GENERAL

Advanced materials for various purposes are widely used in whole world, and among them are so-called smart materials. Smart materials respond to environmental influences, changing some of its characteristics. Depending on the change in external conditions, there is a change of material properties (mechanical, electrical, structural). Smart materials are generally incorporated in systems whose main characteristics may change drastically depending on the need for certain properties. Depending on which properties are changed, different multiple types of smart materials are observed. All of them are functional materials, but the difference is in the degree of smartness depending on the initiation of the environment and the response of the material. So there are materials whose properties change under the influence of electrical, magnetic, thermal or optical environment influence, and in accordance with that and with different types of response or change features.

From a wide range of smart materials the shape memory alloys (SMA) are separate group. These materials react to a thermal stimulus, i.e. change in temperature, and have a mechanical response, i.e. there is a change of their mechanical properties. So, after deformation at a certain temperature, the material returns to its original shape. The change in crystal structure above the transformation temperature leads to a return to its original shape. There are a large group of these materials: SMA based on nickel and titanium, SMA based on copper, and on the basis of iron.

The most used alloys are so-called nitinol alloys [1 - 3], i.e. SMA based on nickel and titanium. These alloys have wide application area because of the high deformation degree (up to 8%), as well as thermal stability and corrosion resistivity. Despite that, the production is limited with certain conditions because of the titanium reactivity, so melting must be done in vacuum, and the transformation temperature will be from -100 up to +100 °C.

The properties of Ni-Ti alloys are given in Table 1.

Table 1 Properties of shape memory alloys Ni-Ti [2]

Physical properties	
Melting Temperature,	1300 °C
Density	6,45 g/cm³
Resistivity	austenite~ 100 μΩcm
	martensite~ 70 μΩcm
Thermal Conductivity	austenite~ 18 W/m°C
	martensite~ 8,5 W/m°C
Corrosion Resistance	Similar 300 series stainless of steel or titanium alloys
Shape Memory Properties	
Transformation Temperatures	-200 up to 110°C
Recoverable Strain	max 8,5 %
Latent Heat of Transformation	167 kJ/kgatom

Table 2 Properties of shape memory alloys based on copper [2]

Physical properties		
	Cu - Zn - Al	**Cu - Al - Ni**
Melting Temperature,	950 - 1020 °C	1000 - 1050 °C
Density	7,64 g/cm³	7,12
Resistivity	8,5 – 9,7 μΩcm	11 - 13 μΩcm
Thermal Conductivity	120 W/m°C	30 – 43 W/m°C
Heat Capacity	400 J/kg °C	373 – 574 J/kg °C
Shape Memory Properties		
Transformation Temperatures	< 120°C	< 200 °C
Recoverable Strain	4 %	4 %
Hysteresis	15 -25 Δ °C	15 -20 Δ °C

Most commercial alloys compared to nitinol are certainly copper-based alloys, due to the fact that they are less expensive and that the melt does not have to be performed in a protective atmosphere. They are mostly a combination of copper with zinc and aluminum or aluminum and nickel [4 - 7]. The degree of elongation for these alloys is slightly lower (4-5%) while the transformation temperature are -180 to + 200 °C for Cu-Zn-Al and -140 to + 100 °C for the Cu-Al-Ni alloys.

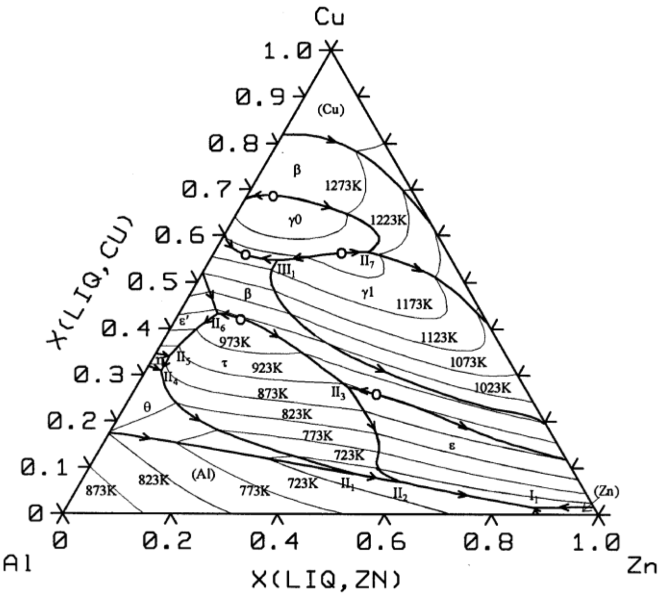


Figure1. Calculated liquidus projection in Cu-Zn-Al system [7]

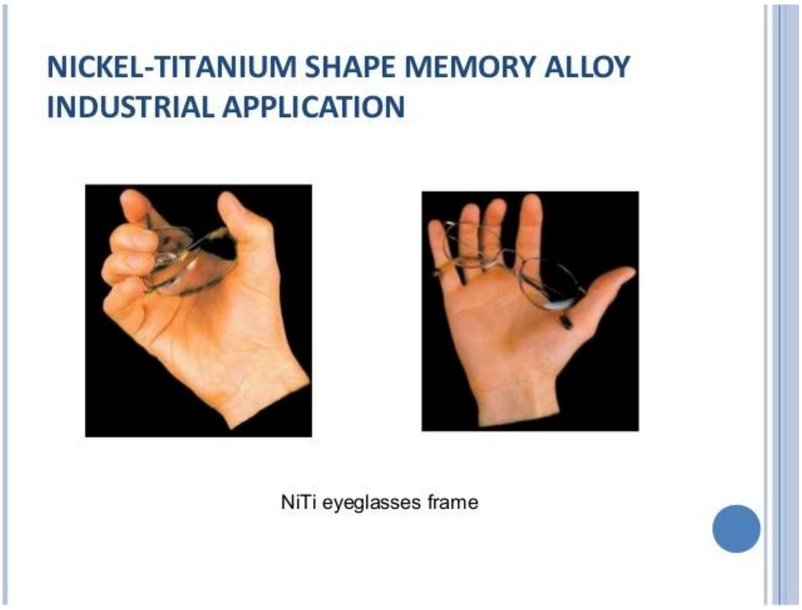
In contrast to the above mentioned, shape-memory alloys based on iron have a deformation capacity of only up to 4%. These are the Fe-Mn-Si alloy, which after only small deformations can return to its original shape.

APPLICATIONS

The application of shape memory alloys can be seen in large systems (industrial systems, aeronautics) and in home use (air conditioners, various safety valves, etc.) as well as in medicine. The greatest application which these alloys have achieved is in mechanical and electromechanical control systems due to the sensitivity of the small and repeated temperature changes. Now, the industrial applications appear in a wide spectrum of commerce. Eyeglass frames were an early example of a new use of super-elasticity which has grown to be a world -wide product.

Here are some photos of applications [8]:


Shape Memory Material Applications


NICKEL-TITANIUM SHAPE MEMORY ALLOY
INDUSTRIAL APPLICATION
NiTi eyeglasses frame

THE SHAPE MEMORY EFFECT

Shape memory effect means the ability of metals and alloys which are plastically deformed in the martensitic state or in a temperature range of martensitic transformation, to establish the original shape during the heating. Heating leads to recovery of high temperature initial phase crystals and removing the plastic deformation. At the same time, all the physical and mechanical properties are returned. Martensitic crystal structure is the basis for achieving the effect of shape memory. This effect can be achieved in two ways: exposing the alloy to a pressure at certain temperature, or rapid quenching alloy at certain critical temperature. The more used methodology is quenching, due to the fact that the martensitic structure occurs spontaneously, with shearing of atoms in the alloy or by nucleation. So, change is characterized by diffusion-free transformation characterized by the coordinated movement of large atomic groups.

In shape-memory alloys two phases are observed: martensite and austenite. Martensite is a relatively soft phase which is easily deformed and exists at lower temperatures as opposed to the austenite. In high-alloyed carbon-free iron alloys, as well as some non-ferrous alloys, during the heating after quenching the diffusion-free transformation of austenite into martensite, or another starting phase is possible. Such a transformation is called a reverse martensitic transformation. It is possible thanks to a large number of alloying elements, which lowers the temperature of phase equilibria and there is no decomposition of austenite phase during the transformation of martensite-austenite.

Although there is a wide range of shape memory alloys the most of practical interest are those alloys which have a reverse effect, those one that can restore a significant part of deformation. One-way shape memory alloys are the alloys which have martensite deformation after heating, so there is a shape-memory effect in one direction (one-way shape memory), while the ones that can change shape in both directions, after cooling again and return to its original shape are so-called the two-way shape-memory alloys.

LITERATURE

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