It can be provided by recessed and tack lighting, pendant lighting and under cabinet lighting, as well as portable floor and desk lamps.

c) **Accent lighting** – It is also a sort of a directional lighting that adds drama to a place by creating visual interest. It is used to draw the eye to houseplants, paintings, sculptures and other prized possessions. It is usually provided by recessed and track lighting or wall-mounted picture lights.

d) **Guidance lighting** – It is designed to help us see our way safely. The light in your closet, light near door bell, night lights, path lighting and motion lights are good examples of informational lighting.

e) **Decorative lighting** – It is used to decorate the interior of a room or auditorium. Light strips, pendants, chandeliers are examples of light fixtures that draw attention and add beauty to the place.

# *UNIT IV*

## NEW ENGINEERING MATERIALS

### 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 (polyster).
(ii) Mat from continuos 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

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 aeroengines, 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.

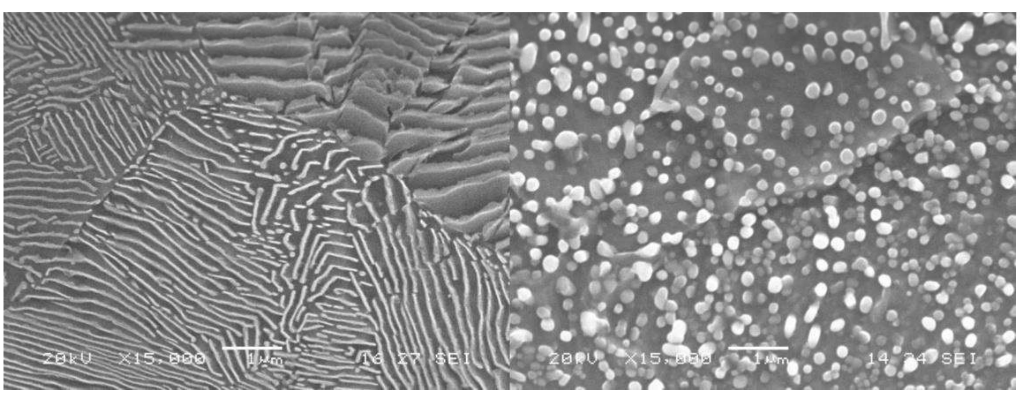
### Disadvantages

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).

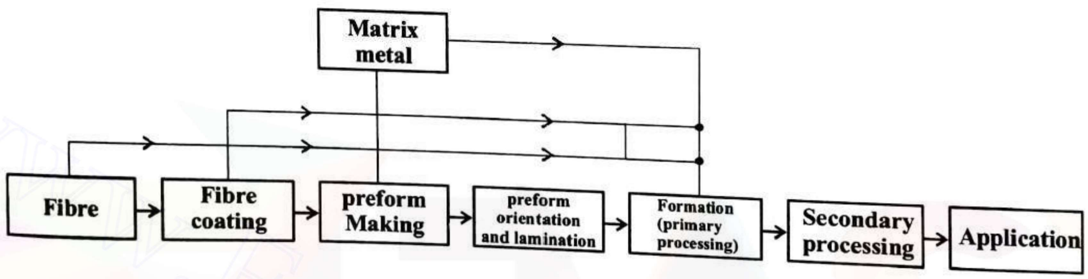


Fabrication of FRM

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

The reinforcement fibers and the corresponding matrix metals used for fabricating FRM are given below.

| 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 ($T_g$).***

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

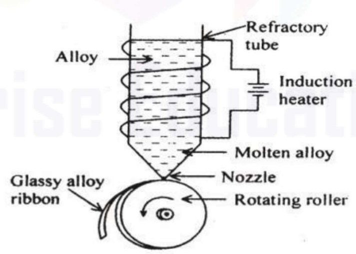
## *PREPERATION OF METALLIC GLASSES*

**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.*

## *Technique*

The process involved in the formation of metallic glasses is melt spinning technique. This technique is illustrated in Fig.5.1




## *Experimental Setup*

Fig.5.1

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 5.1.

## *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 5.2 . In Fig 5.2 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.

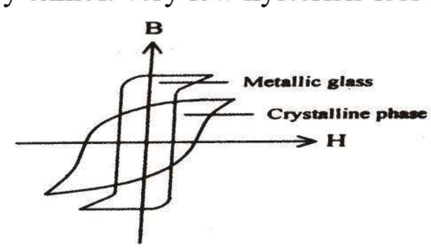



Fig.5.2

### *(iv) Electrical Properties*

**a**.Metallic glasses have high electrical resistance (100 μΩ - cm).

**b**.The electrical resistance for metglasses will not vary with temperature.

hey 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.*** *Examples:* $Fe_{75}P_{15}C_{10}$, $Fe_{24}Zr_{76}$ *etc.*

*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 metglasses 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, marine cables etc.

*Since some metallic glasses can behave as super conductors, they are used in the production of high magnetic fields.
*Since the metglasses are not affected by irradiation, they are used in nuclear reactors.

## 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.,

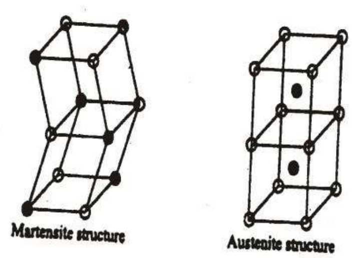



fig 5.3

### *(i) Martensite*

*Martensite is an interstitial supersolution of carbon in γ-iron and it crystallizes into **twinned structure**as shown in fig. 5.3. 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 fig5.3. 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 5.4 [Process 1] i.e., a micro constituent transformation takes place from the platelet structure (Austenite) to needle like structure (martensite).

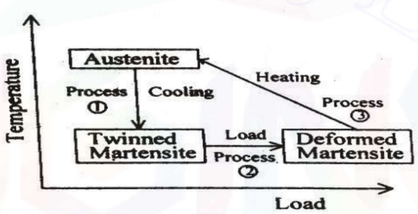



Fig 5.4

During this state the twinned martensite phase will have same size as that of austenite phase as shown in fig 5.5(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.

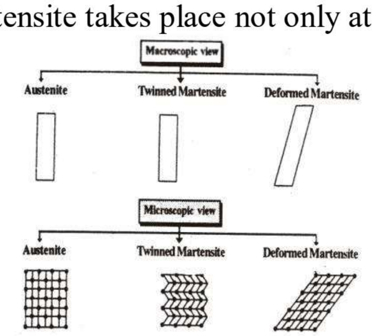



Fig 5.5

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 5.4 (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 5.5.

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 5.4.

## *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.**
(iv) **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 ($A_e$).

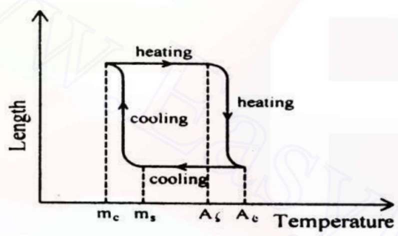



fig.5.6

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.(5.6)
iii. 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.

## *Classification of Ceramics*

**1. Functional Classification**

| | |
|---|---|
| (i) Abrasives | : Alumina, carborundum |
| (ii) Pure oxide ceramics | : MgO, $Al_2O_3$, $SiO_2$ |
| (iii) Fire-clay products | : Bricks, tiles, porcelain etc. |
| (iv) Inorganic glasses | : Window glass, lead glass etc. |
| (v) Cementing materials | : Portland cement, lime etc. |
| (vi) Rocks | : Granites, sandstone etc. |
| (vii) Minerals | : Quartz, calcite, etc. |
| (viii) Refractories | : Silica bricks, magnesite, etc. |

### 2. *Structural Classification*

(i) Crstalline ceramics: Single-phase like MgO or multi-phase form the MgO and $Al_2O_3$binary 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