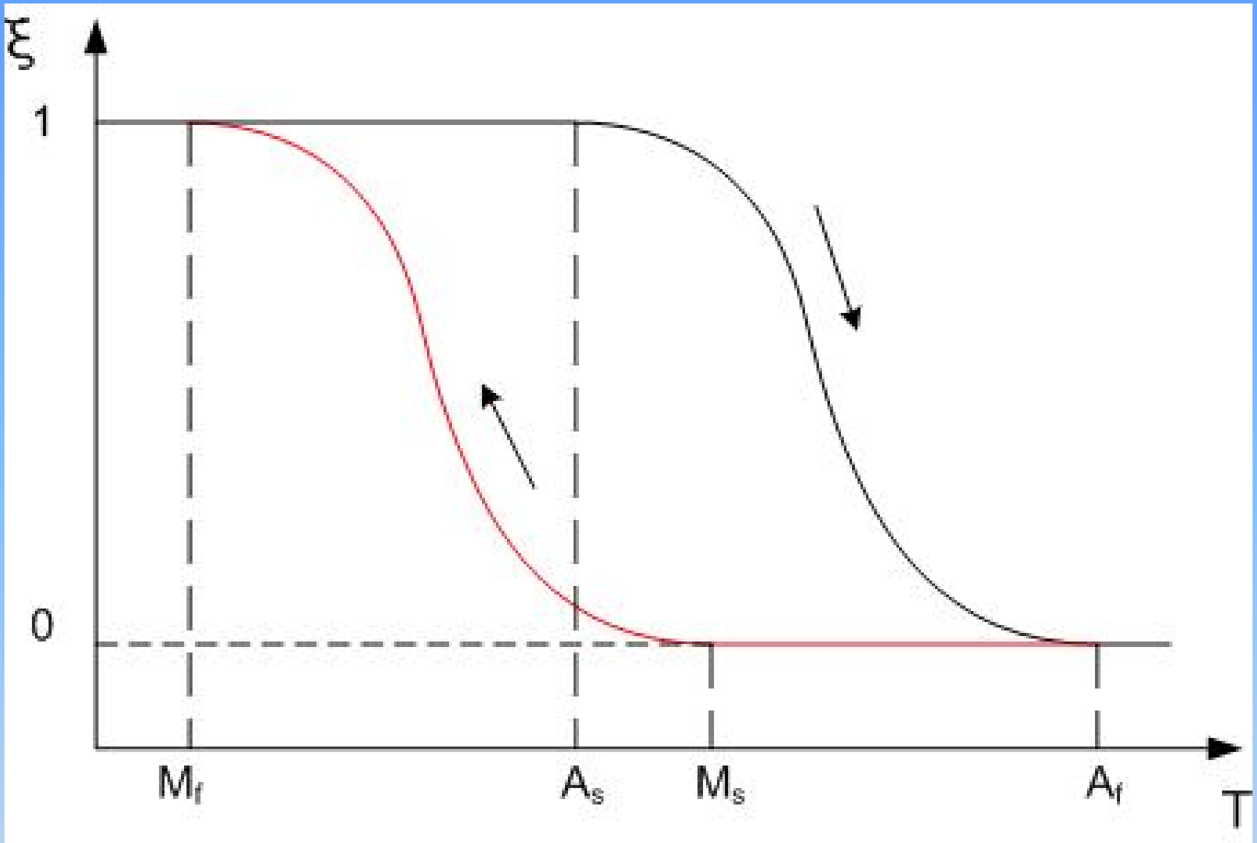
SHAPE MEMORY ALLOYS

A **shape memory alloy** (**SMA**, **smart metal**, **memory metal**, **memory alloy**, **muscle wire**, **smart alloy**) is an alloy that "remembers" its original, cold-forged shape: returning the pre-deformed shape by heating. This material is a lightweight, solid-state alternative to conventional actuators such as hydraulic, pneumatic, and motor-based systems. Shape memory alloys have applications in industries including medical and aerospace.

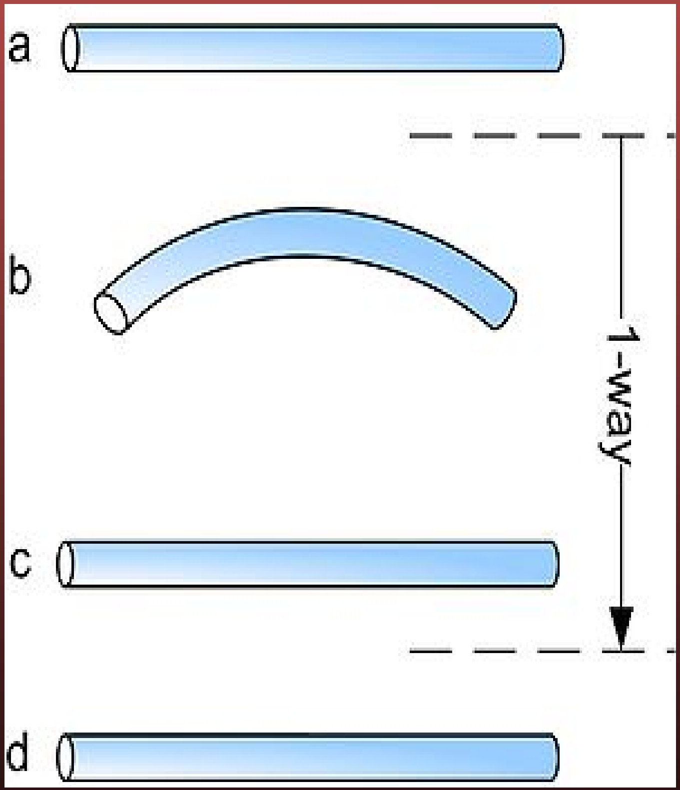
The three main types of shape memory alloys are the copper-zinc-aluminium-nickel, copper-aluminium-nickel, and nickel-titanium (NiTi) alloys but SMA's can also be created by alloying zinc, copper, gold, and iron. NiTi alloys are generally more expensive and change from austenite to martensite upon cooling; *Mf* is the temperature at which the transition to Martensite is finished during cooling. Accordingly, during heating *As* and *Af* are the temperatures at which the transformation from Martensite to Austenite starts and finishes. Repeated use of the shape memory effect may lead to a shift of the characteristic transformation temperatures (this effect is known as functional fatigue, as it is closely related with a change of microstructural and functional properties of the material)



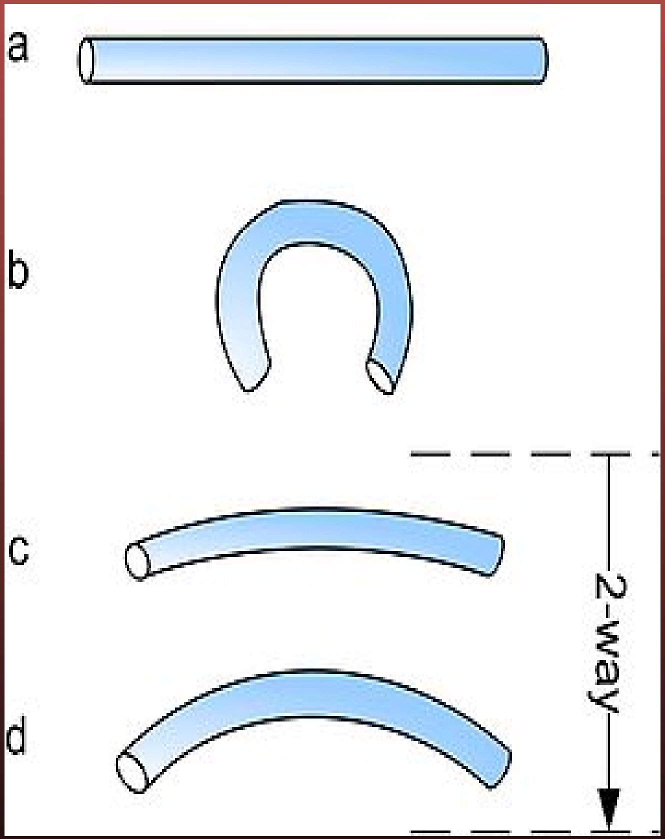
In this figure, ξ (T) represents the martensite fraction. The difference between the heating transition and the cooling transition gives rise to the hysteresis effect where some of the mechanical energy is lost in the process. The shape of the curve depends on the material properties of the shape memory alloy, such as the alloying and work hardening

Types Of SMA's:

- One way SMA:



- Two way SMA:



One way memory effect

- When a shape memory alloy is in its cold state (below As), the metal can be bent or stretched and will hold this shape until heated above the transition temperature.
- Upon heating, the shape changes to its original.
- When the metal cools again, it will remain in the hot shape until deformed again.
- In this case, cooling from high temperature does not cause macroscopic shape change.

Two way memory effect

- This is the effect that the material remembers two shapes: one at high temp and the other at low temperature.
- These metals show shape memory effect during both cooling and heating.
- The metal can be trained to leave some reminders of the deformed low temp condition in the high temp phases.
- Above a certain temp, the metal loses the 2 way memory effect. This is called “amnesia”

Pseudo-Elasticity

- One of the commercial uses of shape memory alloy involves using the pseudo-elastic properties of the metal during the high temperature (austenitic) phase. The frames of reading glasses have been made of shape memory alloy as they can undergo large deformations in their high temperature state and then instantly revert back to their original shape when the stress is removed. This is the result of pseudoelasticity; the martensitic phase is generated by stressing the metal in the austenitic state and this martensite phase is capable of large strains. With the removal of the load, the martensite transforms back into the austenite phase and resumes its original shape.

- This allows the metal to be bent, twisted and pulled, before reforming its shape when released. This means the frames of shape memory alloy glasses are claimed to be "nearly indestructible" because it appears no amount of bending results in permanent plastic deformation.

Manufacture

- Shape memory alloys are typically made by casting, using vacuum arc melting or induction melting. These are specialist techniques used to keep impurities in the alloy to a minimum and ensure the metals are well mixed. The ingot is then hot rolled into longer sections and then drawn to turn it into wire.
- The way in which the alloys are "trained" depends on the properties wanted. The "training" dictates the shape that the alloy will remember when it is heated. This occurs by heating the alloy so that the dislocations re-order into stable positions.
- They are then shaped while hot and are cooled rapidly by quenching in water or by cooling with air.

Applications

- **Aircraft**

  Boeing, General Electric Aircraft Engines, Goodrich Corporation, NASA, and All Nippon Airways developed the Variable Geometry Chevron using shape memory alloy that reduces aircraft's engine noise.

- **Robotics**

  There have also been limited studies on using these materials in robotics (such as "Roboterfrau Lara"), as they make it possible to create very light robots. Weak points of the technology are energy inefficiency, slow response times, and large hysteresis.

- **Medicine**

  Shape memory alloys are applied in medicine, for example, as fixation devices for osteotomies in orthopaedic surgery, in dental braces to exert constant tooth-moving forces on the teeth and in stent grafts where it gives the ability to adapt to the shape of certain blood vessels when exposed to body temperature.

Materials

Alloys of metals having the memory effect at different temperatures and at different percentages of its solid solution contents:

- Ag-Cd 44/49 at.% Cd
- Au-Cd 46.5/50 at.% Cd
- Cu-Al-Ni 14/14.5 wt.% Al and 3/4.5 wt.% Ni
- Cu-Sn approx. 15 at.% Sn
- Cu-Zn 38.5/41.5 wt.% Zn
- Cu-Zn-X (X = Si, Al, Sn)
- Fe-Pt approx. 25 at.% Pt
- Mn-Cu 5/35 at.% Cu