Course/Branch : BE/CIVIL	**Year / Semester** : I/II	Format No.	NAC/TLP-07a.5
Subject Code : PH8201	**Subject Name** :Physics for civil engineering	Rev. No.	02
Unit No 4	**Unit Name : New engineering materials**	Date	14-11-2017

LECTURE NOTES

UNIT IV NEW ENGINEERING MATERIALS

Composites - definition and classification - Fibre reinforced plastics (FRP) and fiber reinforced metals (FRM) - Metallic glasses - Shape memory alloys - Ceramics - Classification - Crystalline - Non Crystalline - Bonded ceramics, Manufacturing methods - Slip casting - Isostatic pressing - Gas pressure bonding - Properties - thermal, mechanical, electrical and chemical ceramic fibres - ferroelectric and ferromagnetic ceramics - High Aluminium ceram

Composites

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

Types

Based on the shape of the reinforcement used, composites are classified as

(i) Particulate reinforced composite
(ii) Discontinuous fiber reinforced composite
(iii) Continuous fiber reinforced composites.

Fibre reinforced plastics

It is a composite material. We know that the composite materials have been developed to get improved or desired properties in them. Nowadays fiber reinforced plastics (FRP) plays an important role in the machine parts where we require high strength, high modulus, heat resistance and light weight.

The fibrous glass is used in reinforced plastics in the form of ravings, chopped strands, milled fibers, yarns, non-woven mats and woven fabrics.

Most commonly used reinforcements are

(i) Random chopped strand mat, bonded together with a resinous binder (polyester).
(ii) Mat from continues strands, deposited in a swirl pattern and loosely bonded together with a resinous binder.
(iii) Filament type thin mats.
(iv) Performs
(v) Woven fibrous glass clothes.
(vi) Parallel stranded glass fibers
(vii) Short stranded

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The glass fibers having a vinyl silence-epoxy surface treatment on the fibers are used. This treatment gives best dry and wet strength. E type glass is one of the important glass fiber materials which use boric acid rather than soda ash as one of the component of the melt. Mostly polyester resin is used as plastic. Epoxy and phenolic resins are also used.

The fibers are made from synthetic textile fibers treated in such a way that the side groups are entirely removed. The carbon fiber reinforced plastics are used in aero engines, high pressure rotor and stator blades since they can withstand higher thrusts. Silica and boron fiber reinforced plastics have high strength and low density. But these are all costlier than glass or carbon fiber reinforced plastics.

Advantages

1. It has high strength to weight ratio
2. It has low cost tooling.
3. Intricate and large shapes are possible in one piece. Since it can be fashioned more easily than a metal it is used in making complicated machine parts.
4. Excellent environment exposure resistance can be obtainable.
5. It has excellent electrical properties.
6. It has higher heat resistance.

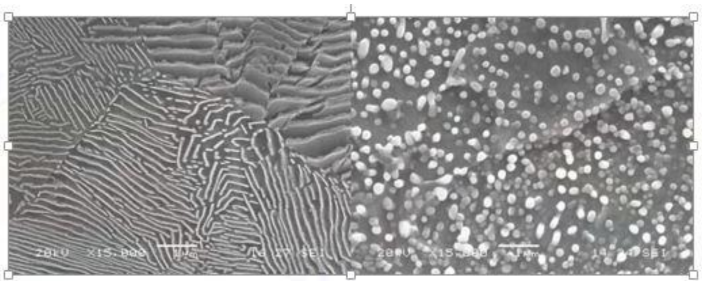
Disadvantages

1. The material cost is so high.
2. The strengths perpendicular to fiber orientations are low.
3. It has low rate of heat transfer and dissipation.
4. It has lower flexural modulus than steel and requires higher thickness for equlistiffness.

Fiber reinforced metal

Fiber reinforced metals (FRM) are composites, which are made up of inorganic fibers fabricate with metal.

FRM are composed of fibers (reinforcement phase) and metals (matrix phase). The following diagram exhibits the FRMs (silicon fiber reinforced in metals).

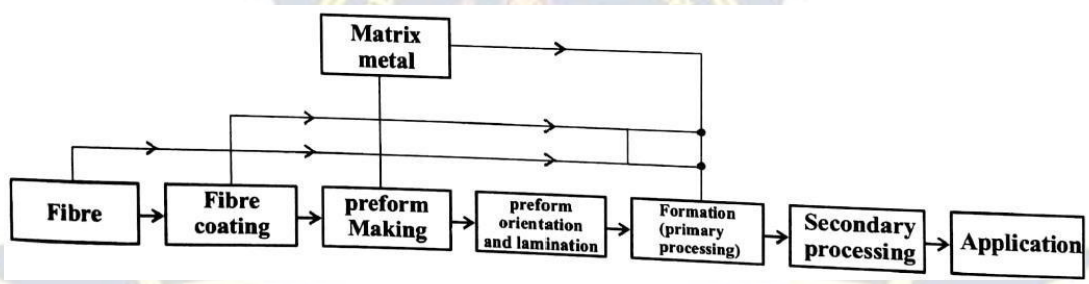


Fabrication of FRM

The fabrication of FRM consists of joining the interfaces of both phases. Before doing the fabrication of FRM, the reinforcement fibers and the matrix materials should be chosen carefully with light weight and high strength materials.

The reinforcement fibers and the corresponding matrix metals used for fabricating FRM given bellow

S. No	Reinforcement Fibers	Matrix metals	Composite System
1.	Boron	Al and Mg	Boron System
2.	Carborundum	Al and Ti	Corborundum System
3.	Carbon	Al, Mg and Cu	Carbon System
4.	Alumina	Al and Mg	Alumina System



1. Depending upon requirements, fibers are given pre-treatment such as fibre coating to improve wetting and joining ability with matrix metals and to prevent failure caused by reaction between different surfaces.
2. Then, performs are made, which are cut to the required dimensions.
3. These performs are oriented and laminated according to the design specifications of the components.
4. The next process is called forming (primary processing) in which composition and shaping is carried out.
5. At this stage the matrix metal and the reinforcement fibers are primarily processed together to form the FRM composite.
6. After forming the FRM, the secondary processing such as cutting, trimming and joining is done. Thus the fabrication is complete and shall be used for further applications.

Properties of FRM

i) FRM is light weight
ii) FRM has a high stiffness
iii) FRM possess high strength at high temperatures [i.e. 200 to 400 ˚C].
iv) FRM are high in inter-lamina strength and stress transmissibility between filaments and highly resistant to polyaxial and complex stress.
v) FRM are resistant to impact and superior in extreme low temperature characteristics.
vi) FRM are infiltrated by water and are not corroded by rain.
vii) They do not require any measures against lightning strike or static, nor any coating for electromagnetic shielding

Applications of FRM

i) FRM are used in constructing space machines and satellite body structures. The material system used for this are B/Al, B/Mg, C/Al, C/Mg.
ii) FRM are to make pylons, frames, beams, fans, compressor blades, fairings, wing boxes, access-doors in air crafts. The material systems used here are B/ Al, SiC/ Al.
iii) FRM are used to make truss structures in helicopters. The promising material systems used are B/ Al, SiC/ Al, Al_2O_3/ Al.
iv) FRM are used to make engine electric components such as motor brushes, cables, etc., C/Cu is the material systems used for these products.
v) FRM are used to make sports goods such as tennis rackets, Golf clubs, etc., the materials systems used for these are B/ Al, SiC/ Al, C/Al, Al_2O_3/ Al.

Metallic glasses

Definition:

Metallic glasses are the amorphous metallic solids which have high strength, good magnetic properties and better corrosion resistance and will possess both the properties of metals and glasses.

Examples: Alloys of Fe, Ni, Al, Mn, Cu, Cr and Co mixed with metalloids such as Si, Ge, As, B, C, P and N.

CONCEPT BEHIND THE FORMATION OF METALLIC GLASSES

Generally liquids can be made into glassy state by increasing the rate of cooling. In a similar manner the metals can also be made into glassy state by increasing the rate to cooling to a very high level [2 x 10^6 °C per second]. At that state the atoms will not be able to arrange orderly because of its rapid cooling rate.

Thus, the atoms will not be allowed to go to crystalline state, rather it goes to amorphous state and it

will form a new type of material. These new type of materials which are made by rapid cooling technique (i.e., the temperature decreases suddenly with respect to time) are called ***metallic glasses.***
The cooling rate for the formation of metallic glasses varies from material to material.

Glass Transition Temperature

The temperature at which the metals [alloys] in the molten form transforms into glasses i.e., liquids to solids is known as **glass transition temperature (Tg).**

It was found that the glass transition temperature for metallic alloys varies from 20°C to 300°C.

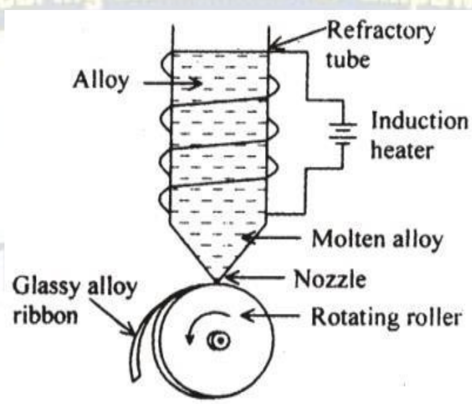
PREPERATION OF METALLIC GLASSES

Principle

"Quenching" is a technique used to form metallic glasses**,** quenching means rapid cooling. Actually atoms of any materials move freely in a liquid state. Atoms can be arranged regularly when a liquid is cooled slowly. Instead, when a liquid is quenched, there will be an irregular pattern, which results in the formation of metallic glasses.

The process involved in the formation of metallic glasses is melt spinning technique. This technique is illustrated in Fig.

Experimental Setup



The setup consists of a refractory tube with fine nozzle at the bottom. The refractory tube is placed over the rotating roller made up of copper. An induction heater is wounded over the refractory tube in order to heat the alloy inside the refractory tube as shown in fig

Preparation

The alloy is put into the refractory tube and the induction heater is switched ON. This heats the alloy and hence the super-heated molten alloy is ejected through the nozzle of the refractory tube onto the rotating roller and is made to cool suddenly. The ejection rate may be increased by increasing the gas pressure inside the refractory tube. Thus due to rapid quenching a glassy alloy ribbon called metallic glass is formed over the rotating roller.

Metallic glasses of various thicknesses can be formed by increasing (or) decreasing the diameter and speed of the roller.

TYPES OF METALLIC GLASSES

Metallic glasses are of two types viz,

(i) Metal-metalloid glasses

Examples: Metals : Metalloids

Fe, Co, Ni: Ge, Si, B, C

(ii) Metal – Metal glasses

Examples: Metals : Metals

Ni : Niobium

Mg : Zn

Cu : Zr

PROPERTIES OF METALLIC GLASSES

Since the atoms in the metallic glasses are disordered, they have some peculiar properties as follows:

(i) Structural Properties

a. Metallic glasses have tetrahedral closely packed (TCP) structure rather than hexagonal closely packed (HCP) structure.

b. They do not have any crystal l defects such as grain boundaries, dislocations etc.

(ii) Mechanical Properties

a. The metallic glasses are very strong in nature.

b. They have high corrosion resistance.

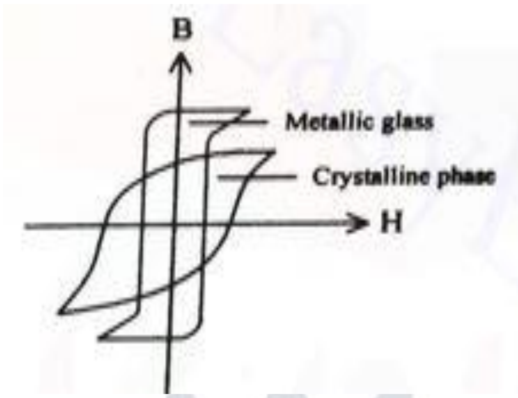
c. They possess malleability, ductility etc.

(iii) Magnetic properties

a. Metallic glasses can be easily magnetized and demagnetized

b. They have very narrow hysterisis loop as shown in fig . In Fig the hysterisis loop of the metal alloy in crystalline phase is also given for reference.

c. They exhibit very low hysterisis loss and hence transformer core loss is very less.



(iv) Electrical Properties

a. Metallic glasses have high electrical resistance (100 μΩ - cm).
b. The electrical resistance for metglasses will not vary with temperature.
c. They possess very low eddy current losses.

APPLICATIONS OF METALLIC GLASSES

* Since the metallic glasses possess low magnetic loss, high permeability, saturation magnetization and low coercivity, **these materials are used in cores of high power transformers.**.

* As the metallic glasses are malleable and ductile, it can be used in simple filament winding to reinforce pressure vessels.

* Since the metallic glasses are very strong/hard they are used to make different kinds of springs.

* As the metallic glasses are similar to the soft magnetic alloys, they are used in leads of tape recorder, cores of transformers and magnetic shields.

* Because of their high resistivity, they are used to make computer memories, magneto- resistance sensors etc.

* Since they have high corrosion resistance, they are used in reactor vessels, surgical clips etc,

* Since some metallic glasses can behave as super conductors, they are used in the production of high magnetic fields.

*Since the metallic glasses are not affected by irradiation, they are used in nuclear reactors.

Course/Branch : BE/CIVIL	**Year / Semester** : I/II	Format No.	NAC/TLP-07a.5
Subject Code : PH8201	**Subject Name** :Physics for civil engineering	Rev. No.	02
Unit No 4	**Unit Name : New engineering materials**	Date	14-11-2017

Shape memory alloys

Shape memory alloys (SMA) are the alloys which change its shape from its original shape to new shape and while heating /cooling it will return to its original shape.

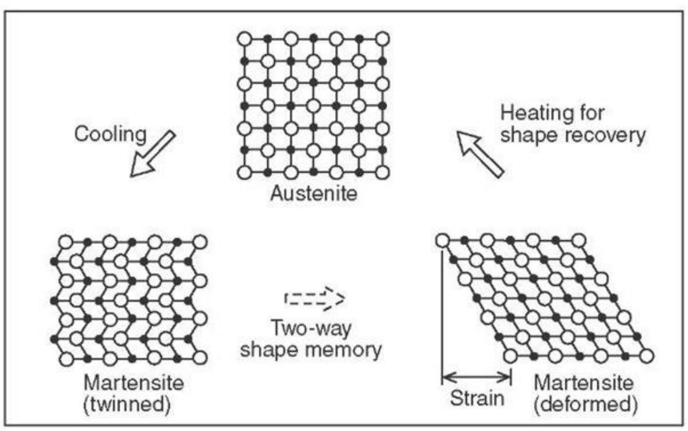
Transformation temperature

In SMA, the shape recovery process occurs not at a single temperature rather it occurs over a range of temperature [may be few degrees].

Thus, the range of temperature at which the SMA switches from new shape to its original shape is called **transformation temperature (or) memory transfer temperature.**

Below the transformation temperature the SMA can be bent into various shapes. Above the transformation 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 (STRUCTURES) OF SMA



In general the SMA has two phases (crystal structures) viz.,

(i) **Martensite**

Martensite is an interstitial supersolution of carbon in γ-iron and it crystallizes into **twinned structure**as shown in fig. The SMA will have this structure generally at lower temperatures and it is softin this phase.

(ii) **Austenite**

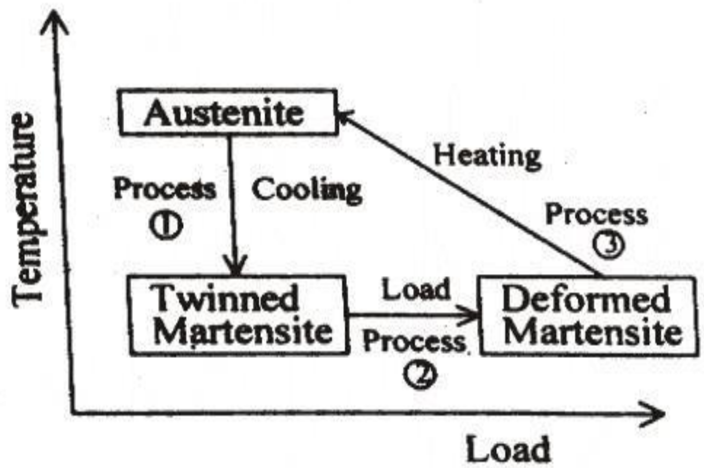
Austenite is the solid solution of carbon and other alloying elements in γ-iron and it crystallizes into **cubic structure** as shown in fig. The SMA will attain this structure at higher temperatures and it is hard in this phase

PROCESSING OF SMA

Shape memory effect

It is very clear that 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.**

Let us consider a shape memory alloy, for which the temperature decreased. Due to decrease in temperature, phase transformation take place from austenite to twinned martensite as shown in fig [Process 1] i.e., a micro constituent transformation takes place from the platelet structure (Austenite) to needle like structure (martensite).



During this state the twinned martensite phase will have same size as that of austenite phase as shown in fig (Macroscopic view). Hence macroscopically if we see, no change in size (or) shape is visible between the Austenite phase and twinned Martensite phase of the SMA.It is found that the transformation from austenite to martensite takes place not only at a single temperature, but over a range of temperatures

Both austenite and twinned martensite is suitable in a particular range of temperature. Now when the twinned martensite is applied a load, it goes to deformed martensite phase as indicated in fig (Process 2). During the transformation from twinned martensite to deformed martensite the change in shape and size occur both microscopically and macroscopically as shown in fig .

Now when the material is further heated it will go from deformed martensite to austenite form (Process 3) and the cycle continues as shown in fig.

CHARACTERISTICS OF SMA

(i) The transformation occurs not only at a single temperature rather they occur over a range of temperatures.

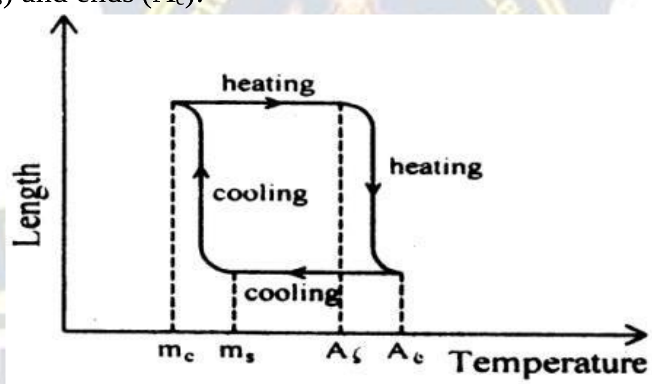
(ii) **Pseudo – elasticity:** Pseudo-elasticity occur in some type of SMA in which the change in its shapewill occur even without change in its temperature

(iii) **Super – elasticity:** The shape memory alloys which have change in its shape at constanttemperature are called **super-elastic SMAs** and that effect is known as super-elasticity.

Here, at a single temperature, when the load is applied the SMA will have a new shape(deformed Martensite) and if the load is removed it will regain its original shape (TwinnedMartensite), similar to pressing a **rubber** (or) **a spring.**

Hysterisis:

For an SMA, during cooling process, a martensite starts (m_s) and ends (m_e) and during heating process, austenite starts (A_s) and ends (A_e).



It is found that they do not overlap with each other and the transformation process exhibits the form of hysterisis curve as shown in fig.

Crystallographically the thermo-elastic martensites are reversible.

APPLICATIONS OF SMA

Shape memory alloys have vast applications in our day-to-day life, as follows:

1. We know that the recently manufactured eye glass frames can be bent back and forth, and can retain its original shape within fraction of time. All these materials are made up of Ni-Ti alloys, which can withstand to maximum deformation.
2. We might have seen toys such as butterflies, snakes etc. which are movable and flexible. These materials are made using SMAs.
3. The life time of Helicopter blades depends on vibrations and their return to its original shape. Hence shape memory alloys are used in helicopter blades.

4. The SMA is cooled and sent into vein, due to body temperature it changes its shape and acts as a blood clot filter, by which it controls the blood flow rate.
5. The SMA is mainly used to control and prevent the fire and toxic gases (or) liquids to a large extent. For example, if an SMA is placed in a fire safety valve, when fire occurs, then due to change in temperature the SMA changes its shape and shuts off the fire. Similar principle has been used in the area of leakage in toxic gases (or) liquids.
6. The Ni-Ti spring is used to release the hot milk and the ingredients at certain temperature and to close it after particular time, thereby we can get coffee automatically [coffee makers].
7. SMA is used for cryofit hydraulic couplings i.e., to join the ends of tubes. Here, the SMA material is pasted in between the two tubes to be joint at a particular temperature when the temperature change the SMA expands and thus the two ends are joined.
8. Using SMA the circuit can be connected and disconnected, depending on the variation in temperature. Hence SMA is used as a circuit edge connector.
9. They are used in controlling and preventing cracks.
10. They are used in relays and activators.
11. They are used for steering the small tubes inserted into the human body.
12. They are used to correct the irregularities in teeth.
13. Ni-Ti SMA is also used in artificial hip-joints, bone-plates, pins for healing bones- fractures and also in connecting broken bones.

Advantages

(I) SMA is very compact in nature.
(II) It is safe and smart.
(III) They are flexible.
(IV) They are Non-Corrosive.

Disadvantages

(i) Cost is high.
(ii) Efficiency is low.
(iii) Transformation occurs over a range of temperatures.
(iv) Structural arrangements may sometime get deformed.

Ceramic materials

"Ceramic materials" are defined as those containing phases that are compounds of metallic and nonmetallic elements.

Course/Branch : BE/CIVIL	**Year / Semester** : I/II	Format No.	NAC/TLP-07a.5
Subject Code : PH8201	**Subject Name** :Physics for civil engineering	Rev. No.	02
Unit No 4	**Unit Name : New engineering materials**	Date	14-11-2017

Classification of Ceramics

1. Functional Classification
2. Abrasives : Alumina, carborundum
3. Pure oxide ceramics : MgO, Al_2O_3, SiO_2
4. Fire-clay products : Bricks, tiles, porcelain etc.
5. Inorganic glasses : Window glass, lead glass etc.
6. Cementing materials : Portland cement, lime etc.
7. Rocks : Granites, sandstone etc.
8. Minerals : Quartz, calcite, etc.
9. Refractories : Silica bricks, magnesite, etc.

Structural Classification

(i) Crstalline ceramics: Single-phase like MgO or multi-phase form the MgO and Al2O3binary system

(ii) Non-crystalline ceramics: Natural and synthetic inorganic glasses.

(iii) "Glass-bonded" ceramics: Fire clay products-crystalline phases are held in glassy matrix.

(iv) Cements: Crystalline and non-Crystalline

Properties of ceramic materials

Mechanical properties

(i) The compressive strength is several items more than the tensile strength.

(ii) Non-ductile/brittle. Stress concentration has little or no effect on compressive strength

(iii) The ceramic materials possess high modulus of elasticity due to ionic and covalentbonds.

(iv) At high temperature, rigidity is high.

Electrical properties

(i)Ceramic exhibits low dielectric constant contributes to low power loss and low loss factor.

(ii) Porcelain has large positive temperature coefficient.

(iii) Rutile bodies have large negative coefficients,

- The specific values of dielectric strength vary from 100 V per mil for low -tension electrical porcelain to 500 V per mil for some special ceramics.
- Rutile bodies show higher breakdown strength at higher frequencies.

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Unit No 4	**Unit Name : New engineering materials**	Date	14-11-2017

Thermal properties

Since the ceramic materials contain relatively few electrons, and ceramic phases are transparent to radiant type energy, their thermal properties differ from that of metals. The following are the most important thermal properties of ceramic materials.

1. Thermal capacity

- The specific heats of fine clay bricks are 0.25 and 0.297 at 1000˚C and 1400˚C respectively.
- Carbon bricks possess specific heats of about 0.812 at 200˚C and 0.412 at 1000˚C

2. Thermal conductivity

- The ceramic material possesses a very low thermal conductivity since they do not have enough free electrons.
- The impurity content, porosity and temperature decrease the thermal conductivity.
- In order to have maximum thermal conductivity, it is imperative to have maximum density which most of the ceramic materials do not possess.

3. Thermal shock

- "Thermal shock resistance" is the ability of a material to resist cracking or disintegration of the material under abrupt or sudden changes in temperature.
- Lithium compounds are used in many ceramic compounds to reduce thermal expansion and to provide excellent thermal shock resistance
- Common ceramic materials graded in order of deceasing thermal shock resistance or given below:
    1. Silicon nitrite 2. Fused silica 3.Cordierite 4.Zircon 5.Silicon carbide 6.Beryllia 7.Alumina 8.Porcelain 9. Steatite

Chemical properties

1. Several ceramic products are highly resistant to all chemicals except hydrofluoric acid and to some extent, hot caustic solutions. They are not affected by the organic solvents.
2. Oxidic ceramics are completely resistant to oxidation, even at very high temperatures.
3. Zirconia, magnesia, alumina, graphite etc., are resistant to certain molten metal and are thus employed for making crucibles and furnace linings.
4. Where resistant to attack from acids, bases and salt solutions is required, ceramics like glass are employed.

Optical properties

1. Several types of glasses have been employed for the production of windows, subjected to high temperatures and opticals lenses.

2. Special glasses used for selective transmission or absorption of particular wavelength such as infrared and ultra violet.

Nuclear properties

As ceramics are refractory, chemically resistant and its different compositions offer a wide range of neutron capture and scattering characteristics. They are finding nuclear applications such as fuel elements, moderators, and controls and shielding.

Classification of Ceramic Products

A general classification of 'ceramic products' is difficult to make because of the great versatility of these materials, but the following list includes the major groups.

1. White wares
2. Bricks and tiles
3. Chemical stones wares
4. Cements and concretes
5. Abrasives
6. Glass
7. Insulators
8. Porcelain enamel
9. Refractories
10. Electrical porcelain
11. Mineral ores
12. Slags and fluxes

Advantages of Ceramic Materials

The ceramic materials have the following advantages

1. The ceramic are hard, strong and dense.
2. They have high resistance to the reaction of chemicals and to the weathering.
3. Possess a high compression strength compared with tension.
4. They have high fusion points.
5. They offer excellent dielectric properties.
6. They are good thermal insulators.
7. They are resistant to high temperature creep.
8. Cheaply available.

Applications of Ceramics

The applications of ceramics are listed below

1. White wares (older ceramics): are largely used as:

- Tiles
- Sanitary wares
- Low and high voltage insulators
- High frequency applications
- Chemical industry - as crucibles, jars and components of chemical reactors;
- Heat resistant applications as pyrometers, burners, burner tips, and radiant heater supports.

2. Newer ceramics: (e.g., borides, carbides, nitrides, single oxides, mixed oxides, silicates, metalloid and intermetallic compounds) which have the high hardness values and heat and oxidation values are largely used in the following applications

- Refractories for industrial furnaces
- Electrical and electronic industries as inductors, semiconductors, dielectrics, ferro-electric crystals, piezo-electric crystals, glass, porcelain alumina, quartz and mica etc.
- Nuclear applications - as fuel elements, fuel containers, moderators, control rods and structural parts. Ceramics such as UO_2, UC, UC_2 are employed for all these purposes.
- Ceramic metal cutting tools-made from glass free Al_2O_3
- Optical applications-ytralox is a ceramic material which is useful as window glass and can resists very high temperature

3. Advanced ceramics: (e.g., ZrO_2, B_4C, SiC, TiB_2 etc)

The advanced ceramics are used in the following areas.

- Internal combustion engines and turbines, as armor plate
- Electronic packaging
- Cutting tools
- Energy conversion, storage and generation

  Structure of crystalline ceramics

  Most ceramic phases, like metals, have crstalline structure. Ceramic crystals are formed by the pure ionic bond, a pure covalent bond or both the ionic and covalent bonds.
- Ionic bonds give ceramic materials of relatively high stability. They are also harder and more resistant to chemical reactions.

  Covalent bond usually gives high hardness, high melting point and low electrical conductivity at room temperature
- The ceramic crystals structures are, however, invariably more complex as compared to those of metals, since atoms of different sizes and electronic configurations are assembled together

Common crystal structure found in crystalline ceramics particularly those of oxide type are:

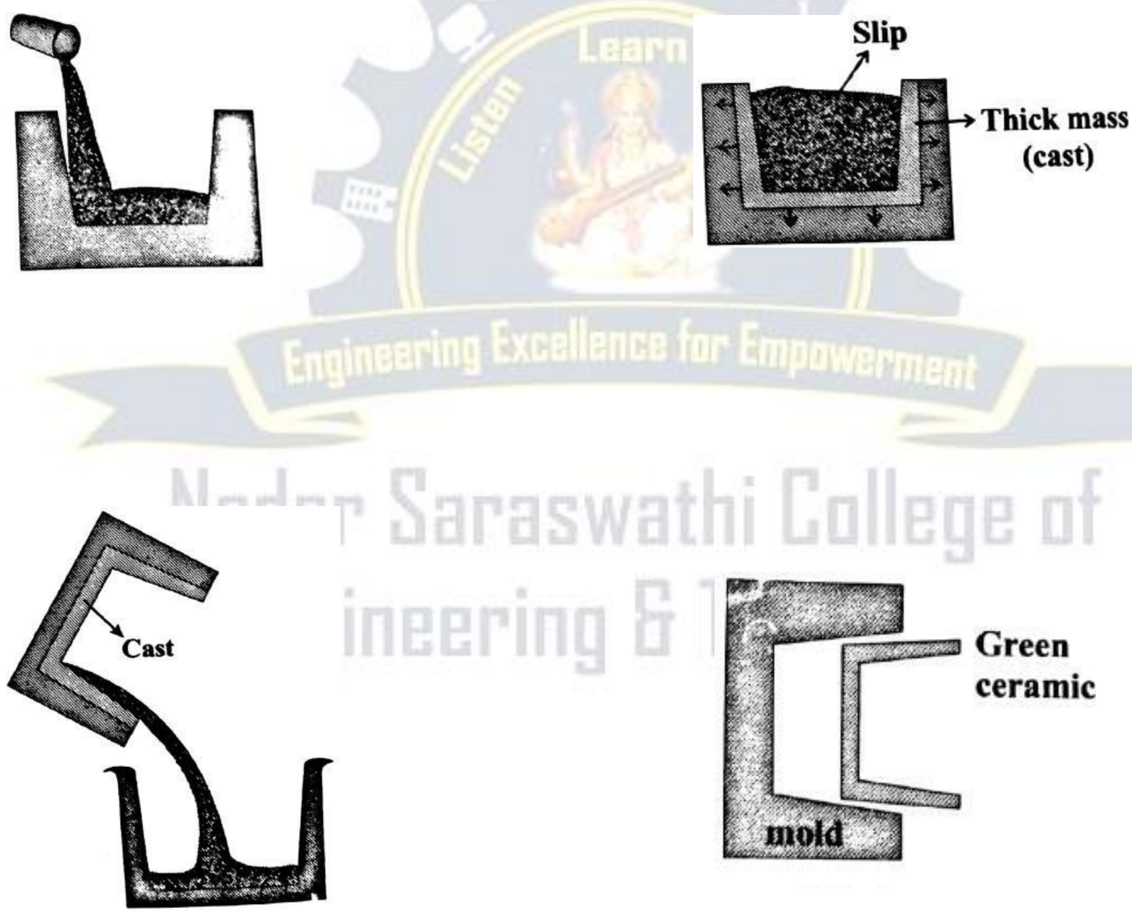
1. Rock salt structure 2. Cerium chloride structure 3. Zinc blend structure 4. Wurzite structure 5. Spinal structure 6. Fluorite structure 7.Ilmenite structure

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.

1. 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].
2. The fineness of the powder and the consequent high surface area ensure that electrostatic forces dominate gravity so that settling does not occur.
3. Now, sodium silicate is added to the slip to deflocculated the particles.
4. When the water from the slurry begins to move out by capillary action, a thick mass builds along the mould wall.
5. When sufficient product thickness is built, so called cast is formed and the rest of the slurry is poured out.
6. Now, the mould and cast are allowed to cry. After drying, casting is removed.
7. The green ceramic is then dried and fired or sintered at high temperature to obtain a dense ceramic material.

Uses of slip casting

1. Slip casting is a low cost way to produce complex shapes.
2. In traditional pottery industry, slip casting method is used for the production of teapots, jugs, statues and other ceramic sanitaryware.
3. 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.

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 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.

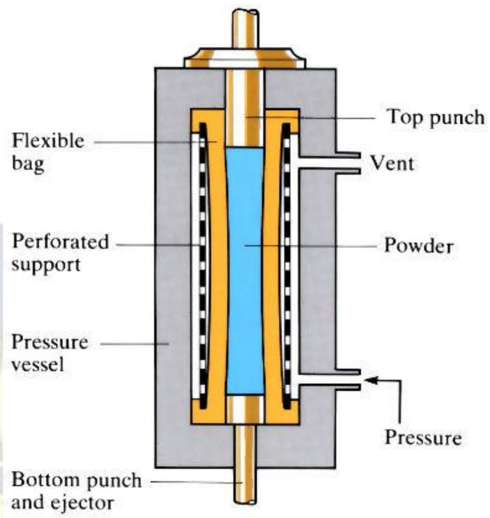
There are two types (i) Wet-bag cold isostatic pressing (ii) Dry-bag cold isostatic pressing

(i) Wet-bag cold isostatic pressing

The following steps are involved in the processing.

1. The powder is weighed into a sealed rubber mould
2. The rubber bag is sealed by using a metal mandrel over which mould seal plate is fixed.
3. Now the sealed bag is placed inside a high pressure chamber that is filled with a fluid and is hydrostatically pressed.

4. The pressure used can vary from about 20 MPa upto 1 GPa depending upon press and the application
5. Once the pressing is complete, the pressure is released slowly
6. After releasing the pressure, the mould is removed from the pressure chamber.
7. 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

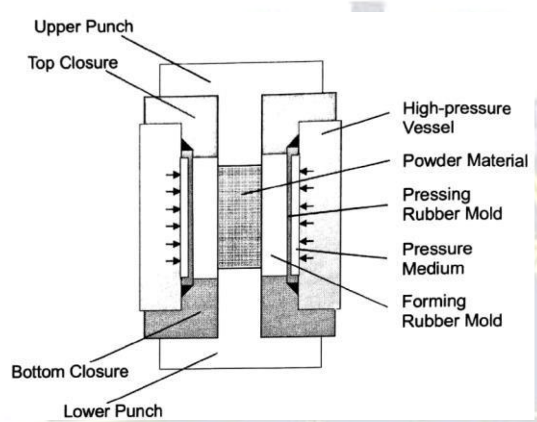
1. Some time it forms poor shape and may not have dimensional control
2. Product often require green machining after pressing
3. It take long cycle time and give low product rates
4. Dry-bag cold isostatic pressing

The following steps are involved in the processing.

- In dry bag process, the rubber mould is an integral part of the press, in which the powder material is taken.

- 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 1 part per second is being achieved industrially.



Uses

1. The dry-bag has been used for many years to press spark plug insulators.
2. The world's largest producers of spark plugs produced by this method are champion and AC spark plug

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.

Construction

1. A basic HIP unit consists of a water-cooled pressure vessel within which a furnace, thermally insulated from the pressure vessel is kept. The pressure vessel is usually made with low alloy steel.
2. Heating elements are arranged in multiple banks to obtain uniform temperature and each bank can be controlled independently. Temperature control is obtained using sensitive thermocouples while the gas pressure is controlled using a compressor system. The gas can be recycled for reuse.
3. It also consists of auxillary systems like vacuum pumps and materials pumps to release the excess pressure.

4. Power connection enables to switch ON and OFF the heater, whenever required.
5. Furnaces used are radiation or convection type heating furnaces with graphite, molybdenum and nichrome heating elements, and hence it is covered by the upper cover and is surrounded by the cooling jacket.

Working

1. The basic function of the HIP unit is to heat the material by applying uniform gas pressure on all the surfaces.
2. The material to be prepared is kept inside the furnace.
3. 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.
4. 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 times.
5. The pressurizing gas is further compressed using a compressor so as to increase the pressure to the desired level
6. Thus, both temperature and pressure are raised to the required values.
7. The furnace is then allowed to cool, followed by depressurizing the chamber and removal of parts.
8. 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

1. The process offers increase in design flexibility
2. The process is not shape or size dependent, which results in optimized usage.
3. HIP results in enhanced quality and improved mechanical properties.
4. Tooling is simple and scrap is minimized and machining is not required
5. HIP produces dense materials without growing the grains.

Disadvantages

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

Uses

1. HIP can be used for fabricating components of aluminum, magnesium, copper-base alloys, cemented tungsten carbides, magnetic materials.
2. HIP can also be used for bonding of dissimilar material, consolidation of plasma coatings,

processing soft and hard magnetic materials.

3. HIP has also been applied to the formation of piezoelectric ceramics such as $BaTiO_3$, $SrTiO_3$, and lead zirconate titanate (PZT) for use in acoustic wave filters and oscillators.
   HIP are mostly used in structural ceramics

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 mm – 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 piezoelectric 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 – $BaTiO_3$
- 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

Ferromagnetic ceramics

- Ferromagnetic ceramics, also known as ferrites, are compounds of various oxides
- General formula $MO.Fe_2O_3$ where M stands for a bivalent metal ion such as Zn, Ni and others
- Ferrites are ceramic materials with a crystalline structure of *spinel type*
- *Mineral magnetite* ($FeO.Fe_2O_3$) is the only naturally occurring mineral of this type

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- 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

High aluminium ceramics

- These ceramics are composed with **more than 92wt% of alumina**, 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

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