Chapter 6. Diffusionless Transformation

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3.5 Interface Migraiton

- **Growth can be categorized into diffusion-controlled growth and interface-controlled growth**

3.5 Interface Migration

- ✓ Phase transformation occurs by nucleation growth process.
- ✓ β forms at a certain sites within α (parent) during nucleation (interface created) then the α/β interface "migrate" into the parent phase during growth.

- **Types of interfaces**

  1. **Glissile**: by ⊥ glide → results in the shearing of parent lattice into the product (β), motion (glide) insensitive to temperature (athermal)
  2. **Non glissile** (most of cases): migration by random jump of individual atoms across the interface (similar to high angle grain boundary migration)

3.5 Interface Migration

A. Heterogeneous Transformation

- Classifying nucleation and growth transformation (=heterogeneous transformation)
  - ✓ Transformation by the migration of a glissile interface
    - → Military transformation
  - ✓ Uncoordinated transfer of atoms across non-glissile interface
    - → Civilian transformation

- **Military transformation**
  - ✓ The nearest neighbors of any atom are unchanged.
  - ✓ The parent product phases – the same composition, no diffusion involved (martensite transformation , mechanical twins)

Classification of Nucleation & Growth Transformation

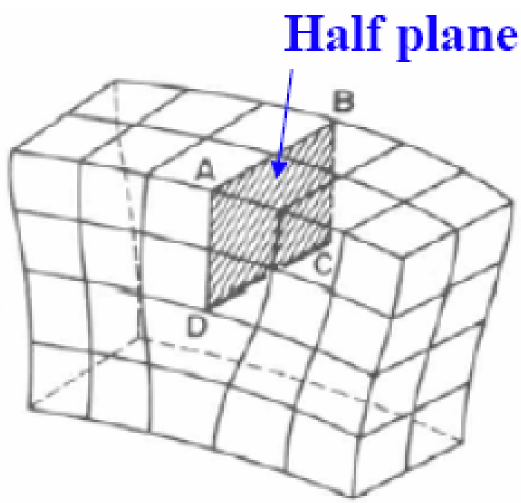
TABLE 3.5

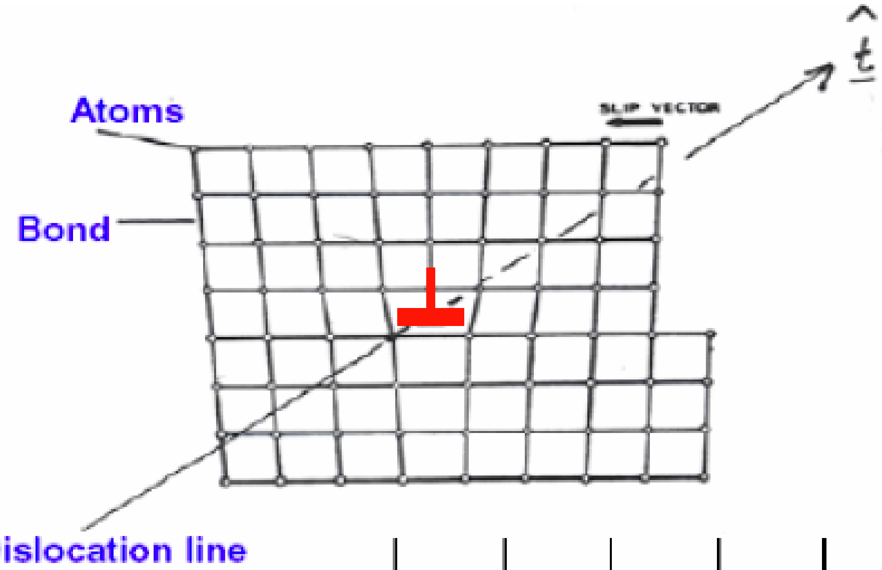
Classification of Nucleation and Growth Transformations

Type	Military	Civilian			
Effect of temperature change	Athermal	Thermally activated			
Interface type	Glissile (coherent or semicoherent)	Non-Glissile (coherent, semicoherent, incoherent, solid/liquid or solid/vapour)			
Composition of parent and product phases	Same composition	Same composition	Different compositions		
Nature of diffusion processes	No diffusion	Short-range diffusion (across interface)	Long-range diffusion (through lattice)		
Interface, diffusion or mixed control?	Interface control	Interface control	Mainly interface control	Mainly diffusion control	Mixed control
Examples	Martensite Twinning Symmetric tilt boundary	Massive Ordering Polymorphic Recrystallization Grain growth Condensation Evaporation	Precipitation Dissolution Bainite Condensation Evaporation	Precipitation Dissolution, Solidification and melting	Precipitation Dissolution Eutectoid Cellular precipitation

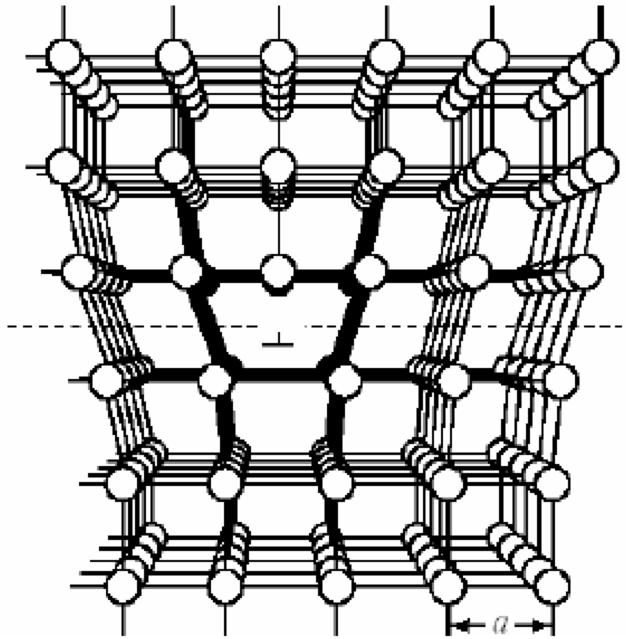
Source: Adapted from J.W. Christian, 'Phase transformations in metals and alloys—an introduction', in *Phase Transformations*, Vol. 1, p. 1, Institute of Metallurgists, 1979.

Model of Edge Dislocation

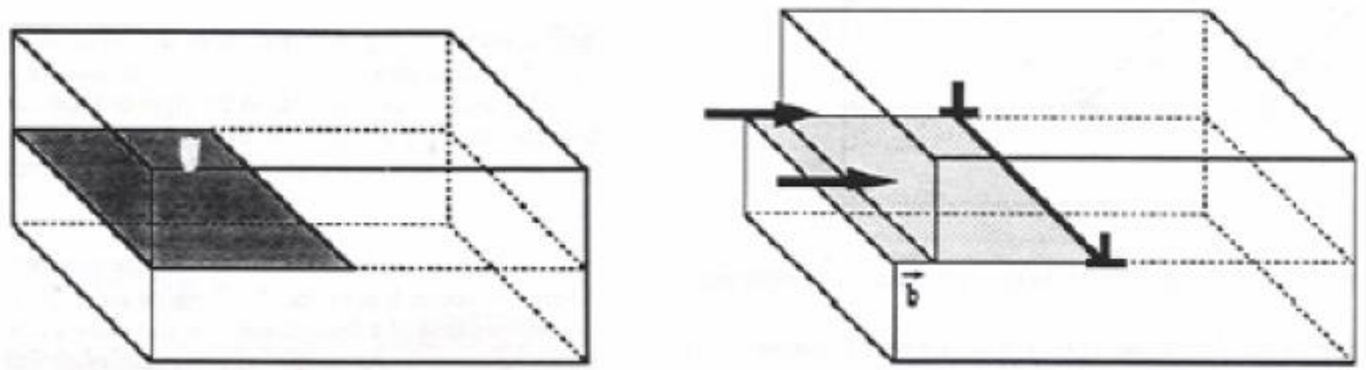




Symbols:
⊥: Positive edge dislocation
T : Negative edge dislocation



Geometry of edge dislocation

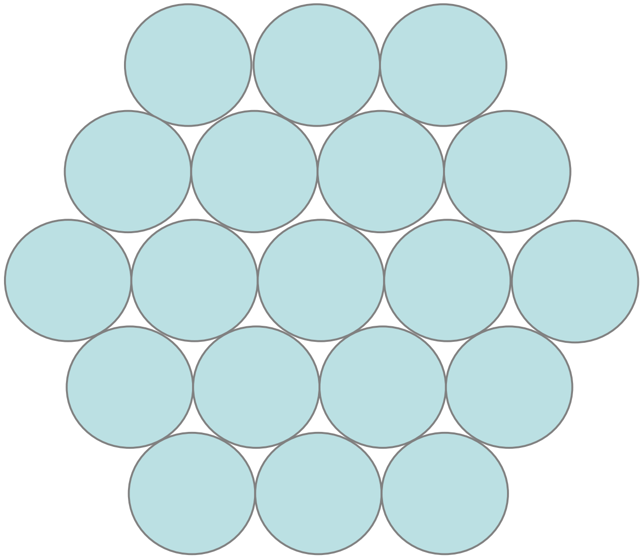


- Slip plane: where slip occurs
- Dislocation line: boundary between the slipped and unslipped part of a crystal
- Slip plane contains both Burgers vectors and dislocation lines
- Edge dislocation: Burgers vector b ⊥ dislocation line

Metallic crystal system

❖ **Close Packing Crystal structure**

❑ **How can we stack metal atoms to minimize empty space?**

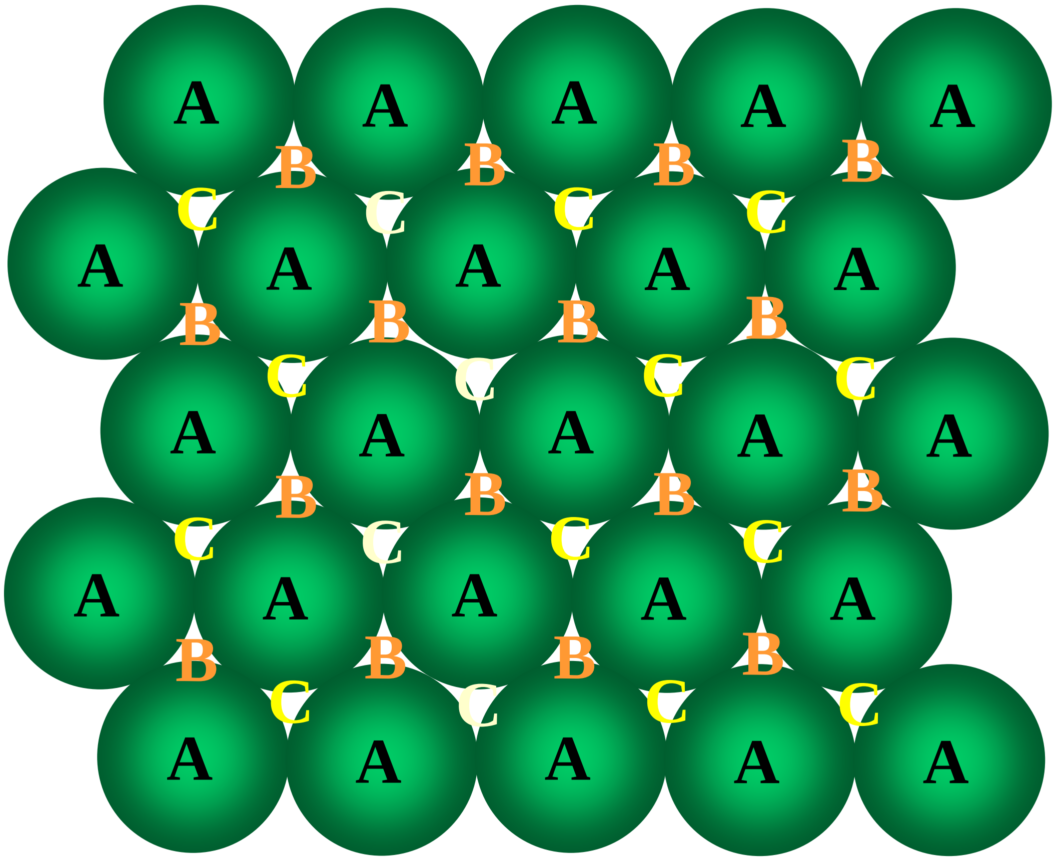


closed packed atomic arrangement in 2-D

Now stack these 2-D layers to make 3-D structures

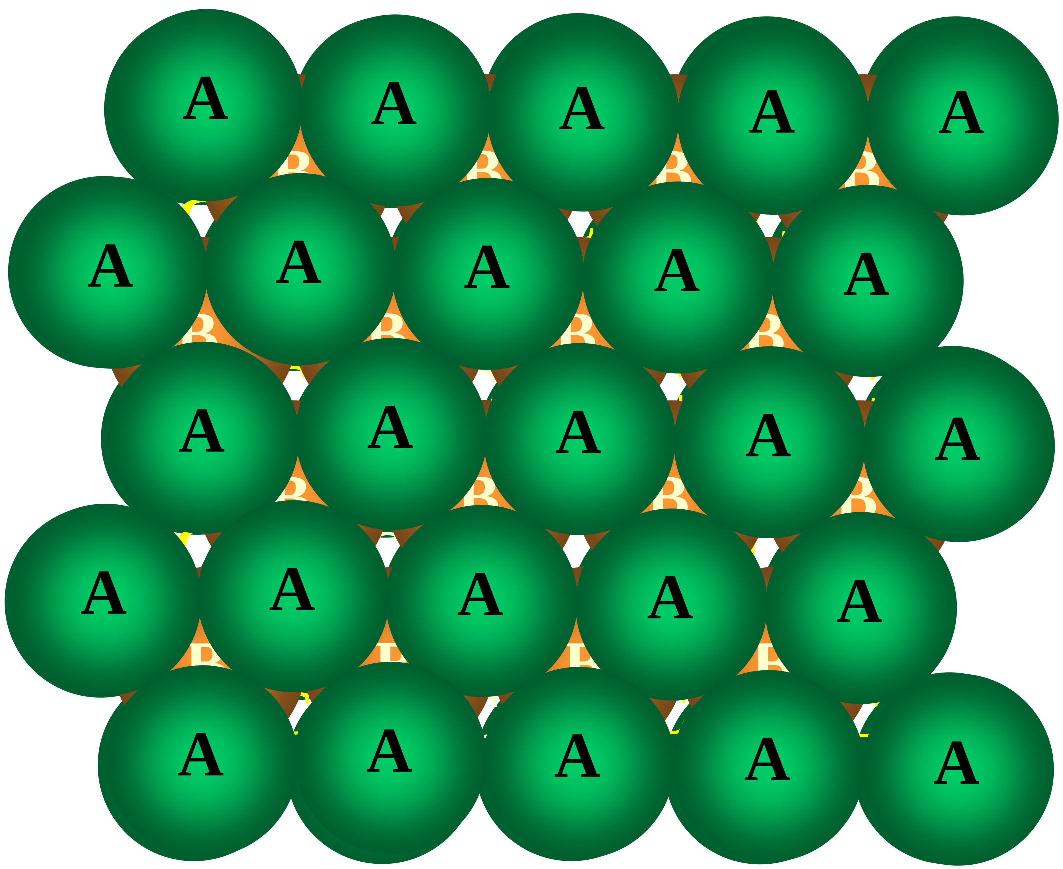
Metallic crystal system

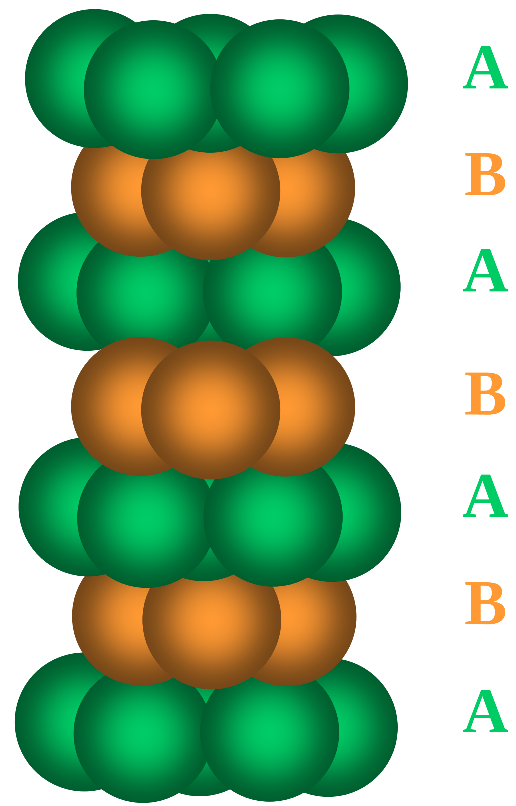
- **Stacking sequence**



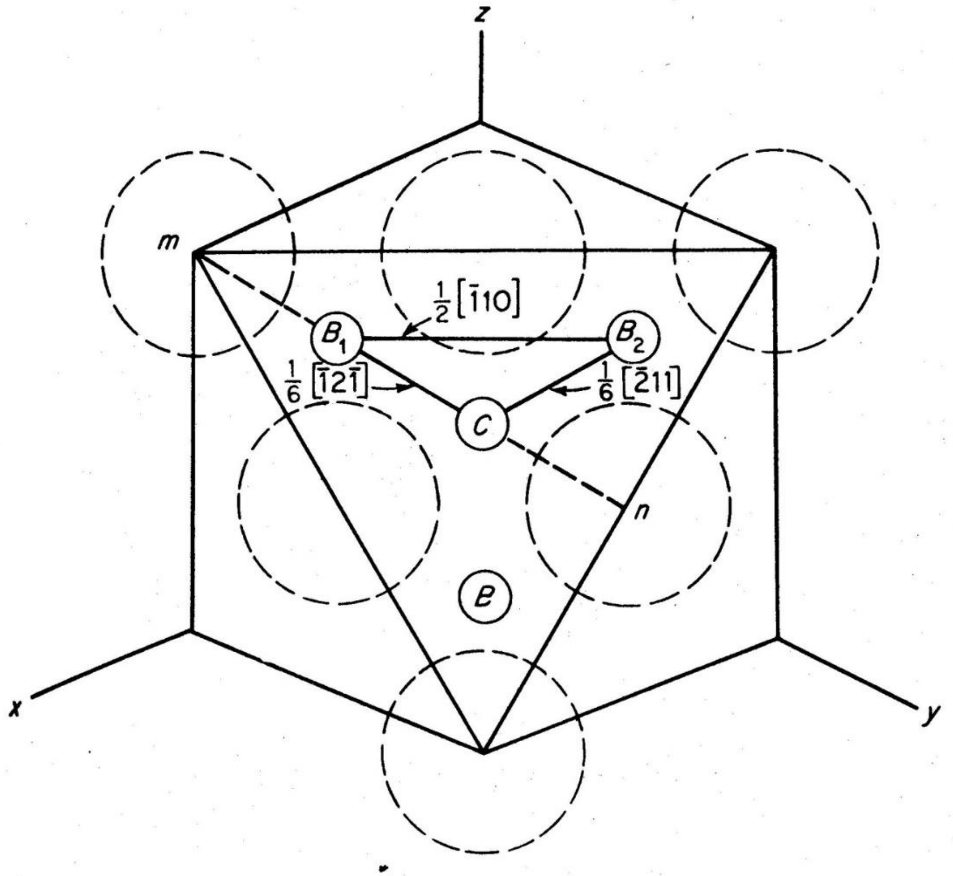
Metallic crystal system

- A – B – A – B stacking sequence → HCP





Dislocation in FCC Crystal



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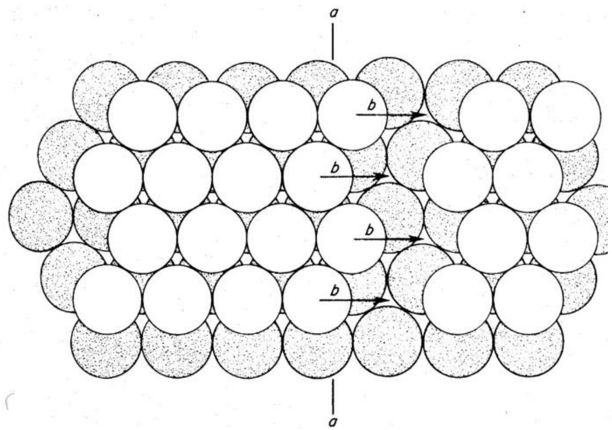
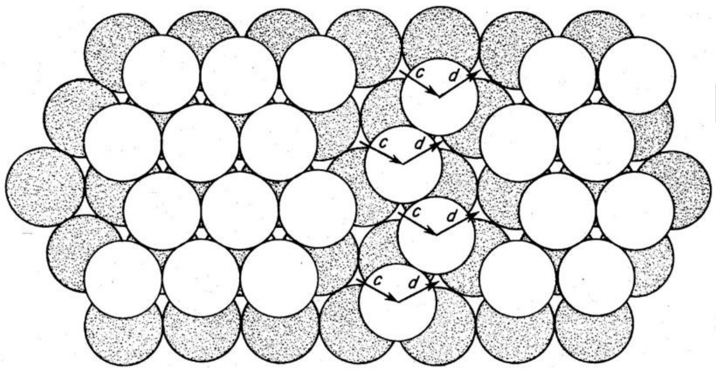
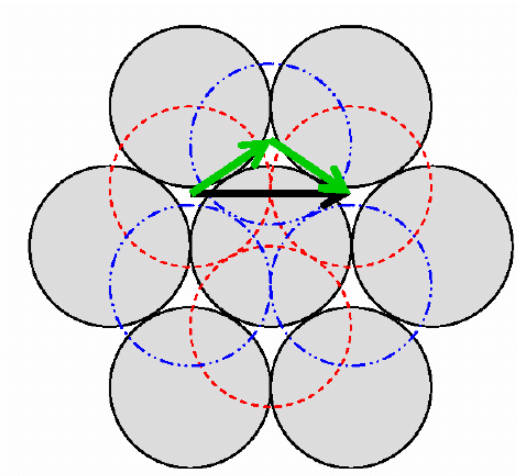
Partial Dislocation (FCC)

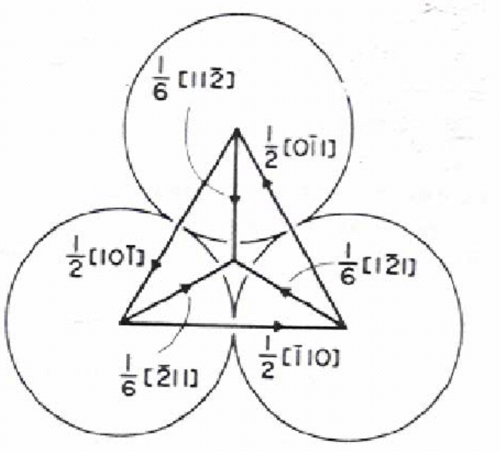
Difficult



Easy





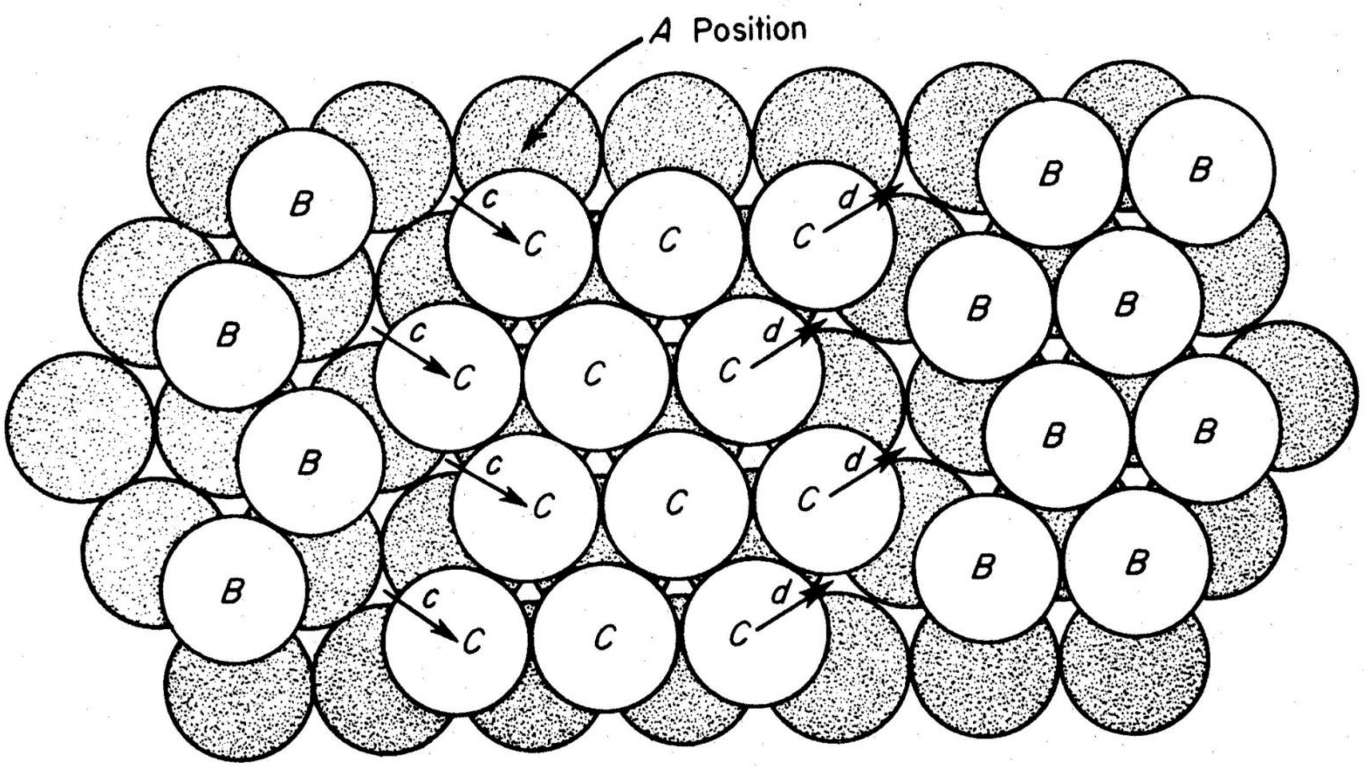


$$\frac{a_o}{2}[10\bar{1}] \rightarrow \frac{a_o}{6}[2\bar{1}\bar{1}] + \frac{a_o}{6}[11\bar{2}]$$

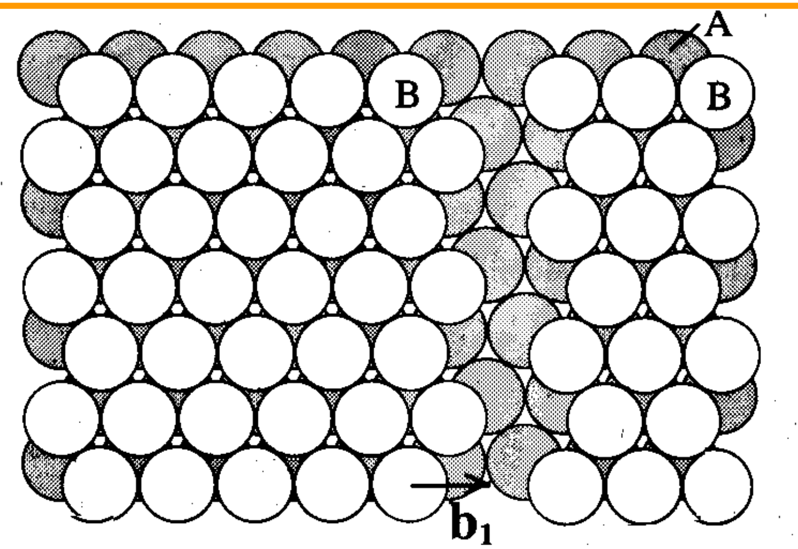
$$\frac{a_o^2}{2} > \frac{a_o^2}{6} + \frac{a_o^2}{6}$$

Stacking Fault

Extended Dislocation (FCC)

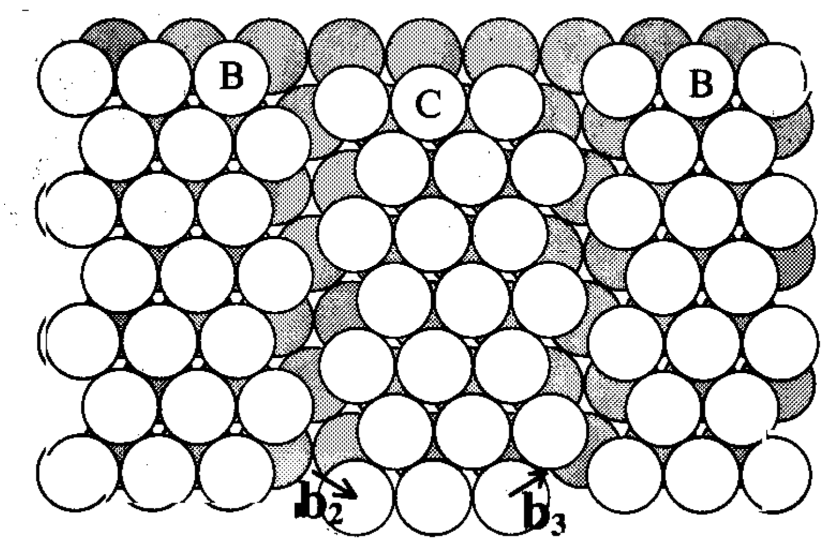


Stacking Fault



ABABAB - hcp

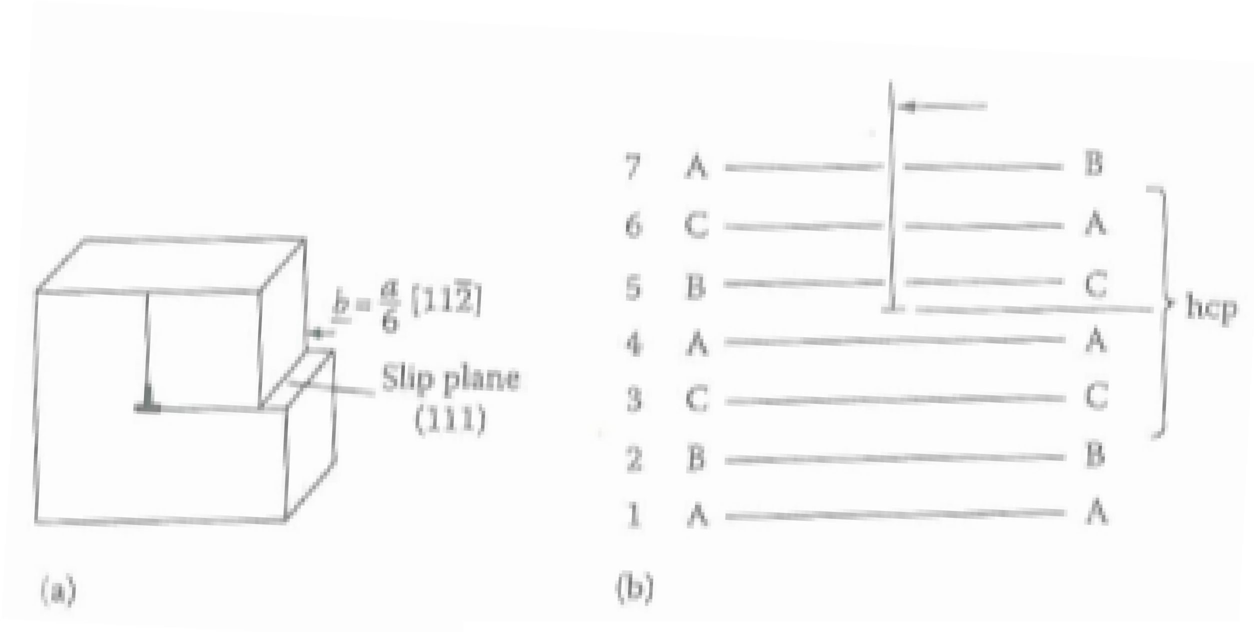
ABCABC - ccp

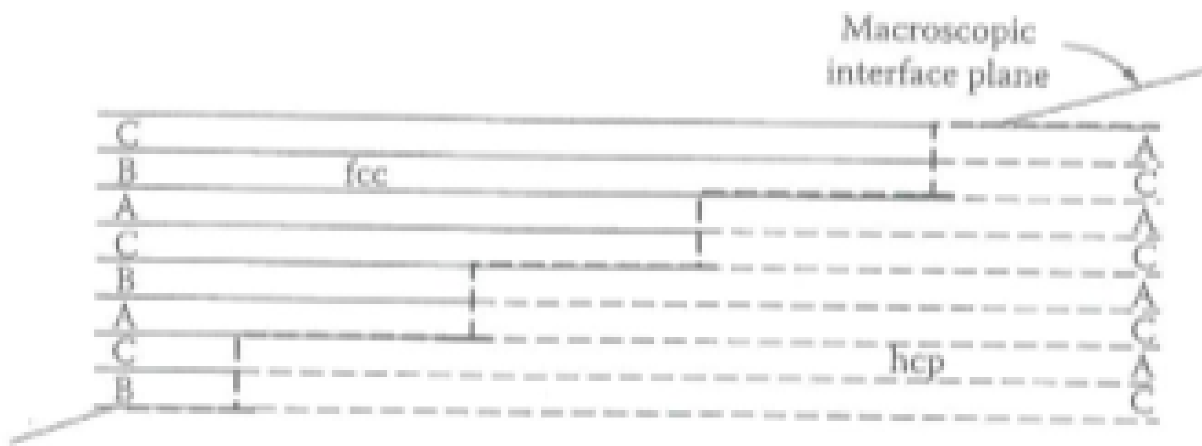


Stacking fault

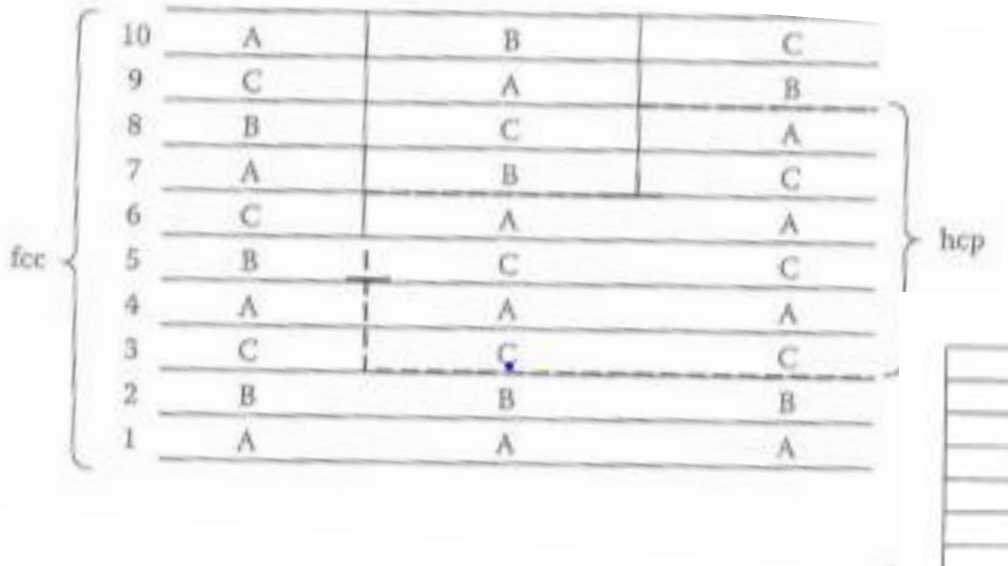
ABCBABC

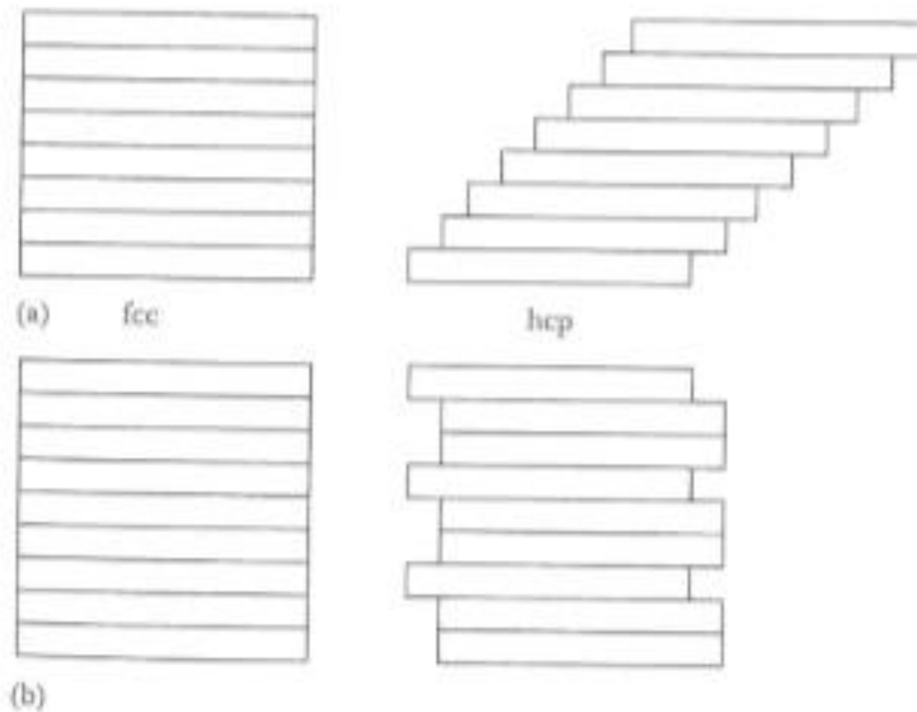
ABCBCABC


b = a/6 [11$\bar{2}$]
Slip plane
(111)
(a)
7 A B
6 C A
5 B C
4 A A
3 C C
2 B B
1 A A
hcp
(b)


Macroscopic interface plane
C
B
A
C
B
A
C
B
fcc
A
C
A
C
A
C
A
C
hcp

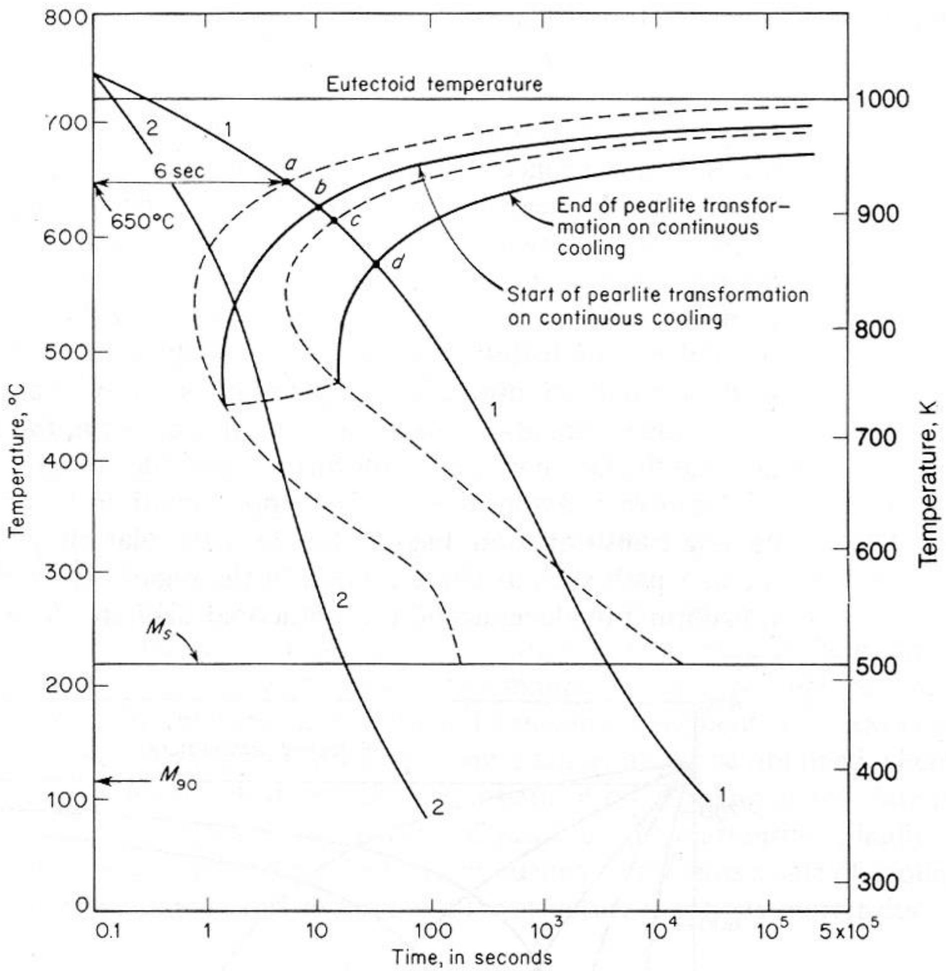
Twin

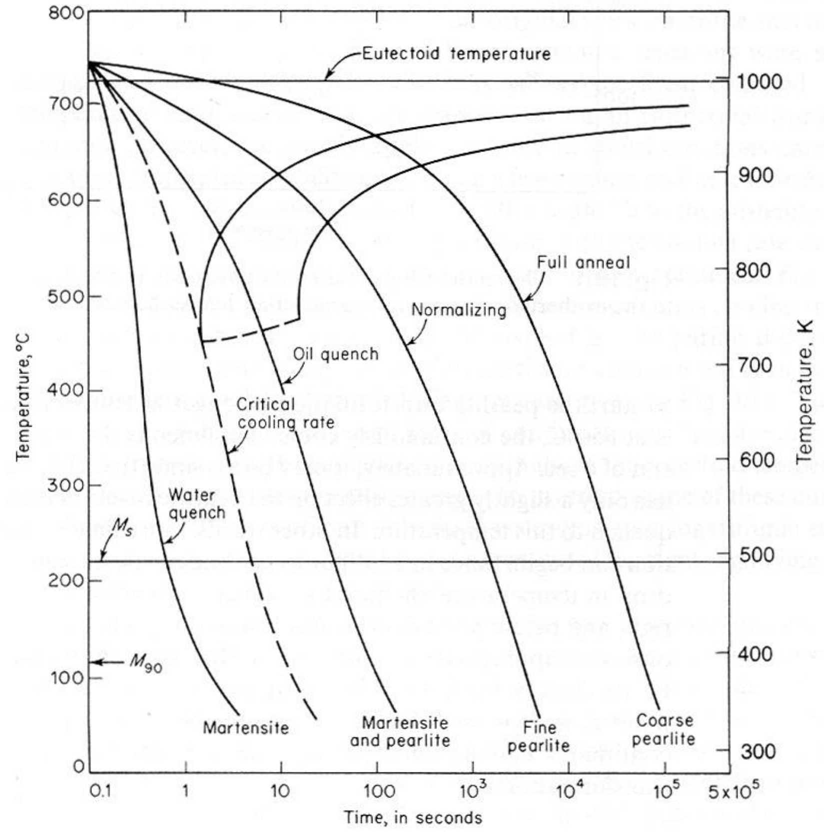

10 A B C
9 C A B
8 B C A
7 A B C
6 C A A
5 B C C
4 A A A
3 C C C
2 B B B
1 A A A
fcc
hcp


(a)
fcc
hcp
(b)

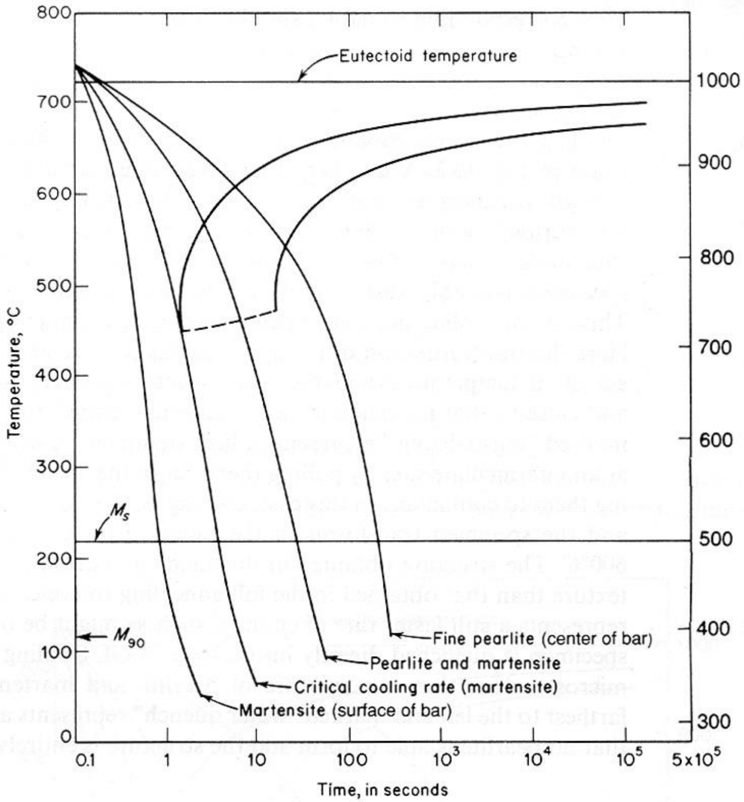
Martensite

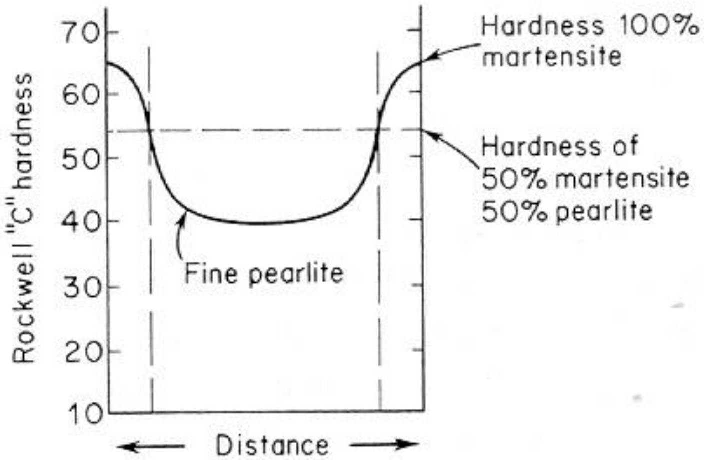
Continuous Cooling Transformation

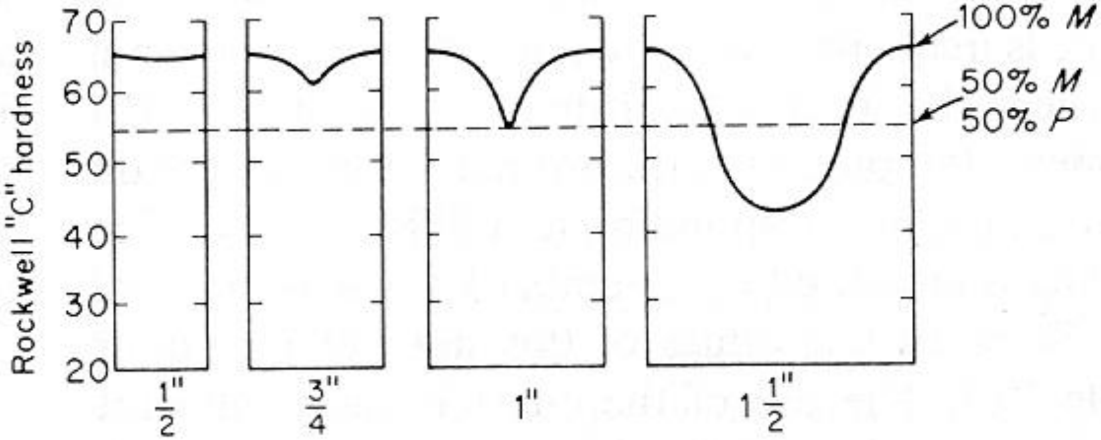




Continuous Cooling Transformation







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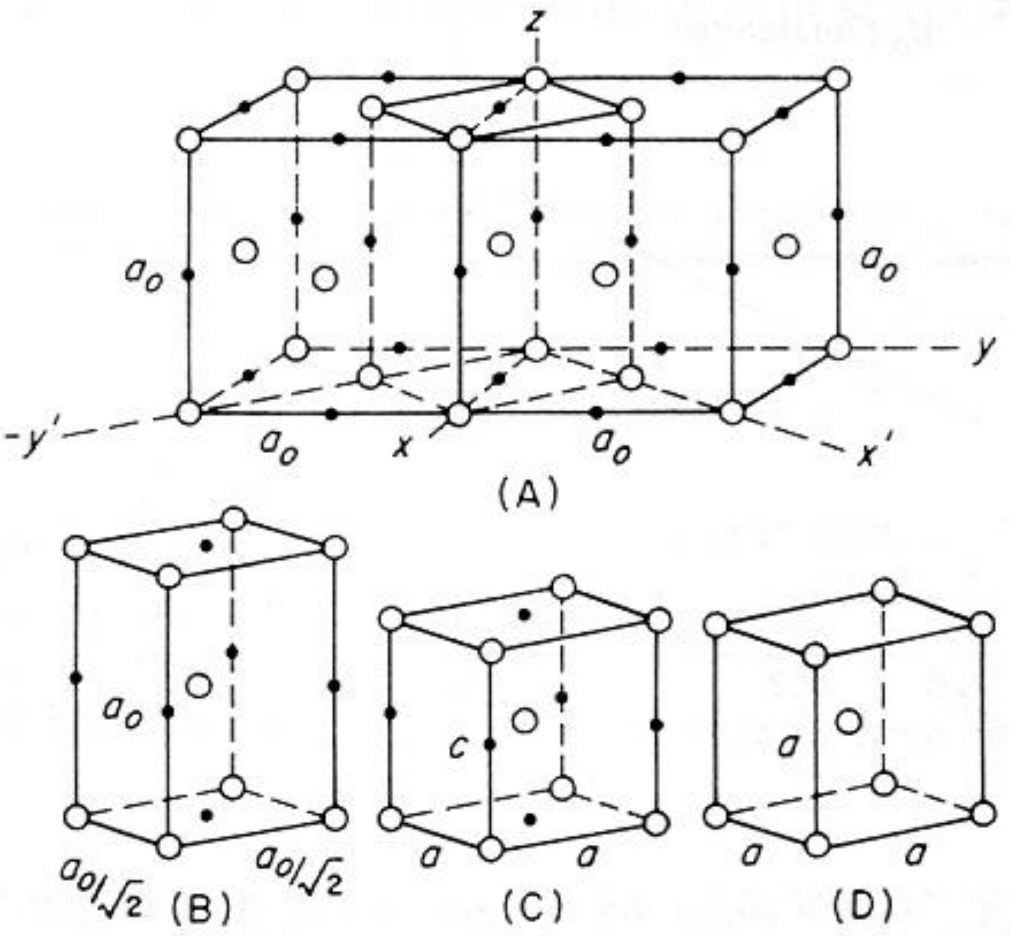
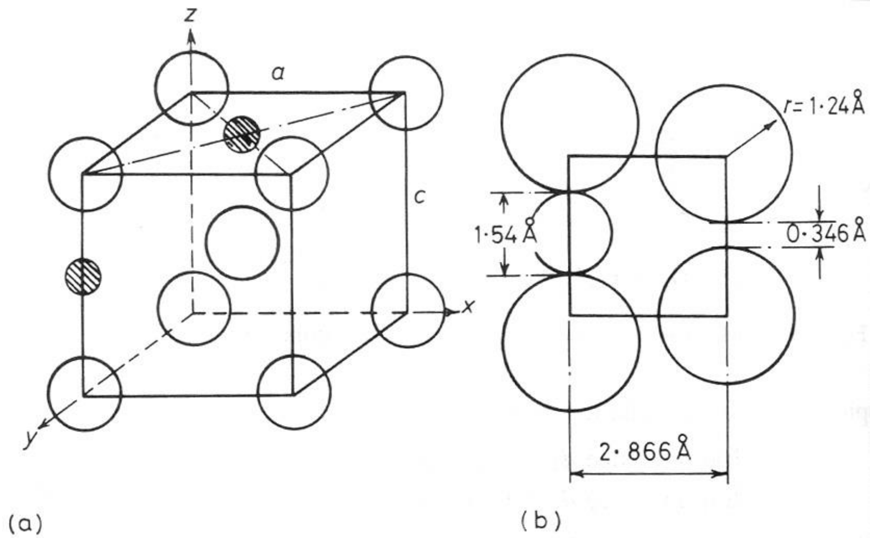
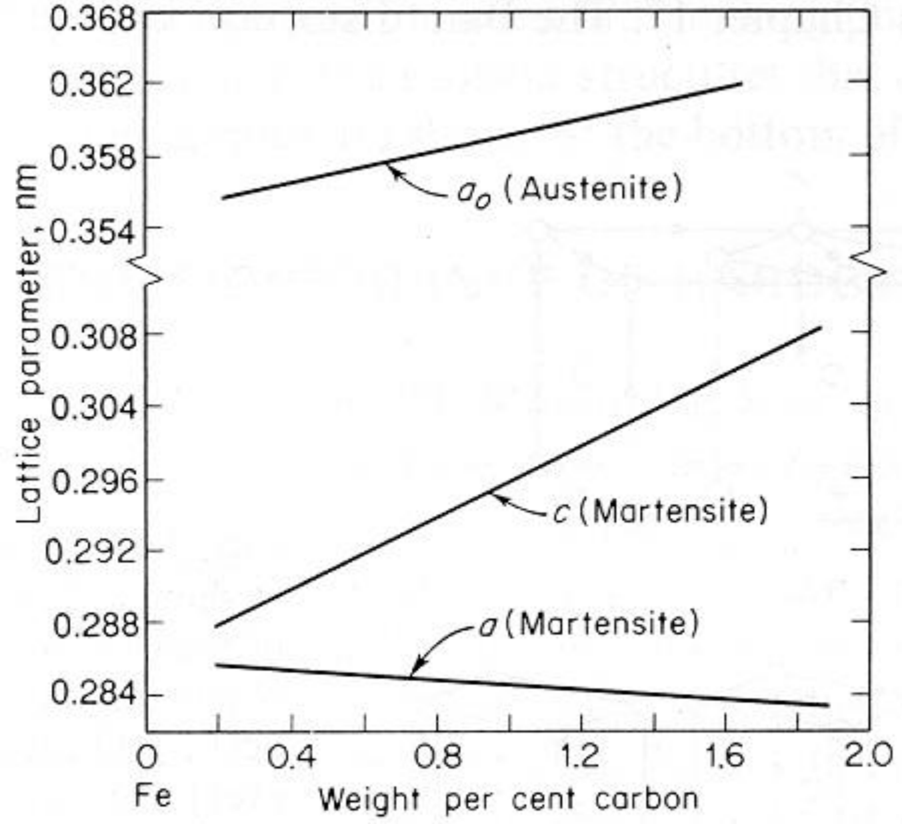
Martensite Transformation in Steel





Martensite Transformation in Steel



Ferrite

$$C = 0.2866 + 0.0166x$$
$$a = 0.2866 + 0.0013x$$

Austenite

$$a_0 = 0.3555 + 0.0044x$$

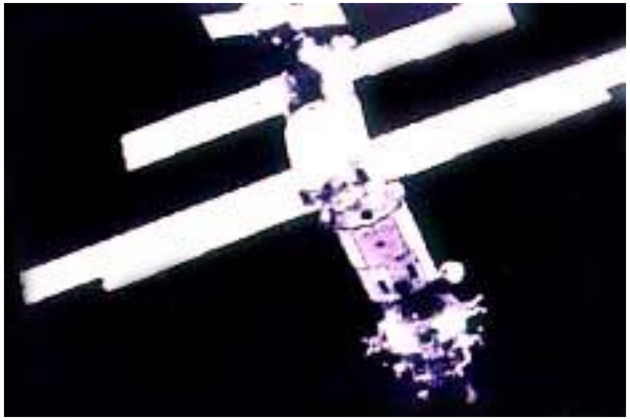
Martensite

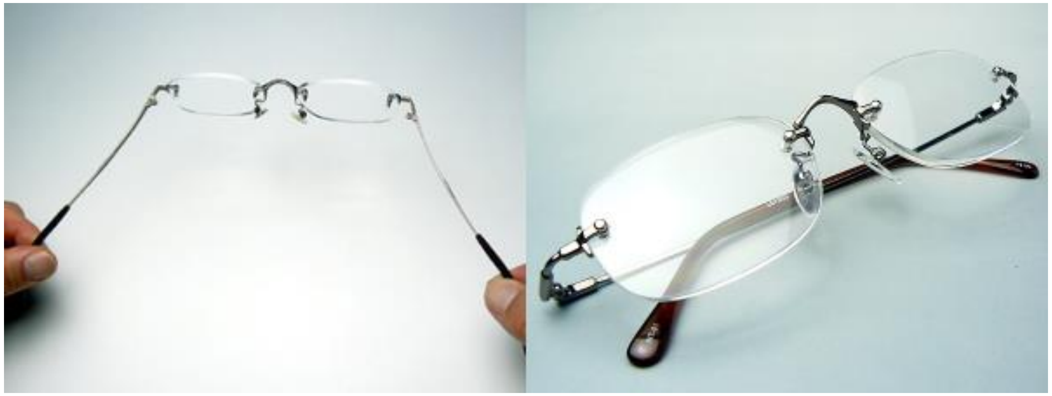
Lath Martensite

Twinned Martensite

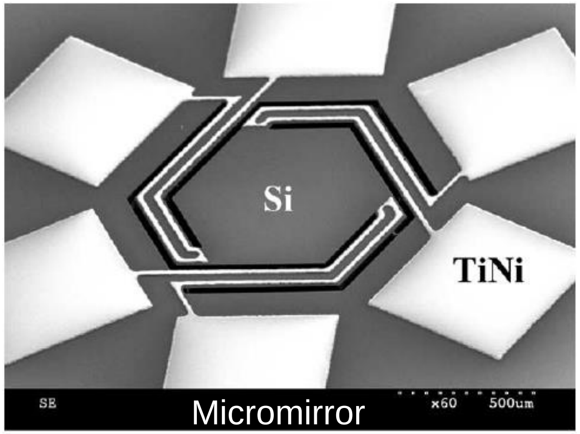
Shape memory alloy

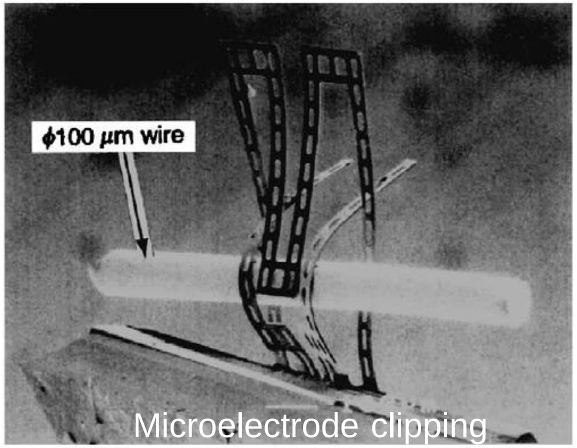
Shape memory alloy





Needs of shape memory alloy thin film



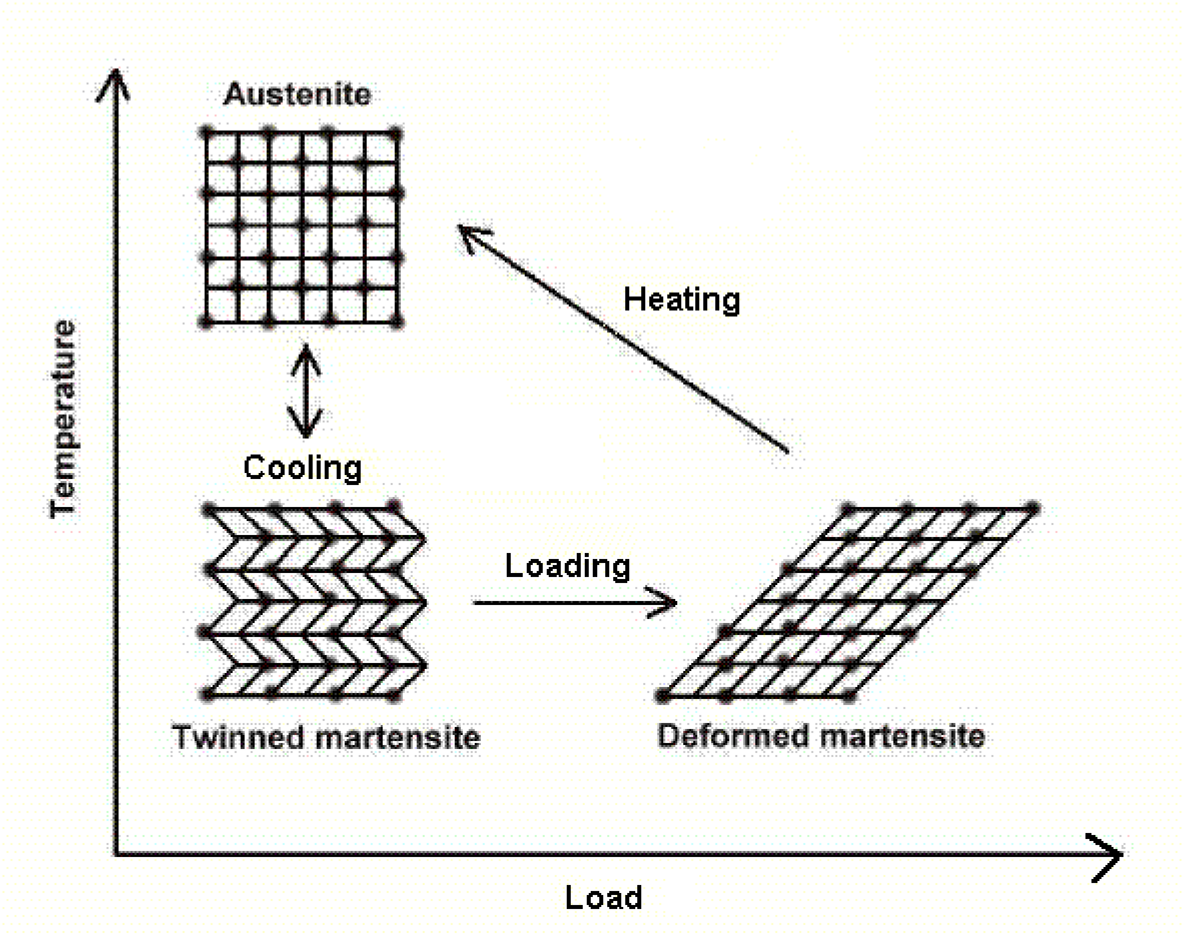


(Y.Fu et al., Sensors and Actuators , 2004)

- **Micro-electro-mechanical system**
  - ✓ Micro scale & great surface / volume ratio
  - ✓ Large deformation
  - ✓ Large recovery force
  - ✓ Fast response rate
  - ✓ micropumps, micro-sensors, microgrippers etc.
- **Biomedical application**

Martensitic transformation

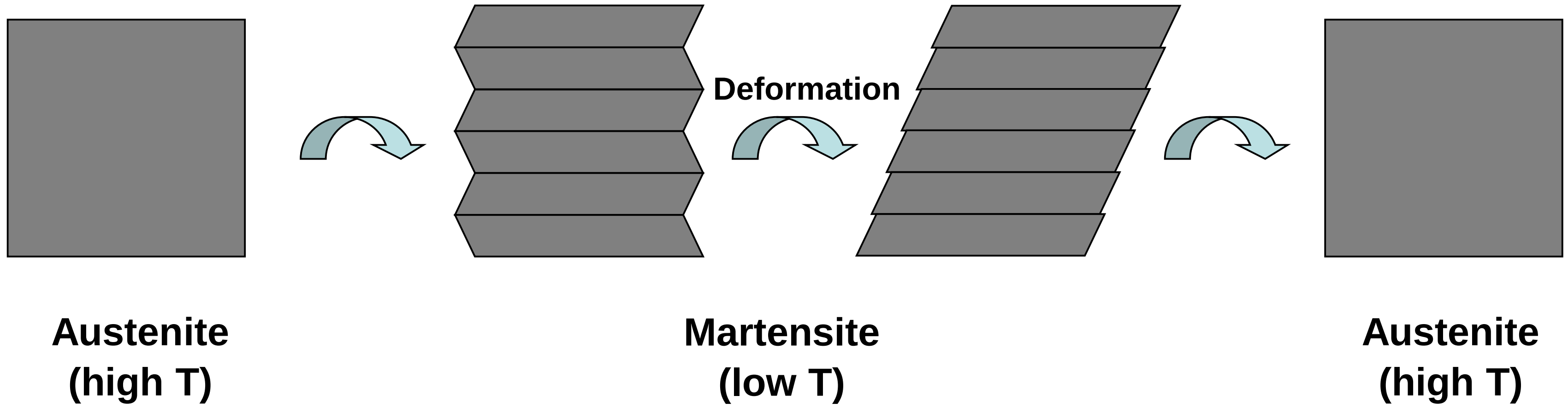
- **Phase transformation that occurs by cooperative atomic movements – military transformation**



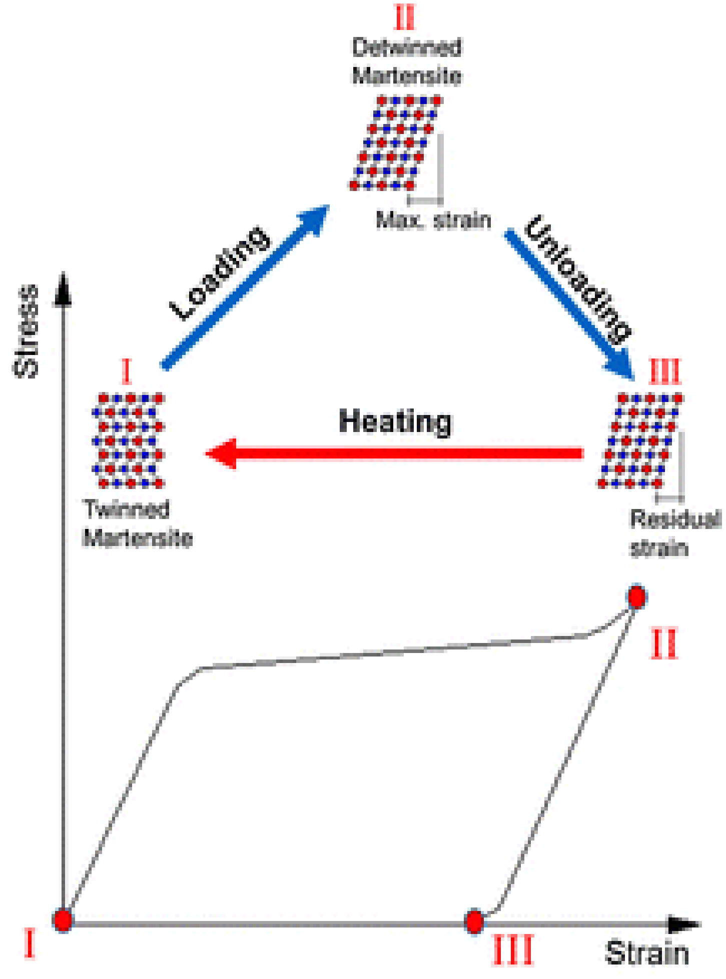
Shape memory effect

❖ **Thermoelastic martensitic transformation**

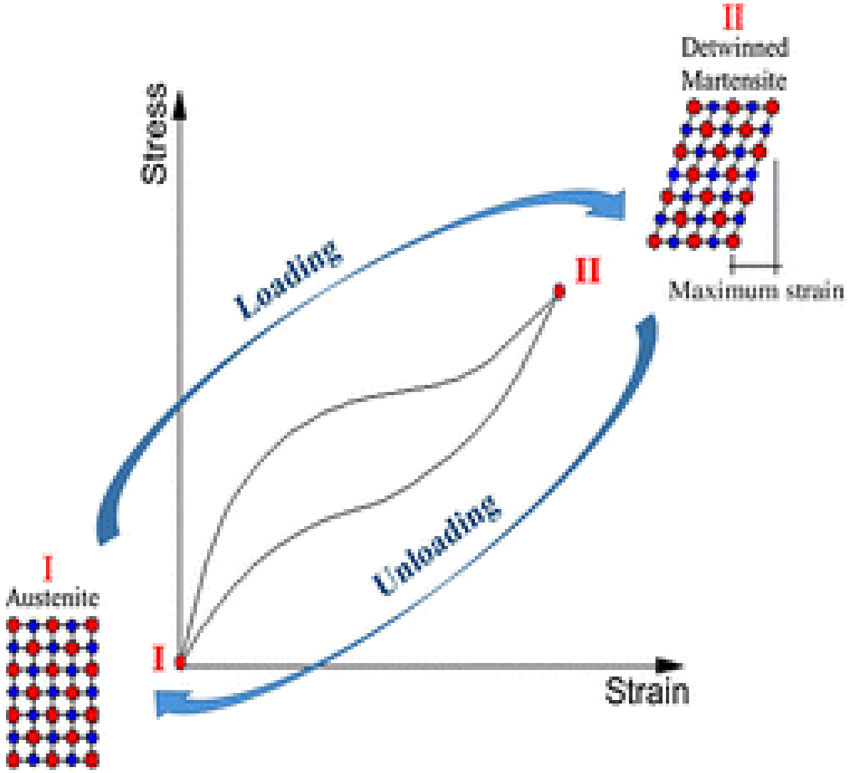
- ✓ Plastic strain that introduced into a material by twinning deformation in martensite recovers completely when the alloy is heated above a certain temperature.
- ✓ Plastic flow occurs by twinning rather than slip



Superelasticity and Shape memory

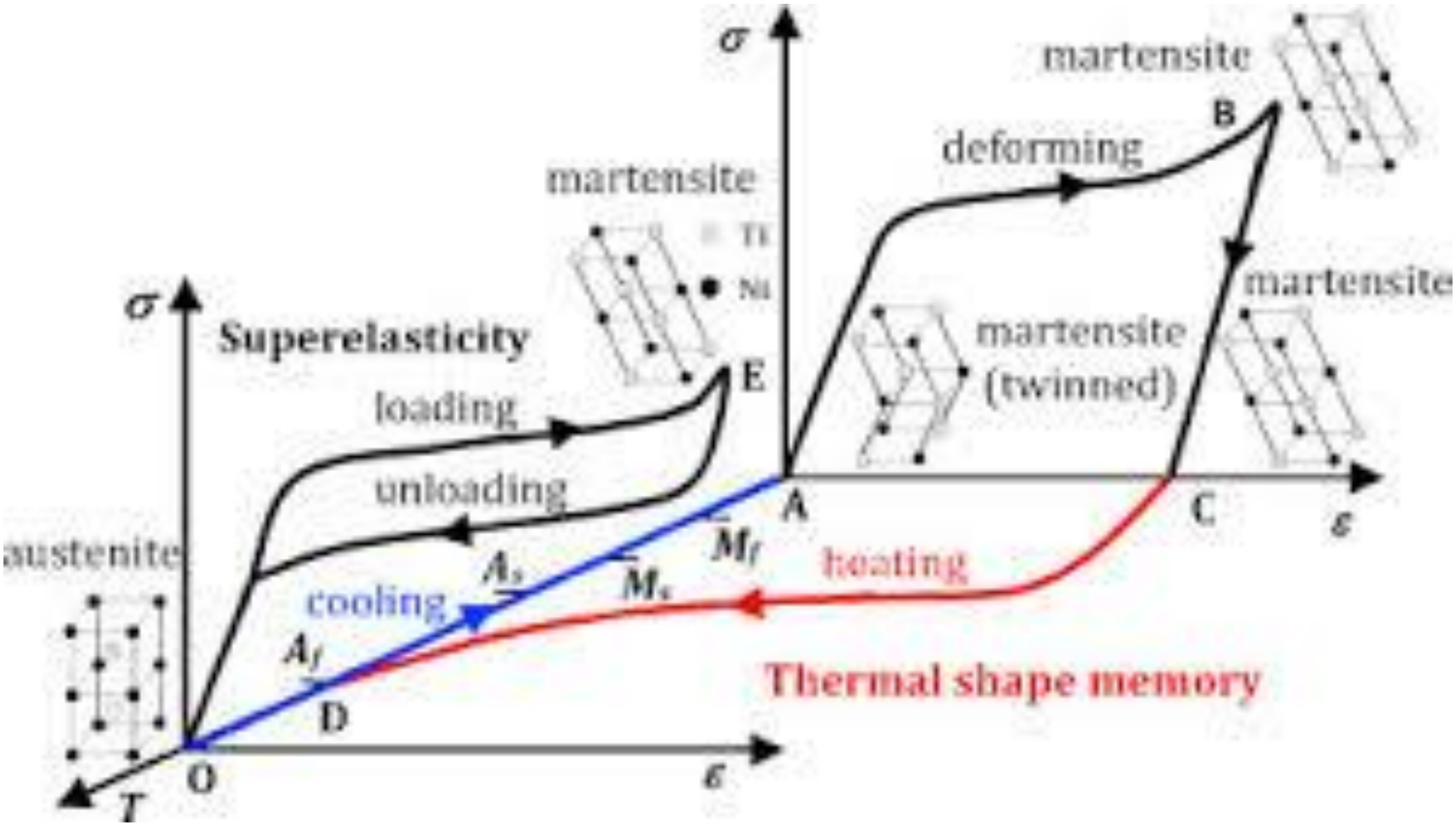


(a)



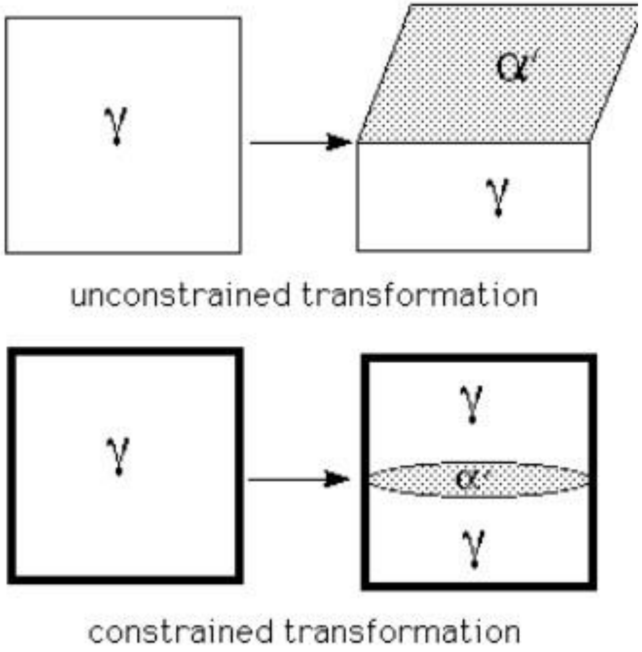
(b)

Superelasticity and Shape memery



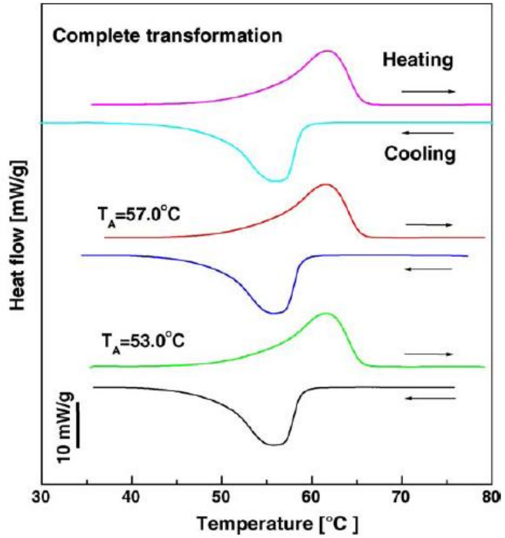
Habit Plane

❖ **The interface plane between austenite and martensite as measured on a macroscopic scale.**

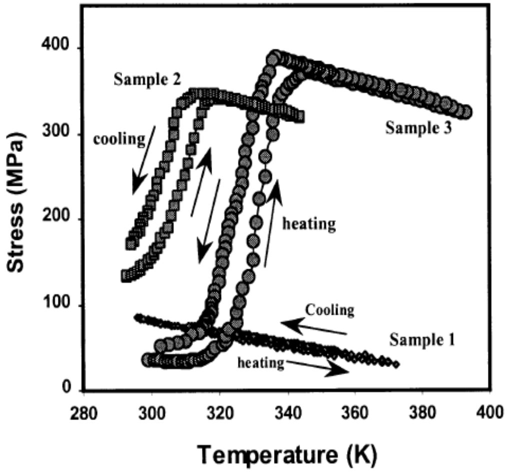


Detecting of Transformation

DSC



Stress



Electrical Resistivity