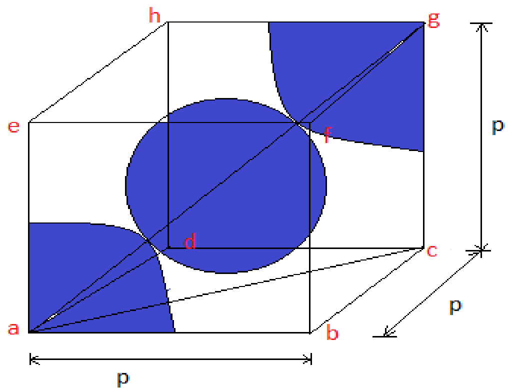

Figure-3

A BCC Unit Cell, showing how the atom at body centre, touching the corner atom and other corner atoms will also touch this, which are not shown.

Number of Atoms in a Unit Cell:

Based on above rules the number of atoms in a unit cell can be found out as below;

In case of BCC = (1/8) x 8 (corners) + 1 (at the center of body) = 2

In case of FCC = (1/8) x 8 (corners) + (1/2) x 6 (at the center of face) = 4

In case of HCP = 2{(1/6) x 6 (corners)} + (1/2) x 2 (at the center of upper and bottom face) + 3 (at thecenter of cell) = 6

Atomic Radius:

Apart from the sharing of atoms,some specific rules are there for atoms in different unit cell. In body centered cubic (BCC) unit cell the atom at the center; touches the atoms at the corner of it. In another case the atom at the center of a face centered cubic (FCC) unit cell touches the four atoms at the corner of the same face.

So based on the above rule; considering atom as sphere the atomic radius of it can be find out.(Figure-2 and figure- 3)

Atomic Packing Factor:

The atomic packing factor of a unit cell is the ratio of volume occupied by the atoms in a unit cell. It can be found out with the help of the relation between atomic radius and the dimension of the unit cell; and the number of atoms in a unit cell. In case of BCC, FCC and HCP unit cell it is 0.67, 0.74 and 0.74 respectively.

This way, development and the role of a unit cell can be understood very well. The internal atomic structure can be studied by X-ray diffraction method.

Crystal Structure and Imperfections:

A crystal is one in which all the atoms are arranged in a particular geometry, following the repetition of the unit cells. Sometimes a crystal is also known as grain. In actual practice; at the start of the atomic arrangement, number of unit cells start to form at various locations in different orientations. These unit cells are known as the nuclei and they grow with adjoining number of unit cells simultaneously at different locations in the molten material. This process of unit cells growing is called nucleation and growth.

With this phenomenon of the nucleation growth, these crystals meet with the nearby crystals and a boundary among them is formed, which is called crystal boundary(Figure-4). As the crystals are also known by grains; so crystal boundary are also known as grain boundary.In polycrystalline metal there are number of crystals which are separated from each other. These crystal structures and their boundaries can be seen by electron diffraction method and X-rays.

The properties of the materials are directly dependent on its structure. Scientists and Engineers are continuously in search of new materials; or creating new structures which are possible only on the basis of knowledge of earlier available structures. This way the new materials are developing since the Stone Age to Tailor Made Materials Age.

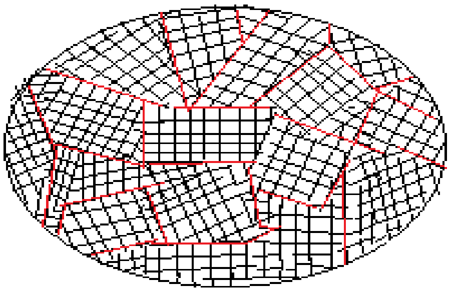

Figure-4A polycrystalline structure: Showing grain boundaries

The main objective of materials scientist is to investigate the relationships between the structure and the properties of a material.

Imperfection in Crystal Structure:

In actual practice itis very difficult task to achieve the perfect structure of a material. There is always some defect or disorder in the structure of a metal. The defects or imperfectionsmay be developed during solidification process. The disorder in the crystal structure may be with zero, one, two or three dimensions. Generally; the imperfections (defects) are classified in following ways;

i) Point Imperfection (Zero dimensional defect)
ii) Line imperfection or Dislocations (One dimensional defect)
iii) Surface or Grain Boundary Imperfection(Two dimensional defect)
iv) Volume Imperfection (Three dimensional defect)

In the interest of the development of metals, it is always made sure that there should not be any kind of imperfection in the crystal structure. Some time there is a need to create the impurities in an existing structure of a material; but actually it is not in sense of the defect rather it is the requirement of the designed material with some specific properties. Steel is an alloy of iron; in whichthe element carbon is added to increase the hardness and strength of it.

There are number of alloys which are developed to achieve some specific properties for engineering purposes.

Properties of Metals:

Materials are required to be tested with proposed standards to know their structure and the properties before use. The selection of material is very important task for an engineer, which is done based on the knowledge of the properties of materials. There are some important properties of engineering materials; such as physical, chemical, mechanical, electrical, thermal, magnetic and optical properties. This way it is very important to know about how the materials are developed and used based on their properties.

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