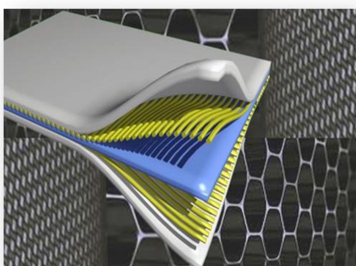
Unit - 4

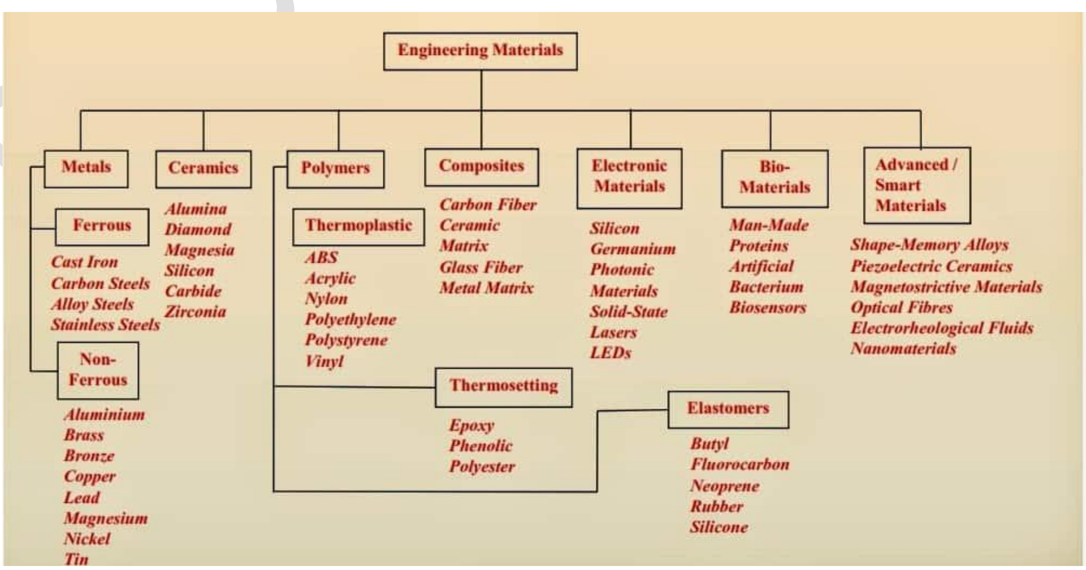
New Engineering Materials

Engineering materials refers to the group of materials that are used in the construction of manmade structures, components and Applications. The primary function of an engineering material is to offer combined benefits of materials.

- The continuous development in the field of science and engineering open the way to new technologies and applications. Scientists and technologists are finding out new materials for 'high-tech' applications
- Advanced Engineering materials are the class of new materials which exhibits Peculiar properties comparing to the conventional one
- Materials used in 'high-tech' applications are usually designed for maximum performance
- Engineering Materials are also called as Modified materials whose properties are modified on our requirement



Classifications Engineering Materials



1. Composites

Composites are combination of two or more materials that are different in chemical composition which results in better properties than those of the individual components used alone.

Sand + Cement

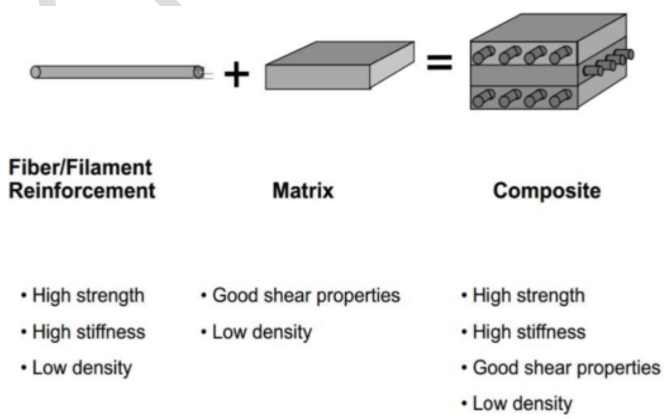
Knee Pad for cricketers

- Composites can be very strong and stiff, yet very light in weight
- Fatigue properties are generally better than common engineering materials
- Toughness is often greater
- Possible to achieve combined properties of metals, polymers and ceramics

1. 1. Components of composites

Composites usually consist of two important parts. They are;

1. The matrix
2. Reinforcements



The matrix holds the reinforcements, transfers the load to the reinforcements, and protects them from mechanical and environmental damage.

The reinforcements carry most of the load and provide stiffness.

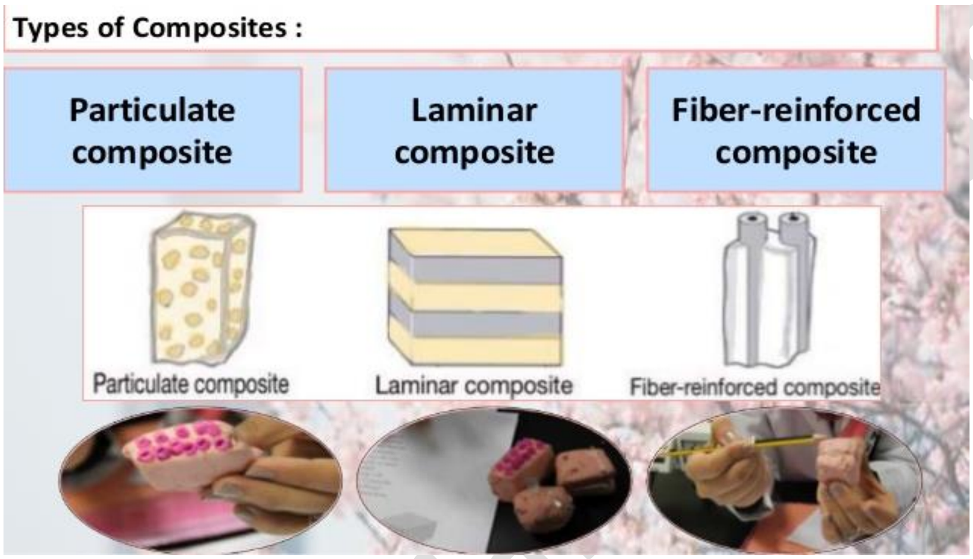
1. 2. Classifications of composites

(a). Based on the shape of the reinforcement used, composites are classified as;

(i) Particulate reinforced composite

(ii) Laminar/Structural reinforced composite

(iii) Fiber reinforced composites.



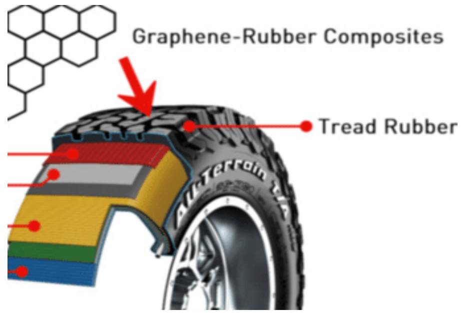
1. 3. Fiber- Reinforced composites

Fiber-reinforced composites consist of thin fibers of a material, which are suspended in a matrix of another material. Matrix is the medium or the substance in which the fibers are suspended.

Matrix distributes the stress across the fibers. The thin continuous or discontinuous fibers provide strength to the composite.

- One of the most common natural fiber-reinforced composite is **bamboo**, where cellulose fibers are suspended in a matrix of lignin.
- One of the manmade fiber-reinforced composites can be seen in a **car tyre**, where nylon or steel wires are suspended in rubber matrix.
- **Concrete** is another manmade composite, where iron rods are used as reinforcing material with sand and gravel in the cement matrix.

Bamboo



Car Tyre

Concrete

1. 3.1. Types of Fiber reinforced composites

- **Polymer matrix composites(FRP):** In this the matrix material is a polymer, reinforced by ceramic. For example carbon or glass fiber reinforced with plastics. Typical polymer matrix resins are epoxy, polyester, polyamide, and thermoplastics. Reinforcements are glass, quartz fiber and Kevlar
- **Metal matrix composites(FRM):** In this composite, the matrix is a pure metal or an alloy and the reinforcement is a ceramic phase. Typical examples of metal matrix composites are Al- Al_2O_3 and Al-S_iC.
- **Ceramic matrix composites(FRC):** The matrix and reinforcements are generally ceramics. In these composites the stiffness and hardness of ceramics is combined with toughness of polymers or metals. Typical examples of ceramic matrix composites are glass-and carbon-fiber-reinforced plastics

1.3.2 Fiber Reinforced Plastics (FRP)

Fiber reinforced plastics consist of fibers in a polymer resin matrix. Because of their room temperature properties, ease of fabrication and cost, they are used in large quantities. The commonly used fibers are;

(a) **Glass Fibre Reinforced Plastics (GFRP)** ***Glass (R) + Polymer (M)***

(b) **Aramid Fibre Reinforced Plastics (AFRP)** ***Aramid (R) + Polymer (M)***

(c) **Carbon Fibre Reinforced Plastics (CFRP)** ***Carbon (R) + Polymer (M)***

(d) ****R – Reinforcement*** ****M - Matrix***

HELMET GLASS

1. 3. 2. 1. Glass Fiber Reinforced Plastics(GFRP)

- Glass fibers reinforced with polymer resin
- Glass fibres are the most widely used and the least expensive of all the fibres.
- The most generally used glass fibre is E- glass and common polymer matrix materials are polyesters and vinyl esters
- GFRP composites have very high specific strength. But they are not rigid and are limited to service temperatures below 200 ºC
- The fiber diameters normally range from 3 to 20 µm.

Glass Fiber

GFRP

Glass is popular as a fiber reinforcement material for the following reasons;

1. It is easily drawn into high strength fibers from the molten state.
2. It is readily available and may be fabricated into a glass-reinforced plastic economically using a wide variety of composite-manufacturing techniques.
3. As a fiber, it is relatively strong, and when embedded in a plastic matrix, it produces a composite having a very good specific strength.
4. When coupled with various plastics, it possesses a chemical inertness that renders the composite useful in a variety of corrosive environments

Applications of FRP

- Used in automotive and marine bodies, leaf springs, pipes, storage containers, sporting goods and industrial floorings.

Leaf Springs in vehicles

1. 3. 2. 2. Aramid Fiber Reinforced Plastics (AFRP)

- Aramids are Aromatic polymide an artificial fiber.
- Aramid fibres, are desirable where light weight, high tensile strength and high impact strength are important. Moreover they provide resistance to creep and fatigue
- Kevlar 49 is the most common Aramid fibre.
- The common matrix materials are the epoxies and polyesters.

Aramid fibers

Applications of AFRP

- Used in bullet proof vests, sporting goods, pressure vessels, missile cases, automotive brake and clutch linings and gaskets.

AFRP – Fire man Suit

1.3.2.3. Carbon Fiber Reinforced Plastics

- Carbon fibre composites have much lower densities, higher strength and higher stiffness-to-weight ratio.
- This composite has low coefficient of thermal expansion and this gives better dimensional stability.
- The commonly used matrix materials are epoxy, polyester, polyether ether ketone (PEEK) and poly-phenylene sulfide (PPS)
- Carbon fibers are not totally crystalline, but are composed of both graphitic and non-crystalline regions. The fiber diameters normally range between 4 and 10 mm

Carbon fiber

Applications of CFRP

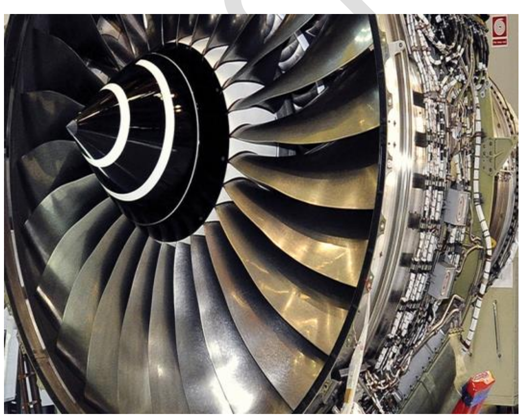
Used in sports and recreational equipment, filament wound rocket motor cases, pressure vessels, commercial and military aircraft, helicopter structures and satellites.

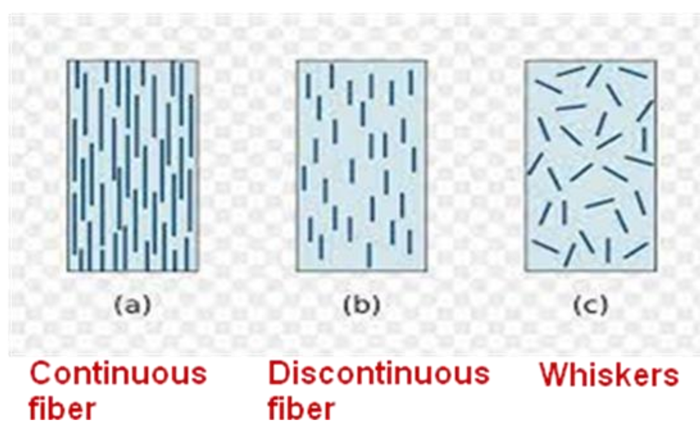
Carbon fiber reinforced plastics

1.3.3. Fiber Reinforced Metals

Metal Matrix Composites (MMC) provide high temperature resistance, non-flammability and greater resistance to degradation by organic fluids when composed to polymer matrix composites

- Fibre reinforced MMCs contain continuous / discontinuous fibres or whiskers in a ductile metal matrix
- The ductile matrix materials are aluminum, magnesium, copper, titanium and super alloys. The continuous fibres are graphite, boron, alumina or silicon carbide.
- The whiskers of silicon carbide and silicon nitride are also used as reinforcement.
- These composites offer high strength and stiffness, high coefficient of thermal expansion and enhanced resistance to fatigue, abrasion and wear. They also give high heat resistance and improved electrical and thermal conductivity





Applications

- Aluminium reinforced with alumina fibres has been used in automotive connecting rods and pistons.

- Aluminium reinforced with boron fibres has been used extensively in aerospace applications, including struts for the space shuttle.
- Aluminium reinforced with SiC whiskers are used in aircraft wing panels.
- Copper based alloys reinforced with SiC fibres are used for producing high strength propellers for ships.
- Titanium reinforced with SiC fibres are considered for turbine blades and discs.
- Super alloys reinforced with tungsten maintain their strength at high temperatures. They are used in jet engines and turbine blades.

MMC Pistons

Turbines

1.4 Advantages of Composites

1. Composite materials exhibit superior mechanical properties such as high strength, toughness, elastic modulus, fairly good fatigue and impact properties.
2. As FRP's are lightweight materials, the specific strength and modulus is much higher than conventional materials.
3. In aero planes power to weight ratio is about 16 with composites compared to 5 with conventional materials. This helps in weight reduction and more pay load carrying capacity.
4. Fabrication of composites to any desired shape and size can be achieved with ease.
5. They exhibit good corrosion resistance.
6. Assembly of components made of composites is much easy and quick.
7. Not much sensitive to thermal shocks and temperature changes.

2. Metallic Glasses

Metallic glasses are the newly developed engineering materials.

- Metallic glasses share the properties of both metals and glasses
- Most metals and alloys are crystalline i.e., their atoms are arranged in a regular pattern that extends over a long distance
- In contrast, a glass in an amorphous non- crystalline) brittle and transparent solid.
- Thus, metallic glasses are the metal alloys that are amorphous

Metallic glasses = Amorphous metals

The major advantages of such glasses are generally, homogeneous in composition, strong and superior corrosion resistance.

2.1. Types of Metallic glasses

Metallic glasses are of two types based on their base material used for preparation.

- **Metal- Metal Glasses**

  [Ex.] Ni- Nb, Mg- Zn and Cu- Zr

- **Metal- Metalloid glasses**

Transition metals like Fe, Co, Ni and Metalloids like B, Si, C, P are used. [Ex.] $Fe_{67}Co_{18}B_{14}Si$, $Fe_{40}Ni_{38}Mo_4B_{18}$

2.3 Preparation of Metallic glasses

The metallic glasses are to be made by cooling a molten metal so rapidly (Quenching). During this process of solidification, the atoms do not have enough time. Various rapid cooling techniques are;

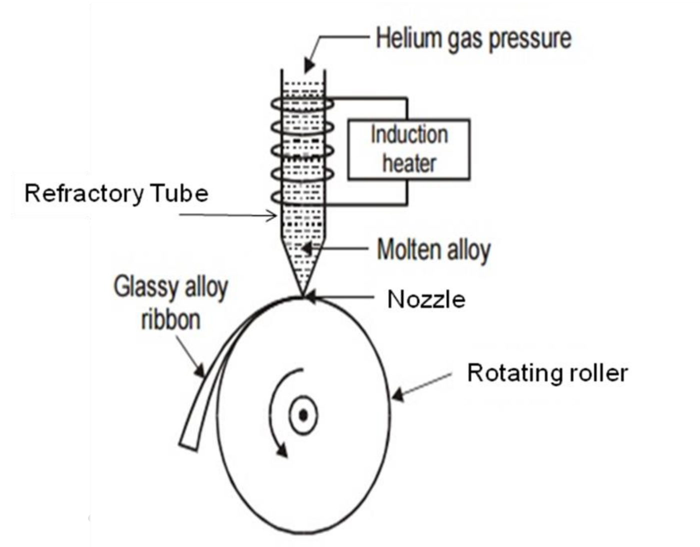
- Spraying
- Melt Spinning
- Laser Deposition

Melt Spinning Method

Principle : *Quenching or rapid cooling* is the principle of Melt spinning process. When a molten alloy is rapidly cooled, a metallic glass is formed with irregular arrangement of atoms.

Components

- Induction heater
- Refractory tube
- Molten alloy
- Helium gas
- Nozzle
- Rotating roller



Working

- Mixture of metal – metal or metal – metalloid is taken in the refractory tube with proper composition
- Heating coil surrounding the tube or induction heater is switched on to achieve molten Material
- The superheated molten alloy is ejected through the nozzle of the quartz tube
- By varying the gas pressure inside the tube the ejection rate can be increased or decreased.
- When the molten alloy falls on the rapidly spinning wheel made of copper, the heat is absorbed by the wheel
- This results quenching and formation of metallic glasses in the form of ribbon

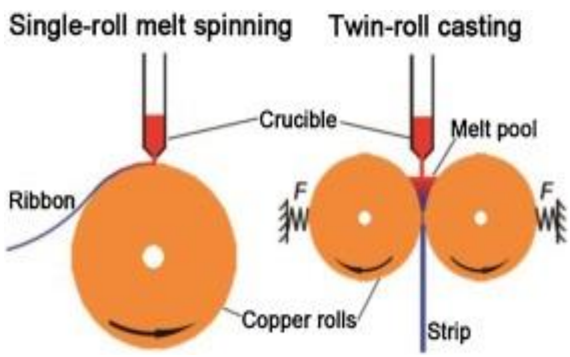
Other Preparation Techniques

- **Twin roller**

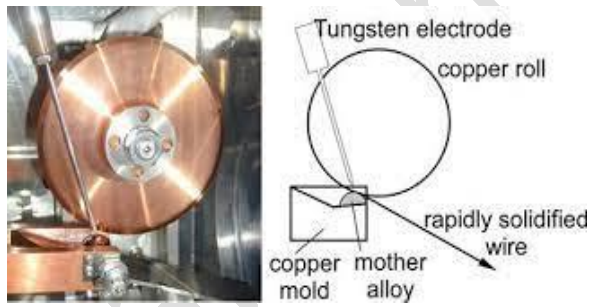
  In this technique molten alloy is passed through two rollers in two opposite direction.

- **Melt extraction Process**

  In this technique fast moving roller sweeps off molten droplet into a strip from solid rod.



Twin roller



Melt extraction

Properties

- The strength of metallic glasses is very high (nearly twice that of stainless steel) lighter in weight
- They are ductile, malleable, brittle and opaque. The hardness is very high
- The toughness is very high, i.e, the fracture resistance is very high
- They have high elasticity. i.e. the yield strength is very high
- They have high corrosion resistance
- They do not contain any crystalline defects like point defects, dislocation, stacking faults etc.,
- They are soft magnetic materials. As a result, easy magnetization and demagnetization is possible

Applications

1. Metallic glasses are used as transformer core material in **high power transformers**.

2. Because of their high electrical resistivity and nearly zero temperature coefficient of resistance, these materials are used in making **cryothermometers, magnetoresistance sensors and computer memories**.
3. As the magnetic properties of the metallic glasses are not affected by radiation they are used in making **containers for nuclear waste disposal**.
4. These materials are used in the preparation of **magnets for fusion reactors** and **magnets for levitated trains** etc.,
5. Metallic glasses can also be used for making watch cases to **replace Ni** and other metals which can cause allergic reactions.
6. The excellent corrosion resistance property makes these materials to be ideal for cutting and in making **surgical instruments**. They can be used as a **prosthetic material** for implantation in the human body.
7. In future, the usage of metallic glasses in the electronic field can yield, stronger, lighter and more easily **moulded castings** for personal electronics products.
8. Metallic glasses are used in **tap recorder as heads**, in manufacturing of springs and standard resistances

3. Shape Memory Alloys (SMA)

A group of metallic alloys which shows the ability to return to their original shape or size (i.e., alloys appears to have memory) when they subjected to appropriate thermal procedure (heating/Cooling) are called shape memory alloys.(SMA).

Examples

Generally, shape memory alloys are inter-metallic compounds having super lattice structures and metallic - ionic- covalent characteristics. Thus, they have the properties of both metals and ceramics

- Ni – Ti alloy (Nitinol)
- Cu – Al – Ni alloy
- Cu – Zn – Al alloy
- Au – Cd alloy

Nickel-Titanium

Shape memory alloys

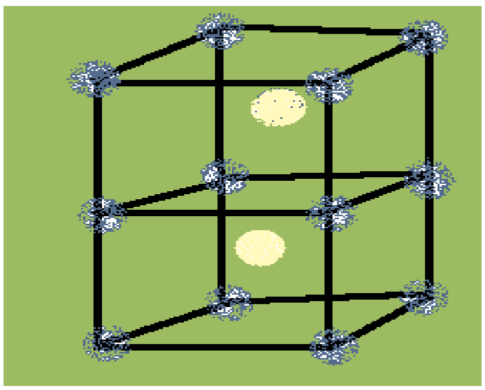
Transformation temperature

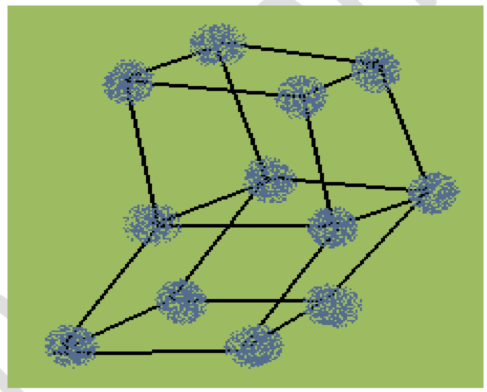
- Shape recovery occurs not at single temperature but at some range of temperature
- The range of temperature at which SMA switches from new shape to its original shape is called transformation temperature (or) memory transfer temperature

- Below transition temperature, SMA can bent into various shapes. Above transition temperature, the SMA returns to its original shape
- This change in shape was mainly caused due to the change in crystal structure (phase) within the materials, due to the rearrangement of atoms within itself

Phases of SMA

In General SMA has two Phases (Crystal structures)





Austenite

- It is high temperature phase
- It crystallizes in cubic structure
- It is hard phase
- Not deformable

Martensite

- It is low temperature phase
- It crystallizes in twinned structure
- It is soft phase
- It is easily deformable

At low temp SMA will be in Martensite and when it is heated it will change its shape to Austenite structure. This effect is called ***Shape Memory Effect (SME)***

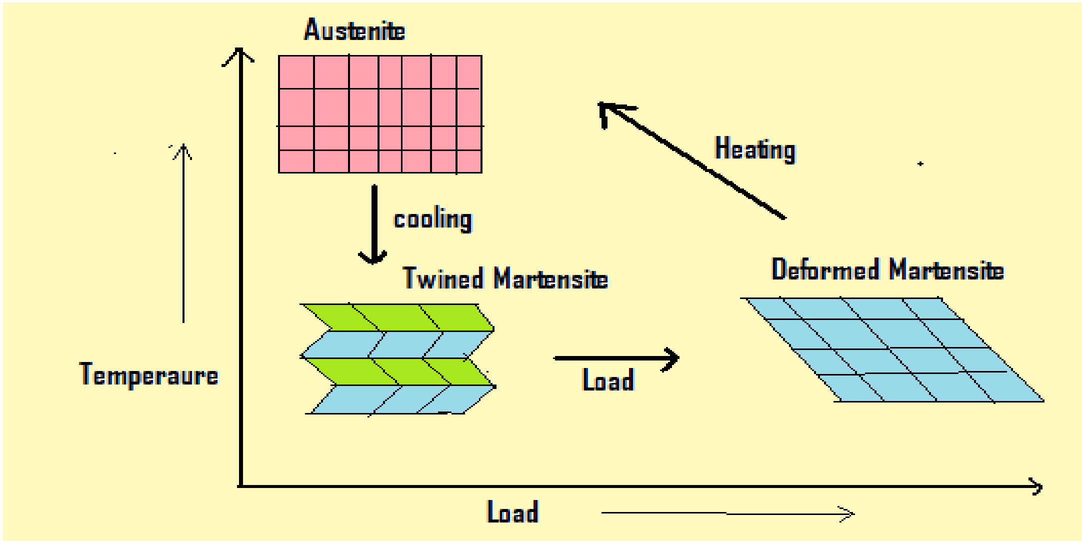
Processing of SMA

Let us consider a shape memory alloy, for which the temperature decreased;

Step 1: Austenite to twinned martensite

Step 2: when twinned martensite is applied with load it deformed into martensite phase

Step 3: When the material is further heated it will regain the austenite form



Types SMA

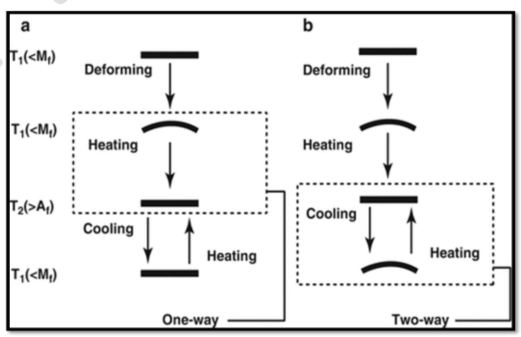
(i). Based on transformation temperature;

a. One way shape memory alloys:

The materials which exhibit shape memory effect (i.e., taking their own shape) only upon heating are said to be one way shape memory alloys.

b. The two way shape memory alloys:

Some materials exhibit shape memory effect both during heating and cooling. Hence, these materials are said to have two way shape memory.



(ii). By the transformation process;

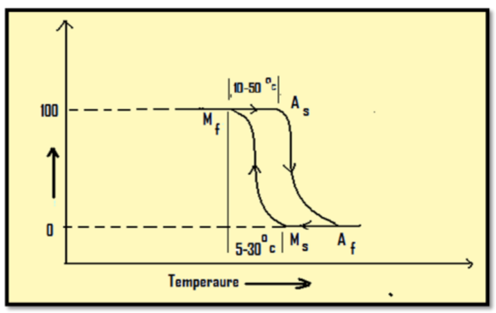
a. Temperature induced shape memory alloys

- Temperature induced transformation is characterized by four temperatures M_s , M_f during cooling and A_s , A_f during heating

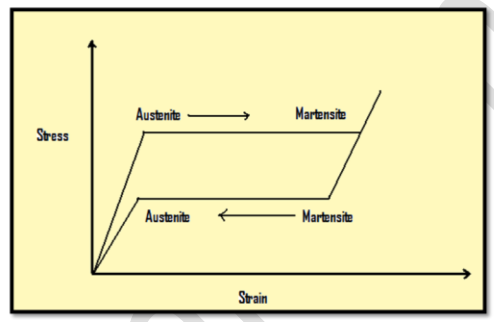
- M_s , M_f indicates the transformation from martensite to austenite and A_s , A_f indicates austenite to martensite

b. Pressure/Stress induced shape memory alloys

- Stress induced transformation take place at constant temperature
- At temperature above A_f martensite phase can be induced by applying stress over the austenite phase



Temperature induced SMA



Pressure induced SMA

Characteristics of SMA

- **Shape memory effect**

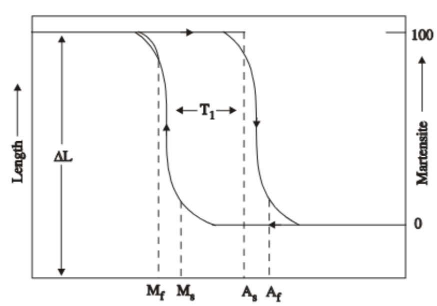
  At lower temperature the SMA will be in martensite structure and when it is heated then it will change its shape to austenite structure and while cooling it will again return to martensite form. This effect is called shape memory effect

- **Pseudo elasticity (or) Super elasticity**

  Pseudo-elasticity occur in some type of SMA in which the change in its shape will occur even without change in its temperature

- **Hystersis**

  For an SMA, during cooling process, a martensite starts (m_s) and ends (m_f) and during heating process, austenite starts (A_s) and ends (A_f). It is found that they do not overlap with each other and the transformation process exhibits the form of hysterisis curve.



Properties of SMA

Nickel – Titanium [Ni-Ti] is a shape memory alloy which has high shape memory strain.
It has following properties, viz.,

- It is more flexible.
- It has high melting point($1300^{o}C$]
- The transformation temperature varies between -200 ^{o}C and 110 ^{o}C.
- It has high thermal stability.
- It has high corrosion resistance.
- Thermal conductivity ranges from 8.5 [Martensite] to 18 [austenite] W^{o}C/Cm

Applications of SMA

- **Aircraft and space industry**
  - helicopter blades
- **Automobile industry**
  - Spring actuators
  - Clutch systems
  - Thermostats
  - Oil pressure control units
- **Medical field**
  - they are used as dental arc wires
  - Micro surgical instruments.
- **Consumer Products**
  - Eye glass frames
  - robotic actuator
  - in fire safety valves
  - in coffee pots

Advantages

- SMA is very compact in nature.

- It is safe and smart.
- They are flexible.
- They are non corrosive.

Disadvantages

- Cost is high.
- Efficiency is low.
- Transformation occurs over a range of temperature. Structural arrangement may sometime get deformed

4. Ceramic Materials

Ceramics materials (most) are compounds of metallic and non-metallic elements. The crystal structure of ceramics is more complex because at least two elements are involved in making a ceramic compound. Ceramics can be used at low as well as high temperatures.

- Traditional ceramics are clay products like bricks, tiles and porcelain. China ceramics are obtained by firing clay products.
- A new generation of ceramics have been developed recently which are used in electronic, computer, communication and aerospace industries
- Examples of ceramic materials are SiC, WC, Al_2O_3 and TiC
- These ceramics possess high Young's modulus, high strength and high fracture toughness, and can be used at high and low temperatures.



Applications

Major applications of ceramic are in furnaces, ovens as insulators and crockeries. Other important applications are;

- In artificial limbs and teeth.

- Super conducting materials,
- In explosive forming,
- As ferrites in microwave gyrators,
- As memory cores of computers,
- As garnets in microwave isolators and
- In sonar devices.

<u>Classification of Ceramic materials</u>

Ceramic Materials

- **Availability**
  1. Natural ceramics
  2. Manufactured Ceramics
- **Functional**
  1. Abrasives
  2. Pure Oxide Ceramics
  3. Fired-clay products
  4. Inorganic glasses.
  5. Cementing materials.
  6. Rocks.
  7. Refractoriness
- **Structural**
  1. Crystalline ceramics
  2. Non-Crystalline Ceramics
  3. Glass-Boned Ceramics

1. <u>Natural and Manufactured ceramics :</u>

(a) **<u>Natural Ceramics</u>** : The most frequently used, naturally occurring ceramics are Silica, SiO_2 Silicates and Clay minerals

(b) **<u>Manufactured Ceramics:</u>** Ceramics include: SiC, Al_2O_3, Silicon Nitride, Si_3N_4 and many varieties of Oxides, Carbides, Nitrides, Borides.

Some naturally occuring ceramics are also, manufactured for enhanced properties, as compared to natural ceramics. However, all the ceramics not available naturally, are manufactured.

The natural ceramics are also called as **"traditional ceramics"**, while manufactured ceramics are usually called as "High-tech ceramics" or "**Engineering Ceramics**".

2. Functional Classification

This classification indicates particular industries and industrial applications of the ceramics, as given below;

(a) Abrasives : Alumina, Carborundum

(b) Pure Oxide Ceramics : MgO, Al_2O_3, SiO_2, Zirconia, ZrO_2, and Berylia (BeO) etc.

(c) Fired-clay products : Bricks, Tiles, Porcelain, etc.

(d) Inorganic glasses : Window glass, lead glass, etc.

(e) Cementing materials : Portland cement, Lime, etc.

(f) Rocks : Granites, Sandstones, etc.

(g) Minerals : Quartz, Calcite, etc.

(h) Refractories: Silica bricks, Magnesite, etc

3. Sructural Classification

This classification indicates the structural criteria as given below;

(a) **Crystalline Ceramics:**

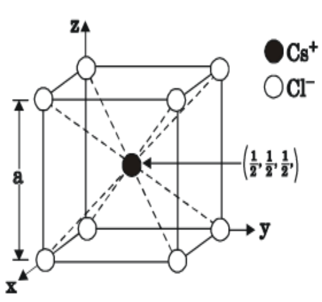
These have simple crystal structure, such as aluminium oxide (corundum), magnesium oxide, silicon carbide.

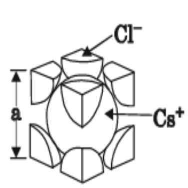
Magnesium oxide is used in refractory furnace lining for steel making. Silicon carbide is used for cutting tools

The crystal structure of ceramic is, more complex, since atom of different size and electronic configuration are assembled together

Common crystal structures found in crystalline ceramics are of the oxide type.

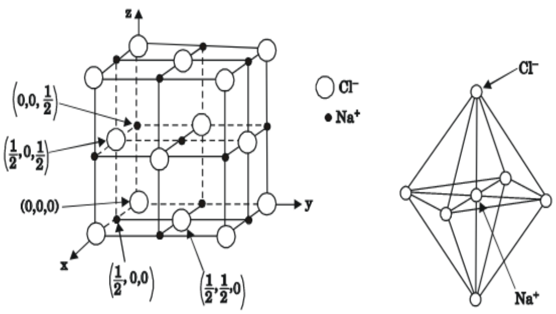
Cesium Chloride Structure





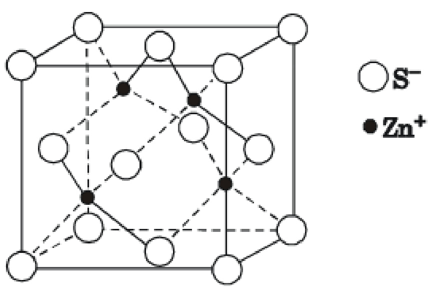
- It is possible for ceramic compounds to have simple cubic structure that are not found among metals. Cesium chloride is a prototype for this case.
- In this structure, chlorine ions are arranged in a simple cubic structure and all interstices are occupied by cesium ions.

Rock Salt Structure



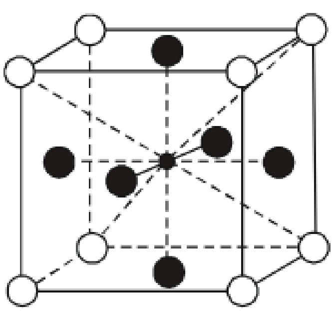
- Most of the oxides and halides crystallize in the closed packed cubic structure similar to that of a rock salt (sodium chloride).
- Here, each metal atom is surrounded by six non-metallic atoms and vice versa

Zinc Blende Structure



- Two of the more cubic ceramic compounds which have atoms in the 4-fold sites, are zinc blende (ZnS), silicon carbide(β-SiC). The atomic coordination is 4.
- The structure is the same as the diamond cubic except that alternate atoms are of different elements

Perovskite Crystal Structure



- Ba^{2+} ions are situated at all eight corners of the cube and a single Ti^{4+} is at the cube center. The O^{2-} ions located at the center of each of the six faces of the unit cell

(b) Non- Crystalline Ceramics:

These are usually regarded super, cooled liquids. Their molecules are not arranged in regular geometric shapes. e.g. amorphous or fused SiO_2 has each Si bonded to four O and each O is bonded to two Si

This type of ceramics is used for mirrors, optical lenses, reinforcement fibres for GRP and optical fibers for data transmission

e.g., Silicates and Silica

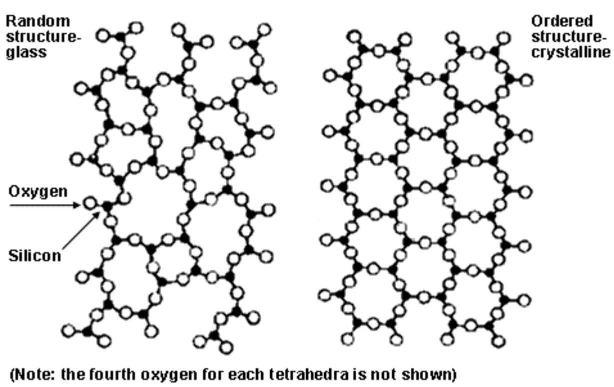
Silicates are composed of silicon and oxygen, which are abundantly available in the earth's crust. For example, rocks, soils and clay come under the classification of silicates.

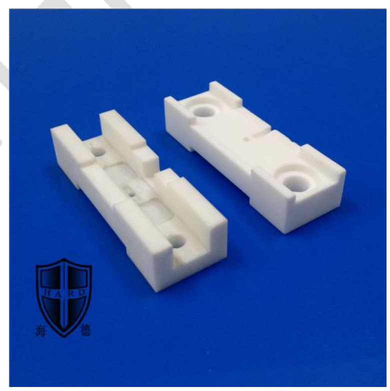
Silica (SiO_2) is the simple form of silicate. This is a three-dimensional network of tetrahedron where every corner oxygen atom is shared by adjacent tetrahedral. This material becomes electrically neutral but electronically stable

(C) Glass Bonded Ceramics:

These ceramics contain both crystalline and non-crystalline materials which are bound together by a glassy matrix after firing. This group includes the lining and clay products.

Bonded ceramics are used as electrical insulators, refractory for furnace, spark plugs etc





4.1. Manufacturing of Ceramic Materials

The raw material powder is thoroughly mixed with water and other ingredients to obtain flow characteristic depending on particular processing technique. The different fabrication processes that are used for many years are;

(a) Slip Casting

(b) Extrusion

(c) Iso- static Pressing

(i) Cold isostatic pressing

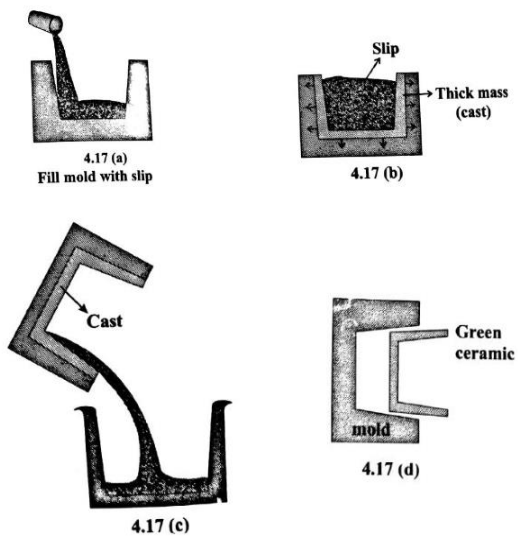
- Wet isostatic pressing
- Dry Isostatic Pressing

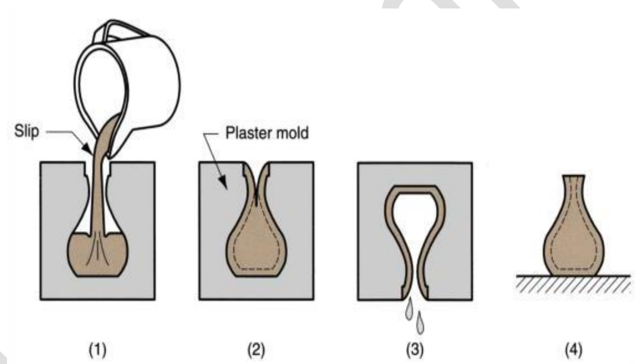
(ii) Hot isostatic pressing

4.1. 1. Slip Casting

Forming a hallow ceramic part by introducing a pourable slurry into a mould is known as slip casting.

Formation: Slip casting is the most conventional method of producing different pieces that can have complex shapes such as refractory, sanitary and technical ceramics, without the use of heat.





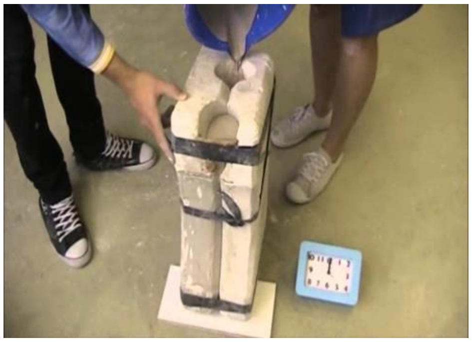
The following steps were involved in slip casting.

- Slip casting technique normally uses aqueous slurry of ceramic powder. The slurry, known as slip, is poured into a mould [usually made of plaster of paris].
- The fineness of the powder and the consequent high surface area ensure that electrostatic forces dominate gravity so that settling does not occur.
- Now, sodium silicate is added to the slip to deflocculate the particles.
- When the water from the slurry begins to move out by capillary action, a thick mass builds along the mould wall.
- When sufficient product thickness is built, so called cast is formed and the rest of the slurry is poured out.
- Now, the mould and cast are allowed to Dry. After drying, casting is removed.
- The green ceramic is then dried and fired or sintered at high temperature to obtain a dense ceramic material

Uses of slip casting

- Slip casting is a low cost way to produce complex shapes.

- In traditional pottery industry, slip casting method is used for the production of teapots, jugs, statues and other ceramic sanitary ware.
- Slip casting method is the standard method to make alumina crucibles which is used to make complex structural ceramic components such as gas turbine rotors.



4.1.2. Isostatic Pressing

Isostatic pressing involves the application of hydrostatic pressure to a powder in a flexible container. The advantage of applying pressure in all directions is that there is more uniform compaction of the powder and more complex shapes can be produced

There are two types of isostatic pressing

(i) Cold isostatic pressing

(ii) hot isostatic pressing

(i) Cold isostatic pressing;

A powder-shaping technique in which hydrostatic pressure alone is applied during compaction is known as cold isostatic pressing. This is used for achieving higher green ceramic density or compaction of more complex shapes.

There are two types

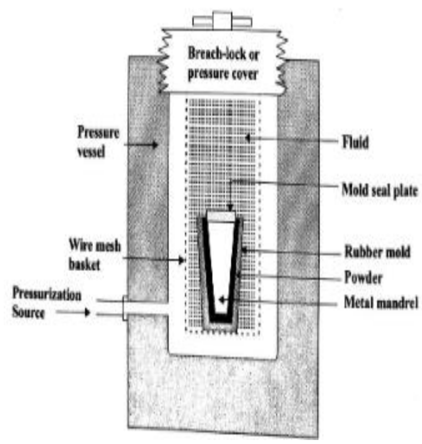
(i) Wet-bag cold isostatic pressing

(ii) Dry-bag cold isostatic pressing

(a) Wet-bag cold isostatic pressing

- The following steps are involved in the processing.
- The Moist powder (Raw material) is weighed into a sealed rubber mould

- The rubber bag is sealed by using a metal mandrel over which mould seal plate is fixed.
- Now the sealed bag is placed inside a high pressure chamber that is filled with a fluid and is hydrostatically pressed.
- The pressure used can vary from about 20 MPa upto 1 GPa depending upon press and the application
- Once the pressing is complete, the pressure is released slowly
- After releasing the pressure, the mould is removed from the pressure chamber.
- Finally the pressed component is removed from the mould



Advantages

1.We can produce wide range of shapes and sizes.

2.Uniform density of the pressed product shall be obtained

3.Tooling costs is very low

Disadvantages

1. Some time it forms poor shape and may not have dimensional control
2. Product often require green machining after pressing
3. It take long cycle time and give low product rates

(b) Dry-bag cold isostatic pressing

The following steps are involved in the processing.

- In dry bag process, the process is similar to the wet bag pressing but the water content of the initial material is only 5 %.
- The high pressure fluid is applied using pressure vessel.
- The top closure, the bottom closure, the upper punch and the lower punch helps to hold the material tightly while pressing.
- After pressing, the pressed part is removed without disturbing the mould.
- Hence the dry bag press can be readily automated, Production rates are as high as 1part per second is being achieved industrially.

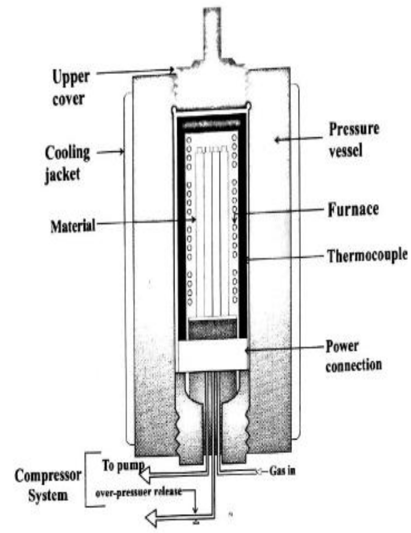
Uses

- The dry-bag has been used for many years to press spark plug insulators.

- The world's largest producers of spark plugs produced by this method are champion and AC spark plug

ii). Hot isostatic pressing (or) Gas pressure bonding

Hot isostatic pressing (or) gas pressure bonding is a method used to densify a material, where in heat and pressure are imposed simultaneously and the pressure is applied from all directions via a pressurized gas such as argon or helium



- The basic function of the HIP unit is to heat the material by applying uniform gas pressure on all the surfaces.
- The material to be prepared is kept inside the furnace.
- Normally,a metal container or glass is used as a flexible, a leak proof mould in hot isostatic pressing. The mould is degassed after filling with powder to remove volatile components then sealed, using upper cover.
- The furnace heats the material to be pressed. At the same time, a pressurizing medium, usually a argon gas is used to apply a high pressure during the process for specific time

- The pressurizing gas is further compressed using a compressor so as to increase the pressure to the desired level
- Thus, both temperature and pressure are raised to the required values.
- The furnace is then allowed to cool, followed by depressurizing the chamber and removal of parts.
- The process results in full density parts with isotropic properties, even in large and complex shaped parts. During HIP, the pores present not only get closed by flow of matter by diffusion and creep, but also bonded across the interface to form a continuous material.

Advantages

- The process offers increase in design flexibility
- The process is not shape or size dependent, which results in optimized usage
- HIP results in enhanced quality and improved mechanical properties.
- Tooling is simple and scrap is minimized and machining is not required

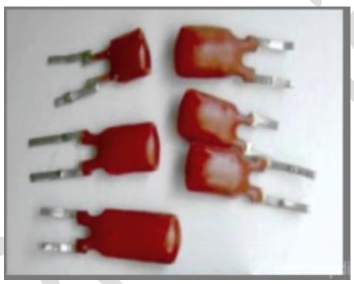
Disadvantages

- The design of the equipment is very complex and critical as it has to withstand a combination of high pressure and high temperature

- Cost is very high

4.3 Ferroelectric Ceramics

- Ferroelectric ceramics exhibit electric polarization even in the absence of electric field
- Fabrication–Powders made by traditional methods – Forming process (like slip casting) is done – Followed by densification by hot isostatic pressing –Later, ceramics are sliced, lapped and finally polished
- Micro-structure –Grain size in the range of 2-6 µm – Uniform grain size is highly desirable
- Electrical / Electro-mechanical property –High dielectric constant – Exhibit hysteresis behavior – PZT and PLZT possess highest electromechanical coupling coefficient
- Thermal / Optical properties – Better choices for thermal imaging applications because of their high pyro-electric coefficients – PLZT have high optical translucency and transparency
- Electro-optic properties –Quadratic, Kerr and birefringence effects are observed



Applications of ferroelectric ceramics

- Ferroelectric ceramics are used as capacitors because of their high dielectric constant– BaTiO3
- Ferroelectric ceramics can convert electrical signal into mechanical signal (such as sound) and vice versa and hence used as transducers
- Ferroelectric ceramics are used as medical ultrasonic composites
- Ferroelectric ceramics can be used in photostrictors and integrated circuit (IC) applications
- Ferroelectric ceramics can be used in medical diagnostics through transducers

4.4 Ferromagnetic Ceramics

- Ferromagnetic ceramics, also known as ferrites, are compounds of various oxides
- The magnetic ceramic materials are classified into three types namely, Spinel, garnets and hexagonal ferrites

- General formula $MO.Fe_2O_3$ where M stands for a bivalent metal ion such as Zn, Ni and others
- Mineral magnetite ($FeO.Fe_2O_3$) is the only naturally occurring mineral of this type
- Properties –High volume resistivity and high permeability –Specific gravity is between 4 and 5, which is less than iron (8) –Can be made both into soft and hard permanent magnetic materials –Exhibit a square hysteresis loop of magnetization –Extremely low switching time between magnetic saturation and demagnetization
- Applications –Cores of radio and television loop antennas, high reception quality and selectivity in antennas –Memory cores in electron computers –Military airborne applications due to 35% lower density than metallic magnets

4. 5. Highalumina Ceramics

- These ceramics are composed with more than 92wt% of alumina (Al_2O_3), along with additives such as silica, iron oxides and alkaline oxides
- High alumina ceramics are readily coupled with metals and other ceramics by metallising and brazing techniques
- Offers a combination of good mechanical and electrical properties leading to wide range of applications

Characteristics of Alumina

1. Alumina have excellent hardness, wear resistance and chemical inertness properties.
2. They are more stiffer than steels.
3. They are more stronger in compression than many hardened tool steels.
4. They retain 50% of their room temperature strength that elevated temperature (about 1093 ^{o}C).
5. They possess very good environmental resistance.
6. These are mechanically strong, dense materials, unlike refractories which are usually porous.
7. They have high corrosion resistance.

Properties

Excellent wear characteristics, white in colour with high hardness, good chemical resistance, good electrical insulation, high mechanical strength, high compressive strength, high dielectric strength, half the density of metals and hence half the weight of metals

Applications

Electric arc furnaces, manufacturing gem stones and laser components, manufacturing insulators and capacitors, bio-ceramic parts for orthopedic and dental surgery, thermocouple protection tubes and refractory parts

High Alumina Ceramics