



AC8005 - AEROSPACE MATERIALS

TWO MARKS WITH ANSWERS

UNIT-1- ELEMENTS OF AEROSPACE MATERIALS

1. Define solid.

A state of matter characterized by particles arranged such that their shape and volume are relatively stable. The constituents of a solid tend to be packed together much closer than the particles in a gas or liquid.

Examples: a brick, a piece of wood.

2. What is State of Matter?

One of the ways in which matter can interact with itself to form homogeneous phase. Examples: solid, liquids, gases, plasma.

3. Define plasma state of matter.

Plasma is not a common state of matter here on Earth, but may be the most common state of matter in the universe. Plasma consists of highly charged particles with extremely high kinetic energy. The noble gases (helium, neon, argon, krypton, xenon and radon) are often used to make glowing signs by using electricity to ionize them to the plasma state. Stars are essentially superheated balls of plasma.

4. What is Materials Science?

Materials Science is an interdisciplinary subject which is concerned with the study of materials as a whole like behavior of the material, production of the material, applications and study of all properties of the material along with its macro and microstructures.

5. Define atom.

An **atom** is the smallest constituent unit of ordinary matter that has the properties of a chemical element. Every solid, liquid, gas, and plasma is composed of neutral or ionized atoms. Every atom is composed of a nucleus and one or more electrons bound to the nucleus.

6. Define nucleus.

The nucleus is at the centre of the atom and made of one or more protons and typically a similar number of neutrons . Protons and neutrons are collectively known as *nucleons*.

7. What is atomic bonding?

The mechanisms of bonding between the atoms are based on electrostatic interatomic interaction.

8. What are the types of atomic bonding?

Atomic bonding can be broadly classified as

- i) Primary bonding
 - ✓ Ionic bond
 - ✓ Covalent bond
 - ✓ Metallic bond
- ii) Secondary bonding
 - ✓ Hydrogen bonding
 - ✓ Van der Waals Bonding

9. Explain ionic bonding?

In ionic bonding, electrons are completely transferred from one atom to another. In the process of either losing or gaining negatively charged electrons, the reacting atoms form ions. The oppositely charged ions are attracted to each other by electrostatic forces, which are the basis of the ionic bond.

10. Explain covalent bonding?

Covalent bonding occurs because the atoms in the compound have a similar tendency for electrons (generally to gain electrons). This most commonly occurs when two non-metals bond together. Because both of the nonmetals will want to

gain electrons, the elements involved will share electrons in an effort to fill their valence shells. A good example of a covalent bond is that which occurs between two hydrogen atoms.

11. Explain metallic bonding?

In metals, the atoms are ionized, losing some electrons from the valence band. Those electrons form a *electron sea*, which binds the charged nuclei in place, in a similar way that the electrons in between the H atoms in the H₂ molecule bind the protons.

12. What is crystal structure?

Crystallography or crystal structure is a unique arrangement of atoms, ions or molecules in a crystalline liquid or solid.. The basic principles of many materials characterization techniques such as X-ray diffraction (XRD), Transmission electron microscopy (TEM)

Lattice + basis = crystal structure

13. Define crystalline solid.

A crystal or crystalline solid is a solid material whose constituents, such as atoms, molecules or ions, are arranged in a highly ordered microscopic structure, forming a crystal lattice that extends in all directions. Periodic arrangement of atoms: definite repetitive pattern

14. Define polycrystalline solid.

Polycrystalline or multicrystalline materials, or polycrystals are solids that are composed of many crystallites of varying size and orientation. Crystallites are also referred to as grains. They are small or even microscopic crystals and form during the cooling of many materials.

15. Define Amorphous.

An amorphous or non-crystalline solid is a solid that lacks the long-range order characteristic of a crystal, the atoms and molecules are not organized in a definite lattice pattern. Such solids include glass, plastic, and gel.

16. Write the difference between crystalline solid and Amorphous.

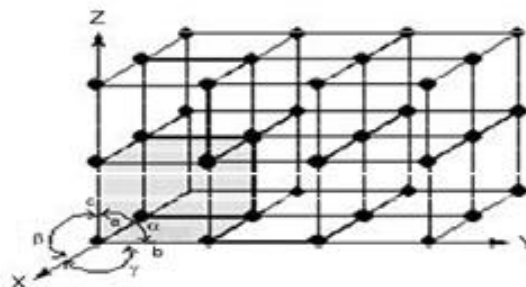
Crystalline solid	Amorphous
<ul style="list-style-type: none"> ✓ They have characteristic geometrical shape. ✓ They have highly ordered three-dimensional arrangements of particles. ✓ They are bounded by planes or faces ✓ Planes of a crystal intersect at particular angles. ✓ They have sharp melting and boiling points. Ex: Copper Sulphate (CuSO_4), NiSO_4, Diamond, Graphite, NaCl, Sugar etc 	<ul style="list-style-type: none"> ✓ In these solids particles are randomly arranged in three dimensions. ✓ They don't have sharp melting points. ✓ Amorphous solids are formed due to sudden cooling of liquid. ✓ Amorphous solids melt over a wide range of temperature Ex: Coal, Coke, Glass, Plastic, rubber etc

17. Define space lattice?

A space lattice can be defined as a three dimensional array of points, each of which has identical surroundings.

18. What is Bravais Lattice?

The unit vectors a , b and c is called lattice parameters. Based on their length equality or inequality and their orientation (the angles between them, α , β and γ) a total of 7 crystal systems can be defined. With the centering (face, base and body centering) added to these, 14 kinds of 3D lattices, known as **Bravais lattices**.



19. Define miller indices?

Vectors and atomic planes in a crystal lattice can be described by a three-value Miller index notation (lmn). The l , m , and n directional indices are separated by 90° , and are thus orthogonal.

20. What is Atomic packing factor?

Atomic packing factor (APF) or packing efficiency indicates how closely atoms are packed in a unit cell and is given by the ratio of volume of atoms in the unit cell and volume of the unit cell

$$\text{APF} = \frac{\text{Volume of atoms in the unit cell}}{\text{Volume of the unit cell}}$$

21. What is Planer density?

Planar density (PD) refers to density of atomic packing on a particular plane.

$$\text{PD} = \frac{\text{Number of atoms per unit area}}{\text{Area of the unit cell}}$$

22. What is linear density?

Linear density (LD) is the number of atoms per unit length along a particular direction.

$$\text{LD} = \frac{\text{Number of atoms per unit length}}{\text{Length of the unit cell}}$$

UNIT-2 - *MECHANICAL BEHAVIOUR OF MATERIALS*

1. What is meant by hardness?

Degree to which a metal will resist cutting, abrasion, penetration, bending and stretching. The indicated hardness of metals will differ somewhat with the specific apparatus measuring hardness. (See Brinell Hardness, Rockwell Hardness, Vickers Hardness, Scleroscope Hardness) Tensile Strength also is an indication of hardness.

2. Define ductility and malleability of materials.

Ductility is the wire drawing capacity of the material by plastic deformation without fracture. Copper and platinum are highly ductile materials. Malleability is the sheet form ability of the material by hammering without fracture. Gold and aluminium are the highly malleable materials.

3. What is meant by strain hardening?

An increase in **hardness** and strength caused by **plastic deformation** at temperatures lower than the **recrystallization** range.

4. What are the factors affecting diffusion?

- ✓ Temperature : increases the rate of diffusion
- ✓ crystal structure : crystal with low packing factor increase the rate of diffusion
- ✓ Grain size : fine grain material has more diffusion rate
- ✓ Concentration : value of diffusion coefficient varies with concentration

5. Define Fracture?

Fracture is a process of breaking a solid into number of pieces as a result of stress. Fracture denotes the complete destruction of the material, resulting separation of a portion of the material body.

6. How does the yield strength vary with grain size?

The variation of yield strength σ_y with grain size is given by Hall-Petch relation

$$\sigma_y = \sigma_o + k_y d^{-1/2}$$

Where d is the average grain diameter, while σ_o and k_y are constants for a particular material. Fine grained material is harder and stronger than one that is coarse grained.

7. What are elastic and plastic materials?

Elastic materials can regain their original shape after removal of the deforming forces and within the elastic limit, the stress is proportional to strain and have high elastic modulus.

Example: Steel, Brasses, Gold. Plastic materials can undergo plastic deformation permanently in shape and size by the deforming forces up to the ultimate strength without any fracture.

Example: PVC, Polymers.

8. What are the uses of Vickers hardness test?

1. The material is tested without any destructions so its a nondestructive testing. After testing the material or product can be used or sold.
2. Only smaller loads are applied. That would not produce cracks or fractures inside the specimen.
3. Micro hardness of the surface hardened materials can be determined accurately.

9. What are creep and creep resistance?

Creep is the property of a material by which it deforms continuously under a steady load (yielding). The deformation during creep is nonrecoverable. The creep can produce fracture or rupture even though the applied stress is lower than the ultimate stress. So the creep in materials should be avoided, particularly at high temperatures.

Creep resistance is the property of the material by which the continuation of creep is stopped.

10. Define creep formation

It involves time-dependent deformation and high temperature creep cracking generally develops in an intercrystalline manner in components of engineering importance that fail over an extended time.

11. What are factors which affect creep resistant materials?

Creep is influenced by minor variations in metallurgical conditions. Some of these affecting variables are:

- ✓ Grain size
- ✓ Prior strain
- ✓ Formation of solid solutions and
- ✓ Precipitation and dispersion hardening

12. What is meant by diffusion process?

At low stress and high temperature atoms diffuse from sides to the top and bottom. The grain becomes longer as the applied stress does work. Atomic diffusion in one direction is same as vacancy diffusion in opposite direction.

13. Which types of materials are preferred for creep application?

A material which posses the following features to avoid creep formation and get creep resistant at high temperatures.

- ✓ Higher creep resistance is observed with metals having high melting point. Creep becomes significant above $0.4 T_m$.
- ✓ A coarse grain metal has high creep resistance than fine grained metals.
- ✓ Single crystals have excellent creep resistance because they have no grain boundary.

14. Name two metallurgical factors that affect creep rate.

- ✓ Work hardening
- ✓ Thermal Softening
- ✓ Grain boundary sliding
- ✓ Diffusion and cavitation

15. What are types of fracture?

Generally fracture can be divided into 2 types such

- ✓ Brittle fracture (eg. Cast iron)
- ✓ Ductile fracture (eg. Mild steel)

Further it can be classified,

Depends on the appearance as

-Shearing fracture and - Cleavage fracture.

Crystallographic nature as -Fibrous fracture and Granular fracture

16. Draw typical creep curve and mark the various stages.

1. Primary Or Transient Creep - **Strain or work hardening**
2. Secondary Or Steady State Or Recovery Creep- **Thermal Softening or Annealing**
3. Tertiary Creep - **Void Propagation and Grain boundary sliding**

17. Write examples for Plastic Deformation/Yielding

Everyday Example:

Deforming a metal paper clip. If we only flex it a small amount- then it springs back to its original shape this is elastic deformation. If we twist enough to deform it permanently, this is plastic deformation. Elastic deformation is acceptable, plastic deformation is not.

Aircraft Examples:

Numerous airframes and propellers have been plastically deformed by hard landings. This often results in the scrapping of the aircraft.

18. What is meant by decarburization?

It is the process of removing the carbon from the outer surface of iron or steel, usually by heating in an oxidizing or reducing atmosphere. Water vapor, oxygen and carbon dioxide are strong decarburizers. Reheating with adhering scale is also strongly decarburizing in action.

19. What is tempering?

Tempering is the process of re-heating the hardened steel to some temperature below its critical temperature in order to impart toughness and to reduce brittleness. This reduces the internal stresses developed during hardening.

20. What are low carbon steels? What are their applications?

Low carbon steels have 0.08% to 0.25% carbon. These are soft, ductile and easy to weld. These are used to make wires, rods and thin sheets and boiler plates.

UNIT-3 - CORROSION & HEAT TREATMENT OF METALS AND ALLOYS

1. What is Corrosion?

Corrosion is the deterioration of materials by chemical interaction with their environment. The term corrosion is sometimes also applied to the degradation of plastics, concrete and wood, but generally refers to metals. The most widely used metal is iron.

2. Define oxidation process.

Oxidation means the loss of electrons. The oxidation of a metal occurs when the metal loses one or more electrons, so that the atoms of the metal go from the neutral state and become a positively charge ion. This commonly results in the formation of a metal oxide (in the case of iron that is known as rust).

3. Define hot corrosion.

Hot corrosion is an high- temperature analog of aqueous atmospheric corrosion. A thin film deposit of fused salt on an alloy surface in a hot oxidizing gas causes accelerated corrosion kinetics.

4. What are the different stages of hot corrosion?

- ✓ Type -I hot CORROSION (Temp Range from 850-950°C)
- ✓ Type -II hot CORROSION (Temp Range from 650-800°C)

5. Define hot corrosion. What are the methods used for combat hot corrosion?

Hot corrosion is defined as an accelerated, often catastrophic surface attack super alloy by hot-gas path component. This is severe in the temperature range 750-1000°C and has affected A/C engines and industrial gas turbines. There are three methods to combat hot corrosion such as

- ✓ Aluminide (diffusion) coatings
- ✓ Thermal barrier coatings
- ✓ Overlay coatings

6. Write any two methods to prevent corrosion.

- ✓ Control or removal of aggressive impurities.
- ✓ Development of new alloys with higher resistance to hot gas corrosion and greater mechanical properties.

✓ Development of protective surface coatings.

7. Define acidic fluxing in hot corrosion.

Acidic Fluxing: It defines dissolution, when a soluble metal M^{2+} and O^{2-} are produced from oxide. The acidic fluxing is generally associated with temperature range of 650°C to 800°C and it is termed as low temperature hot corrosion. Acidic fluxing takes place when the O^{2-} activity in the molten salt is markedly lowered, it leads to much more severe oxidation compared to basic fluxing.

8. Define basic fluxing in hot corrosion.

Basic fluxing: The term basic fluxing describes oxide dissolution, when O^{2-} contains with the oxide to form a soluble MO^{2-} radical. It is generally associated with temperatures $> 900^\circ\text{C}$ and termed as high temperature hot corrosion. These results support a **basic fluxing** reaction, i.e. corrosive attack by forming a basic solute of the protective scale.



9. Name some oxidation resistance materials?

Conventionally **Aluminium, chromium and copper** materials are majorly used towards corrosion resistance. Some metals have naturally slow reaction kinetics, these include such metals as **zinc, magnesium, and cadmium**. While corrosion of these metals is continuous and ongoing, it happens at an acceptably slow rate. An extreme example is **graphite**, which releases large amounts of energy upon oxidation, but has such slow kinetics that it is effectively immune to electrochemical corrosion under normal conditions.

10. Define Pilling Bed worth theory.

The Pilling-Bedworth ratio, (P-B ratio) R , of a metal oxide is defined as the ratio of the volume of the metal oxide, which is produced by the reaction of metal and oxygen, to the consumed metal volume:

$$R = \frac{V_{\text{metal oxide produced}}}{V_{\text{metal consumed}}} = \frac{Md}{amD}$$

M and D are the molecular weight and density of the metal oxide whose composition is $(\text{Metal})_a(\text{oxygen})_b$; m , and d are the atomic weight and density of the metal.

11. What are the Kinetic Laws of Oxidation?

- ✓ Parabolic rate law
- ✓ logarithmic rate law
- ✓ Linear rate law

12. What is meant by heat treatment? What are the different methods of heat treatment?

Heating and cooling a solid metal or alloy in such a way as to obtain desired conditions or properties is called heat treatment. There are different methods of strengthening and hardening by heat treatment. They are

- ✓ Age hardening (precipitation hardening)
- ✓ Annealing
- ✓ Normalizing
- ✓ Tempering and
- ✓ Case hardening

13. What is age hardening or precipitation hardening?

By uniformly dispersing extremely small particles within the original phase matrix the strength and hardness of metal alloys may be enhanced; this process of heat treatment is called precipitation hardening or age hardening.

14. What is overaging?

For some alloys, aging occurs spontaneously at room temperature over extended time periods. With increase of time the strength increases and after reaching a maximum a value, it finally diminishes. This type of reduction in yield strength and hardness that occurs after long time periods is known as overaging.

15. What is annealing and what is its purpose?

Annealing means heating the material to and holding at a suitable temperature and then cooling at a suitable rate. Annealing is for the purpose of

- ✓ Reducing hardness
- ✓ Improving machinability
- ✓ Facilitating cold working
- ✓ Producing a desired microstructure and
- ✓ Obtaining desired mechanical, physical and other properties.

16. Distinguish between hardening and annealing.

Hardening gives hardness to a material so that its yield strength, corrosion resistance, wear resistance and cutting ability are increased.

Annealing gives softness and ductility to the materials and also refines the grain size and removes the internal stresses.

17. What is normalizing?

Heating a ferrous alloy to a suitable temperature above the transformation range and then cooling in air to a temperature substantially below the transformation range is called normalizing.

18. What is high brass?

65% - A copper-zinc alloy containing 35% zinc. Possesses high tensile strength and is used for springs, screws, rivets, etc.

19. What is air hardening steel?

Alloy steel which may be hardened by cooling in air from a temperature above the transformation range. Such steels attain their martensitic structure without going through the quenching process. Additions of chromium, nickel, molybdenum and manganese are effective toward this end.

20. What is alloy steel?

Steel containing substantial quantities of elements other than carbon and the commonly accepted limited amounts of manganese, sulfur, silicon, and phosphorous. Addition of such alloying elements is usually for the purpose of increased hardness, strength or chemical resistance. The metals most commonly used for forming alloy steels are: nickel, chromium, silicon, manganese, tungsten, molybdenum and vanadium. "Low Alloy" steels are usually considered to be those containing a total of less than 5% of such added constituents.

21. Which steel is called as carbon steel?

Common or ordinary steel as contrasted with special or alloy steels, which contain other alloying metals in addition to the usual constituents of steel in their common percentages.

22. State the meaning of carburizing.

(Cementation) It is the process of adding carbon to the surface of iron-base alloys by absorption through heating the metal at a temperature below its

melting point in contact with carbonaceous solids, liquids or gasses. It is the oldest method of case hardening.

23. What is meant by decarburization?

It is the process of removing the carbon from the outer surface of iron or steel, usually by heating in an oxidizing or reducing atmosphere. Water vapor, oxygen and carbon dioxide are strong decarburizers. Reheating with adhering scale is also strongly decarburizing in action.

24. What is tempering?

Tempering is the process of re-heating the hardened steel to some temperature below its critical temperature in order to impart toughness and to reduce brittleness. This reduces the internal stresses developed during hardening.

25. What are low carbon steels? What are their applications?

Low carbon steels have 0.08% to 0.25% carbon. These are soft, ductile and easy to weld. These are used to make wires, rods and thin heats and boiler plates.

26. What are the effects of addition of boron, chromium and cobalt in steels?

Boron: increase the hardness

Chromium: improves wear and impact resistance and increases its strength.

Cobalt: increase its hardness, and residual magnetic induction.

27. What is an alloy?

An alloy is a mixture of two or more metals, or a mixture of metal and a non-metal, with the mixture exhibiting metallic properties.

28. Define eutectic reaction

A reaction wherein, upon cooling, one liquid phase transforms isothermally and reversibly into two new solid phases that are intimately mixed is called eutectic reaction.

29. Define eutectoid reaction

A reaction wherein, upon cooling, one solid phase transforms isothermally and reversibly into two new solid phases that are intimately mixed is called eutectoid reaction.

30. What is a hypereutectoid steel?

A steel having more than the eutectoid percentage of carbon.

31. What is a hypoeutectoid steel?

Steel with less than eutectoid percentage of carbon.

32. What do you understand by allotropy?

The possibility of existence of two or more different crystal structures for a substance (generally an elemental solid such as iron) is known as allotropy.

33. What is stainless steels and what are the possible classifications based on their microstructure?

The stainless steels are iron-chromium alloys with atleast 11 wt% of chromium. Addition of nickel and molybdenum enhances the corrosion resistance. Stainless steels are divided into three classes on the basis of the microstructure

- ✓ Martensitic stainless steels
- ✓ Ferritic stainless steels and
- ✓ Austenitic stainless steels

UNIT-4 - CERAMICS AND COMPOSITES

1. What are metallic glasses?

Metallic glasses have the properties of metals and glasses such that they have ductility, malleability and brittleness. Ferromagnetic metallic glasses are in the form of ribbons and are used as light weight magnetic cores having no losses and high energy products.

2. What is Ceramic materials?

Ceramic materials are complex chemical compounds containing both metallic and non metallic elements. Alumina (Al_2O_3) is a ceramic composed of both metallic aluminum and non metallic oxygen atoms. Ceramics are formed because of ionic or covalent bonding, hence are usually hard, brittle and have high melting point.

3. What is FRP?

Fibre-reinforced plastic (FRP) is a composite material made of a polymer matrix reinforced with fibers. The fibres are usually glass, carbon, aramid, or basalt. The polymer is usually an epoxy, vinylester or polyester thermosetting plastic, and phenol formaldehyde resins are used.

4. What are advantages of FRP?

- ✓ high strength to weight ratio
- ✓ high heat resistance
- ✓ low cost tooling
- ✓ high electrical conductivity

5. Mention few applications of fine ceramics.

- ✓ Piezoelectric ceramics are used as SAW devices. ✓
- $Ti_2 Ba_2 Ca_2 Cu_3 O_3$ is a high T_c superconductor. ✓
- Si C is used as a substrates and varistors.
- ✓ $Ba Ti O_3$ is used as a capacitor dielectric and ferroelectric energy converter.

6. Mention few biomaterials and their applications.

- a. Stainless steels (ASTMF - 138) have high tensile strength and high biocompatibility and are used as steel wires, plates and implant devices.
- b. Porous high density polyethylene is used in dental and cortical implants
- c. Ceramic implants (Al_2O_3 with some SiO_2 and alkali metal oxide) are used to make femoral head.

7. What are cermets?

Cermets are the composite materials having metallic and ceramic properties. Examples : iron, nickel and cobalt carbide ceramics.

Uses : Due to their higher hardness they are used as cutting tools and to shape the Refractories through machining.

8. What are intermetallic compounds?

Intermetallic compounds have combined properties of metal and nonmetals. Example : Cu Zn alloy. It has ionic bond along with metallic bond. So that it behaves as insulator with high brittleness.

9. What are elastic and plastic materials?

Elastic materials can regain their original shape after removal of the deforming forces and within the elastic limit, the stress is proportional to strain and have high elastic modulus. Example: Steel, Brasses, Gold.

Plastic materials can undergo plastic deformation permanently in shape and size by the deforming forces up to the ultimate strength without any fracture. Example: PVC, Polymers.

10. What are the applications of conducting polymers?

Conducting polymers are used to make transistors and diodes, large area light emitting device display and photoconductors. They also act as piezo and pyroelectric materials.

11. What is cementite?

A compound of **iron** and carbon known as “Iron Carbide,” which has the approximate chemical formula Fe_3C containing 6.69% of carbon. Hard and brittle, it is the hard constituents of cast iron, and the normal form in which **carbon** is present in steel. It is magnetizable, but not as readily as ferrite.

12. What is meant by cyaniding?

It is the process of Surface hardening of an iron-base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

13. What is mean by composites?

It is fiber reinforced composite materials which consists of fibers of high strength and modulus embedded in or bonded to a matrix with distinct Interfaces between them.

14. What is application of ceramic matrix?

CMS are finding increase application in high temperature areas where MMC and PMC cannot be used this is not to say that CMC are not attractive otherwise especially if you look at their high strength and modules and low density.

15. What are carbon carbon composites?

It is used carbon fibers in a carbon matrix .It is used in very high temperature environments of up to 60000F and are 20 times stronger and 30% lighter than graphite fibers.

16. What are applications of carbon carbon composites?

- ✓ Space shuttle nose cones,
- ✓ Aircraft Slakes,
- ✓ Mechanical fasteners.

17. Discuss the types of Open mould process.

- ✓ Spray layup,
- ✓ Hand layup,
- ✓ Filament winding,
- ✓ Sheet molding compound, Contact molding.

18. Write the Advantages of open mould process.

- ✓ Freedom to design,
- ✓ Easy to change design,
- ✓ Low mould and tooling cost,
- ✓ Tailored properties possible

19. Write the disadvantages of open mould process.

- ✓ Low to medium number of parts,
- ✓ Long cycles times per molding, ✓
- Operator skill depended

20. Discuss the types of close mould process.

- ✓ Compression molding,
- ✓ Vacuum bag,
- ✓ Pressure bag ,
- ✓ Autoclave ,
- ✓ Injection molding
- ✓ Resin transfer

21. Discuss the types of glass fiber.

- E-Glass -E stands for electrical
- S-Glass -S stands for high silica content
 - High thermal expansion coefficient,
 - High fatigue strength
- C-Glass - C stands for Corrosion
 - Used in Chemical applications
 - Storage tanks
- R-Glass - R stands for Rigid
 - Structural applications
- D-Glass - D stands for Dielectric
 - Low dielectric constants
- A-Glass - A Stands for appearance
 - To improve surface appearance
 - For ornamental works
- E-CR Glass - E-CR stands for Electrical and corrosion resistance ➤
- AR Glass - AR stands for Alkali resistance

UNIT-5 - HIGH TEMPERATURE MATERIALS

CHARACTERIZATION

1. What are the required properties of the materials for making thermocouples?

- ✓ The thermocouple material should have larger thermoelectric effect (i.e., produce more voltage or more cooling effect per unit rise of temperature.)
- ✓ It should have high melting point.

Example: Lead telluride semiconductor (where lead is the n type and tellurium is the p type semiconductor with 61.9% Pb + 38.1% Te). It has more thermoelectric generators to produce more electric power and thermoelectric refrigerators to produce more cooling effects.

2. What are the uses of high resistivity materials?

High resistivity materials are used

- ✓ In resistor applications
- ✓ As heating elements and
- ✓ In resistance thermometers

3. Define Super alloys. What are the properties of super alloys?

Super alloys, or high performance alloys, are alloys that exhibit excellent mechanical strength and creep resistance at high temperatures, good surface stability, and corrosion and oxidation resistance. They typically have an *austenitic face-centered cubic crystal structure* with a base alloying element of *nickel, cobalt, or nickel-iron*.

4. Why are super alloys preferred for high temperature application?

Super alloys, or high performance alloys, are alloys that exhibit excellent mechanical strength and creep resistance at high temperatures, good surface stability, and corrosion and oxidation resistance. The development of super alloys has primarily been driven by the *aerospace and power industries*.

5. Name a few examples for super alloys applicable for high temperature applications.

Examples of superalloys are Hastelloy, Inconel (e.g. IN100, IN600, IN713), Waspaloy, Rene alloys (e.g. Rene 41, Rene 80, Rene 95, Rene N5), Haynes alloys, Incoloy, MP98T, TMS alloys, and CMSX (e.g. CMSX-4) single crystal alloys.

6. What are Super alloys and their applications?

Super alloys are generally in three ways such as Nickel base, cobalt base and iron base super alloys. These superalloys are majorly available in many industries such Aerospace, Turbine blades and jet/rocket engines, Marine industry, Submarines, Chemical processing industry, Nuclear reactors, Heat exchanger tubing, Industrial gas Turbines.

7. What are the factors influencing functional life of components at elevated temp?

- ✓ Creep
 - ✓ Corrosion
 - ✓ High temperature fracture
 - ✓ Thermo mechanical Fatigue
 - ✓ Interaction of all above with each other
 - ✓ Metallurgical ageing and metallurgical stability ✓
- Micro structural changes

8. What are the problems associated with materials used at elevated temperature?

Generally a material subjected to high temperature reduces the strength of the material and failure mechanisms affecting the functional life of components are totally different. At high temperature the strength of material has strong dependence on time.

9. What materials are used for aerospace structures?

Aluminum	Very common, traditional aircraft material, light, strong, good corrosion resistance
Steel/Stainless Steel	Very high strength, for highly loaded components
Titanium	Roughly the strength of steel but 2/3 the weight
Magnesium	Similar to aluminum in properties but even lighter
Superalloys	Nickel based high temperature resistant alloys for use in engines
Ceramics	Combinations of metals and non-metals, strong but brittle, high temperature resistance
Plastics/Elastomers	Aircraft interiors, tires, sealants, adhesives
Composites	Rapid growth in use of complex engineered materials to replace much of the traditional materials

10. What are the failure modes of these materials?

- ✓ Fatigue
- ✓ Abrasion/ Wear
- ✓ Corrosion
- ✓ Thermal Shock
- ✓ Fracture
- ✓ Melting
- ✓ Impact
- ✓ Buckling
- ✓ Creep
- ✓ Plastic Deformation/ Yielding

11. What are the root causes of these failures?

Possible root causes:

- ✓ Misuse or abuse
- ✓ Assembly errors
- ✓ Processing/Manufacturing errors ✓
- Improper material choice
- ✓ Non-optimized geometry design ✓
- Improper maintenance
- ✓ Unforeseen operating conditions ✓
- Inadequate quality control
- ✓ Inadequate environmental protection

12. Write the possible Percentage breakdown of types of failures.

- | | |
|------------------------------|-----|
| ✓ Fatigue | 55% |
| ✓ Corrosion | 16% |
| ✓ Overload | 14% |
| ✓ Stress Corrosion Cracking | 7% |
| ✓ Wear/ Abrasion | 6% |
| ✓ High Temperature Corrosion | 2% |

13. Define precipitation strengthening.

Precipitation hardening, also called **age hardening**, is a heat treatment technique used to increase the yield strength of malleable materials, including most structural alloys of aluminium, magnesium, nickel, titanium, and some stainless steels. In super alloys, it is known to cause yield strength anomaly providing excellent high temperature strength.

14. Define TCP phases and its significance in super alloys.

In some alloys, if composition has not been carefully controlled, undesirable phases can form either during heat treatment or, more commonly, during service. These phases affect the creep resistance; fracture strength, premature cracking, and yield strength. These precipitates are known as TCP phases Topologically close-packed (TCP) type phases, which are plate-like or needle- like phases such as σ , and μ that may form for some compositions

and under certain conditions. These cause lowered rupture strength and ductility.

15. Explain why the single crystal turbine blades perform better than directionally solidified and coarse grained cast products.

Single crystal has the mechanical advantage of being able to operate at a much higher temperature than crystalline materials. Creep is a common cause of failure in turbine blades and is in fact the life limiting factor. When temperatures of a material under high stress are raised to a critical point, the creep rate quickly increases. The single crystal structure has the ability to withstand creep at higher temperatures than crystalline turbine blades due to the lack of grain boundaries present.

16. Name two chemical composition of super alloys.

Many **wrought nickel-base super alloys** contain 10 to 20% Cr, up to about 8% Al and Ti combined, 5 to 15% Co, and small amounts of boron, zirconium, magnesium, and carbon.

17. Define and list various TCP phases and explain whether they are beneficial or detrimental for high temperature properties.

The composition has to be carefully controlled in order to avoid topologically close packed (TCP) phases, for example γ phase, μ phase or Laves. These phases can be formed under certain conditions, usually during service. They are distinguished by their plate like or needle like shapes. Alloys containing transition metals, such as tantalum, niobium, chromium, tungsten or molybdenum, are the alloys the most vulnerable to the formation of TCP phases.

18. What are the effects of addition of boron, chromium and cobalt in steels?

Boron: increase the hardness

Chromium: improves wear and impact resistance and increases its strength.

Cobalt: increase its hardness, and residual magnetic induction.

19. What is an alloy?

An alloy is a mixture of two or more metals, or a mixture of metal and a non-metal, with the mixture exhibiting metallic properties.

20. Define eutectic reaction

A reaction wherein, upon cooling, one liquid phase transforms isothermally and reversibly into two new solid phases that are intimately mixed is called eutectic reaction.