

**2009 fall**

**Advanced Physical Metallurgy**  
**“Phase Equilibria in Materials”**

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# Phase Equilibria in Materials

## *Thermodynamics*

## *Solidification*

*one specific example of phase transformation*

## *Phase diagrams*

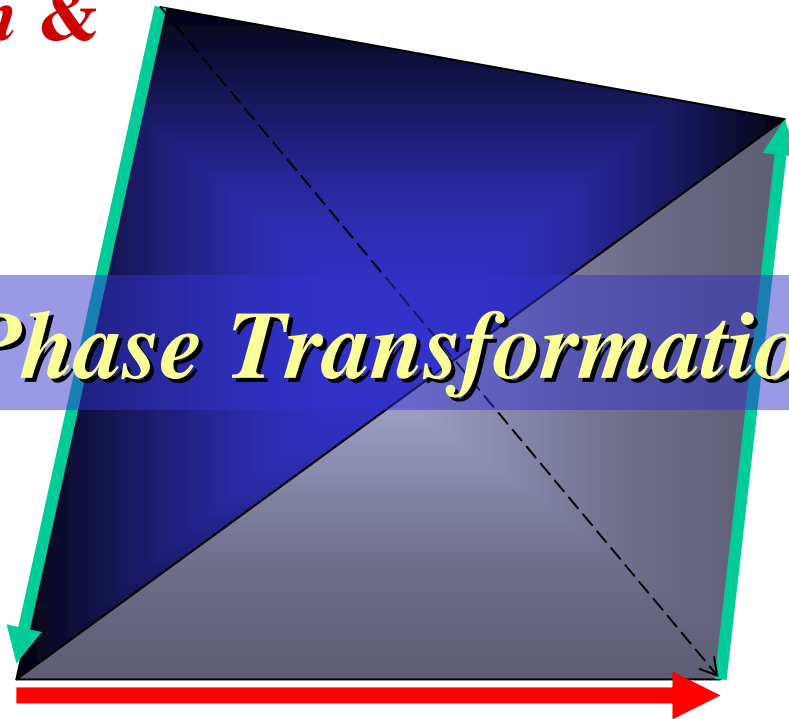
*Binary, Ternary, Quarternary phase diagram*

# Microstructure-Properties Relationships

*Alloy design & Processing*

*Performance*

*“Phase Transformation”*



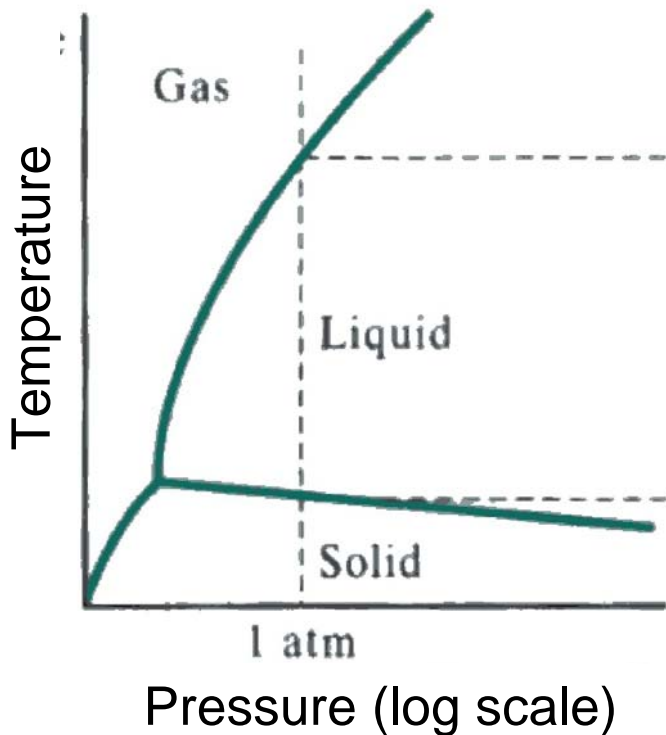
*Microstructure*  
*down to atomic scale*

*Properties*

*“Tailor-made Materials Design”*

# Basic Ideas

**Phase** is a chemically and structurally homogeneous portion of the microstructure.



**Phase diagram** used to show conditions at which thermodynamically-distinct phases can occur at equilibrium.

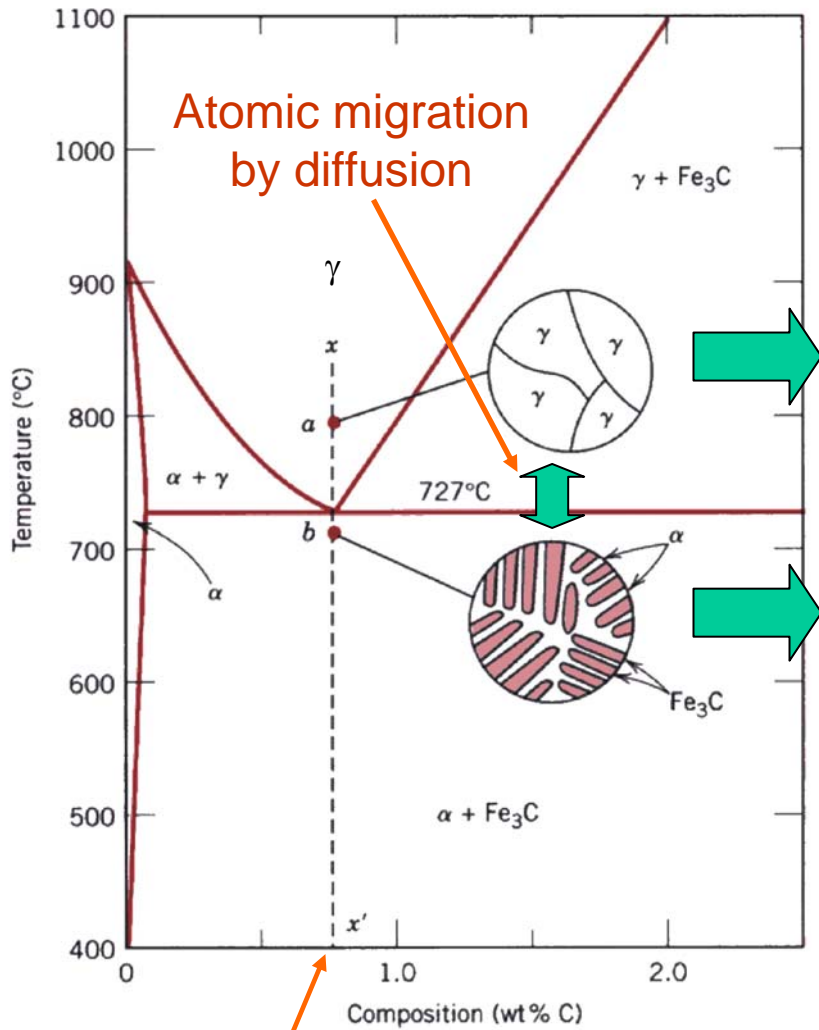
→ **Thermodynamics**

**Phase Transformation**

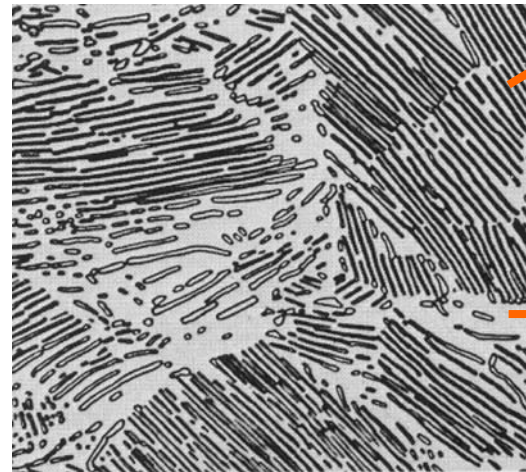
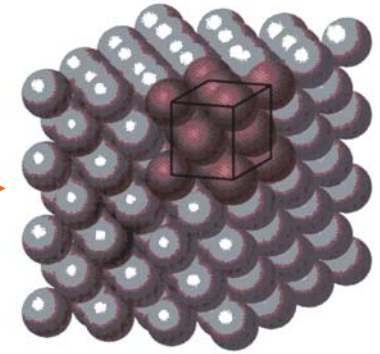
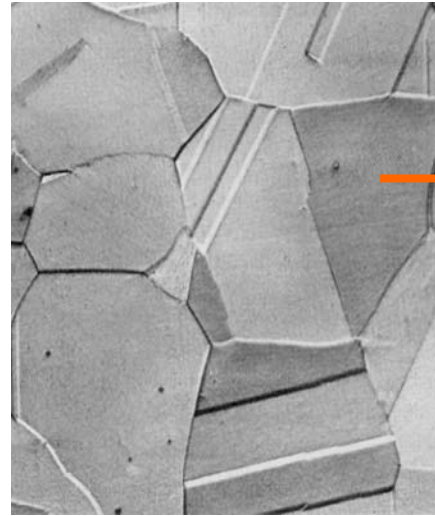
Change structure or composition or order

→ **Thermodynamics & Kinetics**

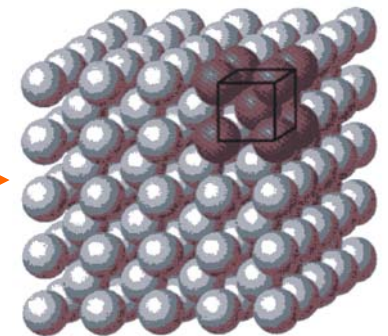
# Equilibrium Phases of Iron-Carbon Alloy



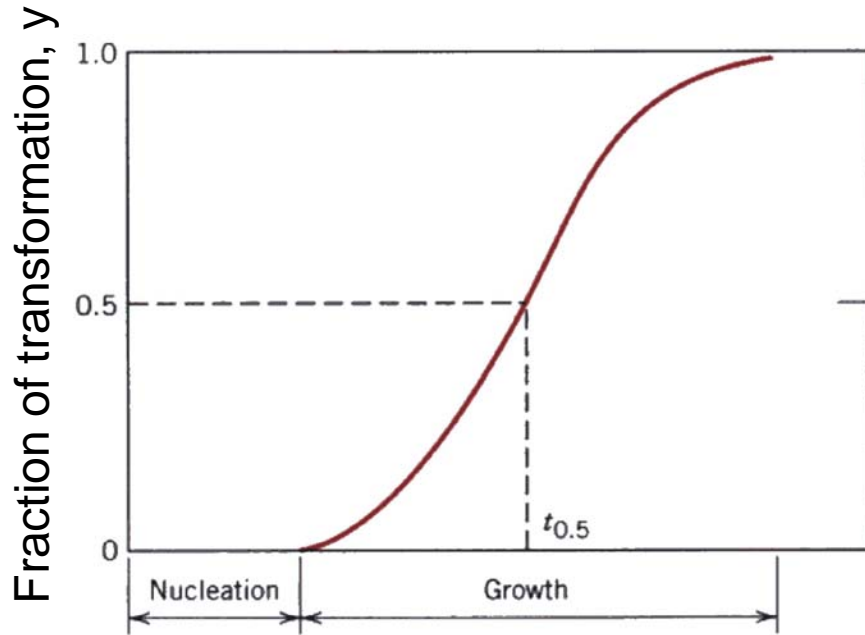
Eutectoid composition



$\text{Fe}_3\text{C}$  phase

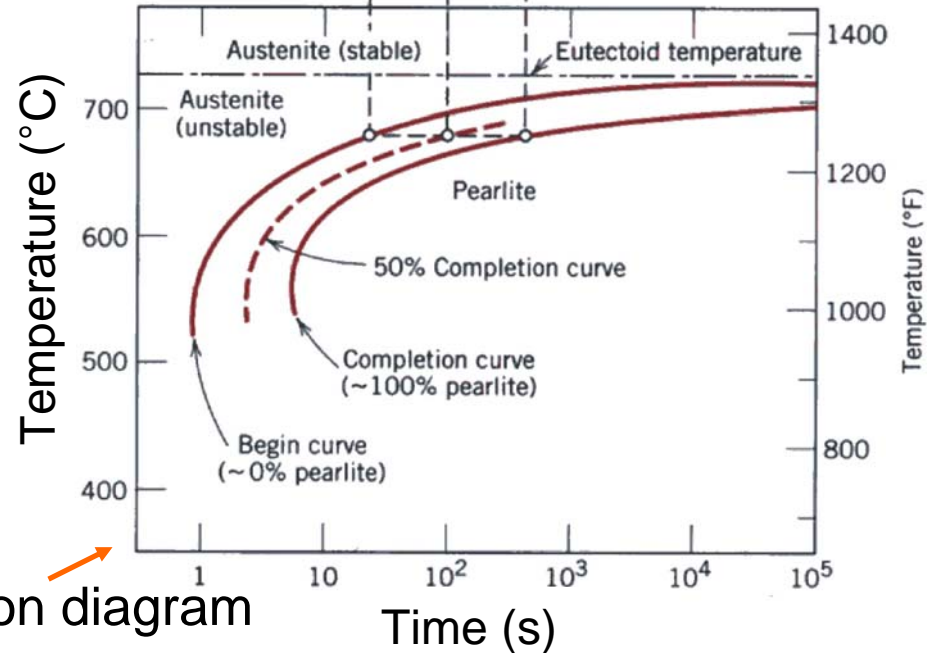
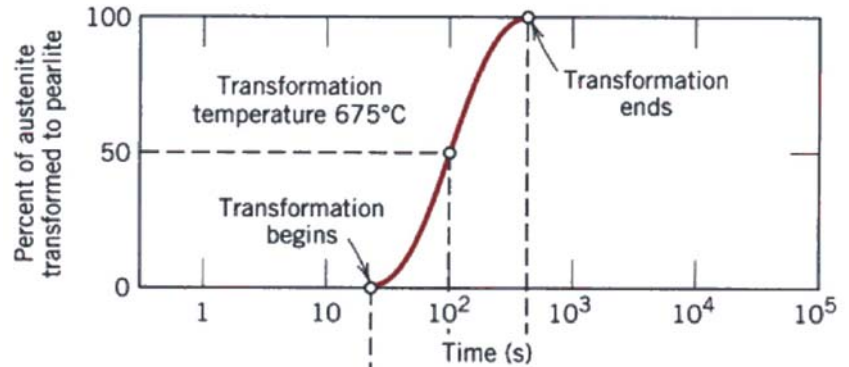


# Transformation Kinetics and Isothermal Transformation Diagram



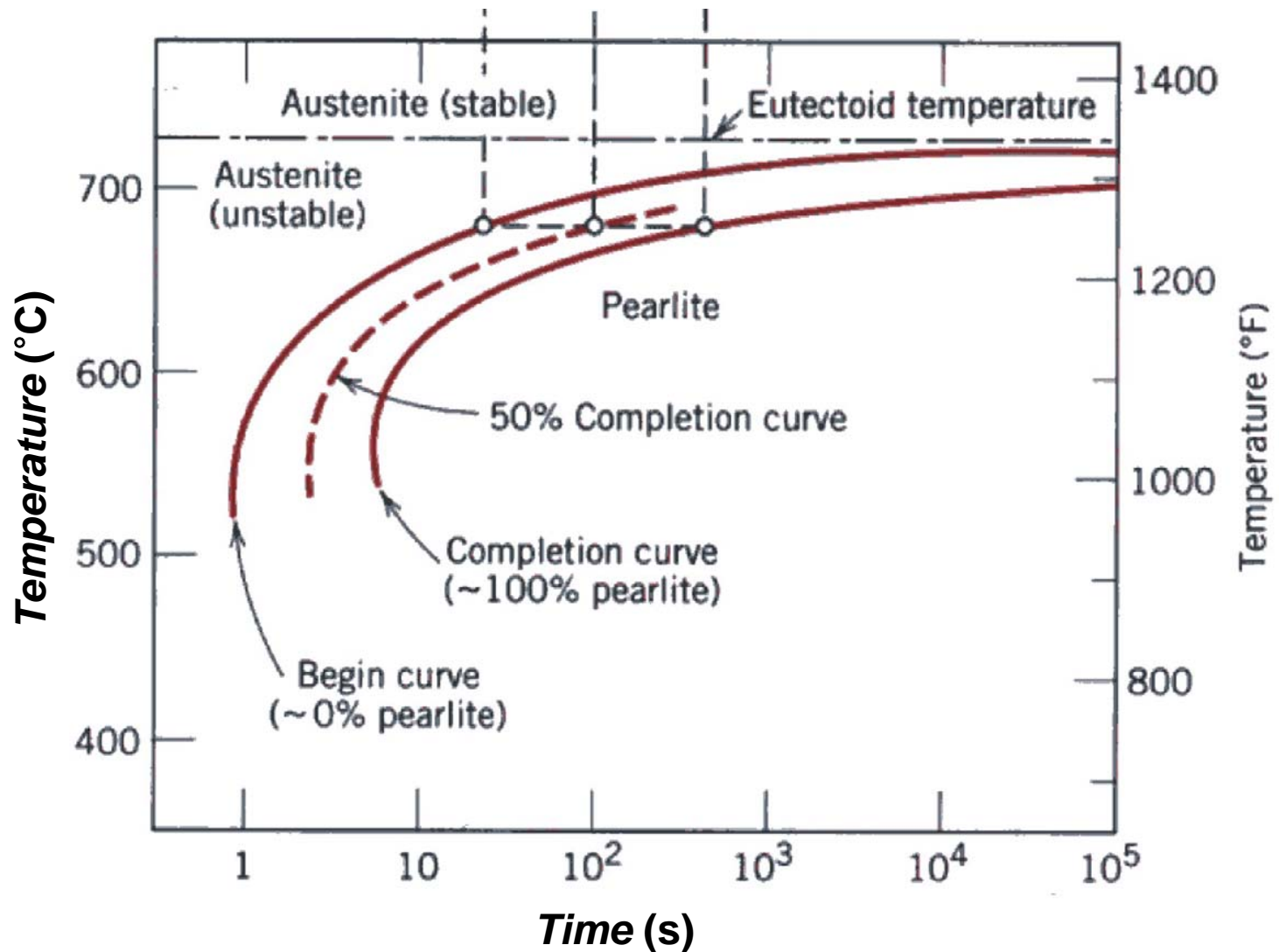
$$y = \exp(-kt^n)$$

Kinetics of diffusion-controlled solid-state transformation



Isothermal transformation diagram

# Transformation Kinetics and Isothermal Transformation Diagram



TTT diagram ~ Isothermal transformation diagram