

14. Assignment topics with materials

1. What are the advanced materials?

These are materials used in *High-Tech* devices those operate based on relatively intricate and sophisticated principles (e.g. computers, air/space-crafts, electronic gadgets, etc.). These materials are either traditional materials with enhanced properties or newly developed materials with high-performance capabilities. Hence these are relatively expensive. Typical applications: integrated circuits, lasers, LCDs, fiber optics, thermal protection for space shuttle, etc. Examples: Metallic foams, inter-metallic compounds, multi-component alloys, magnetic alloys, special ceramics and high temperature materials, etc.

2. What are the future materials?

Group of new and state-of-the-art materials now being developed, and expected to have significant influence on present-day technologies, especially in the fields of medicine, manufacturing and defense. Smart/Intelligent material system consists some type of sensor (*detects an input*) and an actuator (*performs responsive and adaptive function*). Actuators may be called upon to change shape, position, natural frequency, mechanical characteristics in response to changes in temperature, electric/magnetic fields, moisture, pH, etc.

Four types of materials used as actuators: Shape memory alloys, Piezo-electric ceramics, Magnetostrictive materials, Electro-/Magneto-rheological fluids. Materials / Devices used as sensors: Optical fibers, Piezo-electric materials, Micro-electro-mechanical systems (MEMS), etc.

Typical applications: By incorporating sensors, actuators and chip processors into system, researchers are able to stimulate biological human-like behavior; Fibers for bridges, buildings, and wood utility poles; They also help in fast moving and accurate robot parts, high speed helicopter rotor blades; Actuators that control chatter in precision machine tools; Small microelectronic circuits in machines ranging from computers to photolithography prints; Health monitoring detecting the success or failure of a product.

3. What is anisotropy?

It's been agreed that many of the materials properties depend on the crystal structure. However, crystals are not symmetric in all directions, or not the crystal planes same with respect to atomic density/packing. Different directions in the crystal have different packing. For instance, atoms along the edge of FCC crystals are more separated than along its face diagonal. This causes properties to be different in different directions. This directionality of properties is termed as *Anisotropy*.

Substances in which measured properties are independent of direction in which they are measured are called *isotropic*. Though, in polycrystalline materials, the crystallographic orientations of individual grains are random, specimen may behave isotropically.

4. What is Elastic Behavior of Composites?

The idea is that by combining two or more distinct materials one can engineer a new

material with the desired combination of properties (e.g., light, strong, corrosion resistant). The idea that a better combination of properties can be achieved is called the *principle of combined action*.

For example, Pearlitic steel that combines hard and brittle Cementite with soft and ductile ferrite to get a superior material.

5. What are Atomic vibrations?

Atomic vibrations occur, even at zero temperature (a quantum mechanical effect) and increase in amplitude with temperature. In fact, the temperature of a solid is really just a measure of average vibrational activity of atoms and molecules. Vibrations displace *transiently* atoms from their regular lattice site, which destroys the perfect periodicity. In a sense, these atomic vibrations may be thought of as imperfections or defects. At room temperature, a typical vibrational frequency of atoms is of the order of 10^{13} vibrations per second, whereas the amplitude is a few thousandths of a nanometer. Many properties and processes in solids are manifestations of this vibrational atomic motion. For example:

melting occurs once the atomic bonds are overcome by vigorous vibrations.

6. Write about Kinetics of nucleation and growth

Structural changes in metallic systems usually take place by nucleation and growth whether it is just a phase change within one of the three states, or a simple structural rearrangement within a single phase, or a phase transformation. An equilibrium phase diagram presents the phases and phase changes expected under equilibrium conditions, but it provides no information about the rates of transformation. Although changes in pressure, composition, or temperature can cause phase transformations, it is temperature changes that are more important. From a micro structural standpoint, the first process to accompany a phase transformation is nucleation (i.e. the formation of very small particles or nuclei of the product phase from the parent phase) of the new phase particles which are capable of growing. The second stage is growth, in which the nucleated particles increase their size. The transformation reaches completion if growth of these new phase particles is allowed to proceed until the equilibrium fraction is attained.

7. Write about Growth kinetics

Many transformations occur as a result of continuous formation of critical nuclei in the parent phase and the subsequent growth of the particles. Growth is the increase in size of the particle after it has nucleated i.e. growth kinetics become important once an embryo has exceeded the critical size and become a stable nucleus.

8. Mechanisms of plastic deformation in metals

Plastic deformation, as explained in earlier section, involves motion of dislocations. There are two prominent mechanisms of plastic deformation, namely *slip* and *twinning*.

Slip is the prominent mechanism of plastic deformation in metals. It involves sliding of blocks of crystal over one other along definite crystallographic planes, called slip planes. In physical words it is analogous to a deck of cards when it is pushed from one end. Slip occurs when shear stress applied exceeds a critical value. During slip each atom usually moves same integral number of atomic distances along the slip plane producing a step, but the orientation of the crystal remains the same. Steps observable under microscope as straight lines are called slip lines.

Slip occurs most readily in specific directions (slip directions) on certain crystallographic planes. This is due to limitations imposed by the fact that single crystal remains homogeneous after deformation. Generally slip plane is the plane of greatest atomic density, and the slip direction is the close packed direction within the slip plane. It turns out that the planes of the highest atomic density are the most widely spaced planes

9. Explain Strengthening mechanism in Metals

Ability of a metal to deform plastically depends on ease of dislocation motion under applied external stresses. As mentioned in earlier section, strengthening of a metal consist hindering dislocation motion. Dislocation motion can be hindered in many ways, thus are strengthening mechanisms in metals. Strengthening by methods of grain-size reduction, solid-solution alloying and strain hardening applies for single-phase metals. Precipitation hardening, dispersion hardening, fiber strengthening and Martensite strengthening are applicable to multi-phase metallic materials.

10. What is strain hardening?

Strain Hardening

Two most important industrial processes used to harden metals or alloys are: strain hardening and heat treatment. Strain hardening is used for hardening/strengthening materials that are not responsive to heat treatment. The phenomenon where ductile metals become stronger and harder when they are deformed plastically is called strain hardening *or* work hardening.

Intensity of strain hardening can be gaged from the slope of the flow curve, defined by the parameter strain hardening exponent, n . It is measure of the ability of a metal to strain harden. For a given amount of plastic strain, higher the value of n , greater is the strain hardening. Increasing temperature lowers the rate of strain hardening, and thus the treatment is given, usually, at temperatures well below the melting point of the material. Thus the treatment is also known as *cold working*. Most metals strain hardens at room temperature. The consequence of strain hardening a material is improved strength and hardness but material's ductility will be reduced.

16. Unit wise-Question bank

Unit wise-Question bank

1	Two marks question with answers	5 questions
2	Three marks question with answers	5 questions
3	Five marks question with answers	5 questions
4	Objective question with answers	10 questions
5	Fill in the blanks question with answers	10 questions

UNIT I

2MARKS QUESTIONS WITH ANSWERS

1. What is A.P.F?

It can be defined as the ratio between the volume of the basic atoms of the unit cell (which represent the volume of all atoms in one unit cell) to the volume of the unit cell itself.

2. What is grain boundary?

A grain boundary (GB) is the interface between two grains, or crystallites, in a polycrystalline material. Grain boundaries are defects in the crystal structure, and tend to decrease the electrical and thermal conductivity of the material.

3. Write in brief about ASTM method.

ASTM method:

In this method the grain size is determined by the formula

$$N=2n-1 \text{ Where } n= \text{ASTM grain size } n \text{ number}$$

4. Define solid solution.

When two metals are mixed together they form an alloy if one metal is soluble in the other one in solid state. Therefore, an alloy is a solid solution of two or more metals.

5. Define substitutional solid solution.

Substitutional– Solute atoms occupy the regular lattice sites of the parent metal (solvent). Substitutional solid solutions can be random (Cu-Ni) or ordered (Cu-Au).

These are further divided into two types

1) Ordered solid solutions

2) Disordered solid solutions.

3MARKS QUESTIONS WITH ANSWERS

1. What is the methodology to define crystallographic directions in cubic crystal?

Methodology to define crystallographic directions in cubic crystal:

- A vector of convenient length is placed parallel to the required direction.
- The length of the vector projection on each of three axes is measured in unit cell dimensions.
- These three numbers are made to smallest integer values, known as indices, by multiplying or dividing by a common factor.
- The three indices are enclosed in square brackets, [uvw]. A family of directions is represented by $\langle uvw \rangle$.

2. What is the methodology to define crystallographic planes in cubic crystal?

Methodology to define crystallographic planes in cubic crystal:

- Determine the intercepts of the plane along the crystallographic axes, in terms of unit cell dimensions. If plane is passing through origin, there is a need to construct a plane parallel to original plane.
- Take the reciprocals of these intercept numbers.
- Clear fractions.
- Reduce to set of smallest integers.
- The three indices are enclosed in parenthesis, (hkl). A family of planes is represented by {hkl}.

3. Explain planimetric method used for determination of grain size

The Planimetric Method

Planimetric method written by Zay Jeffries, based upon earlier work. The ASTM equation relating the number of grains per in² at 100X and the ASTM grain size number were introduced in 1951 by an undocumented Timken member of E-4 when E 91-51T was introduced [5]. The equation is: $n = 2G-1$

4. Explain Heyn Intercept method used for determination of grain size

The Heyn Intercept Method

To do the intercept method, one counts either grain boundary intersections, P, or grains intercepted, N, by the circles. For a single phase structure, it is easier to do P counts. The P or N count is divided by the true line length, LT, which is the line length divided by the magnification, L/M. The mean lineal intercept is related to G by the following empirical equation:

$$G = (-6.6457 \log L3) - 3.298$$

5. What is phase equilibrium?

Phase equilibrium – it refers to the set of conditions where more than one phase may exist. It can be reflected by constancy with time in the phase characteristics of a system. In most metallurgical and materials systems, phase equilibrium involves just solid phases. However the state of equilibrium is never completely achieved because of very slow rate of approach of equilibrium in solid systems.

5MARKS QUESTIONS WITH ANSWERS

1. What are point defects? Explain in detail.

Defects exist in all solid materials. For ease of their characterization, defects are classified on the basis of their geometry, which is realistic as defects are disrupted regions. Point defects, as the name implies, are imperfect point-like regions in the crystal. Typical size of a point defect is about 1-2 atomic diameters. Different point defects are explained in the following paragraphs. Figure-3.2 depicts various point defects.

A vacancy is a vacant lattice position from where the atom is missing. It is usually created when the solid is formed by cooling the liquid. There are other ways of making a vacancy, but they also occur naturally as a result of thermal excitation, and these are thermodynamically stable at temperatures greater than zero. At equilibrium, the fraction of lattice sites that are vacant at a given temperature (T) are:

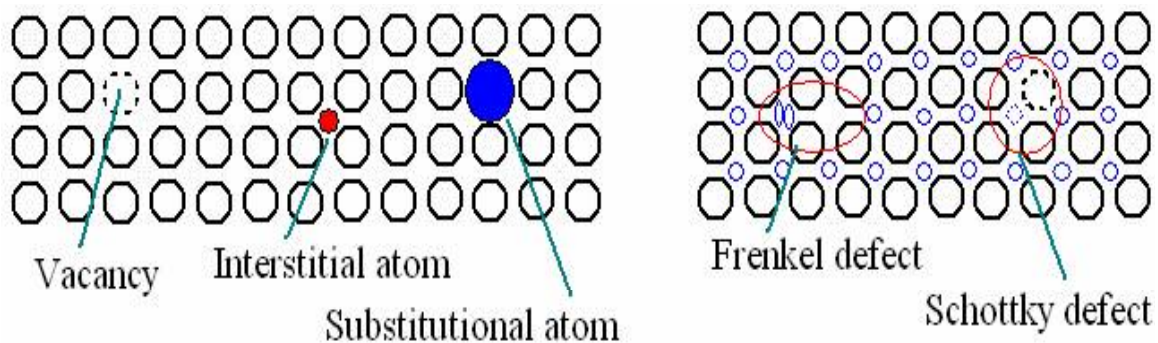


Figure: Schematic depiction of various point defect

An interstitial atom or interstitiality is an atom that occupies a place outside the normal lattice position. It may be the same type of atom as the rest surrounding it (self interstitial) or a foreign impurity atom. Interstitiality is most probable if the atomic packing factor is low.

Another way an impurity atom can be fitted into a crystal lattice is by substitution. A substitutional atom is a foreign atom occupying original lattice position by displacing the parent atom

In ionic crystals, existence of point defects is subjected to the condition of charge neutrality. There are two possibilities for point defects in ionic solids.

When an ion displaced from a regular position to an interstitial position creating a vacancy, the pair of vacancy-interstitial is called Frenkel defect. Cations are usually smaller and thus displaced easily than anions. Closed packed structures have fewer interstitials and displaced ions than vacancies because additional energy is required to force the atoms into the interstitial positions.

A pair of one cat ion and one anion can be missing from an ionic crystal, without violating the condition of charge neutrality when the valency of ions is equal. The pair of vacant sites, thus formed, is called Schottky defect. This type of point defect is dominant in alkali halides. These ion-pair vacancies, like single vacancies, facilitate atomic diffusion.

2. What are line defects? Explain in detail.

Line defects or Dislocations:

Line imperfections (one-dimensional defects) are also called Dislocations. They are abrupt changes in the regular ordering of atoms along a line (dislocation line) in the solid. They occur in high densities and strongly influence the mechanical properties of material. They are characterized by the Burgers vector (**b**), whose direction and magnitude can be determined by constructing a loop around the disrupted region and noticing the extra inter-atomic spacing needed to close the loop. The Burgers vector in metals points in a close packed lattice direction. It is unique to a dislocation.

Dislocations occur when an extra incomplete plane is inserted. The dislocation line is at the end of the plane. Dislocations can be best understood by referring to two limiting cases - Edge dislocation and Screw dislocation.

3. What is edge dislocation?

Edge dislocation or Taylor-Orowan dislocation is characterized by a Burger's vector that is perpendicular to the dislocation line. It may be described as an edge of an extra plane of atoms within a crystal structure. Thus regions of compression and tension are associated with an edge dislocation. Because of extra incomplete plane of atoms, the atoms above the dislocation line are squeezed together and are in state of compression whereas atoms below are pulled apart and experience tensile stresses. Edge dislocation is considered positive when compressive stresses present above the dislocation line, and is represented by \perp . If the stress state is opposite i.e. compressive stresses exist below the dislocation line, it is considered as negative edge dislocation, and represented by \top . A schematic view of edge dislocations are shown in figure.



Figure Edge dislocations.

A pure edge dislocation can glide or slip in a direction perpendicular to its length i.e. along its Burger's vector in the slip plane (made of \mathbf{b} and \mathbf{t} vectors), on which dislocation moves by slip while conserving number of atoms in the incomplete plane. It may move vertically by a process known as climb, if diffusion of atoms or vacancies can take place at appropriate rate. Atoms are added to the incomplete plane for negative climb i.e. the incomplete plane increases in extent downwards, and vice versa. Thus climb motion is considered as non-conservative, the movement by climb is controlled by diffusion process.

4. What is screw dislocation?

Screw dislocation or Burgers dislocation has its dislocation line parallel to the Burger's vector. A screw dislocation is like a spiral ramp with an imperfection line down its axis. Screw dislocations result when displacing planes relative to each other through shear. Shear stresses are associated with the atoms adjacent to the screw dislocation; therefore extra energy is involved as it is in the case of edge dislocations. Screw dislocation is considered positive if Burger's vector and \mathbf{t} -vector or parallel, and vice versa. (\mathbf{t} -vector – an unit vector representing the direction of the dislocation line). A positive screw dislocation is represented by \odot "a dot surrounded by circular direction in clock-wise direction", whereas the negative screw dislocation is represented by \ominus "a dot surrounded by a circular direction in anti-clock-wise direction". A schematic view of a negative screw dislocation is shown in figure

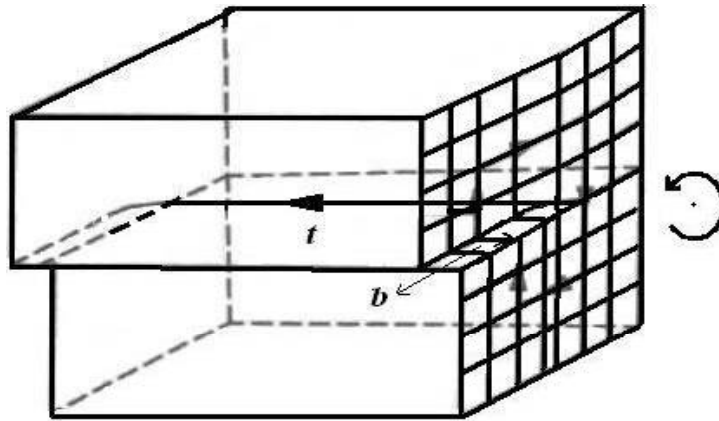


Figure-3.4: Negative screw dislocation.

A screw dislocation does not have a preferred slip plane, as an edge dislocation has, and thus the motion of a screw dislocation is less restricted than the motion of an Edge dislocation. As there is no preferred slip plane, screw dislocation can cross-slip on to another plane, and can continue its glide under favorable stress conditions. However, screw dislocation cannot move by climb process, whereas edge dislocations can not cross-slip.

5. Explain interfacial defects in detail

Interfacial defects

Interfacial defects can be defined as boundaries that have two dimensional imperfections in crystalline solids, and have different crystal structures and/or crystallographic orientations on either side of them. They refer to the regions of distortions that lie about a surface having thickness of a few atomic diameters.

Grain boundaries: Crystalline solids are, usually, made of number of grains separated by grain boundaries. Grain boundaries are several atoms distances wide, and there is mismatch of orientation of grains on either side of the boundary as shown in figure-3.6. When this misalignment is slight, on the order of few degrees ($< 10^\circ$), it is called low angle grain boundary. These boundaries can be described in terms of aligned dislocation arrays. If the low grain boundary is formed by edge dislocations, it is called tilt boundary, and twist boundary if formed of screw dislocations. Both tilt and twist boundaries are planar surface imperfections in contrast to high angle grain boundaries. For high angle grain boundaries, degree of disorientation is of large range ($> 15^\circ$). Grain boundaries are chemically more reactive because of grain boundary energy. In spite of disordered orientation of atoms at grain boundaries, polycrystalline solids are still very strong as cohesive forces present within and across the boundary.

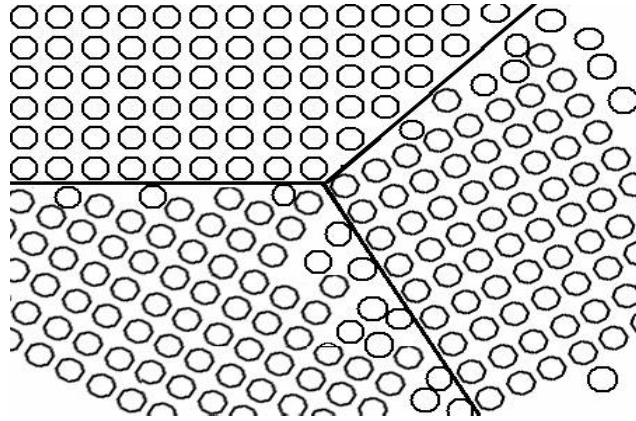


Figure: Schematic presentation of grain boundaries

MULTIPLE CHOICE QUESTIONS WITH ANSWERS

1. Particles that most effects material properties
 - (a) Neutrons
 - (b) Protons
 - (c) Electrons
 - (d) Valence electrons
2. Mean distance between atoms in the range of
 - (a) 25 nm
 - (b) 2.5 nm
 - (c) 0.25 nm
 - (d) 0.025 nm
3. Which one of the following is not a strong bond?
 - (a) van der Waals bond
 - (b) Covalent bond
 - (c) Metallic bond
 - (d) Ionic bond
4. Bond strength of secondary bonds is in the range of
 - a) 1 kJ/mol
 - b) 10 kJ/mol
 - c) 100 kJ/mol
 - d) 1000 kJ/mol
5. Electron sea exists in
 - (a) Polar bonds
 - (b) Ionic bond
 - (c) Covalent bond
 - (d) Metallic bond

6. Repeatable entity of a crystal structure is known as
 (a) Crystal
 (b) Lattice
 (c) Unit cell
 (d) Miller indices
7. Coordination number for closest packed crystal structure
 (a) 16 (b) 12 (c) 8 (d) 4
8. Atomic packing factor is
 (a) Distance between two adjacent atoms
 (b) Projected area fraction of atoms on a plane
 (c) Volume fraction of atoms in cell
 (d) None
9. Coordination number in simple cubic crystal structure
 (a) 1
 (b) 2
 (c) 3
 (d) 4
10. The atomic diameter of an BCC crystal (if a is lattice parameter) is
 (a) a
 (b) $a/2$
 (c) $a/(4/\sqrt{3})$
 (d) $a/(4/\sqrt{2})$
1. d 2. c 3. a 4. b 5. d 6. c 7. b 8. c 9. b 10. c

FILL IN THE BLANKS WITH ANSWERS

11. A family of directions is represented by _____
12. Miller indices for Octahedral plane in cubic crystal _____
13. The plane (1- 11) is parallel to _____
14. The angle between [111] and [11-2] directions in a cubic crystal is (in degrees)

15. Miller indices of the line of intersection of (-1-11) and (110) are _____
16. Repeatable unit of polymers is _____
17. What is the example thermo-plastic _____
18. For coordination number of four, anion sits at the center ofwhere corners are occupied by cations _____
19. Layered silicate structures in clays consists the following group _____
20. Schottky-defect in ceramic material is _____

ANSWERS

- 11) $\langle uvw \rangle$ 12) (111) 13) (-11-1) 14) 90 15) [-110] 16) mer
 17) Vinyls 18) Tetrahedron 19) Si2O5 20) Pair of nearby cation and anion vacancies

UNIT II

2MARKS QUESTIONS WITH ANSWERS

1. Define phase

A phase can be defined as a physically distinct and chemically homogeneous portion of a system that has a particular chemical composition and structure.

2. Define component

Component – is either pure metal and/or compounds of which an alloy is composed. The components of a system may be elements, ions or compounds. They refer to the independent chemical species that comprise the system.

3. Define system

System – it can either refer to a specific body of material under consideration or it may relate to the series of possible alloys consisting of the same components but without regards to alloy composition.

4. Define solid solution

Solid solution – it consists of atoms of at least two different types where solute atoms occupy either substitutional or interstitial positions in the solvent lattice and the crystal structure of the solvent is maintained.

5. Define eutectic system

Eutectic system: Many binary systems have components which have limited solid solubility, e.g.: Cu-Ag, Pb-Sn. The regions of limited solid solubility at each end of a phase diagram are called terminal solid solutions as they appear at ends of the diagram.

3MARKS QUESTIONS WITH ANSWERS

1. Define gibb's phase rule

The number of degrees of freedom, F (no. of independently variable factors), number of components, C , and number of phases in equilibrium, P , are related by Gibbs phase rule as

$$F = C - P + 2$$

Number of external factors = 2 (pressure and temperature).

For metallurgical system pressure has no appreciable effect on phase equilibrium and hence, $F = C - P + 1$

2. What is solubility limit?

Solubility limit – for almost all alloy systems, at a specific temperature, a maximum of solute atoms can dissolve in solvent phase to form a solid solution. The limit is known as solubility limit. In general, solubility limit changes with temperature. If solute available is

more than the solubility limit that may lead to formation of different phase, either a solid solution or compound.

3. What are variables in phase diagram

Variables of a system – these include two external variables namely temperature and pressure along with internal variable such as composition (C) and number of phases (P). Number of independent variables among these gives the degrees of freedom (F) or variance.

4. What is the procedure for finding equilibrium relative amounts of phases

Procedure to find equilibrium relative amounts of phases (lever rule):

A tie-line is constructed across the two phase region at the temperature of the alloy to intersect the region boundaries.

The relative amount of a phase is computed by taking the length of tie line from overall composition to the phase boundary for the other phase, and dividing by the total tie-line length.

5. What are Isomorphous binary phase diagrams?

Isomorphous binary phase diagrams are found in a number of metallic and ceramic systems. In the isomorphous systems, only one solid phase forms; the two components in the system display complete solid solubility.

5MARKS QUESTIONS WITH ANSWERS

1. What is equilibrium phase diagram?

Equilibrium Phase Diagrams

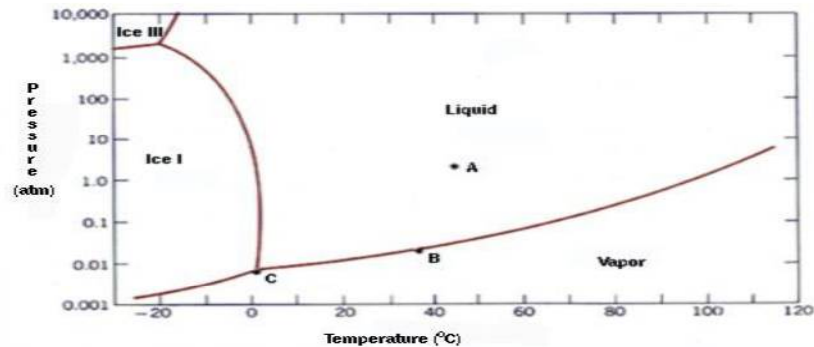
A diagram that depicts existence of different phases of a system under equilibrium is termed as phase diagram. It is also known as equilibrium or constitutional diagram. Equilibrium phase diagrams represent the relationships between temperature and the compositions and the quantities of phases at equilibrium. In general practice it is sufficient to consider only solid and liquid phases, thus pressure is assumed to be constant (1 atm.) in most applications. These diagrams do not indicate the dynamics when one phase transforms into another. However, it depicts information related to microstructure and phase structure of a particular system in a convenient and concise manner. Important information, useful for the scientists and engineers who are involved with materials development, selection, and application in product design, obtainable from a phase diagram can be summarized as follows:

- To show phases are present at different compositions and temperatures under slow cooling (equilibrium) conditions.
- To indicate equilibrium solid solubility of one element/compound in another.
- To indicate temperature at which an alloy starts to solidify and the range of solidification.
- To indicate the temperature at which different phases start to melt.

- Amount of each phase in a two-phase mixture can be obtained.

2. Explain unary phase diagram.

Unary diagrams: In these systems there is no composition change ($C=1$), thus only variables are temperature and pressure. Thus in region of single phase two variables (temperature and pressure) can be varied independently. If two phases coexist then, according to Phase rule, either temperature or pressure can be varied independently, but not both. At triple points, three phases can coexist at a particular set of temperature and pressure. At these points, neither temperature nor the pressure can be changed without disrupting the equilibrium i.e. one of the phases may disappear. Figure-1 depicts phase diagram for water.



3. What are intermediate phases?

Intermediate phases: An intermediate phase may occur over a composition range (intermediate solid solution) or at a relatively fixed composition (compound) inside the phase diagram and are separated from other two phases in a binary diagram by two phase region. Many phase diagrams contain intermediate phases whose occurrence cannot be readily predicted from the nature of the pure components. Intermediate solid solutions often have higher electrical resistivities and hardness than either of the two components. Intermediate compounds form relatively at a fixed composition when there exists a stoichiometric relationship between the components, for example: Mg_2Ni and $MgNi_2$ in Mg-Ni system. These are called inter-metallic compounds, and differ from other chemical compounds in that the bonding is primarily metallic rather than ionic or covalent, as would be found with compounds in certain metal-nonmetal or ceramic systems. Some metal-nonmetal compounds, Fe_3C , are metallic in nature, whereas in others, MgO and Mg_2Si , bonding is mainly covalent. When using the lever rules, inter-metallic compounds are treated like any other phase, except they appear not as a wide region but as a vertical line.

4. What is precipitation strengthening?

The precipitation strengthening process involves the following three basic steps:

Solutionizing (solution heat treatment), where the alloy is heated to a temperature

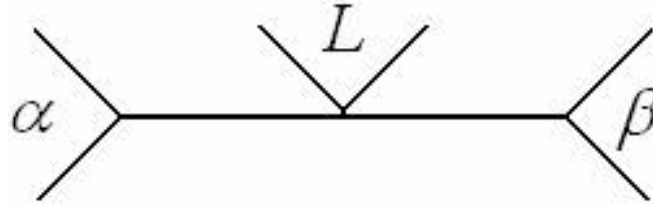
between solvus and solidus temperatures and kept there till a uniform solid- solution structure is produced.

Quenching, where the sample is rapidly cooled to a lower temperature (room temperature) and the cooling medium is usually water. Alloy structure in this stage consists of supersaturated solid solution.

Aging is the last but critical step. During this heat treatment step finely dispersed precipitate particle will form. Aging the alloy at room temperature is called natural aging, whereas at elevated temperatures is called artificial aging. Most alloys require artificial aging, and aging temperature is usually between 15-25% of temperature difference between room temperature and solution heat treatment temperature.

5. Explain invariant reactions?

Invariant reactions: The eutectic reaction, in which a liquid transforms into two solid phases, is just one of the possible three-phase invariant reactions that can occur in binary systems those are not isomorphous. Schematically it can be shown as in figure-9. It represents that a liquid phase, **L**, transforms into two different solids phases (**α** and **β**) upon cooling during the eutectic reaction.



Schematic of eutectic invariant reaction.

Reaction	Symbolic equation	Schematic presentation	Example
Eutectic	$L \leftrightarrow \alpha + \beta$		Fe-C, 4.27% C,
Eutectoid	$\alpha \leftrightarrow \beta + \gamma$		Fe-C, 0.80% C,
Peritectic	$L + \alpha \leftrightarrow \beta$		Fe-C, 0.16% C, 1495 °C
Peritectoid	$\alpha + \beta \leftrightarrow \gamma$		
Monotectic	$L_1 \leftrightarrow L_2 + \alpha$		Fe-C, 0.51% C, 1495 °C

MULTIPLE CHOICE QUESTIONS WITH ANSWERS

1 .Gibbs phase rule for general system:

- (a) $P+F=C-1$
- (b) $P+F=C+1$
- (c) $P+F=C-2$
- (d) $P+F=C+2$

2. In a single-component condensed system, if degree of freedom is zero, maximum number of phases that can co exist .

- (a) 0
- (b) 1
- (c) 2
- (d) 3

3. The degree of freedom at triple point in unary diagram for water.

- (a) 0
- (b) 1
- (c) 2
- (d) 3



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4. above the following line, liquid phase exist for all compositions in a phase diagram.

- (a) Tie-line
- (b) Solvus
- (c) Solidus
- (d) Liquidus

5. Following is wrong about a phase diagram.

- (a) It gives information on transformation rates.
- (b) Relative amount of different phases can be found under given equilibrium conditions.
- (c) It indicates the temperature at which different phases start to melt.
- (d) Solid solubility limits are depicted by it.

6. Not a Hume-Ruthery condition:

- (a) Crystal structure of each element of solid solution must be the same.
- (b) Size of atoms of each two elements must not differ by more than 15%.
- (c) Elements should form compounds with each other.
- (d) Elements should have the same valence.

7. Pick the odd one in the following:

- (a) Isomorphous alloy
- (b) Terminal solid solution
- (c) Intermediate solid solution
- (d) Compound

8. The boundary line between (liquid) and (liquid+solid) regions must be part of _____.

- (a) Solvus
- (b) Solidus
- (c) Liquidus
- (d) Tie-line

9. The boundary line between (liquid+solid) and (solid) regions must be part of _____.

- (a) Solvus
- (b) Solidus
- (c) Liquidus
- (d) Tie-line

10. The boundary line between (alpha) and (alpha+beta) regions must be part of _____.

- (a) Solvus
- (b) Solidus
- (c) Liquidus
- (d) Tie-line

ANSWERS

1. d 2.c 3.a 4.c 5.a 6.c 7.a 8.c 9.b 10.a



FILL IN THE BLANKS WITH ANSWERS

11. Horizontal arrest in a cooling curve represents _____
12. Relative amounts of phases in a region can be deduced using _____
13. An invariant reaction that produces a solid up on cooling two liquids is _____
14. A solid + a liquid result in a liquid up on heating during _____ reaction.
15. A solid + a liquid result in a solid up on cooling during _____ reaction.
16. On heating, one solid phase results in another solid phase plus on liquid phase during ____ reaction.
17. A solid phase results in a solid plus another solid phase up on cooling during _____ reaction.
18. A solid phase results in a solid plus another solid phase up on heating during _____ reaction.
19. A liquid phase produces two solid phases during _____ reaction up on cooling.
20. Liquid phase is involved in the following reaction:

ANSWERS

- 11) Invariant reaction 12) Lever rule 13) Syntectic
14) Monotectic 15) Peritectic 16) Peritectic
17) Eutectoid 18) Peritectoid 19) Eutectic 20) Eutectoid



2MARKS QUESTIONS WITH ANSWERS

1. What is α -ferrite?

α -ferrite - solid solution of C in BCC Fe

It is Stable form of iron at room temperature. The maximum solubility of C is 0.022wt% it transforms to FCC-austenite at 912 °C

2. What is γ -austenite?

γ -austenite - solid solution of C in FCC Fe

The maximum solubility of C is 2.14 wt %. It transforms to BCC δ -ferrite at 1395 °C. It is not stable below the eutectic temperature (727° C) unless cooled rapidly

3. What is δ -ferrite?

δ -ferrite solid solution of C in BCC Fe The same structure as α -ferrite. It is stable only above 1394 °C Melts at 1538 °C

4. What are the Factors affecting TTT diagram?

Factors affecting TTT diagram Composition of steel-

(a) Carbon wt%,

(b) Alloying element wt%

5. What is Case Hardening?

In case hardening, the surface of the steel is made hard and wear resistant, but the core remains soft and tough. Such a combination of properties is desired in applications such as gears.

3MARKS QUESTIONS WITH ANSWERS

1. Define cementite?

Fe_3C (iron carbide or cementite)

This is intermetallic compound is meta stable, it remains as a compound indefinitely at room T, but decomposes (very slowly, within several years) into α -Fe and C (graphite) at 650 - 700

2. What is Flame hardening?

Flame hardening

For large work pieces and complicated cross-sections induction heating is not easy to apply. In such cases, flame hardening is done by means of an oxyacetylene torch. Heating should be done rapidly by the torch and the surface quenched, before appreciable heat transfer to the core occurs



3. How Austempering is different from martempering?

Austempering is different from martempering in the sense that it involves austenite-to-bainite transformation. Thus, the structure of austempered steel is bainite. Advantages of austempering are – improved ductility; decreased distortion and disadvantages are – need for special molten bath; process can be applied to limited number of steels.

4. What is tempering?

Tempering is the process of heating martensitic steel at a temperature below the eutectoid transformation temperature to make it softer and more ductile. During the tempering process, Martensite transforms to a structure containing iron carbide particles in a matrix of ferrite.

5. What is hardenability?

The hardenability of a metal alloy is the depth up to which a material is hardened after putting through a heat treatment process. The unit of hardenability is the same as of length. It is an indication of how deep into the material certain hardness can be achieved. It should not be confused with hardness, which is a measure of a sample's resistance to indentation or scratching. It is an important property for welding, since it is inversely proportional to weldability, that is, the ease of welding a material.

5MARKS QUESTIONS WITH ANSWERS

1. Explain Bainite in detail.

Bainite: first described by E. S. Davenport and Edgar Bain, is a phase that exists in steel microstructures after certain heat treatments. Bainite is one of the decomposition products that may form when austenite is cooled past the eutectoid temperature of 727 °C. Appearing as a fine non-lamellar structure, bainite commonly consists of ferrite, carbide, and retained austenite. In these cases it is similar in constitution to pearlite, but with the ferrite forming by a displacement mechanism similar to martensite formation, usually followed by precipitation of carbides from the supersaturated ferrite or austenite. The temperature range for transformation to bainite is between those for pearlite and martensite. When formed during continuous cooling, the cooling rate to form bainite is higher than that required to form pearlite, but lower than that to form martensite, in steel of the same composition.

2. Write notes on hardenability of ferrous alloys.

The hardenability of ferrous alloys, i.e. steels, is a function of the carbon content and other alloying elements and the grain size of the austenite. The relative importance of the various alloying elements is calculated by finding the equivalent carbon content of the material. The fluid used for quenching the material influences the cooling rate due to varying thermal conductivities and specific heats. Substances like brine and water cool much more quickly than oil or air. Additionally, if the fluid is agitated cooling occurs even more quickly. The geometry of the part also affects the cooling rate: of two samples of equal volume, the one with higher surface area will cool faster.

The hardenability of a ferrous alloy is measured by a Jominy test: a round metal bar of standard size (indicated in the top image) is transformed to 100% austenite through heat treatment, and is then quenched on one end with room-temperature water. The cooling rate



will be highest at the end being quenched, and will decrease as distance from the end increases. Subsequent to cooling a flat surface is ground on the test piece and the hardenability is then found by measuring the hardness along the bar.

3. Write notes on alloy steels.

Alloy steel is steel that is alloyed with a variety of elements in total amounts between 1.0% and 50% by weight to improve its mechanical properties. Alloy steels are broken down into two groups: low-alloy steels and high-alloy steels.

Strictly speaking, every steel is an alloy, but not all steels are called "alloy steels". The simplest steels are iron (Fe) alloyed with carbon (C) (about 0.1% to 1%, depending on type). However, the term "alloy steel" is the standard term steels with other alloying elements added deliberately in addition to the carbon. Common include manganese (the most common one), nickel, chromium, molybdenum, vanadium, silicon, and boron. Less include aluminum, cobalt, copper, cerium, niobium, titanium, tungsten, tin, zinc, lead, and zirconium

The following is a range of improved properties in alloy steels (as compared to carbon steels): strength, hardness, toughness, wear resistance, corrosion resistance, hardenability, and hot hardness. To achieve some of these improved properties the metal may require heat treating.

Some of these find uses in exotic and highly-demanding applications, such as in the turbine blades of jet engines, in spacecraft, and in nuclear reactors. Because of the ferromagnetic properties of iron, some steel alloys find important applications where their responses to magnetism are very important, including in electric motors and in transformers.

4. Explain isothermal transformations in detail

Isothermal transformation diagrams (also known as time-temperature-transformation (TTT) diagrams) are plots of temperature versus time (usually on a logarithmic scale). They are generated from percentage transformation-vs time measurements, and are useful for understanding the transformations of an alloy steel at elevated temperatures. An isothermal transformation diagram is only valid for one specific composition of material, and only if the temperature is held constant during the transformation, and strictly with rapid cooling to that temperature. Though usually used to represent transformation kinetics for steels, they also can be used to describe the kinetics of crystallization in ceramic or other materials.

Isothermal transformation (IT) diagram or the C-curve is associated with mechanical properties, micro constituents/microstructures, and heat treatments in carbon steels. Diffusion transformations like austenite transforming to cementite and ferrite mixture can be explained using the sigmoidal curve; For example the beginning of pearlitic transformation is represented by the pearlite start (P_s) curve. This transformation is complete at P_f curve. Nucleation requires an incubation time. The rate of nucleation increases and the rate of micro constituent growth decreases as the temperature decreases from the liquidus temperature reaching a maximum at the bay or nose of the curve. Thereafter, the decrease in



diffusion rate due to low temperature offsets the effect of increased driving force due to greater difference in free energy.

5. What is annealing process?

Annealing processes

The term annealing was used by craftsmen who discovered the beneficial effects of heating the material at elevated temperatures followed by slow cooling of it to room temperature. Annealing can be defined as a heat treatment process in which the material is taken to a high temperature, kept there for some time and then cooled. High temperatures allow diffusion processes to occur fast. The time at the high temperature (soaking time) must be long enough to allow the desired transformation to occur. Cooling is done slowly to avoid the distortion (warping) of the metal piece, or even cracking, caused by stresses induced by differential contraction due to thermal non homogeneities. Benefits of annealing are:

- relieve stresses
- increase softness, ductility and toughness
- produce a specific microstructure

Depending on the specific purpose, annealing is classified into various types: process annealing, stress relief, full annealing and normalizing.

Process annealing is primarily applied to cold worked metals to negate the effects of cold work. During this heat treatment, material becomes soft and thus its ductility will be increased considerably. It is commonly sandwiched between two cold work operations. During this, recovery and recrystallization are allowed whereas grain growth was restricted.

Process annealing, also called intermediate annealing, subcritical annealing, or in-process annealing, is a heat treatment cycle that restores some of the ductility to a product being cold-worked so it can be cold-worked further without breaking.

The temperature range for process annealing ranges from 260 °C (500 °F) to 760 °C (1400 °F), depending on the alloy in question. This process is mainly suited for low-carbon steel. The material is heated up to a temperature just below the lower critical temperature of steel. Cold-worked steel normally tends to possess increased hardness and decreased ductility, making it difficult to work. Process annealing tends to improve these characteristics. This is mainly carried out on cold-rolled steel like wire-drawn steel, etc.

MULTIPLE CHOICE QUESTIONS WITH ANSWERS

1. Melting point of iron in degree centigrade is equal to
 - a) 768
 - b) 1535



- c) 1410
- d) 910

2. Iron carbon phase diagram is

- a) Unary phase
- b) Binary phase
- c) Tertiary phase
- d) none of the mentioned

3. Peritectic reaction in iron carbon diagram takes place at temperature (in degree centigrade) is

- a) 1539
- b) 1493
- c) 910
- d) 1175

4. Eutectic reaction in iron carbon diagram takes place at temperature (in degree centigrade) is

- a) 1539
- b) 1493
- c) 910
- d) 1150

5. Eutectoid reaction in iron carbon diagram takes place at temperature (in degree centigrade) is

- a) 1120
- b) 725
- c) 910
- d) 820

6. Percentage of carbon at eutectic point is equal to

- a) 2.1
- b) 4.3
- c) 0.83
- d) 0.02

7. Percentage of carbon at eutectoid point is equal to

- a) 2.1
- b) 4.3
- c) 0.83
- d) 0.11

8. Percentage of carbon at peritectic point is equal to

- a) 2.1
- b) 4.3
- c) 0.83



d) 0.18

9. In which of the following reaction in iron carbon diagram no mushy zone is obtained?

- a) Eutectic reaction
- b) Peritectic reaction
- c) Eutectoid reaction
- d) Peritectoid reaction

10. γ form of iron has which of the following property?

- a) Magnetic
- b) Non magnetic
- c) Occurs below 768 degree centigrade
- d) Occurs above 1410 degree centigrade

1.b	2.c	3.b	4.c	5.b	6.b	7.c	8.d	9.b	10. b
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FILL IN THE BLANKS WITH ANSWERS

- 11. Which is not equilibrium heat treatment _____
- 12. The hardenability is not affected by _____
- 13. The slowest cooling rate is obtained when steel is quenched in _____
- 14. The fastest cooling rate is achieved when steel is quenched in _____
- 15. Which one of the following is not correct _____
- 16. Harden ability of steel is assessed by _____
- 17. Annealing temperature is _____
- 18. Heat treatment that requires heating a part below A_1 temperature, i.e. between 550°C and 650° is called as _____
- 19. What is the maximum solubility of carbon in iron _____
- 20. Which is the hardest structure of iron carbide diagram _____

ANSWERS

11) Precipitation 12) air 13) air 14) brine 15) The marten site which is formed during quenching is too brittle 16) hardness test 17) less than normalizing temperature 18) process annealing 19) 6.67 20) martensite



Unit IV

2MARKS QUESTIONS WITH ANSWERS

1. What is θ' phase in aluminium phase diagram?

θ' phase:- This phase nucleates heterogeneously especially on dislocations. It has tetragonal structure but is partially coherent with the matrix. This phase forms platelets with thickness 10-150 nm.

2. Write about Commercially Pure Titanium Grade 1.

Commercially Pure Titanium Grades

Grade 1

Grade 1 titanium is the first of four commercially pure titanium grades. It is the softest and most ductile of these grades. It possesses the greatest formability, excellent corrosion resistance and high impact toughness.

Applications:

Chemical processing, Chlorate manufacturing, Dimensional stable anodes, Desalination, Architecture, Medical industry, Marine industry, Automotive parts, Airframe structure

3. Write about Commercially Pure Titanium Grade 2.

Grade 2

Grade 2 titanium is called the “workhorse” of the commercially pure titanium industry, thanks to its varied usability and wide availability. It shares many of the same qualities as Grade 1 titanium, but it is slightly stronger. Both are equally corrosion resistant.

Applications:

Architecture, Power generation, Medical industry, Hydro-carbon processing, Marine industry, Exhaust pipe shrouds

4. Define Nickel Brass.

This is an alloy that contains copper, nickel and zinc. The nickel gives the material an almost silver appearance. This material has moderate strength and fairly good corrosion resistance.

5. What is aluminum bronze?

This has an aluminum content range of 6% – 12%, an iron content of 6% (max), and a nickel content of 6% (max). These combined additives provide increased strength, combined with excellent resistance to corrosion and wear. This material is commonly used in the manufacturing of marine hardware, sleeve bearings and pumps or valves that handle corrosive fluids.



3MARKS QUESTIONS WITH ANSWERS

1. Define cast iron?

Cast iron is iron or a ferrous alloy which has been heated until it liquefies, and is then poured into a mould to solidify. It is usually made from pig iron. The alloy constituents affect its colour when fractured: white cast iron has carbide impurities which allow cracks to pass straight through. Grey cast iron has graphite flakes which deflect a passing crack and initiate countless new cracks as the material breaks

2. What are the applications of aluminum alloys?

Aluminum alloys are widely used in automotive engines, particularly in cylinder blocks and crankcases due to the weight savings that are possible. Since aluminium alloys are susceptible to warping at elevated temperatures, the cooling system of such engines is critical. Manufacturing techniques and metallurgical advancements have also been instrumental for the successful application in automotive engines.

3. Write in brief about brass.

Brass is a metallic alloy that is made of copper and zinc. The proportions of zinc and copper can vary to create different types of brass alloys with varying mechanical and electrical properties. It is a substitutional alloy: atoms of the two constituents may replace each other within the same crystal structure.

In contrast, bronze is an alloy of copper and tin. Both bronze and brass may include small proportions of a range of other elements including arsenic, lead, phosphorus, aluminium, manganese, and silicon. The distinction is largely historical. Modern practice in museums and archaeology increasingly avoids both terms for historical objects in favour of the all-embracing "copper alloy".

4. Write about heat treatment of cast iron.

The gray **irons** typically contain from 1.7% - 4.5% carbon and 1% - 3% silicon as major constituents. The most common **heat treatments** applied to gray **cast irons** are stress relief because of nonuniform cooling of **cast-** ings and annealing to improve machinability. Subcritical heating is used for both.

5. What are the applications of bronze

Bronze is an alloy that consists primarily of copper with the addition of other ingredients. In most cases the ingredient added is typically tin, but arsenic, phosphorus, aluminum, manganese, and silicon can also be used to produce different properties in the material. All of these ingredients produce an alloy much harder than copper alone.



5MARKS QUESTIONS WITH ANSWERS

1. How the cast iron properties change with the addition of alloying elements?

Cast iron's properties are changed by adding various alloying elements, or alloyants. Next to carbon, silicon is the most important alloying because it forces Carbon out of solution. Instead the carbon forms graphite which results in a softer iron, reduces shrinkage, lowers strength, and decreases density. Sulfur, when present, forms iron sulfide, which prevents the formation of graphite and increases hardness. The problem with sulfur is that it makes molten cast iron sluggish, which causes short run defects. To counter the effects of sulfur, manganese is added because the two form into manganese sulfide instead of iron sulfide. The manganese sulfide is lighter than the melt so it tends to float out of the melt and into the slag. The amount of manganese required to neutralize sulfur is $1.7 \times \text{sulfur content} + 0.3\%$.

Nickel is one of the most common alloying elements because it refines the pearlite and graphite structure, improves toughness, and evens out hardness differences between section thicknesses. Chromium is added in small amounts to the ladle to reduce free graphite, produce chill, and because it is a powerful carbide stabilizer; nickel is often added in conjunction. A small amount of tin can be added as a substitute for 0.5% chromium. Copper is added in the ladle or in the furnace, on the order of 0.5–2.5%, to decrease chill, refine graphite, and increase fluidity. Molybdenum is added on the order of 0.3–1% to increase chill and refine the graphite and pearlite structure; it is often added in conjunction with nickel, copper, and chromium to form high strength irons. Titanium is added as a degasser and deoxidizer, but it also increases fluidity. 0.15–0.5% vanadium is added to cast iron to stabilize cementite, increase hardness, and increase resistance to wear and heat. 0.1–0.3% zirconium helps to form graphite, deoxidize, and increase fluidity.

2. Explain the microstructure of white cast iron

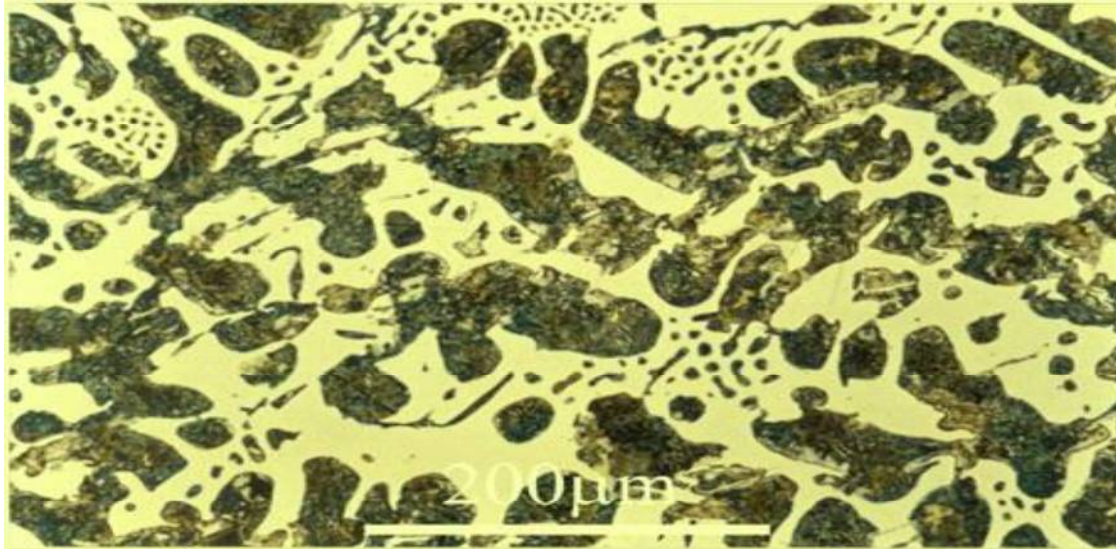
White cast iron displays white fractured surfaces due to the presence of an iron carbide precipitate called cementite. With a lower silicon content (graphitizing agent) and faster cooling rate, the carbon in white cast iron precipitates out of the melt as the meta stable phase cementite, Fe_3C , rather than graphite. The cementite which precipitates from the melt forms as relatively large particles. As the iron carbide precipitates out, it withdraws carbon from the original melt, moving the mixture toward one that is closer to eutectic, and the remaining phase is the lower iron-carbon austenite (which on cooling might transform to martensite). These eutectic carbides are much too large to provide the benefit of what is called precipitation hardening (as in some steels, where much smaller cementite precipitates might inhibit plastic deformation by impeding the movement of dislocations through the pure iron ferrite matrix). Rather, they increase the bulk hardness of the cast iron simply by virtue of their own very high hardness and their substantial volume fraction, such that the bulk hardness can be approximated by a rule of mixtures. In any case, they offer hardness at the expense of toughness. Since carbide makes up a large fraction of the material, white cast iron could reasonably be classified as a cermet. White iron is too brittle for use in many structural components, but with good hardness and abrasion resistance and relatively low cost, it finds use in such applications as the wear surfaces (impeller and volute) of slurry pumps, shell liners and lifter bars in ball mills and autogenous grinding mills, balls and rings



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in coal pulverisers, and the teeth of a backhoe's digging bucket (although cast medium-carbon martensitic steel is more common for this application).



3. Explain the microstructure of malleable cast iron

Malleable iron starts as a white iron casting that is then heat treated at about 900 °C (1,650 °F). Graphite separates out much more slowly in this case, so that surface tension has time to form it into spheroidal particles rather than flakes. Due to their lower aspect ratio, spheroids are relatively short and far from one another, and have a lower cross section propagating crack or phonon. They also have blunt boundaries, as opposed to flakes, which alleviates the stress concentration problems faced by grey cast iron. In general, the properties of malleable cast iron are more like mild steel. There is a limit to how large a part can be cast in malleable iron, since it is made from white cast iron



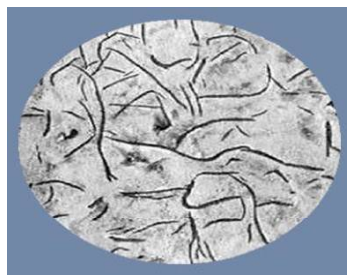


4. Explain the microstructure of gray cast iron

Grey cast iron is characterized by its graphitic microstructure, which causes fractures of the material to have a grey appearance. It is the most commonly used cast iron and the most widely used cast material based on weight. Most cast irons have a chemical composition of 2.5–4.0% carbon, 1–3% silicon, and the remainder is iron. Grey cast iron has less tensile strength and shock resistance than steel, but its compressive strength is comparable to low and medium carbon steel.

A typical chemical composition to obtain a graphitic microstructure is 2.5 to 4.0% carbon and 1 to 3% silicon by weight. Graphite may occupy 6 to 10% of the volume of grey iron. Silicon is important for making grey iron as opposed to white cast iron, because silicon is a graphite stabilizing element in cast iron, which means it helps the alloy produce graphite instead of iron carbides; at 3% silicon almost no carbon is held in chemical form as iron carbide. Another factor affecting graphitization is the solidification rate; the slower the rate, the greater the time for the carbon to diffuse and accumulate into graphite. A moderate cooling rate forms a more pearlitic matrix, while a fast cooling rate forms a more ferritic matrix. To achieve a fully ferritic matrix the alloy must be annealed.^{[1][4]} Rapid cooling partly or completely suppresses graphitization and leads to the formation of cementite, which is called white iron.

The graphite takes on the shape of a three-dimensional flake. In two dimensions, as a polished surface, the graphite flakes appear as fine lines. The graphite has no appreciable strength, so they can be treated as voids. The tips of the flakes act as preexisting notches at which stresses concentrate and it therefore behaves in a brittle manner. The presence of graphite flakes makes the Grey Iron easily machinable as they tend to crack easily across the graphite flakes. Grey iron also has very good damping capacity and hence it is often used as the base for machine tool mountings.



5. Explain about bronze and types of bronze

Bronze is an alloy that consists primarily of copper with the addition of other ingredients. In most cases the ingredient added is typically tin, but arsenic, phosphorus, aluminum, manganese, and silicon can also be used to produce different properties in the material. All of these ingredients produce an alloy much harder than copper alone.

Bronze is characterized by its dull-gold color. You can also tell the difference between bronze and brass because bronze will have faint rings on its surface.



Applications

Bronze is used in the construction of sculptures, musical instruments and medals, and in industrial applications such as bushings and bearings, where its low metal on metal friction is an advantage. Bronze also has nautical applications because of its resistance to corrosion.

Phosphor Bronze (or Tin Bronze)

This alloy typically has a tin content ranging from 0.5% to 1.0%, and a phosphorous range of 0.01% to 0.35%. These alloys are notable for their toughness, strength, low coefficient of friction, high fatigue resistance, and fine grain. The tin content increases the corrosion resistance and tensile strength, while the phosphorous content increases the wear resistance and stiffness. Some typical end uses for this product would be electrical products, bellows, springs, washers, corrosion resistant equipment.

Aluminum Bronze

This has an aluminum content range of 6% – 12%, an iron content of 6% (max), and a nickel content of 6% (max). These combined additives provide increased strength, combined with excellent resistance to corrosion and wear. This material is commonly used in the manufacturing of marine hardware, sleeve bearings and pumps or valves that handle corrosive fluids.

Silicon Bronze

This is an alloy that can cover both brass and bronze (red silicon brasses and red silicon bronzes). They typically contain 20% zinc and 6% silicon. It is commonly used in the manufacturing of pump and valve components.

Nickel Brass (or Nickel Silver)

This is an alloy that contains copper, nickel and zinc. The nickel gives the material an almost silver appearance. This material has moderate strength and fairly good corrosion resistance.

Copper Nickel (or Cupronickel)

This is an alloy that can contain anywhere from 2% to 30% nickel. This material has a very high corrosion-resistance and has thermal stability. Higher nickel content in this material will have improved corrosion resistance in seawater, and resistance to marine biological fouling.



MULTIPLE CHOICE QUESTIONS WITH ANSWERS

- 1) The gray cast iron has
 - a. high melting point
 - b. high thermal conductivity
 - c. low compressive strength
 - d. all of the above

- 2) In mottled cast iron, slow cooling rate is used to obtain
 - a. white cast iron
 - b. gray cast iron
 - c. Both a. and b.
 - d. None of the above

- 3) What is the effect of silicon on the structure of cast iron?
 1. Blowholes are present in the castings
 2. Increases fluidity
 3. Influences the solidification of liquid alloys
 4. Reacts with iron to form iron sulphide
 - a. 1 and 2
 - b. 2 and 3
 - c. 3 and 4
 - d. All of the above

- 4) Nodules of graphite are observed in the microstructure of
 - a. white cast iron
 - b. malleable cast iron
 - c. spheroidal cast iron
 - d. all of the above

- 5) Which of the following parameters is/are false for steel?
 - a. High carbon content
 - b. High melting point
 - c. Low damping capacity
 - d. None of the above

- 6) What is the effect of increased carbon content on chilled cast iron?
 - a. Chilling depth increases
 - b. Hardness of chilled zone increases
 - c. Both a. and b.
 - d. None of the above

- 7) Which of the following elements increase/s chilled depth for chilled cast irons?
 - a. Silicon
 - b. Manganese



- c. Manganese sulphide
- d. All of the above

- 8) Rosettes of tempered carbon in the matrix of ferrite are observed in the microstructure of _____
- a. gray cast iron
 - b. spheroidal cast iron
 - c. malleable cast iron
 - d. none of the above

- 9) Which desulphurising agent is used to remove sulphur from iron during melting?
- a. Calcium carbide
 - b. Sodium carbonate
 - c. Soda ash
 - d. All of the above

- 10) Why is gray cast iron annealed?
- a. Graphitize carbide
 - b. Decrease ductility
 - c. Both a. and b.
 - d. None of the above

ANSWERS

1. b 2. b 3. c 4. c 5. a 6. b 7. c 8. c 9. d 10. a

FILL IN THE BLANKS WITH ANSWERS

- 11) In Muntz metal, if 1% of tin is added it forms _____
- 12) What is the composition of cartridge brass _____
- 13) In precipitation hardening, at 540o C when θ phase (CuAl_2) completely dissolves at grain boundaries the single phase α is obtained known as _____
- 14) At room temperature, hardness of precipitation hardening alloys _____
- 15) The solubility of tin in copper above 580oC _____
- 16) Which of the following cold working operations are suitable for α brass?
- 17) Inconel nickel alloy contains _____
- 18) A bearing material should not possess the characteristic of high _____.
- 19) The alloy of Ti + 5% Al, + 2.5 Sn has _____.
- 20) Which of the following is $\alpha - \beta$ brass _____



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11) naval brass 12) 70 % Cu and 30 % Zn 13) homogeneous solid solution 14) decreases with time 15) increases 16) Cold rolling 17) 75% Ni, 15% Cr and 9% Fe 18) coefficient of friction 19) good corrosion 20) Brazing brass



UNIT V

2MARKS QUESTIONS WITH ANSWERS

1. What are elastomers?

Elastomers: Also known as rubbers, these are polymers which can undergo large elongations under load, at room temperature, and return to their original shape when the load is released. There are number of man-made elastomers in addition to natural rubber. These consist of coil-like polymer chains those can reversibly stretch by applying a force.

2. What are thermosets?

Thermosets: These plastics require heat and pressure to mold them into shape. They are formed into a permanent shape and cured or 'set' by chemical reactions such as extensive cross-linking. They cannot be re-melted or reformed into another shape but decompose upon being heated to too high a temperature.

3. Define AX-type ceramic crystal structures.

AX-type ceramic crystal structures: Most common ceramics are made of equal number of cations and anions, and are referred to as AX compounds (A-cation, and X-anion). These ceramics assume many different structures, named after a common material that possesses the particular structure.

4. Write short notes on zinc blend structure?

Zinc Blende structure: here the coordination number is 4. Unit cell is composed of one kind of ions occupying corners and face centers of a cube, while the other kind of ions occupies the interior tetrahedral positions. E.g.: ZnS, SiC.

5. Write short notes on $A_mB_nX_p$ -type structures?

$A_mB_nX_p$ -type structures: it is possible that ceramics do have more than one kind of cations. E.g.: $BaTiO_3$. unit cell is made of cube where Ba^{2+} ions occupies all eight corners, T^{4+} occupies cube center, while O^{2-} are at center of each face. This structure is called perovskite crystal structure.

3MARKS QUESTIONS WITH ANSWERS

1. Write short notes on A_mX_p -type structures?

A_mX_p - type structures: when the charges of cation and anions are not the same, to maintain the neutrality, ceramic structures with chemical formula would exist. For example – CaF_2 with $r_c/r_a = 0.8$, and thus coordination number of 8. It can be expected that crystal structure could be the same as that of CsCl. However cations are half many as anions, thus only half the center positions are occupied. One unit cell shall be made of eight cubes. E.g.: UO_2 , ThO_2 , PuO_2 .



2. What are laminates?

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.

3. What are the applications of composites?

Space craft: Antenna structures, Solar reflectors, Satellite structures, Radar, Rocket engines, etc.

Aircraft: Jet engines, Turbine blades, Turbine shafts, Compressor blades, Airfoil surfaces, Wing box structures, Fan blades, Flywheels, Engine bay doors, Rotor shafts in helicopters, Helicopter transmission structures, etc.

4. Write in brief about applications of glass

Glass is used in the following non-exhaustive list of products:

Packaging (jars for food, bottles for drinks, flacon for cosmetics and pharmaceuticals)

Tableware (drinking glasses, plate, cups, bowls)

Housing and buildings (windows, facades, conservatory, insulation, reinforcement structures)

Interior design and furniture (mirrors, partitions, balustrades, tables, shelves, lighting)

Appliances and Electronics (oven doors, cook top, TV, computer screens, smart-phones)

5. Write in brief about applications of cermets.

Cermets are used instead of tungsten carbide in saws and other brazed tools due to their superior wear and corrosion properties. Titanium nitride (TiN), [titanium carbonitride](#) (TiCN), titanium carbide (TiC) and similar can be brazed like tungsten carbide if properly prepared however they require special handling during grinding.

5MARKS QUESTIONS WITH ANSWERS

1. Explain in detail about thermoplastics.

Thermo plastics

1. Acrylonitrile-butadiene-styrene (ABS):

Application: Refrigerator lining, lawn and garden equipment, toys, highway safety devices.

2. Acrylics (poly-methyl-methacrylate)

Application: Lenses, transparent aircraft enclosures, drafting equipment, outdoor signs

3. Fluorocarbons (PTFE or TFE)

Application: Anticorrosive seals, chemical pipes and valves, bearings, anti adhesive coatings, high temperature electronic parts.

Thermo setting polymers



1. Epoxies

Application: Electrical moldings, sinks, adhesives, protective coatings, used with fiberglass laminates.

2. Phenolics

Application: Motor housing, telephones, auto distributors, electrical fixtures.

2. Explain about ceramics in detail.

Ceramics (ceramic materials) are non-metallic inorganic compounds formed from metallic (Al, Mg, Na, Ti, W) or semi-metallic (Si, B) and non-metallic (O, N, C) elements. Atoms of the elements are held together in a ceramic structure by one of the following bonding mechanism: Ionic Bonding, Covalent Bonding, Mixed Bonding (Ionic-Covalent). Most of ceramic materials have a mixed bonding structure with various ratios between Ionic and Covalent components. This ratio is dependent on the difference in the electro negativity of the elements and determines which of the bonding mechanisms is dominating ionic or covalent.

Ceramics form an important part of materials group. Ceramics are compounds between metallic and nonmetallic elements for which the inter-atomic bonds are either ionic or predominantly ionic. The term ceramics comes from the Greek word keramikos which means 'burnt stuff'. Characteristic properties of ceramics are, in fact, optimized through thermal treatments. They exhibit physical properties those are different from that of metallic materials. Thus metallic materials, ceramics, and even polymers tend to complement each other in service.

3. What is glass and explain in detail

Glass is a non-crystalline amorphous solid that is often transparent and has widespread practical, technological, and decorative usage in, for example, window panes, tableware, and optoelectronics. The most familiar, and historically the oldest, types of glass are "silicate glasses" based on the chemical compound silica (silicon dioxide, or quartz), the primary constituent of sand. The term glass, in popular usage, is often used to refer only to this type of material, which is familiar from use as window glass and in glass bottles. Of the many silica-based glasses that exist, ordinary glazing and container glass is formed from a specific type called soda-lime glass, composed of approximately 75% silicon dioxide (SiO_2), sodium oxide (Na_2O) from sodium carbonate (Na_2CO_3), calcium oxide, also called lime (CaO), and several minor additives.

Silica (the chemical compound SiO_2) is a common fundamental constituent of glass. In nature, vitrification of quartz occurs when lightning strikes sand, forming hollow, branching root like structures called fulgurite.

Fused quartz is a glass made from chemically-pure SiO_2 (silica). It has excellent resistance to thermal shock, being able to survive immersion in water while red hot. However, its high melting temperature (1723 °C) and viscosity make it difficult to work with. Normally, other substances are added to simplify processing. One is sodium carbonate (Na_2CO_3 , "soda"), which lowers the glass-transition temperature. The soda makes the glass water-soluble, which is usually undesirable, so lime (CaO , calcium oxide, generally obtained



from limestone), some magnesium oxide (MgO) and aluminium oxide (Al_2O_3) are added to provide for a better chemical durability. The resulting glass contains about 70 to 74% silica by weight and is called a soda-lime glass. Soda-lime glasses account for about 90% of manufactured glass

4. What is cermet? Explain in detail

A **cermet** is a composite material composed of ceramic (cer) and metallic (met) materials.

A cermet is ideally designed to have the optimal properties of both a ceramic, such as high temperature resistance and hardness, and those of a metal, such as the ability to undergo plastic deformation. The metal is used as a binder for an oxide, boride, or carbide. Generally, the metallic elements used are nickel, molybdenum, and cobalt. Depending on the physical structure of the material, cermets can also be metal matrix composites, but cermets are usually less than 20% metal by volume.

Cermets are used in the manufacture of resistors (especially potentiometers), capacitors, and other electronic components which may experience high temperature.

Cermets are used instead of tungsten carbide in saws and other brazed tools due to their superior wear and corrosion properties. Titanium nitride (TiN), titanium carbonitride (TiCN), titanium carbide (TiC) and similar can be brazed like tungsten carbide if properly prepared however they require special handling during grinding.

5. Write about the classification of composites.

Composite materials are commonly classified at following two distinct levels:

The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.

The second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres.

Fibre Reinforced Composites are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced.

Laminar Composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category.



MULTIPLE CHOICE QUESTIONS WITH ANSWERS

1. The word 'ceramic' meant for
 - (a) soft material
 - (b) hard material
 - (c) burnt material
 - (d) dry material

2. Not a characteristic property of ceramic material
 - (a) high temperature stability
 - (b) high mechanical strength
 - (c) low elongation
 - (d) low hardness

3. Major ingredients of traditional ceramics
 - (a) silica
 - (b) clay
 - (c) feldspar
 - (d) all

4. Not a major contributor of engineering ceramics
 - (a) SiC
 - (b) SiO₂
 - (c) Si₃N₄
 - (d) Al₂O₃

5. The following ceramic product is mostly used as pigment in paints
 - (a) TiO₂
 - (b) SiO₂
 - (c) UO₂
 - (d) ZrO₂

6. Most commercial glasses consist of
 - (a) lime
 - (b) soda
 - (c) silica
 - (d) all

7. Hot isostatic pressing is not a viable option if the chief criterion is
 - (a) strength without grain growth
 - (b) lost cost
 - (c) zero porosity
 - (d) processing refractory ceramics

8. During sintering densification is not due to
 - (a) atomic diffusion
 - (b) surface diffusion



- (c) bulk diffusion
- (d) grain growth

9. The word 'polymer' meant for material made from _____.
- (a) Single entity
 - (b) Two entities
 - (c) Multiple entities
 - (d) Any entity

10. One of characteristic properties of polymer material _____ .
- (a) High temperature stability
 - (b) High mechanical strength
 - (c) High elongation
 - (d) Low hardness

FILL IN THE BLANKS WITH ANSWERS

- 11. Composite materials are classified based on _____
- 12. Major load carrier in dispersion-strengthened composites _____
- 13. Usually softer constituent of a composite is _____
- 14. Usually stronger constituent of a composite is _____
- 15. Last constituent to fail in fiber reinforced composites _____
- 16. Size range of dispersoids used in dispersion strengthened composites _____
0.01-0.1 μm
- 17. Rule-of-mixture provides _____ bounds for mechanical properties of particulate composites.
- 18. Al-alloys for engine/automobile parts are reinforced to increase their Strength _____
- 19. Mechanical properties of fiber-reinforced composites depend on _____
- 20. Longitudinal strength of fiber reinforced composite is mainly influenced by _____

ANSWERS

1.c	2.d	3.d	4.b	5.a	6.d	7.b	8.b	9.c	10.c
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- 11) Type of matrix and Size-and-shape of reinforcement 12) Matrix 13) Matrix 14) Matrix
15) Fiber 16) 0.01-0.1 μm 17) Lower AND Upper 18) Wear resistances 19) Properties of constituents 20) Fiber strength