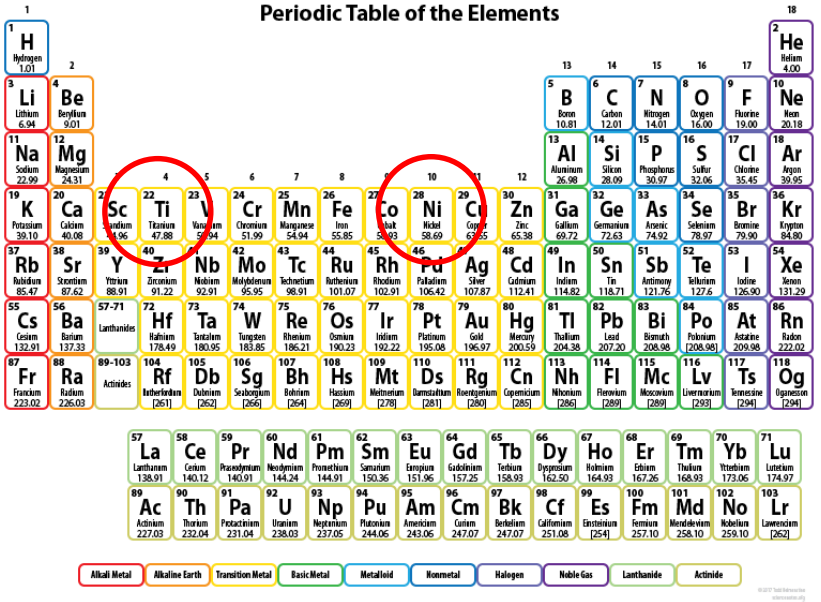
Memory of shape

Nanotechnology 2019

Memory metal

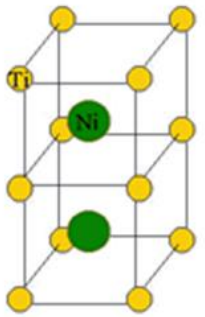
- Nitinol – an alloy of Ni and Ti discovered in 1959.
- Property of “remembering” a shape in which it is *annealed*
- (annealing is the process of heating a piece of metal to a high temperature then cooling rapidly in water)



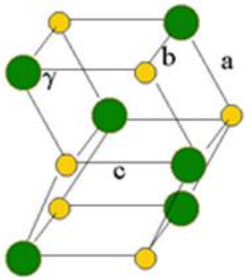
How does Nitinol work?

- Nitinol exists in two forms which are stable at different temperatures
- **Austenite** = high temperature
- **Martensite** = low temperature

Austenite



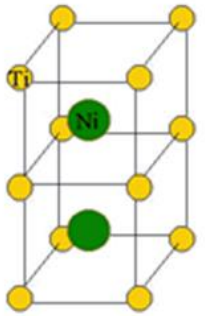
Martensite



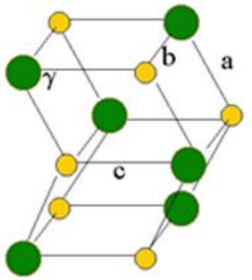
How does Nitinol work?

- Austenite and martensite have different structures
- **Austenite**: body-centred-cube
- **Martensite**: monoclinic twin

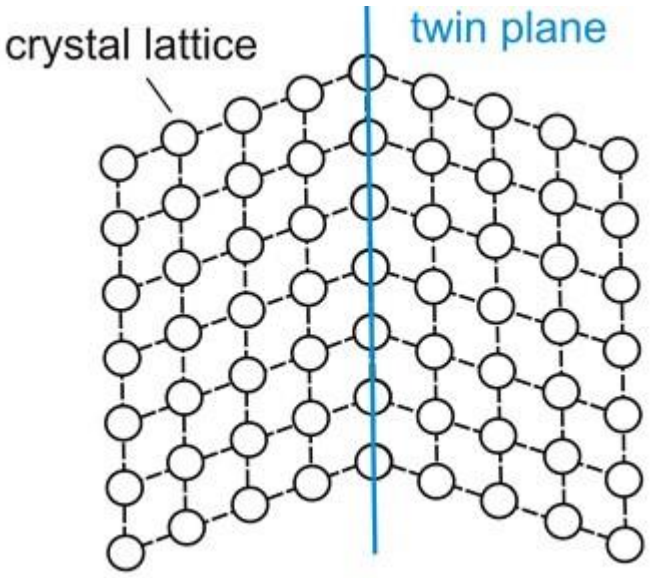
Austenite



Martensite



Twinning in crystals

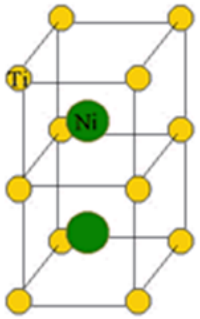


Twinned selenite

How does Nitinol work?

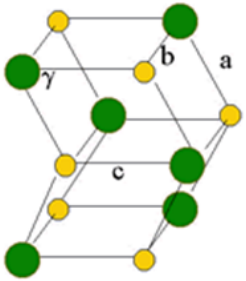
- Martensite is flexible because the crystal planes of the twinned form can slide across each other to give a detwinned form.
- This allows the crystal to be deformed like an accordion

Austenite

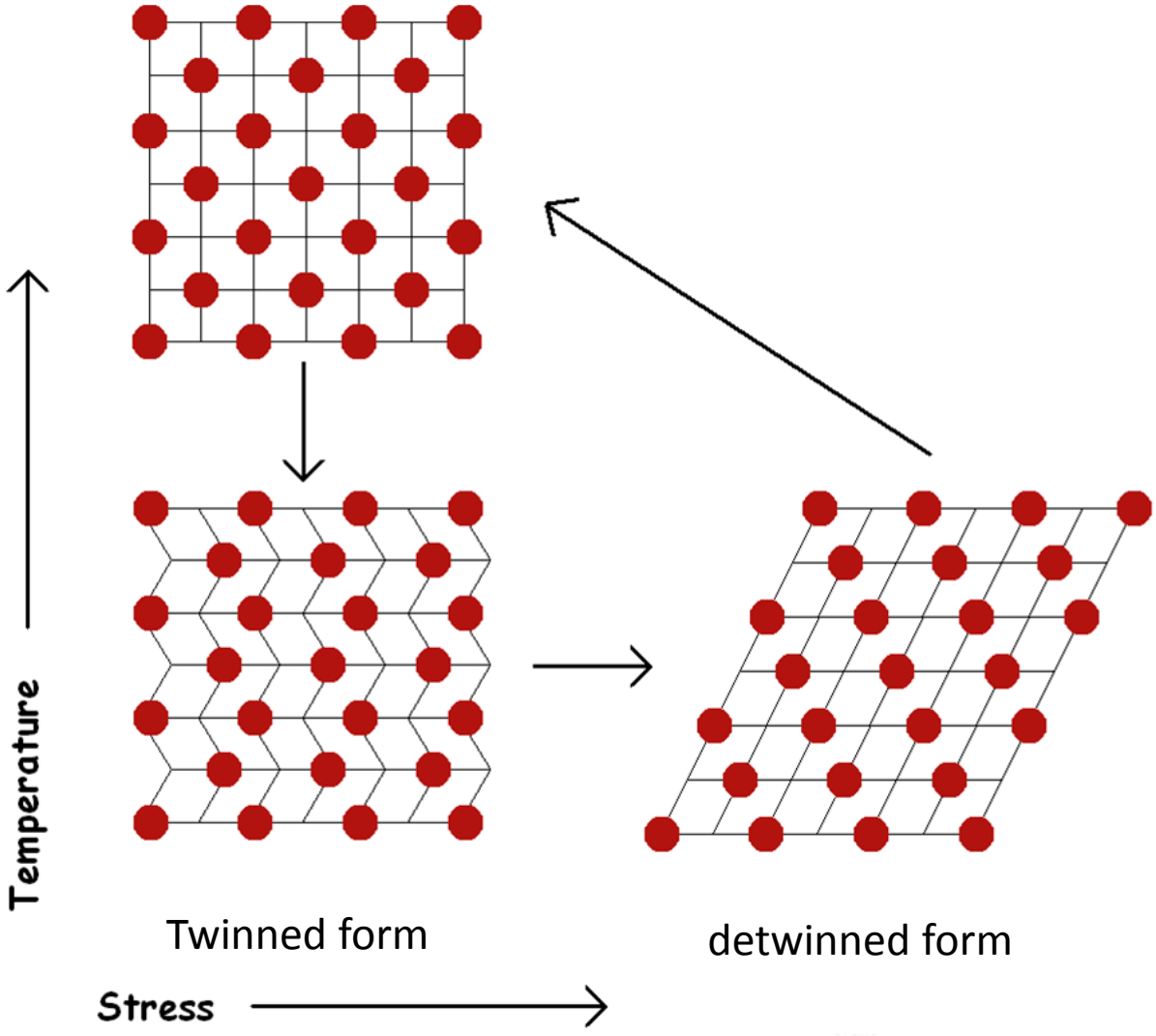


Body centred cubic

Martensite



Monoclinic twinned

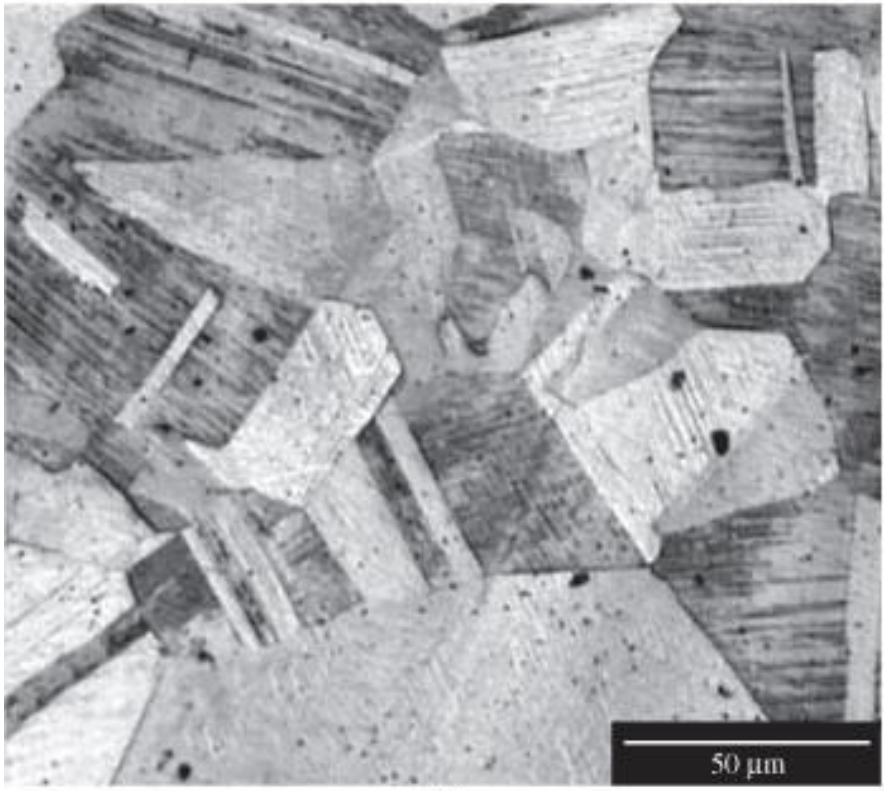


Twinned form

detwinned form

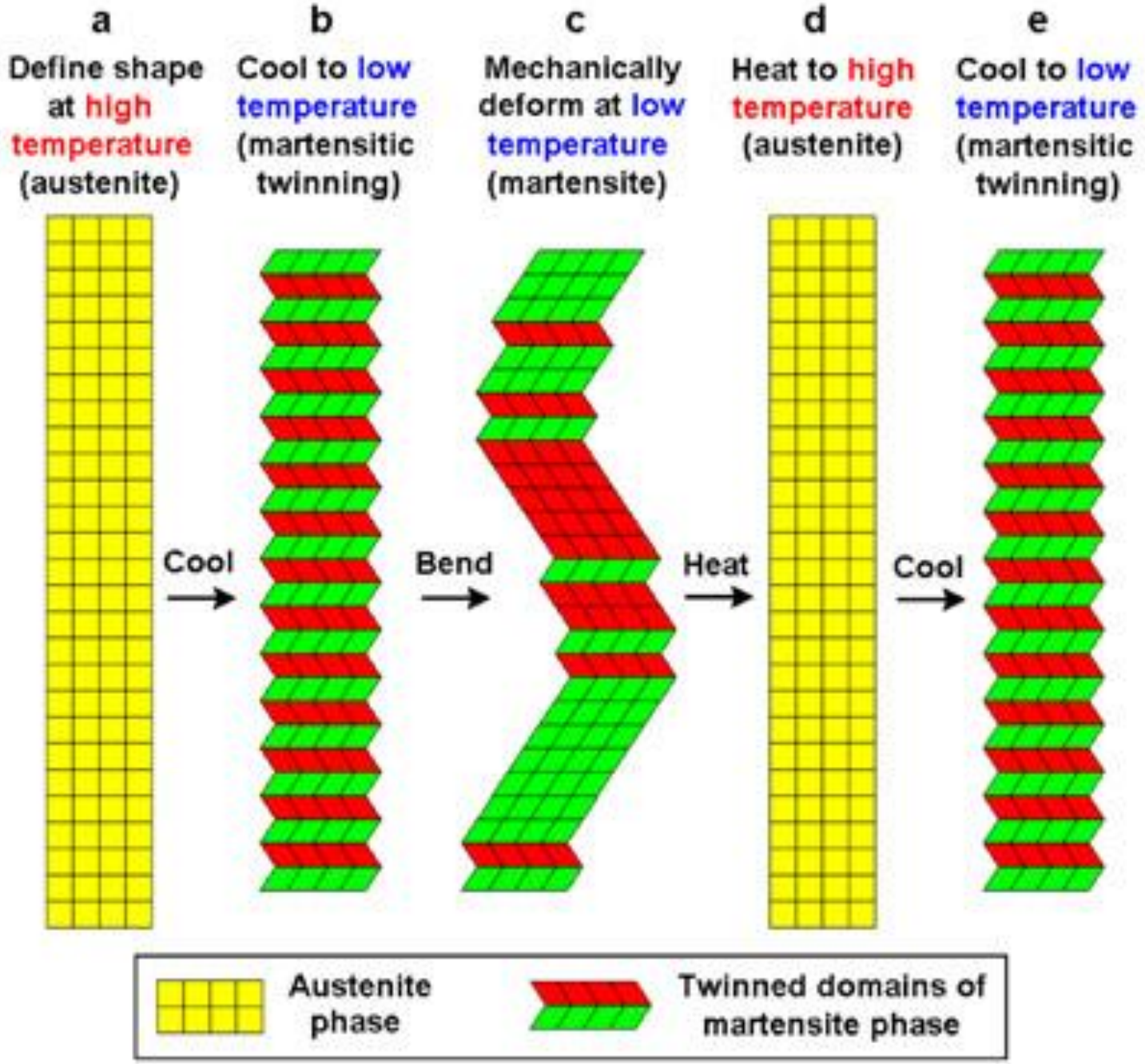
Solid-solid phase transition

- Upon heating, the nitinol returns to its annealed form (austenite)
- The transition from one form to the other does NOT occur at a single temperature.
- Domains of martensite and austenite mix within the structure as it converts



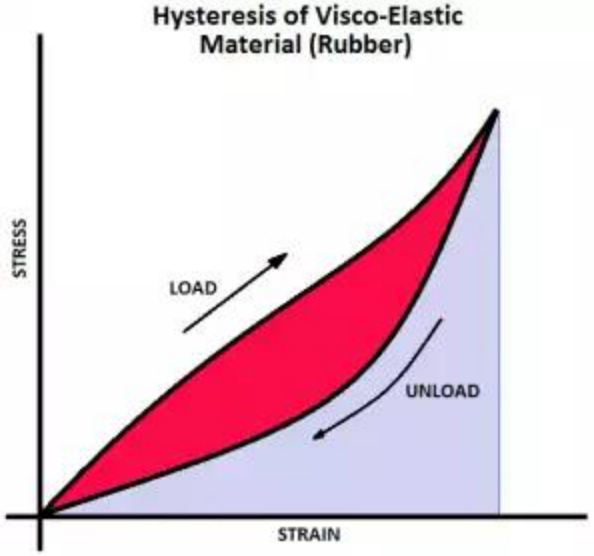
(b)

Figure 1. Optical microscopy: a) grain boundary of austenitic matrix, GS = 106 µm. Etchan: 2mlHNO_3 + 2ml$NHCl$, and b) stress induced ε_{hcp} - martensite (dark region) and γ_{fcc} - austenite (bright region), 6th thermo-mechanical cycle, GS = 75 µm. Color Etching: $K_2S_2O_5$ + NH_4HF_2 in distilled water[19].


a
Define shape at high temperature (austenite)
b
Cool to low temperature (martensitic twinning)
c
Mechanically deform at low temperature (martensite)
d
Heat to high temperature (austenite)
e
Cool to low temperature (martensitic twinning)
Cool
Bend
Heat
Cool
Austenite phase
Twinned domains of martensite phase

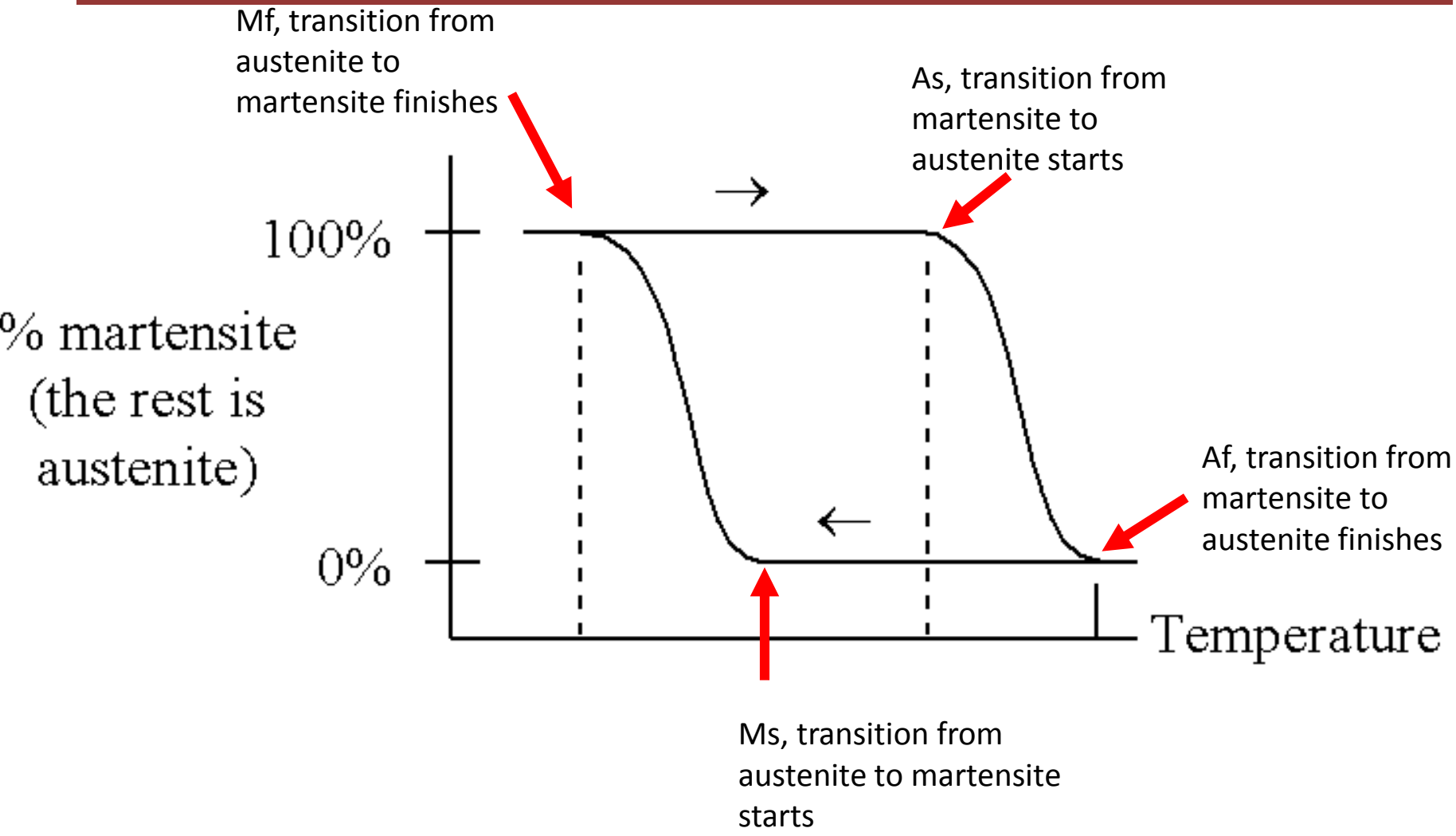
Hysteresis

- The heating and cooling curves *do not superimpose upon each other*
- This is described as hysteresis which is also encountered in magnetism
- It is caused because the metal *is not a homogeneous structure: i*t is composed of domains which are of one form or the other.
- The domains require time and energy to interconvert.



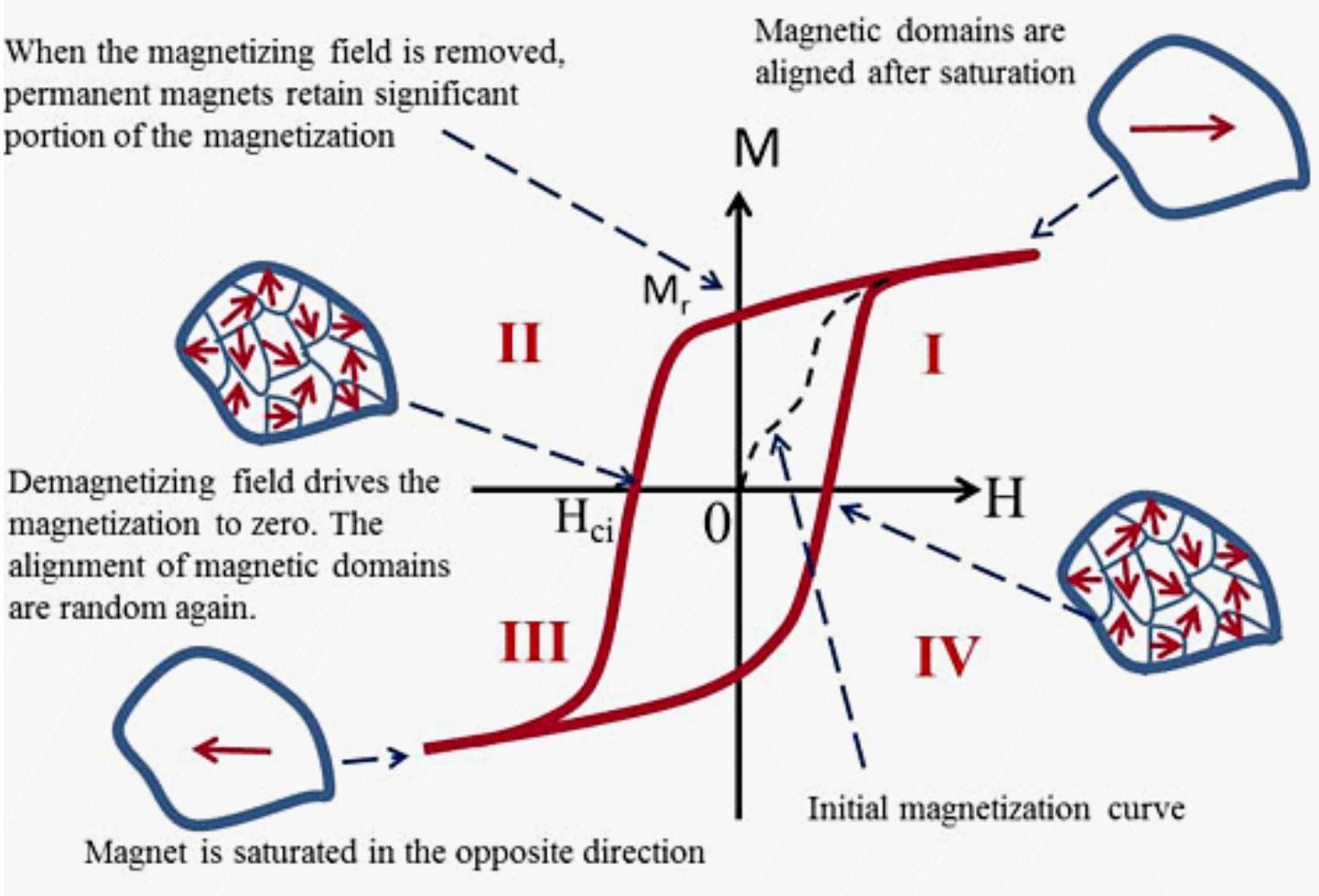
http://www.bulldogcastors.co.uk/blog/rubber-caster-wheels-hysteresis/

Hysteresis in memory metal



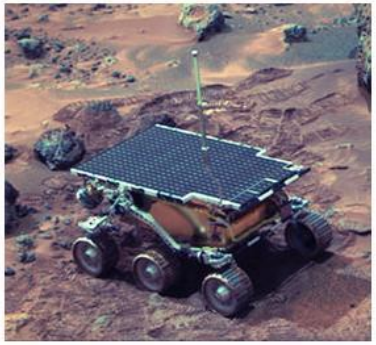
From: http://www.google.com/patents/US6688828

Magnetic Hysteresis



Magnetisation vs magnetic field (external)

Uses of nitinol



Flexinol on Mars

Flexinol operated a dust sensor on the Sojourner rover which landed on Mars July 4, 1997.