Part IV : Solid-Solid Phase Transformations I
Module 4. Massive transformations

4 Massive transformations

4.1 Motivation

What is a diffusionless, civilian transformation?

4.2 Massive transformation

Massive transformations are transformations in systems in which an alloy of a given composition and a particular structure (say, β) changes its structure to another with the same composition (say, α). An example is shown in Fig. 33: in Cu-Zn system, when an alloy of 38 at.% Zn is cooled from 850°C to say 400°C at fast enough cooling rates, the structure changes from that of β to α albeit with the same composition. Since the composition is the same, there is no need for long range diffusion and hence the transformation is very fast. Such changes in structure without changes in composition can be achieved in two ways: massive which is through thermally activated jumps of atoms from regions of one phase to another (discussed in this module) and martensitic which is through diffusionless (military) (which is discussed in the next module).

Typically, systems which undergo massive transformation also undergo martensitic transformation at higher cooling rates; this is indicated in the schematic CCT diagram in Fig. 34. The mechanism of formation of massive transformation can be understood with reference to this CCT diagram. At slow cooling rates and at smaller undercoolings, precipitation and growth of α leads to equiaxed α. At higher cooling rates and larger undercoolings Widmanstatten α formation takes place. In both these cases, since the growth of α requires long range diffusion (see Fig. 33 for example, where it is the long range diffusion of Zn that is needed), it requires long time to form. However, relatively faster cooling rates would nucleate the α phase at the grain boundaries; since the growth of this α only requires that atoms jump across the α-β interface, and since the driving forces for the formation of α are very large (see Fig. 35) the growth is very fast; the resultant microstructures are as shown in Fig. 36.

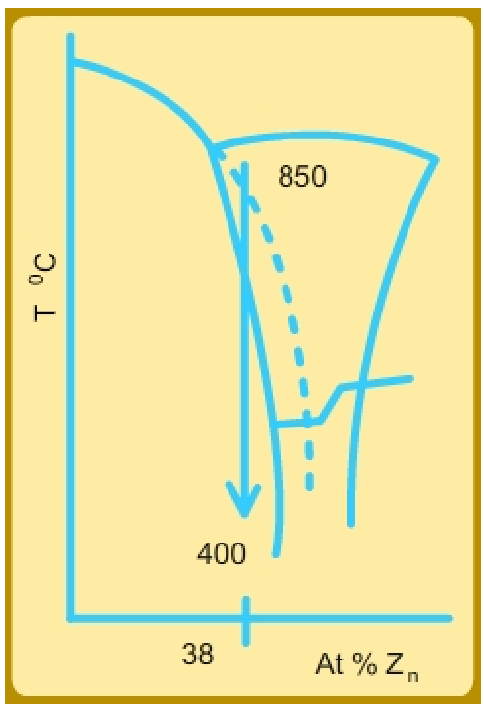

Figure 33: Massive transformation.

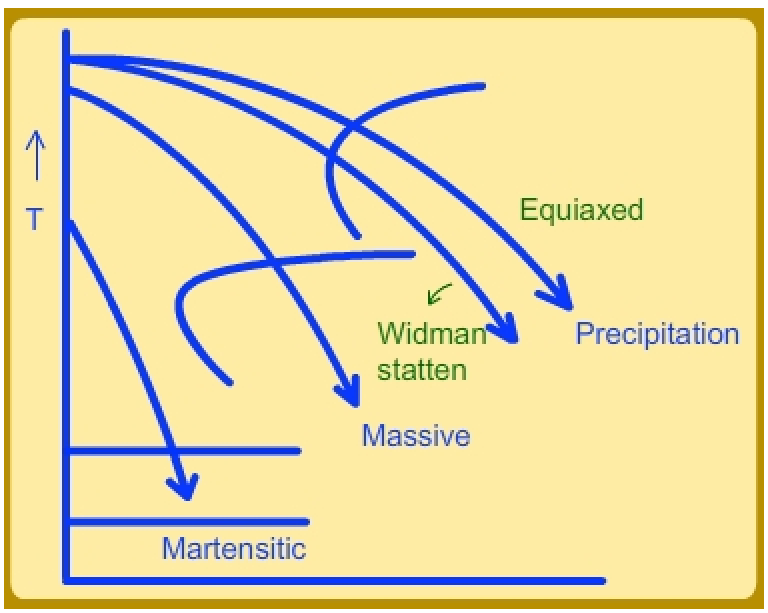

Figure 34: CCT diagram showing precipitation, Widmanstatten growth, massive transformation and martensitic transformations.

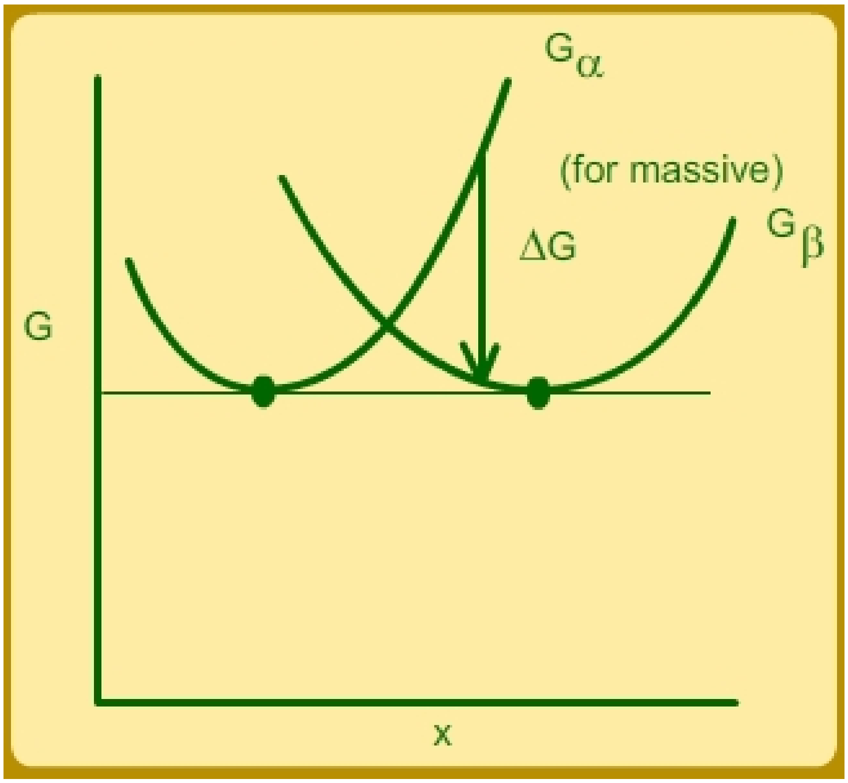

Figure 35: Driving force for massive transformation.

Massive transformations are found in Cu-Zn (as noted above), Cu-Al and Fe-C systems.

4.3 Tutorial problems and questions

- Using free energy versus composition diagrams show that massive transformation can also take place even in a two phase region.

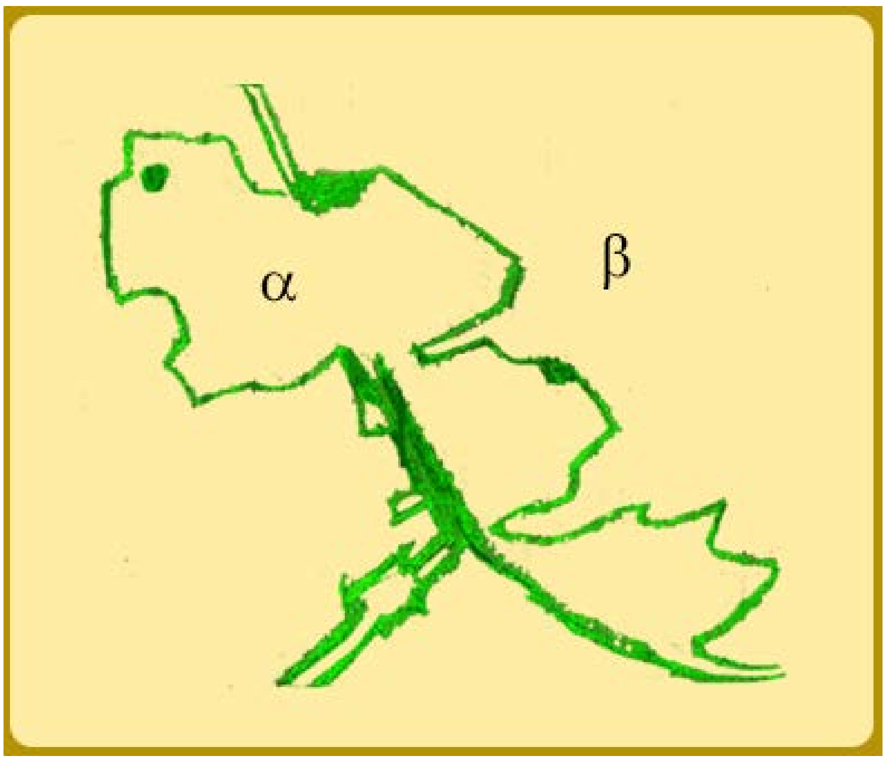

Figure 36: Massively transformed system: microstructure.

4.4 Solutions to the tutorial

- See Fig. 37.

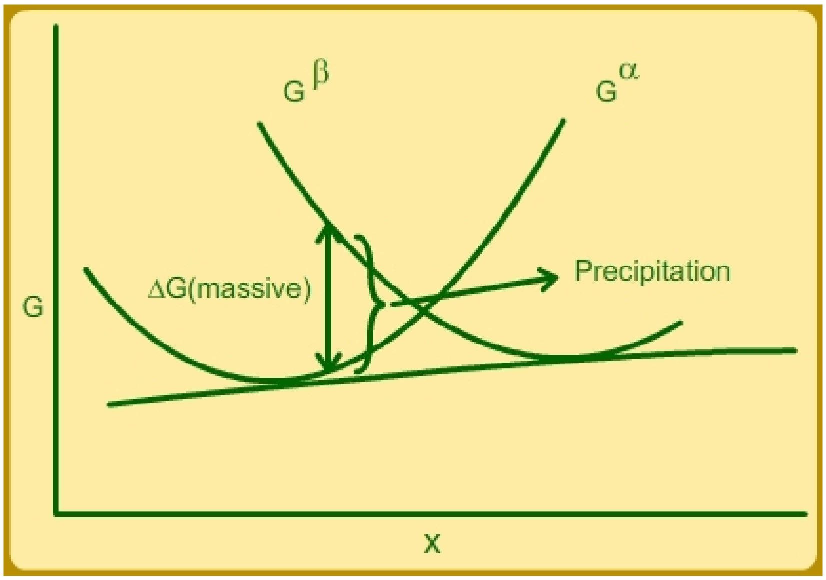

Figure 37: Massive transformation in a two phase region.

4.5 Supplementary information

Massive transformations can also take place with metastable phases being formed in a massive manner; in such systems, it is not necessary that phase diagrams should have the characteristics shown in Fig. 33; for example, the phase diagram shown (Fig. 37) can lead to massive transformation of β into a metastable α.