Nitinol Characteristics

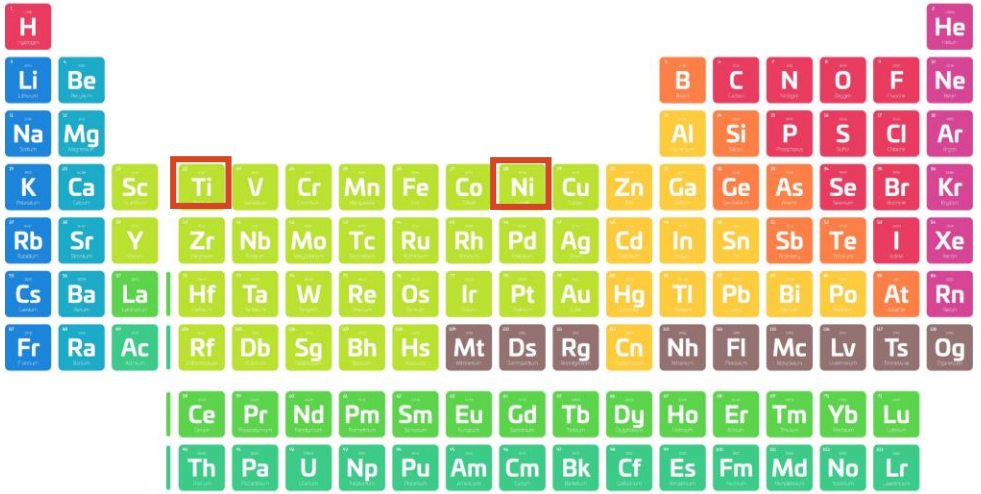
Shape Memory Alloy, Superelasticity, Shape Memory Effect

Self Expanding Stents

Ansys

Introduction of Nitinol and Shape Memory Alloy (SMA)

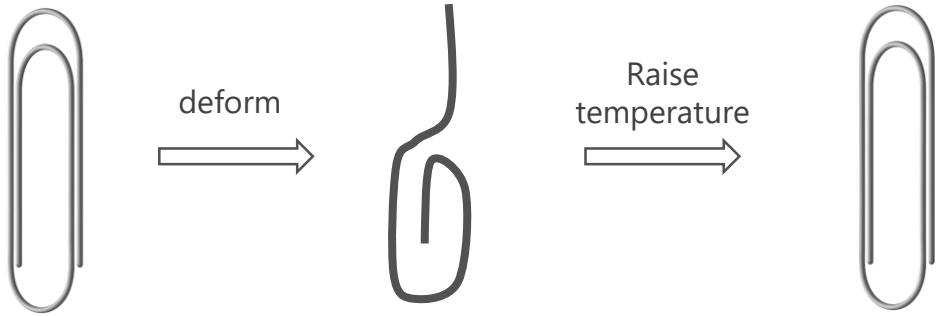
- Nitinol is a nickel titanium alloy.
- Nitinol is a shape memory alloy (SMA).
- Nitinol exhibits the following mechanical properties:
  - Shape memory effect
  - Superelasticity
- Nitinol has good bio-compatibility:
  - Remain non-toxic
  - Does not produce allergic reaction
  - Does not cause inflammatory response through its functional period inside the human body.
- Nitinol is a the most common material in self-expanding stent.



Shape Memory Alloy (SMA)

An SMA is a metallic alloy that exhibits shape memory effect (SME) and superelasticity.

- Shape memory effect:
  - The ability to deform at one temperature (a lower temperature) and return to its undeformed shape at another temperature (a higher temperature).



- Superelasticity:
  - The ability to undergo large deformation without incurring plastic strain.

Microstructure of the SMA

An SMA has two phases: Martensite(M) phase and Austenite(A) phase.

Low temperature
Product phase

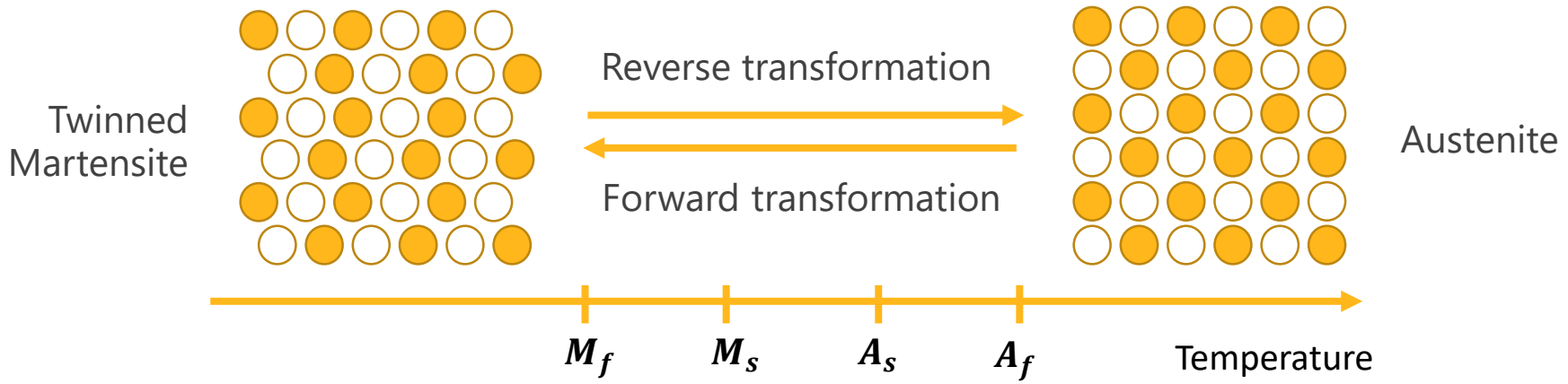
High temperature
Parent phase

Several terminologies:

A_s	Austenite start temperature
A_f	Austenite finish temperature
M_s	Martensite start temperature
M_f	Martensite finish temperature

Microstructure of the SMA

A metallurgical phase diagram is used to represent phases in a metal alloy.

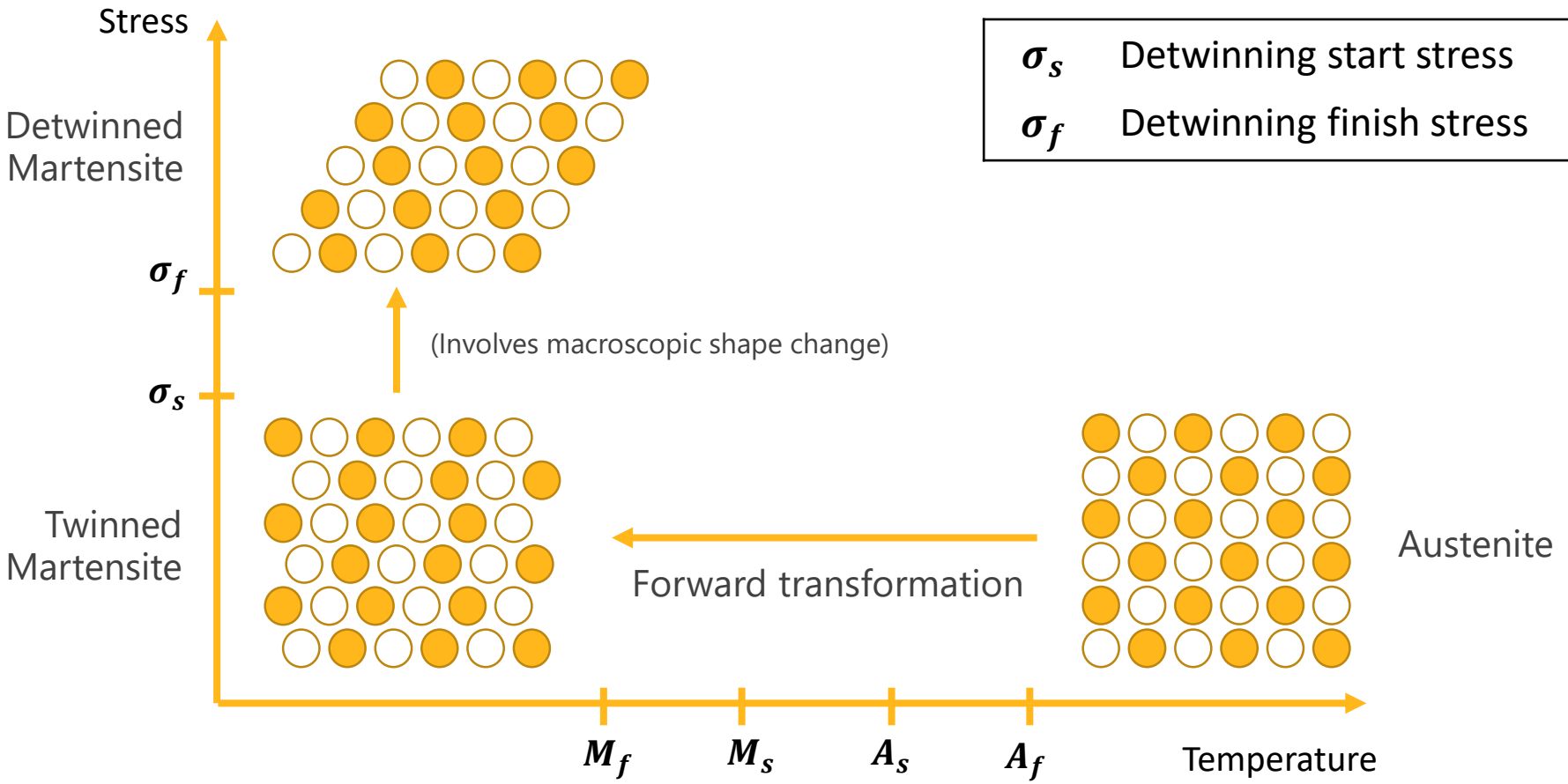


The above process does **not** change the macroscopic shape.

Apart from temperature, stress is also a factor associated with phase change, as will be seen in the next slide.

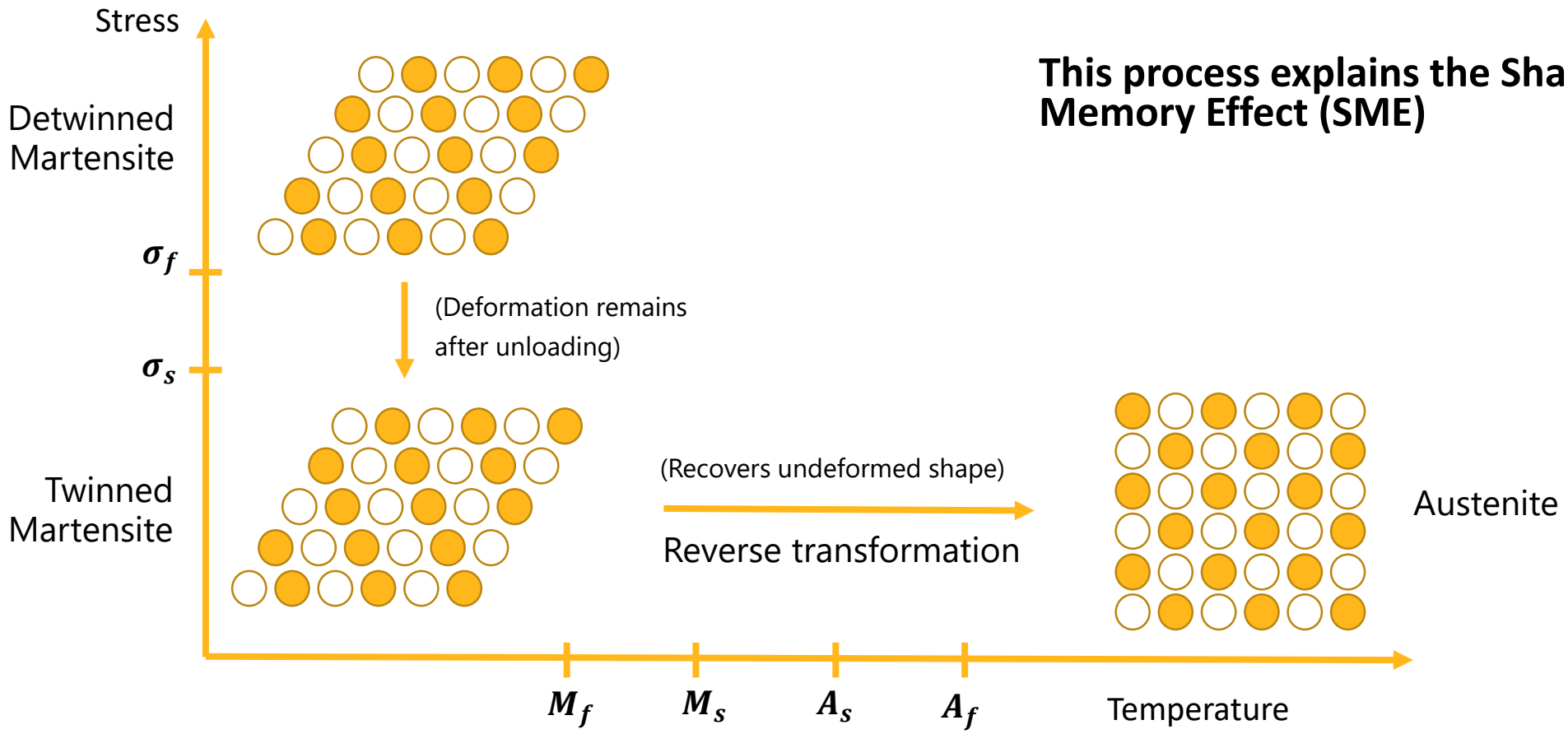
Microstructure of the SMA

Shape change become observable when stress is involved.



Microstructure of the SMA

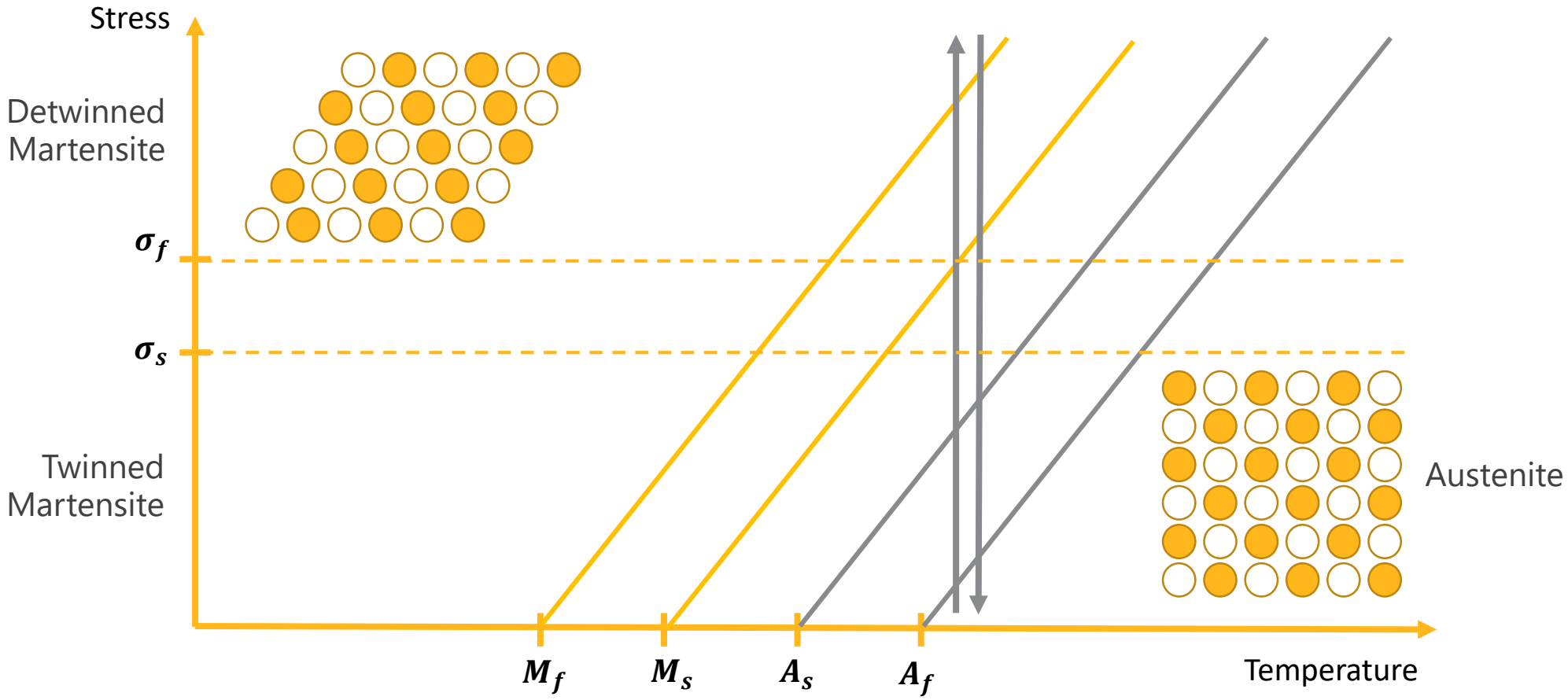
Deformation remains after unloading, but diminishes after raise temperature above A_f



This process explains the Shape Memory Effect (SME)

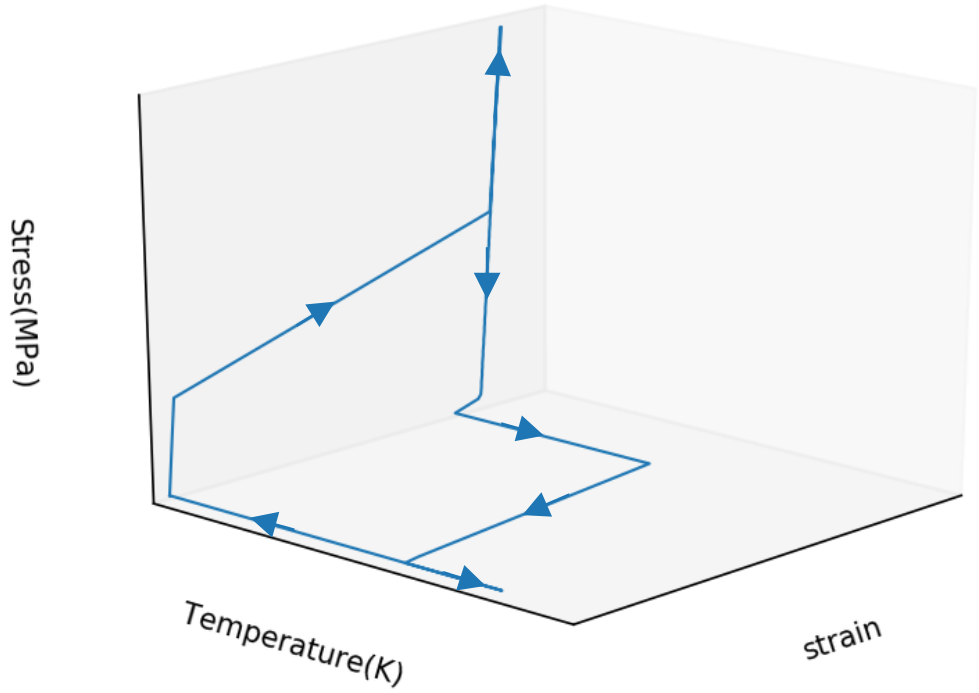
Microstructure of the SMA

When SMA is loaded from a temperature above A_f , it exhibits a superelastic behavior

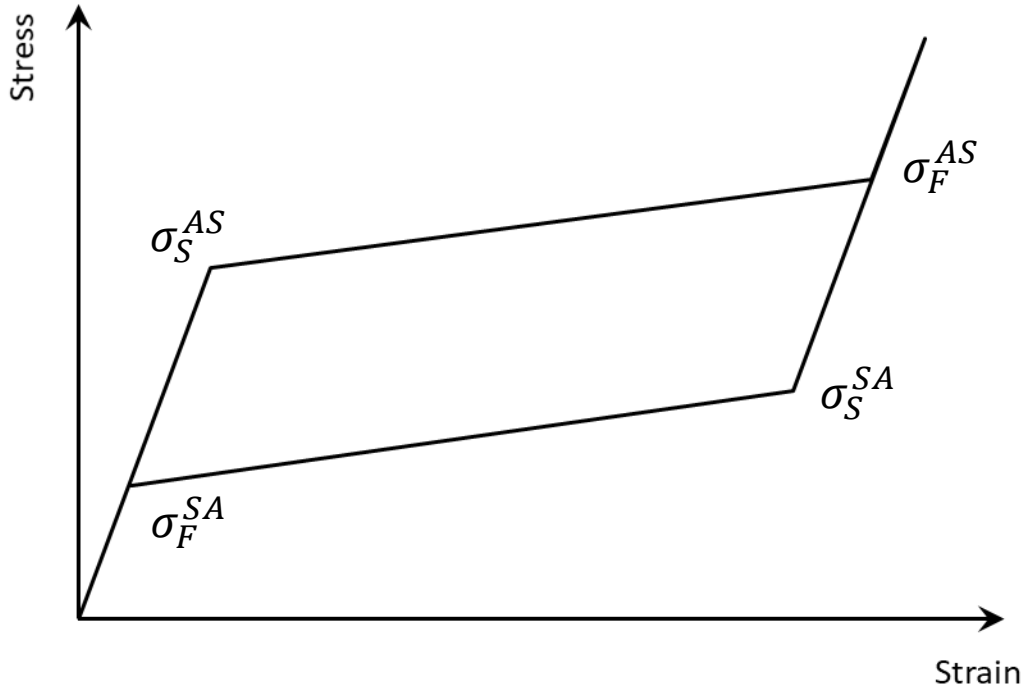


Mechanical Properties of Nitinol

Shape memory effect

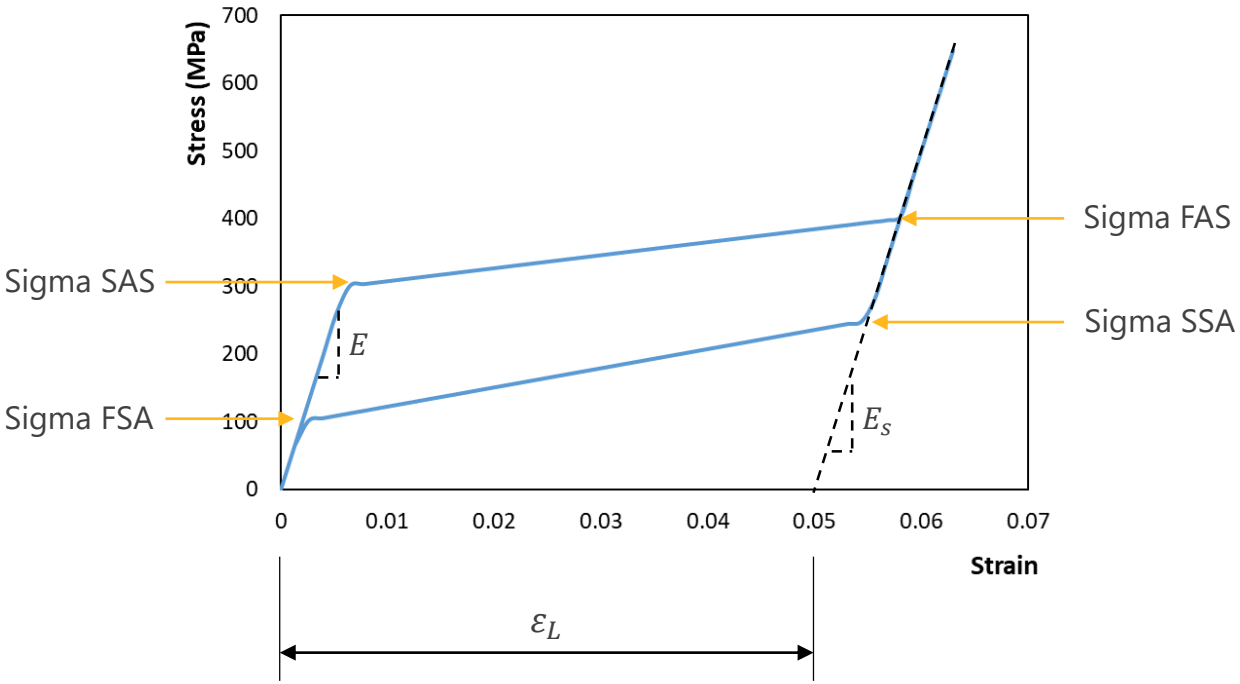


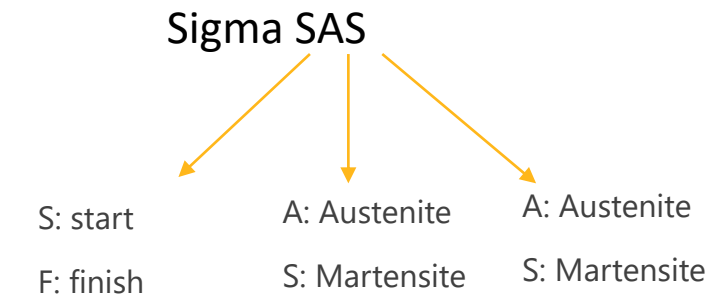
Superelasticity



Ansys Superelasticity Material Model

Property name	Symbol	Unit
Young's modulus	E	MPa
Poisson's ratio	v	
Sigma SAS	σ_s^{AS}	MPa
Sigma FAS	σ_F^{AS}	MPa
Sigma SSA	σ_s^{SA}	MPa
Sigma FSA	σ_F^{SA}	MPa
Epsilon	ε_L	mm/mm
Alpha	α	
Elastic modulus of the full martensite phase	E_s	MPa





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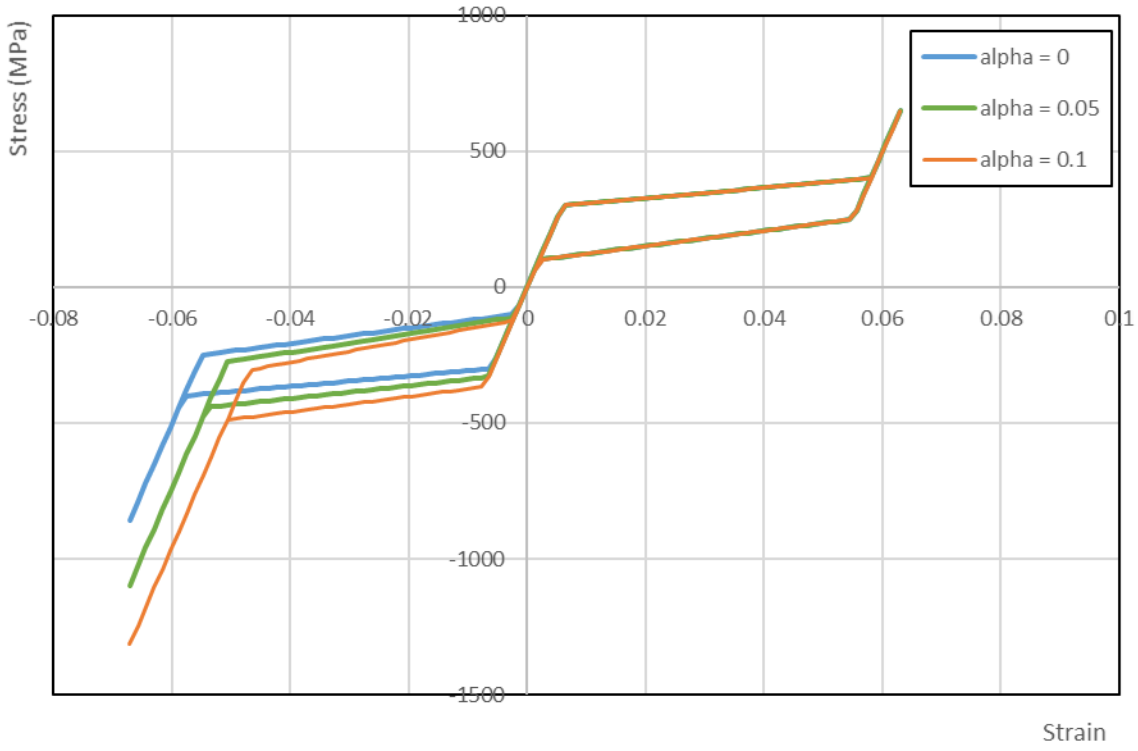


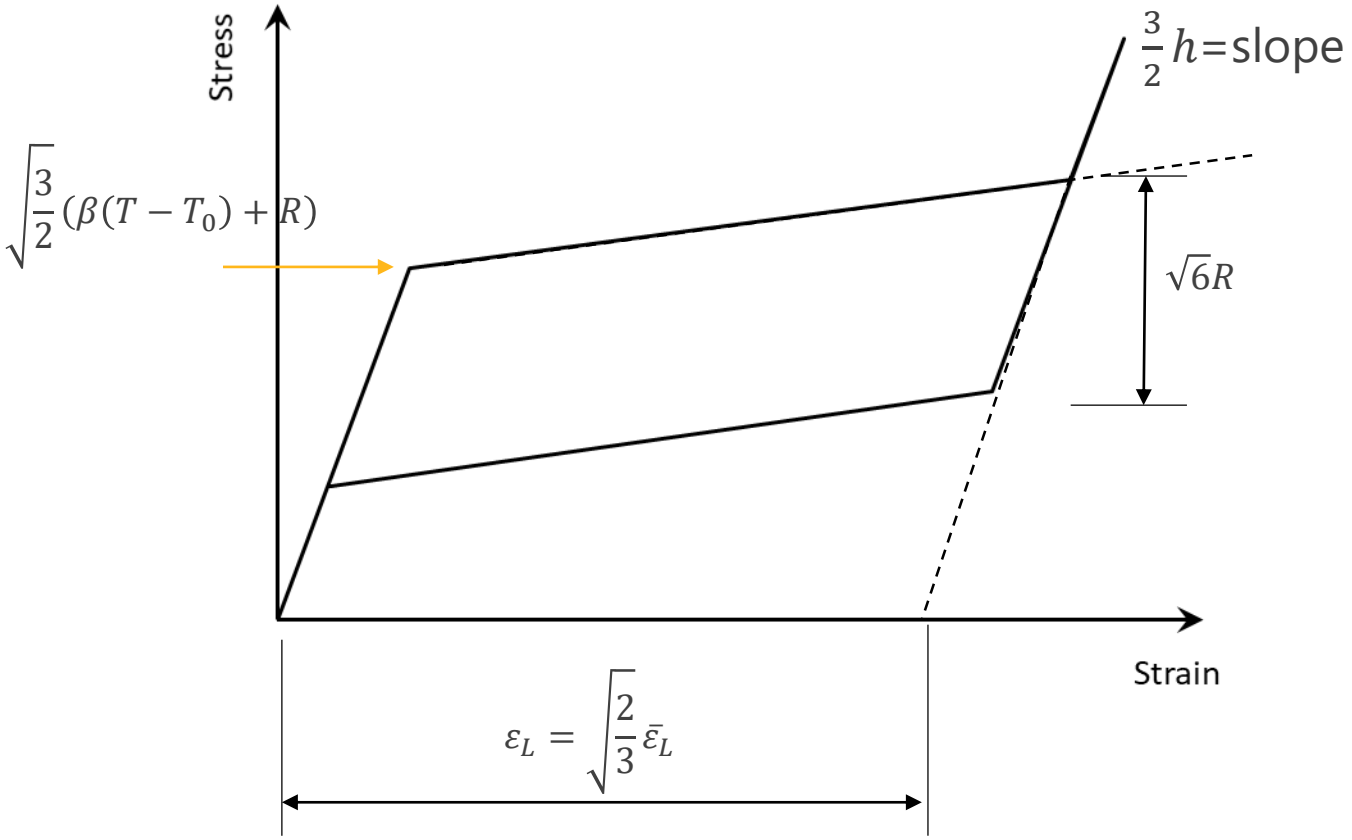
$$\alpha = \frac{\sigma_c^{AS} - \sigma_t^{AS}}{\sigma_c^{AS} + \sigma_t^{AS}}$$

σ_c^{AS}: austenite to martensite transformation beginning stress in compression

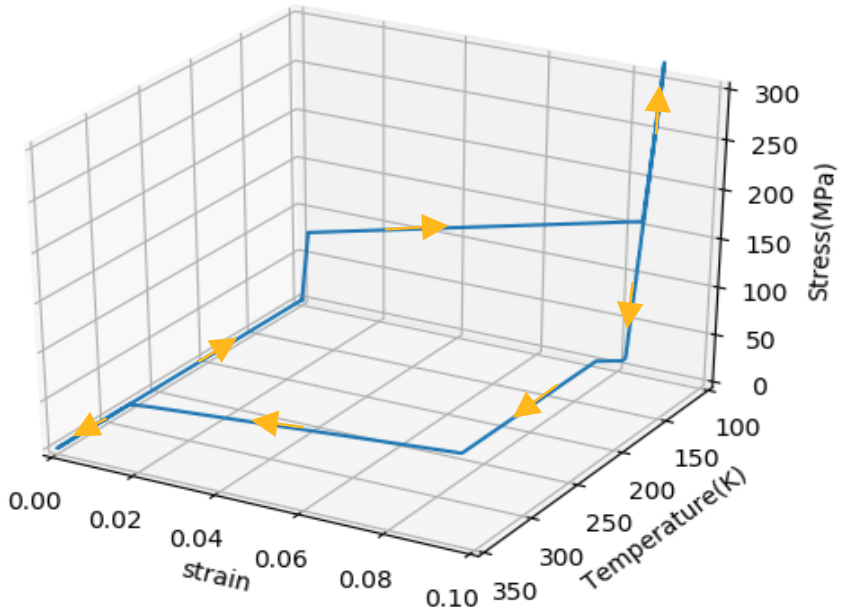
σ_t^{AS}: austenite to martensite transformation beginning stress in tension

Ansys Shape Memory Effect Material Model

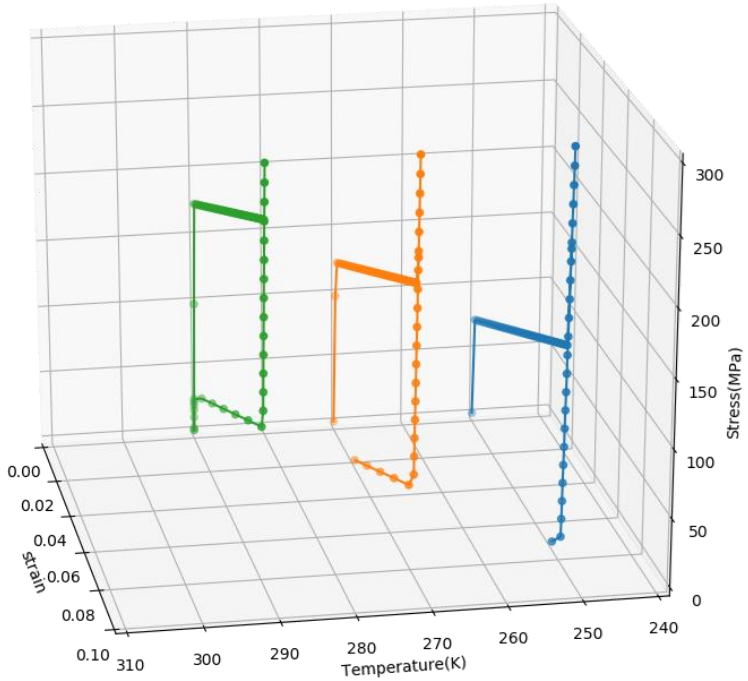
Property name	Symbol	Unit
Hardening parameter	h	MPa
Martensite finishing temperature	T_0	K
Elastic limit	R	MPa
Temperature scaling parameter	β	$MPa \cdot K^{-1}$
Maximum transformation strain	$\bar{\varepsilon}_L$	mm/mm
Martensite modulus	E_m	MPa
Load dependency parameter	m	



Ansys Shape Memory Effect Material Model

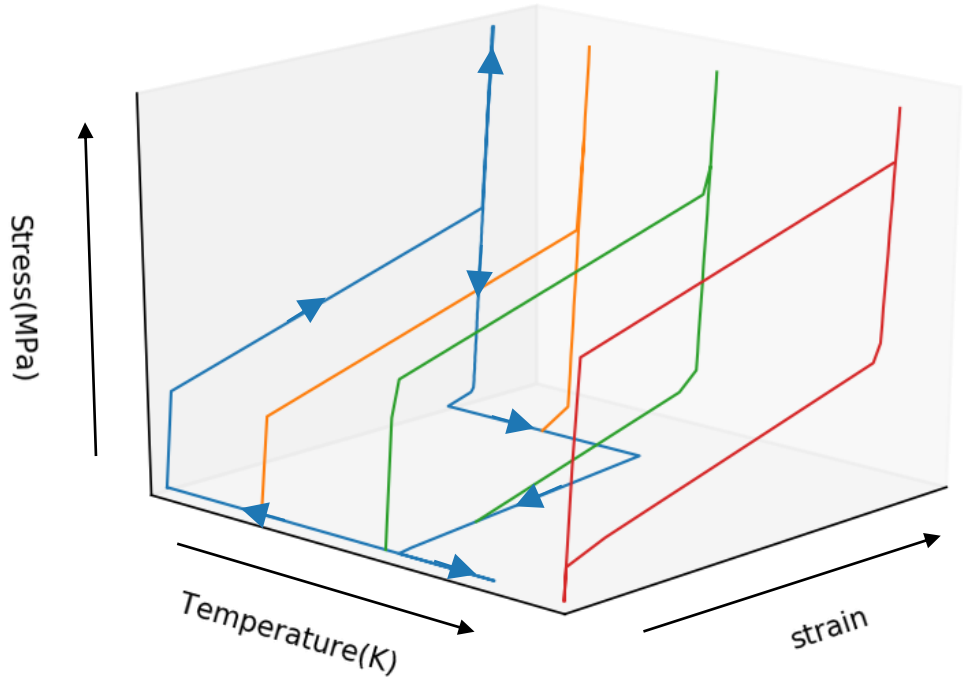


As temperature increases, the residual strain decreases to zero

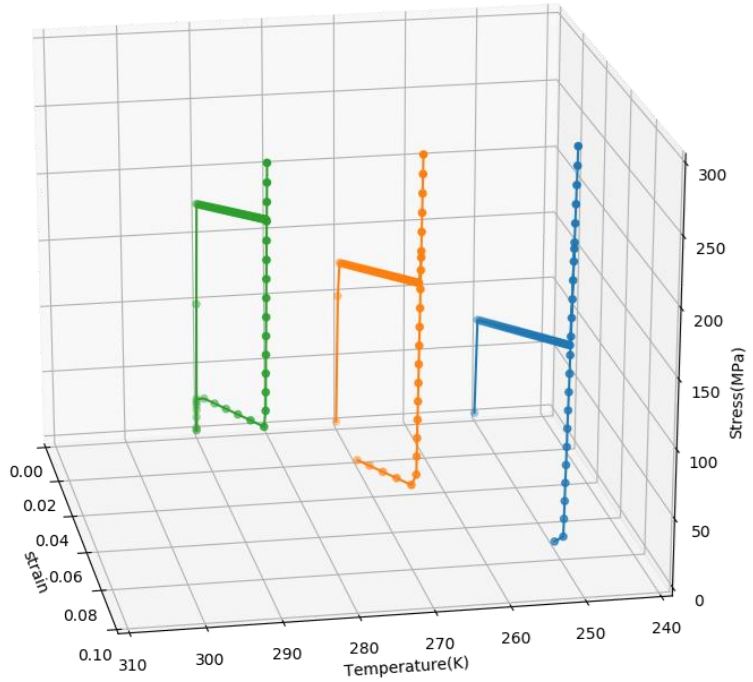


stress strain curve at different temperatures. As temperature drops below M_s, residual strain starts to appear

Ansys Shape Memory Effect Material Model



As temperature increases, the residual strain drecreases to zero.



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