Outline

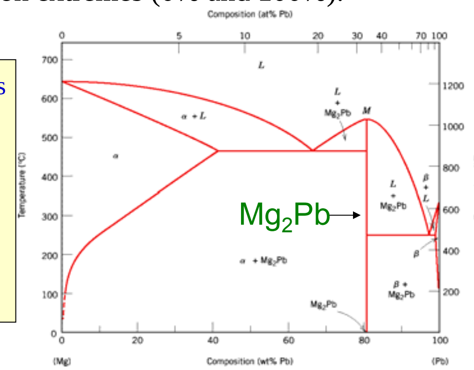
- ✓ Phase diagram with intermediate phases
  - solid solutions
  - compounds
- ✓ **Fe–Fe_3C phase diagram**
- ✓ Classifications of Fe-C alloys
- ✓ Microstructure of Fe-C alloys

Phase Diagrams with Intermediate Phases

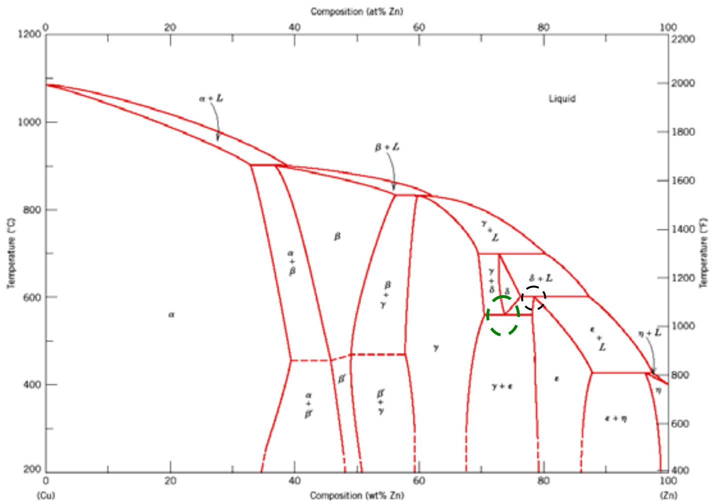
• Eutectic systems that we have studied so far have only two solid phases (α and β) that exist near the ends of phase diagrams. These phases are called **………….. solid solutions.**

• Some binary alloy systems have **……………… solid solution** phases (*see next slide*). In phase diagrams, these phases are separated from the composition extremes (0% and 100%).

- α and β are the terminal solid solutions
- Mg_2Pb is an intermetallic compound
  - ratio (2:1) (Mg:Pb)
  - 67 mol% Mg and 33 mol% Pb
  - 19 wt% Mg and 81 wt% Pb
- melts at a fixed temperature M
- Intermetallic compounds are very common in metal alloy systems.



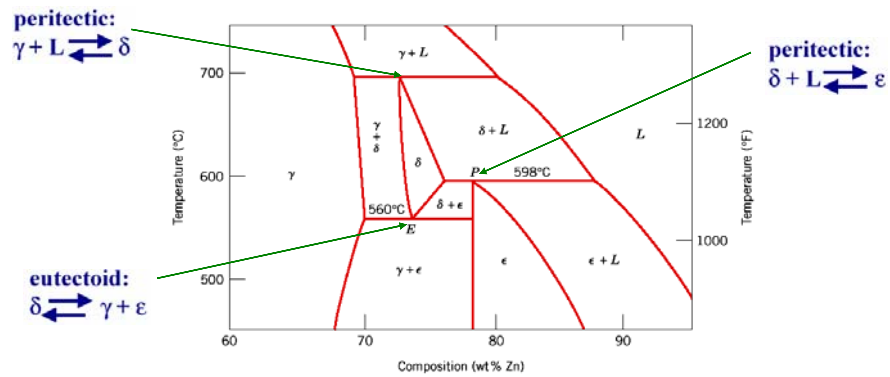
Cu-Zn Phase Diagram



• α and η are terminal solid solutions
• β, β’, γ, δ and ε are intermediate solid solutions.
• new phenomena exist: - ………… reaction – ……… reaction

Cu-Zn Phase Diagram

Eutectoid and Peritectic Reactions

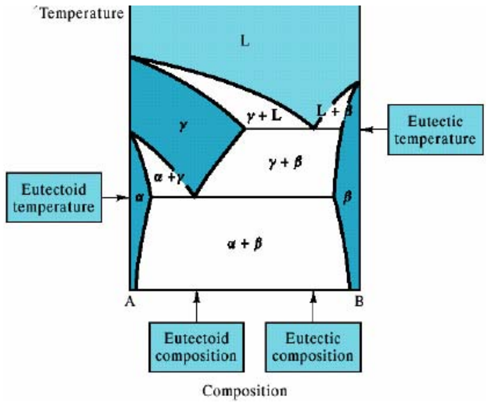


Eutectoid: **one** solid phase transforms into **two** other solid phases upon cooling

Peritectic: one solid and one liquid phase transform into another solid phase upon cooling

Eutectoid Reactions

The **eutectoid** *(eutectic-like* in Greek) reaction is similar to the eutectic reaction but occurs from one solid phase to two new solid phases.



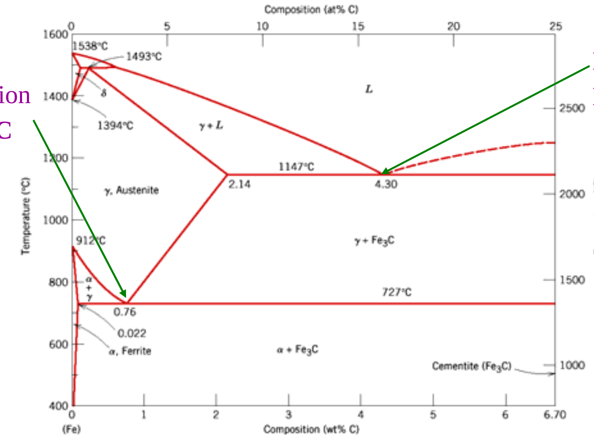
The above phase diagram contains both an eutectic reaction and (its solid-state analog) an eutectoid reaction

The Iron–Iron Carbide ($Fe–Fe_3C$) Phase Diagram

*In their simplest form, steels are alloys of Iron (Fe) and Carbon (C). The Fe-C phase diagram is a fairly complex one, but we will only consider the part up to around **7%** carbon of the diagram.*

Eutectoid reaction
$\gamma \leftrightarrow \beta + Fe_3C$

Eutectic reaction
$L \leftrightarrow \gamma + Fe_3C$



912°C 1394°C 1538°C

α (BCC) ↔ γ (FCC) ↔ δ (BCC) ↔ liquid

Phases in $Fe–Fe_3C$ Phase Diagram

α -ferrite - solid solution of C in …….. Fe
- Stable form of iron at room temperature.
- The maximum solubility of C is 0.022 wt% (interstitial solubility)
- Soft and relatively easy to deform

γ -austenite - solid solution of C in …….. Fe
- The maximum solubility of C is 2.14 wt % at 1147°C.
- Interstitial lattice positions are much larger than ferrite (higher C%)
- Is not stable below the eutectic temperature (727 °C) unless cooled rapidly (*Chapter 10*).

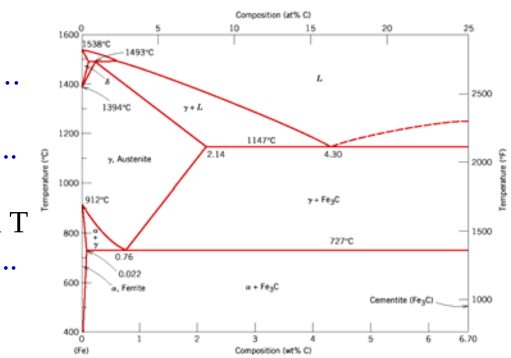
δ -ferrite solid solution of C in ……. Fe
- The same structure as α -ferrite
- Stable only at high T, above 1394 °C
- Also has low solubility for carbon (BCC)

Fe_3C (iron carbide or cementite)
- This intermetallic compound is metastable, it remains as a compound indefinitely at room T, but decomposes (very slowly, within several years) into α -Fe and C (graphite) at 650 - 700 °C

Fe-C liquid solution

Classifications of Fe-C alloys

- < 0.008 wt% Carbon → …….
  - α-ferrite at room T
- 0.008 – 2.14 wt% C → ……..
  - usually < 1 wt %
  - α -ferrite + Fe_3C at room T
- 2.14 – 6.7 wt% C → ………..
  - usually < 4.5 wt %



- Magnetic properties: α -ferrite is magnetic (below 768 °C), austenite is non-magnetic.
- Mechanical properties: Cementite is very hard and brittle thus it can strengthen steels.
- Mechanical properties also depend on ……………………, that is, how ferrite and cementite are mixed.

Development of Microstructure in Iron - Carbon alloys

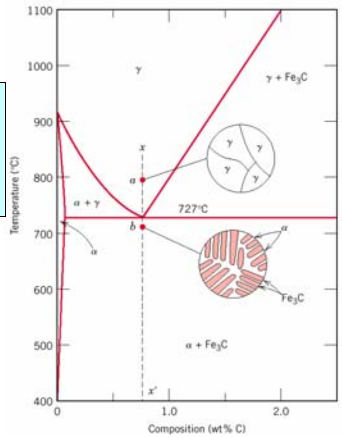
• Microstructure depends on composition (carbon content) and heat treatment.

• In the discussion below we consider slow cooling in which equilibrium is maintained.

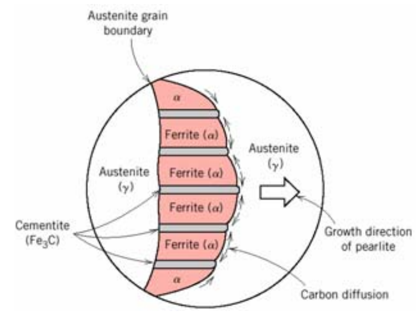
Eutectoid steel

When alloy of eutectoid composition (0.76 wt % C) is cooled slowly it forms a lamellar or layered structure of α and cementite (Fe_3C). This structure is called **pearlite.**

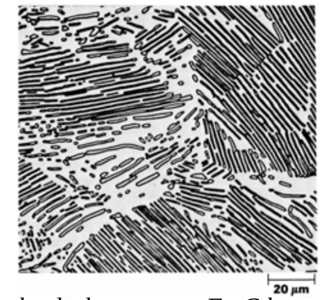
Mechanically, pearlite has properties intermediate to soft, ductile ferrite and hard, brittle cementite.



Development of Microstructure in Iron - Carbon alloys



The layers of alternating phases in pearlite are formed for the same reason as layered structure of eutectic phases: redistribution C atoms between ferrite (0.022 wt%) and cementite (6.7 wt%) by atomic diffusion.



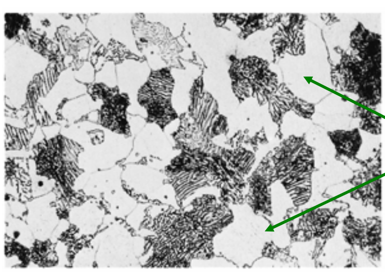
the dark areas are Fe_3C layers, the light phase is α -ferrite

Microstructure of hypoeutectoid steel

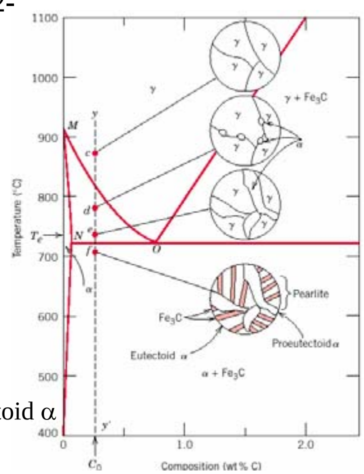
Compositions to the left of eutectoid (0.022-0.76 wt % C) **hypoeutectoid** alloys

- *less than eutectoid* (Greek)

Hypoeutectoid alloys contain proeutectoid ferrite (*formed above the eutectoid temperature*) plus the eutectoid pearlite that contain eutectoid ferrite and cementite.



Proeutectoid α

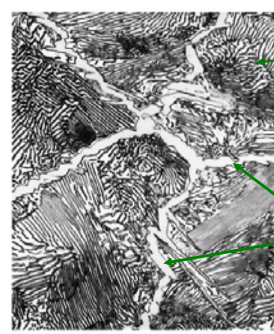


Microstructure of hypereutectoid steel

Compositions to the right of eutectoid (0.76 - 2.14 wt % C) **hypereutectoid** alloys.

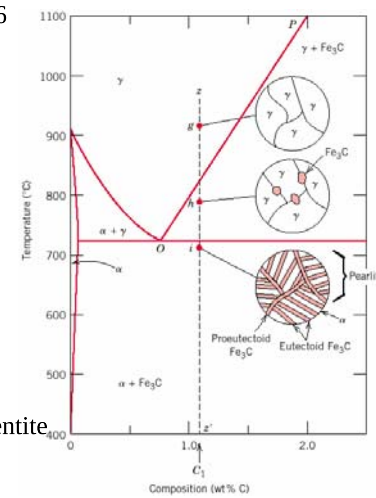
- *more than eutectoid* (Greek)

$$\gamma \rightarrow \gamma + Fe_3C \rightarrow \alpha + Fe_3C$$



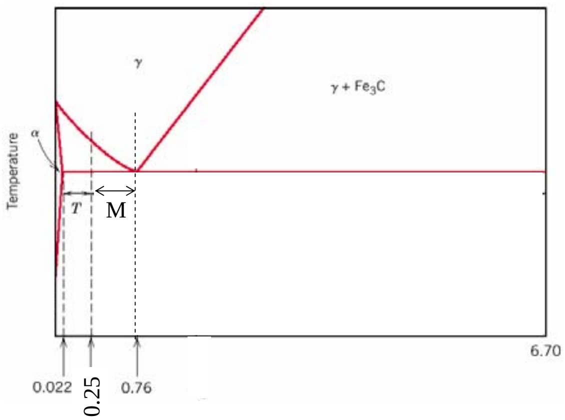
pearlite

Proeutectoid cementite



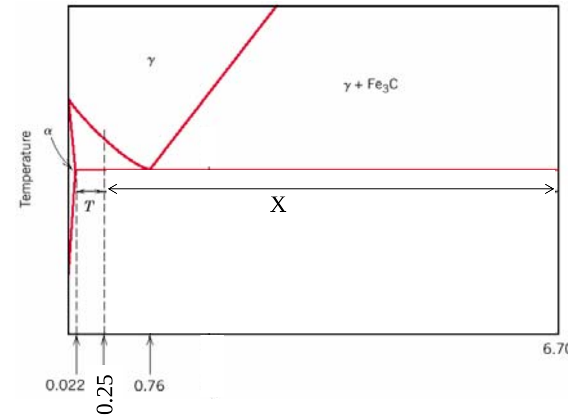
Example 1

Compute the mass fractions of proeutectoid ferrite and pearlite that form in an Fe – C alloy containing 0.25 wt% C, at a temperature just below the eutectoid.



Example 2

Compute the mass fractions of total ferrite and cementite that form in an Fe – C alloy containing 0.25 wt% C at a temperature just below the eutectoid.



Finally, determine the fraction of eutectoid ferrite?

Next topic:
Ceramic Materials