



Phase Transformations in Materials

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Topics

Overview about Phase Transformations

- General Aspects
- Schemes



Phase Transformations in General



- Based on the definition of a phase in Ch. 1a, a phase transformation occurs when one or more phases in a material change their chemical or physical (incl. structural) properties upon a change of the external conditions.
- For the phase transformations mostly addressed in this lecture, we focus on phase transformations due to changing temperatures. The principles might easily be transferred to the application of stress/strain to a material.
- Before starting with the details on the specific types of transformations, this chapter provides an overview about the different reactions and potential types of categories.



Phase Transformations in General



Туре	Displacive	Reconstructive			
Effect of Temperature Change	Athermal	Thermally activated			
Interface Mobility	Glissile	Non-glissile			
Interface Structure	Coherent	Coherent, semi-coherent, incoherent for solid state transformations Solid-liquid for solidification			
	Semi-coherent				
Change of the Composition	No change	No change	Change		
Atomic Motion	Diffusionless by deformation (cooperative)	Diffusionless by motion across the interface (non-cooperative)	Diffusion		
Rate-Controlling Factor	Interface mobility	Interface mobility	Interface mobility	Diffusion	Mixed diffusion and interface mobility
Examples	Martensite Formation	Massive Transformation Ordering Polymorphic Transformation	Precipitation Dissolution Bainitic	Precipitation Dissolution	Precipitation Dissolution Eutectoid
		Allotropic Transformation	Transformation		Cellular Precipitation



Solidification



Materials undergo solidification by nucleation and growth when sufficiently super-cooled below the melting temperature.





Solidification



When nucleation is sufficiently depressed, the material can also form a solid glass, a liquid of such low viscosity and can thus be considered solid.





Allotropic Transformation



Solid materials might exist in different stable crystallographic modifications as a function of temperature. The transformation by nucleation and growth following super cooling below the equilibrium transformation temperature is a reconstructive transformation.





Allotropic Transformation



In the case of solid-solid transformation, a sufficient super cooling might suppress nucleation of the α phase and internal stresses increase up to a critical amount. When the critical stress is achieved, a displacive transformation to α' occurs.





























Spinodal Decomposition



The spinodal decomposition is a reaction (often) free of nucleation and growth, only involving long-range "up-hill" diffusion. It occurs spontaneously without energy barrier.







Other diffusion-controlled reactions involving thermally activated nucleation and growth are obtained by eutectic and peritectic reactions. During the eutectic decomposition, the metastable liquid is replaced by the stable two-phase solid condition. During the peritectic reaction, the stable phase is formed at the interface of the metastable solid and liquid high temperature phases with the restrictions of atomic flux through the phase formed.







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Ordering



Disordered phases might undergo crystallographic ordering below certain temperatures. Since only rearrangement of atoms within unit cells are required to obtain the different site occupations, no long-range diffusion is required. The reaction can be discontinuous (1st order) by thermal activation due to domain growth or continuous (2nd order).



Note that apart from variation in site occupation, slight modifications of the crystal structure (symmetry, dimensions) might be obtain as well. In contrast to pure elements (allotropic transf.), the transition from one crystal structure to another in alloys is usually referred to as polymorphic transformation.



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Massive Transformation



During massive transformation, a single-phase condition transforms into one or several phases of the same composition. In contrast to the martensitic transformation where the structural change is obtained by deformation, the restructuring occurs by thermally activated short-range rearrangement of atoms during massive transformation.





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