

INFO SHEET No. 1

Glossary for NiTiNol Shape Memory Alloys

A_f -Temperature: Temperature, above which the phase transformation from Martensite to Austenite is fully completed during heating of the alloy.

Actuator: Device made out of a shape memory alloy, which is able to provide a significant amount of mechanical work due to the occurrence of the phase transformation during heating. Actuation force and displacement are functions of the actuator geometry and design.

A_{peak} - or A_p -Temperature: Temperature, at which the phase transformation from Martensite to Austenite shows the maximum of heat flow during heating. The alloy needs a certain amount of energy (heat flow) to initiate the phase transformation and to move the phase boundary through the alloy. The maximum is a value which can be accurately measured in a DSC equipment, whereas the A_s - and A_f -temperature measurements are sometimes lacking reproducibility.

A_s -Temperature: Temperature, at which the phase transformation from Martensite to Austenite is initiated during heating of the alloy.

Austenite: Crystallographic description of the high temperature phase of a shape memory alloy, which starts to form during heating of the low temperature phase Martensite when the A_s -temperature is passed. The formation of Austenite is completed above the A_f -temperature.

Biocompatibility: General expression for the suitability of a material for use in the human body and in the endogenous fluids. For NiTiNol, a multitude of clinical studies and long clinical history have shown that the biocompatibility is excellent, especially in terms of cytocompatibility, haemocompatibility, genocompatibility, and corrosion performance. The most current studies report that the overall biocompatibility of NiTi alloys is comparable to stainless steel and Titanium alloys. In some applications, such as stents, recent studies suggest that the biocompatibility of NiTi alloys may be even superior to stainless steel.

DSC (Differential Scanning Calorimetry): Calorimetric method for the characterization of a shape memory alloy with respect to its transformation temperatures. The DSC measures the specific heat flow, which changes constantly during the phase transformation. The overall accuracy and the ease of usage of the DSC equipment together with the high reproducibility makes it the most suitable method for alloy characterization. The main disadvantage of the DSC is the fact, that material deformation and external load cannot be simulated with this measurement.

Hysteresis:

a) thermal hysteresis:

The thermal hysteresis means generally the difference between the A_{peak} - and the M_{peak} -temperatures. The hysteresis appears during passing of the transformation temperatures and is affected by a number of parameters (alloy composition, thermo-mechanical treatment, external load, etc.).

b) mechanical hysteresis:

The mechanical hysteresis appears during loading and unloading of a shape memory component in its high temperature phase above A_f . The NiTiNol component shows a large amount of strain during loading, which recovers during unloading. The necessary force to initiate the transformation during loading is higher as the released force during unloading.

Martensite: Crystallographic description of the low temperature phase of a shape memory alloy, which starts to form during cooling of the high temperature phase Austenite when the M_s -temperature is passed. The formation of Martensite is completed below the M_f -temperature. But the Martensite can also be induced during loading of the Austenite above M_f . This is related to a large amount of recoverable strain and is called 'Superelasticity'.

NiTiNOL: Common trade name for the commercially most important family of shape memory alloys (NiTi alloys).

One way effect (or „thermal shape memory“): The one way effect occurs in a shape memory alloy, which has been deformed below its lower transformation temperature M_s . The obvious deformation is called pseudoplastic because the alloy recovers shape during subsequent heating into its austenitic high temperature phase. During this shape change the shape memory alloy is capable of providing a significant amount of work output and can be used as an actuator. The subsequent cooling in to the austenitic phase is normally not subject to a reverse shape change, as long as there is no external stress during Austenite - Martensite transformation..

Phase transformation (here: martensitic phase transformation): Physical mechanism, which is the metallurgical basis of the shape memory effect. The term martensitic phase transformation describes the formation of Martensite during cooling OR during loading with an external stress of the austenitic high temperature phase.

R-Phase: Phase, which appears under certain conditions in for instance NiTiNol alloys and which is still considered as being a 'pre-martensitic'. The R-phase is related to some anomalies of certain functional properties. The R-phase transformation shows a very narrow thermal hysteresis, but at the same time a very small amount of work output. Applications of the R-phase transformation are very hard to find in the market.

Superelasticity: Sometimes compared to a rubber-like deformability of shape memory alloys, which occurs during application of an external stress on the austenitic high temperature phase above A_f . Thus, the superelastic effect is related to about 8% of recoverable elastic stress, for which temperature changes are not necessary. The superelasticity occurs basically in the same alloys as the thermal shape memory (one way effect).

Thermomechanical treatment:

Treatment of a shape memory alloy consisting out of a combination between cold working steps and annealing processes. The purpose of the thermomechanical treatment is the adjusting of a number of functional properties, like e.g. the phase transformation temperatures. Usually the annealing of the component or the semi-finished shape is the last step of the fabrication process.

Transformation temperatures: Temperature values, at which start and finish of the phase transformation can be measured (M_s , M_f , A_s , A_f -temperature).

Two way effect: Special form of the thermal shape memory effect, in which not just the heating but also the cooling of the shape memory element are subject to shape changes. This effect is induced either by a special thermomechanical treatment ('Training') or through external stresses during cooling. For design and industrial application of actuators this latter option is highly preferred for a multitude of reasons.