

UNIT V MODERN ENGINEERING MATERIALS**Shape Memory Alloys****Two Phases**

- a) Austenite
 - a) Hard, firm
 - b) Inelastic
 - c) Resembles titanium
 - d) Simple FCC structure
- b) Martensite
 - a) Soft
 - b) Elastic
 - c) Complex structure

Shape Memory Alloy Qualities

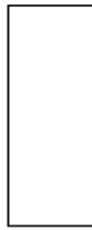
- a) Ability to “remember” its austenite phase
 - a) As the metal is cooled to the martensite phase, it can be easily deformed. When the temperature is raised to the austenite phase, it reforms to the original shape of the material.
- b) Pseudoelasticity
 - a) When the metal is changed to the martensite phase simply by strain. The metal becomes pliable and can withstand strains of up to 8%.
- c) A mix of roughly 50% nickel and 50% titanium is the most common SMA. Also CuZnAl and CuAlNi are widely used.

Shape Memory

Macroscopic View
Austenite



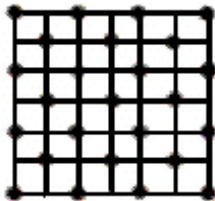
Twinned Martensite



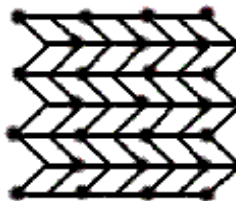
Deformed Martensite



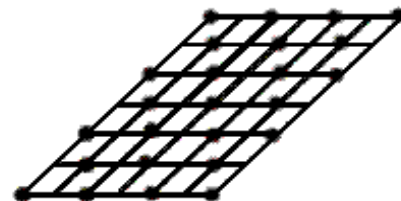
Microscopic View



Austenite



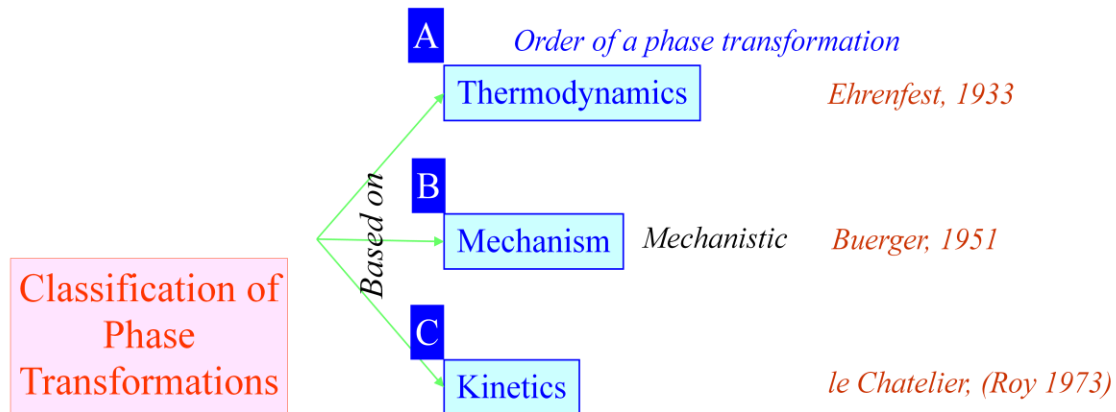
Twinned Martensite



Deformed Martensite

Biological Applications

- a) Bone Plates
 - a) Memory effect pulls bones together to promote healing.
- b) Surgical Anchor
 - a) As healing progresses, muscles grow around the wire. This prevents tissue damage that could be caused by staples or screws.
- c) Clot Filter
 - a) Does not interfere with MRI from non-ferromagnetic properties.
- d) Catheters
- e) Retainers
- f) Eyeglasses



Magnetic Shape Memory Alloys

Shape Memory Alloys

-General Description of how they work

-Twinning

Combinatorial Approach

-Cantilever Fabrication

-Deposition

-Rapid Analysis

Magnetic Shape Memory Alloys

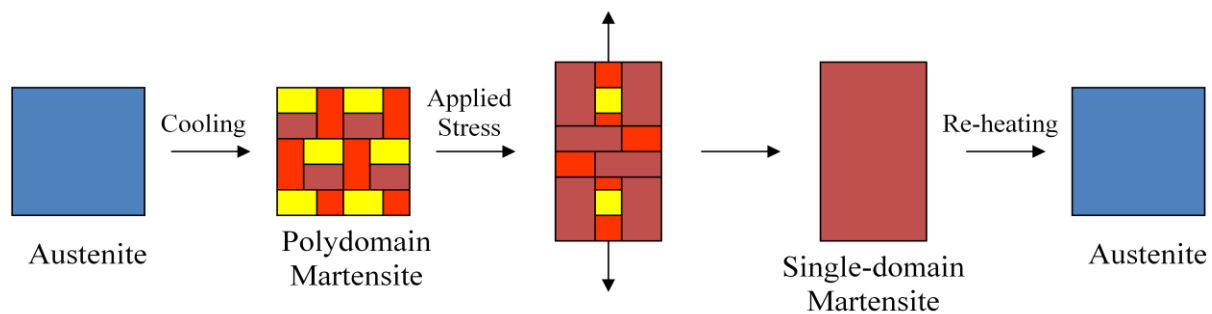
-Similar functionality to SMA

-Magnetostriiction

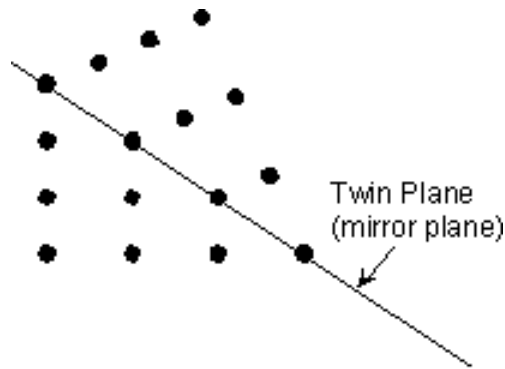
-Applications and downfalls

Shape Memory Alloys (NiTi, NiMnGa) are used in switches, actuators, airplane components, and other applications.

-Austenite-Martensite Transformation



Twinning- Formation of symmetrical, inter-grown crystals



Magnetic Shape Memory Alloys: What are they?

- An alloy that demonstrates the Austenite to Martensite phase transformation (Shape Memory Effect)
- An alloy that is ferromagnetic (possibly a need for Iron, Cobalt, or Nickel in the alloy)
- The most well known “MSMA” is NiMnGa
- Nickel Manganese Gallium has an L_{21} crystal structure

Magnetostriction

Definition: Spontaneous deformation of a solid in response to its magnetization (James and Wuttig)

- Discovered in 1842 by James Joule while experimenting with nickel (a ferromagnetic material)
- examples: Terfenol-D, Alloys including Iron, Cobalt, or Nickel, PZT, etc...
- If martensitic material is ferromagnetic there is a possibility that application of a magnetic field will rearrange the martensite variants! This results in strains one order of magnitude or higher than that of Giant Magnetostrictive materials.

- Switches and Actuators that are both more responsive and more cost-efficient.
- Microwrapper – used for controlling micro-organisms and even tumor removal in the medical industry
- Metal MSMA more responsive and less brittle than Terfenol-D
- MSMA's exist due to their ferromagnetic and phase transformation characteristics
- Metal Alloys such as NiMnGa exhibit strains on the order of 6% as compared to the .2% exhibited by Terfenol-D
- Actuation by application of a magnetic field is inexpensive, very sensitive, and requires less time than the heating required for general SMA's
- Very few MSMA's well known at this point paving the way for Combinatorial Discovery

Actuator and Sensor Materials Chromic materials

This group of materials refers to those which change their colour in response to a change in their environment, leading to the suffix chromic. A variety of chromic materials exist and they are described in terms of the stimuli which initiate a change, thus:

Thermochromic materials change with temperature;

Photochromic materials change with the light level;

Piezochromic materials change with applied pressure;

In the case of electrochromic, solvatochromic and carsochromic materials the stimulus is either an electrical potential, a liquid or an electron beam respectively.

Thermochromic, photochromic and piezochromic materials are the most popular with the first two groups finding everyday applications. How do thermochromic materials work? There are two types of thermochromic systems: those based on liquid crystals and those which rely on molecular.

Electrorheological fluids

The rheology of electrorheological fluids With electrorheological fluids' rheology, the electric field must be taken into the calculations. For example, with the shear stress from Equation (2), the force needed to separate the particles from each other, when an electric field is present, can be calculated through the polarization contribution. The shear resistance of an ER fluid reflects the combined action of polarization and viscous forces, giving for the flow stress

$$\tau = \tau_E + \eta \dot{\gamma}$$

where τ_E is the polarization contribution, called the Bingham yield strength, η is the dynamic viscosity of the suspension at zero electric field and $\dot{\gamma}$ is the shear strain rate [32]. Bingham materials are plastic masses that have a flow index. For Bingham plastic fluids, the Newtonian model is:

$$\tau = \tau_y + \eta \frac{du}{dy}, \text{ if } \tau > \tau_y$$

where τ_y is the limiting yield stress and du/dy is the shear rate's speed gradient. Over this index their rheological behaviour is Newtonian and under it nonNewtonian. Equation (1) expresses the plastic flow of a Bingham material. It can be developed to give the following equation for the relative viscosity η_r of an ER fluid in terms of the Mason number (Mn), which indicates the relation between viscous force and polarization force.

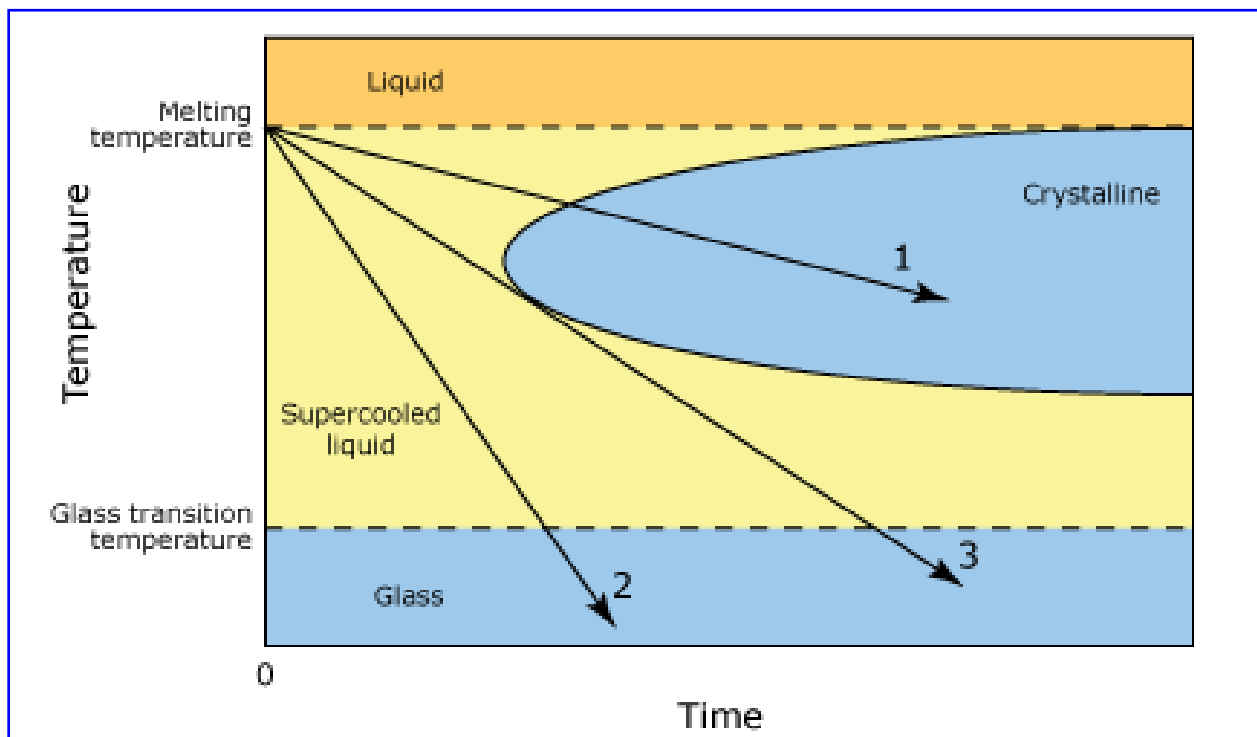
PROCESSING OF METALLIC GLASSES

Virtually any liquid can be turned into a glass if it is cooled quickly enough to avoid crystallization. The question is, how fast does the cooling need to be?

Common oxide glasses (such as ordinary window glass) are quite resistant to crystallization, so they can be formed even if the liquid is cooled very slowly. For instance, the mirror for the 200" telescope at the Palomar Observatory weighed 20 tons and was cooled over a period of eight months, but did not crystallize.

Many polymer liquids can also be turned into glasses; in fact, many polymers cannot be crystallized at all.

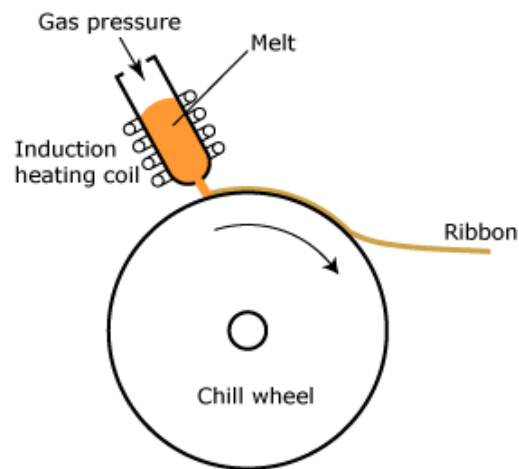
For both oxides and polymers, the key to glass formation is that the liquid structure cannot be rearranged to the more ordered crystalline structure in the time available.



Metallic glasses are another story. Because the structural units are individual atoms (as opposed to polymer chains or the network structure of an oxide), in most alloys it is relatively easy for crystals to nucleate and grow. As a result, the earliest metallic glasses (which were discovered at Caltech in the late 1950s) required very rapid cooling - around one million degrees Celsius per second - to avoid crystallization. One way to do it is by single-roller melt spinning, as shown here:

SINGLE-ROLLER MELT SPINNING

In this process, the alloy is melted (typically in a quartz tube) by induction heating, and then forced out through a narrow nozzle onto the edge of a rapidly rotating chill wheel (typically made of copper). The melt spreads to form a thin ribbon, which cools rapidly because it is in contact with the copper wheel.



SUCTION CASTING

An ingot in the upper chamber under an inert atmosphere is melted with an electric arc (much like in arc welding) and then sucked into a mold when the lower chamber is opened to vacuum. One of the potentially useful properties of metallic glasses is that they do not melt abruptly at a fixed temperature. Instead, like ordinary oxide glasses, they gradually soften and flow over a range of temperatures. By careful control of temperature, the viscosity of the softened glass can be precisely controlled. This ability can be used to form metallic glasses into complex shapes by techniques similar to those used for molding polymers.