IRON –CARBON PHASE DIAGRAM

Definition of structures:

- Various phases that appear on the Iron-Carbon equilibrium phase diagram are as under:

- Austenite
- Ferrite
- Pearlite
- Cementite
- Martensite
- Ledeburite

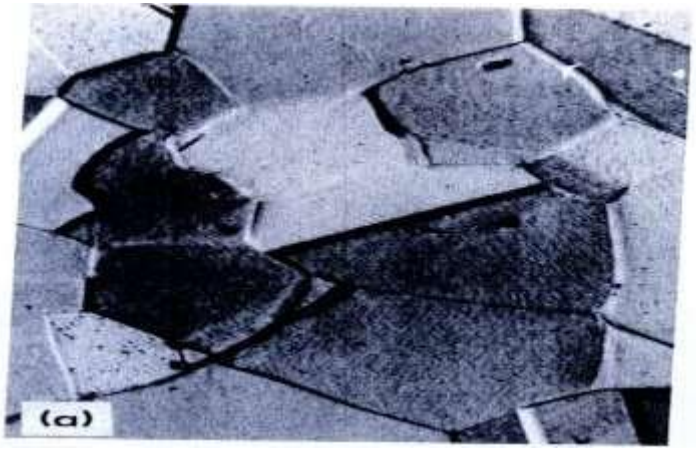
Definition of structures:

- **Austenite** is an interstitial solid solution of Carbon dissolved in γ(F.C.C.) iron.
- Maximum solubility is 2.0 % C at 1130°C.
- High formability, most of heat treatments begin with this single phase.
- It is normally not stable at room temperature. But, under certain conditions it is possible to obtain austenite at room temperature.

Austenite

- Average properties are:
  - Tensile strength = 150,000 psi;
  - Elongation = 10 percent in 2 in.;
  - Hardness = Rockwell C 40, approx;

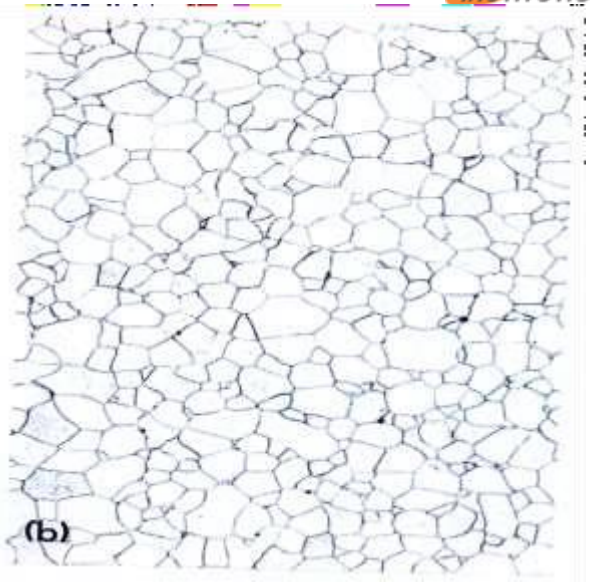
  and
  - toughness = high



Definition of structures:

- **Ferrite is known as *a* solid solution.**
- **It is an interstitial solid solution of a small amount of carbon dissolved in *a* (BCC) iron.**
- **stable form of iron below 912 deg.C.**
- **The maximum solubility is 0.025 % C at 723°C and it dissolves only 0.008 % C at room temperature.**
- **It is the softest structure that appears on the diagram.**

Ferrite



Average properties are:

- Tensile strength = 40,000 psi;
- Elongation = 40 % in 2 in;
- Hardness > Rockwell C 0 or > Rockwell B 90

Definition of structures:

- **Pearlite** is the eutectoid mixture containing 0.80 % C and is formed at 723°C on very slow cooling.
- It is a very fine platelike or lamellar mixture of ferrite and cementite.
- The white ferritic background or matrix contains thin plates of cementite (dark).

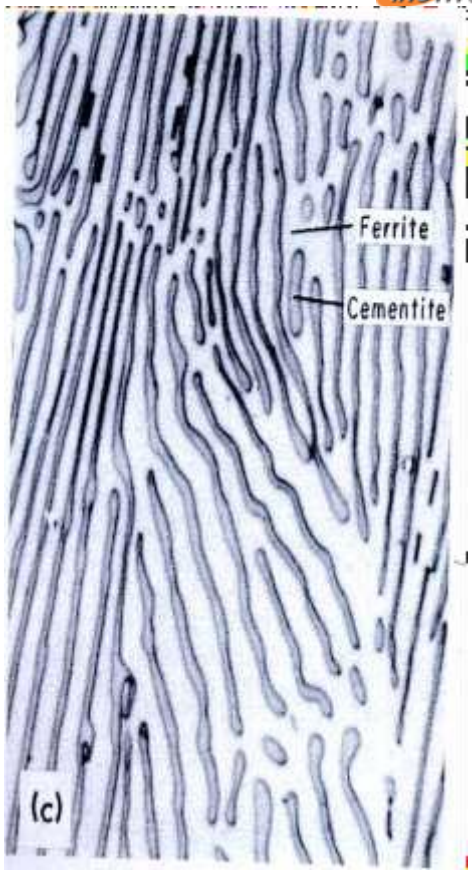
Pearlite

Average properties are:

Tensile strength = 120,000 psi;

Elongation = 20 % in 2 in.;

Hardness = Rockwell C20, BHN-300



Definition of structures:

- **Cementite** or iron carbide, is very hard, brittle intermetallic compound of iron & carbon, as Fe_3C, contains 6.67 % C.
- It is the hardest structure that appears on the diagram, exact melting point unknown.
- Its crystal structure is orthorhombic.
- It is has
  - low tensile strength (approx. 5,000 psi), but
  - high compressive strength.

Definition of structures:

- **Martensite - a super-saturated solid solution of carbon in ferrite.**
- **It is formed when steel is cooled so rapidly that the change from austenite to pearlite is suppressed.**
- **The interstitial carbon atoms distort the BCC ferrite into a BC-tetragonal structure (BCT).; responsible for the hardness of quenched steel**

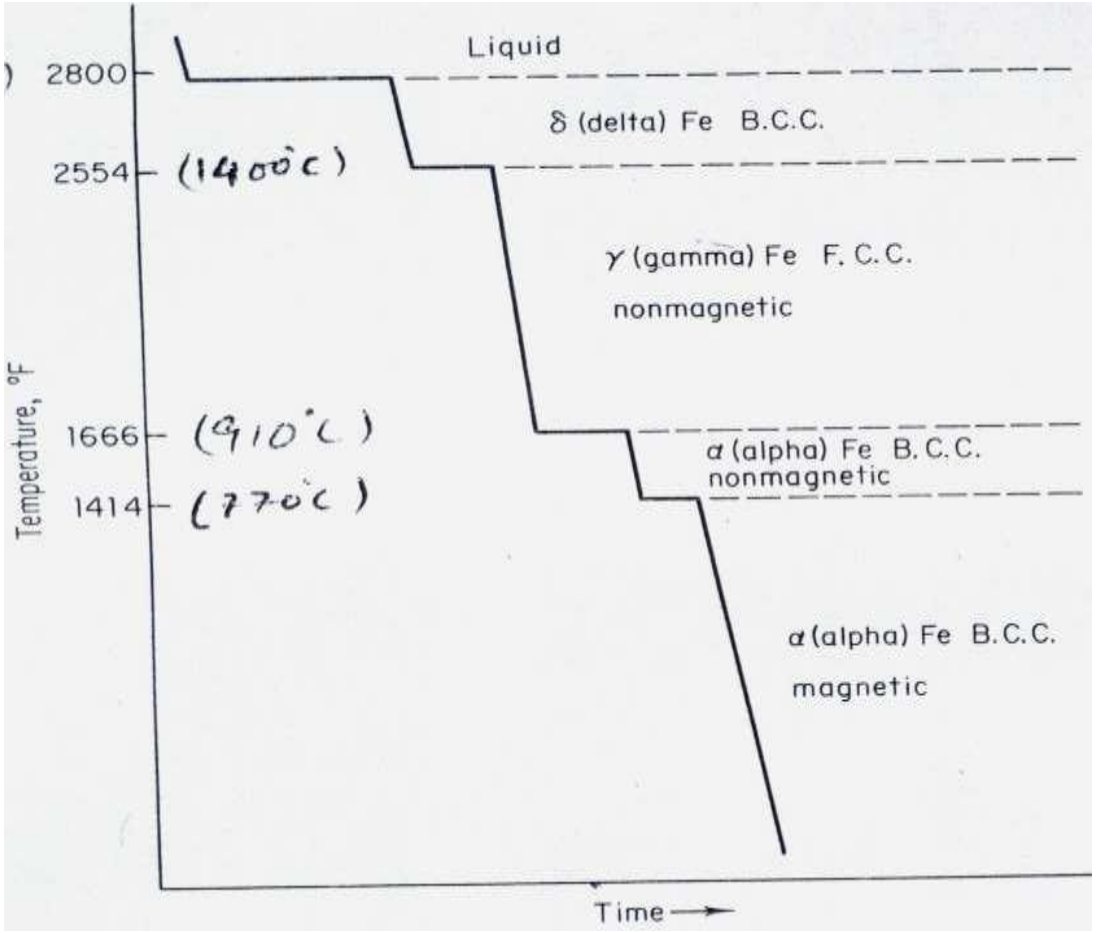
Definition of structures:

- **Ledeburite** is the eutectic mixture of austenite and cementite.
- It contains 4.3 percent C and is formed at 1130°C.

The Iron-Carbon Diagram:

- A map of the temperature at which different phase changes occur on very slow heating and cooling in relation to Carbon, is called Iron- Carbon Diagram.
- Iron- Carbon diagram shows -
  - the type of alloys formed under very slow cooling,
  - proper heat-treatment temperature and
  - how the properties of steels and cast irons

Cooling curve for pure iron



Various Features of Fe-C diagram

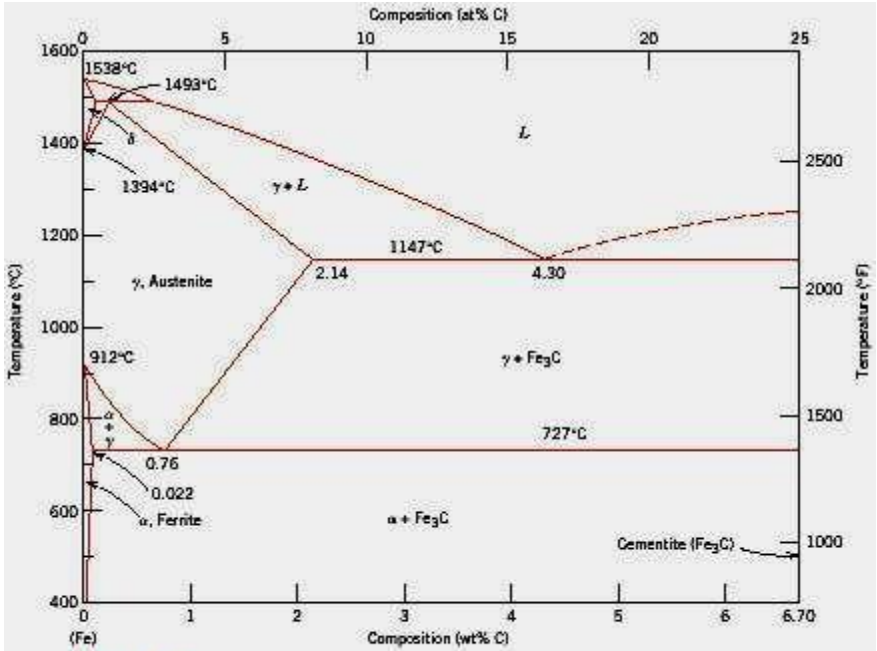


FIGURE 9.22 The iron–iron carbide phase diagram. (Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski, Editor-in-Chief, 1990. Reprinted by permission of ASM International, Materials Park, OH.)

Max. solubility of C in ferrite=0.022%

Max. solubility of C in %austenite=2%

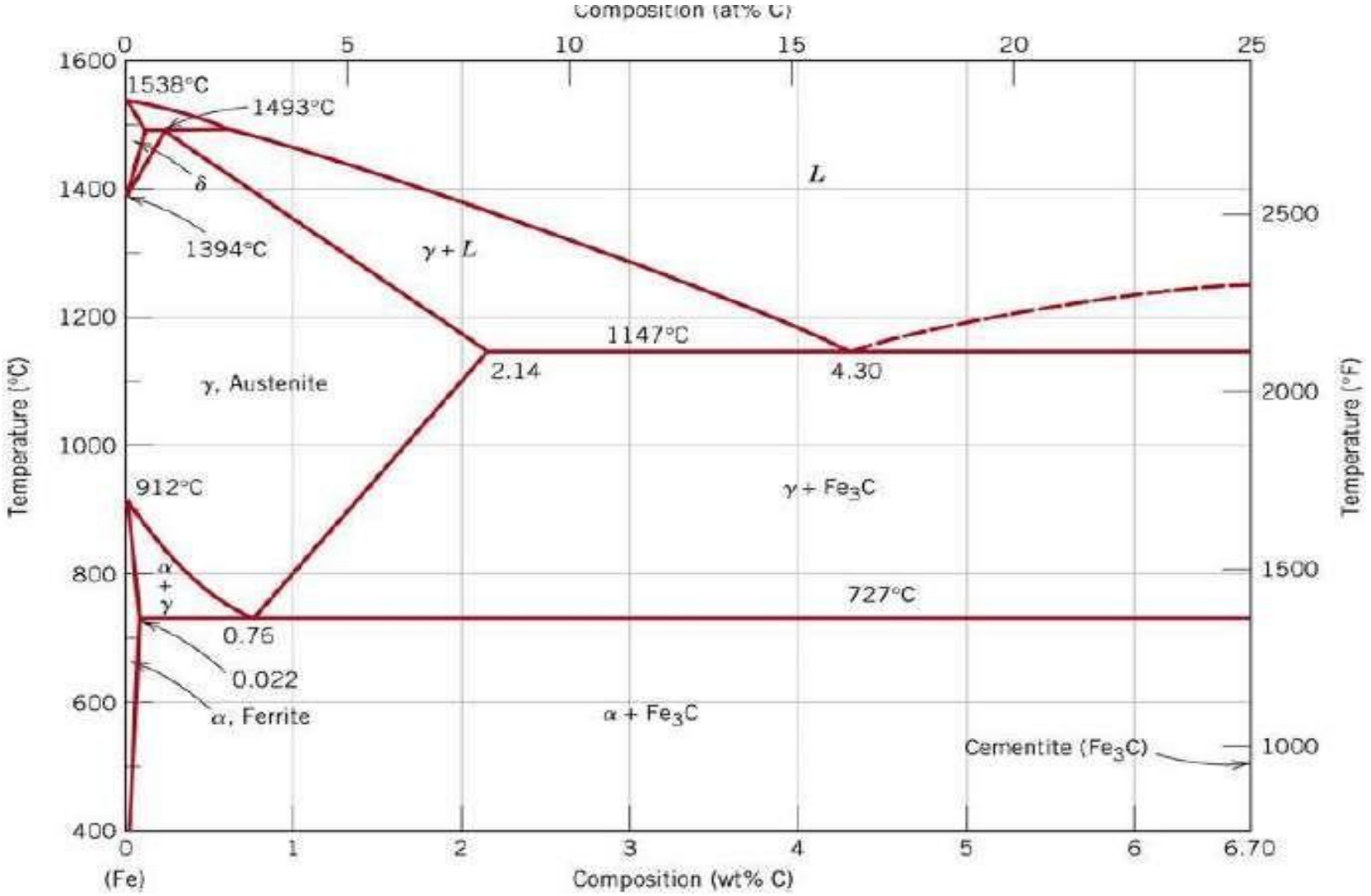
- **δ–iron** exists between 1394°C and 1538 °C It may exist in combination with the melt to ~ 0.5 %wt C, with austenite to ~ 0.18 %wt C and in a single phase state to ~0.10 %wt C. Delta iron has the B.C.C crystal structure and is magnetic

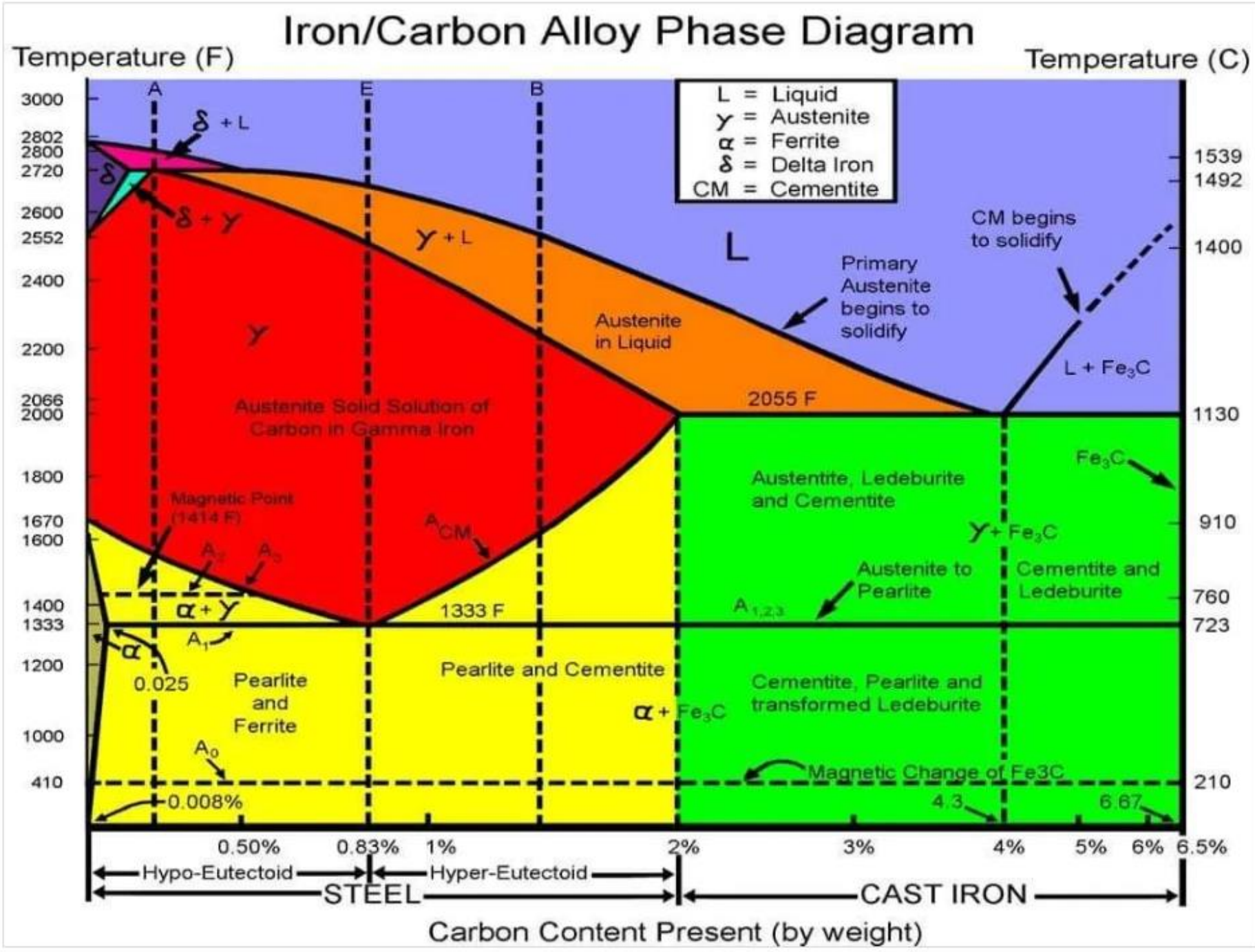
- **Austenite- (γ) gamma-iron:** interstitial solid solution of carbon (up to 2.14wt%) dissolved in iron with a (F.C.C) structure. Stable up to 1394 °C. Non-magnetic phase.

- **Ferrite** - (α) ***alpha -iron***, which is an interstitial solid solution of a small amount (up to 0.022wt%) of carbon dissolved in iron with a B.C.C.crystal structure. Possesses polymorphic transformation to γ–iron at 912C It is the softest structure on the iron-iron carbide diagram. Magnetic below 768°C

Cementite - ***iron carbide:*** chemical formula, Fe_3C, contains 6.67 % wt C. It is a typical hard and brittle interstitial compound of low tensile but high compressive strength. Its crystal structure is orthorhombic. Metastable phase: at~700 °C slowly (several years) decomposes to α-iron and carbon

IRON –CARBON DIAGRAM




Iron/Carbon Alloy Phase Diagram
Temperature (F)
Temperature (C)
L = Liquid
γ = Austenite
α = Ferrite
δ = Delta Iron
CM = Cementite
A
E
B
δ + L
δ
δ + γ
γ + L
L
CM begins to solidify
Primary Austenite begins to solidify
Austenite in Liquid
L + Fe3C
γ
Austenite Solid Solution of Carbon in Gamma Iron
2055 F
Austentite, Ledeburite and Cementite
Fe3C
γ + Fe3C
Magnetic Point (1414 F)
ACM
A2
A3
Austenite to Pearlite
Cementite and Ledeburite
A1,2,3
α + γ
1333 F
A1
α
0.025
Pearlite and Ferrite
Pearlite and Cementite
α + Fe3C
Cementite, Pearlite and transformed Ledeburite
A0
Magnetic Change of Fe3C
0.008%
4.3
6.67
3000
2802
2800
2720
2600
2552
2400
2200
2066
2000
1800
1670
1600
1400
1333
1200
1000
410
1539
1492
1400
1130
910
760
723
210
0.50%
0.83%
1%
2%
3%
4%
5%
6%
6.5%
Hypo-Eutectoid
Hyper-Eutectoid
STEEL
CAST IRON
Carbon Content Present (by weight)

Three Phase Reactions

- **Peritectic, at 1490 deg.C, with low wt% C alloys (almost no engineering importance).**
- **Eutectic, at 1130 deg.C, with 4.3wt% C, alloys called cast irons.**
- **Eutectoid, at 723 deg.C with eutectoid composition of 0.8wt% C, two-phase mixture (ferrite & cementite). They are**

Eutectic, Eutectoid, & Peritectic:

- **Peritectic** - liquid and one solid phase transform to a 2nd solid phase

$$Solid_1 + \quad Liquid \leftrightarrow Solid_2$$

$$\delta + L \underset{heat}{\overset{cool}{\rightleftharpoons}} \beta$$

- **Eutectic** - liquid transforms to two solid phases

$$L \underset{heat}{\overset{cool}{\rightleftharpoons}} \alpha + \beta$$

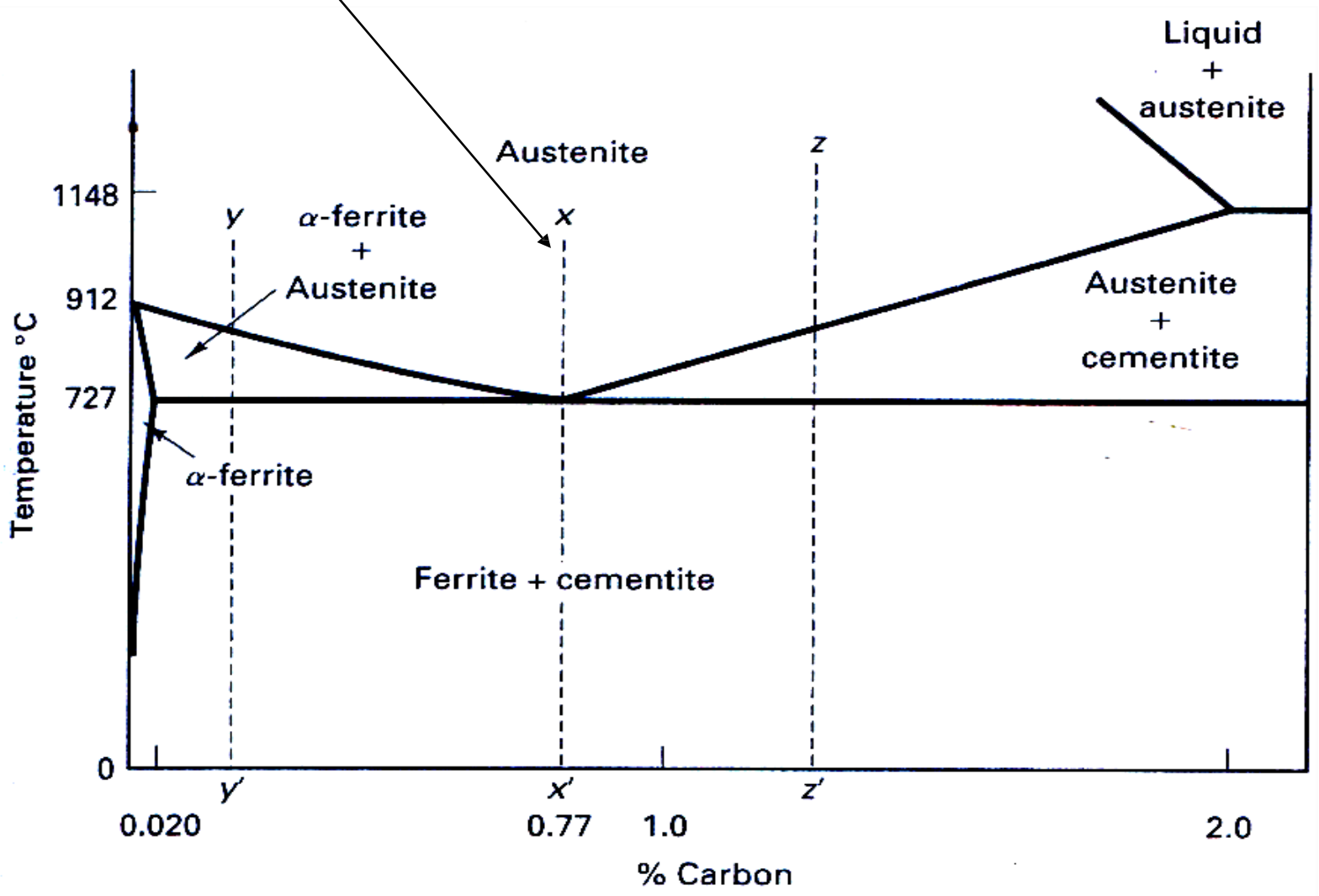
- **Eutectoid** – one solid phase transforms to two other solid phases

$$Solid_1 \leftrightarrow Solid_2 + Solid_3$$

$$\gamma \underset{heat}{\overset{cool}{\rightleftharpoons}} \alpha + Fe_3C$$

diagram

- austenite ↔ pearlite (mixture of ferrite & cementite)

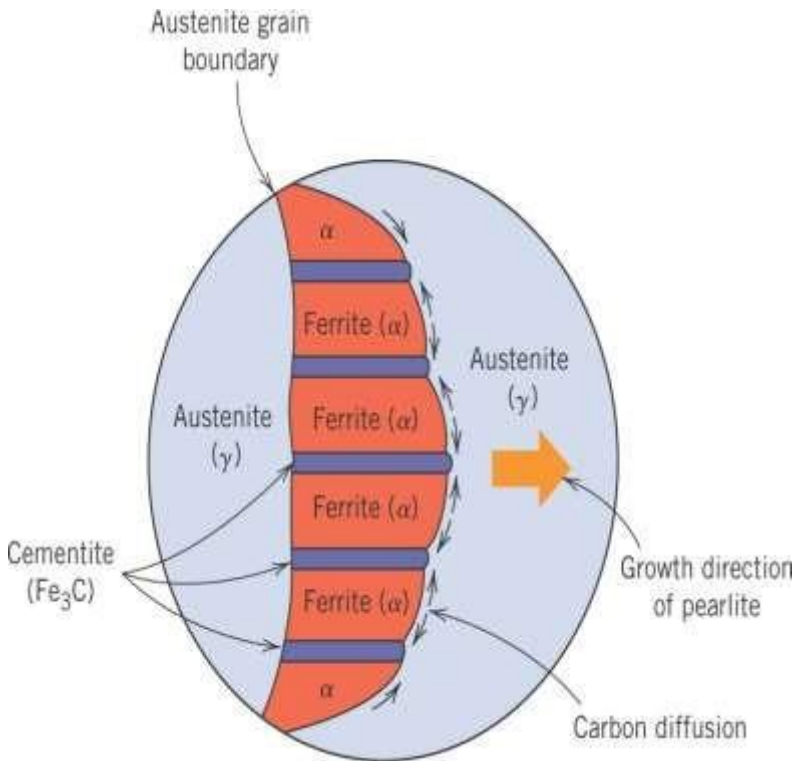


Eutectoid reaction

Pearlite

$y \leftrightarrow \alpha + Fe_3C$

- formation of the pearlite structure
  - nucleating at γ grain boundaries
  - growth by diffusion of C to achieve the compositions of α and Fe_3C (with structural changes)
  - α lamellae much thicker



Redistribution of carbon by diffusion

Austenite – 0.76 wt% C
Ferrite - 0.022 wt% C
Cementite - 6.70 wt% C

Transformation in relation to Fe-C diagram

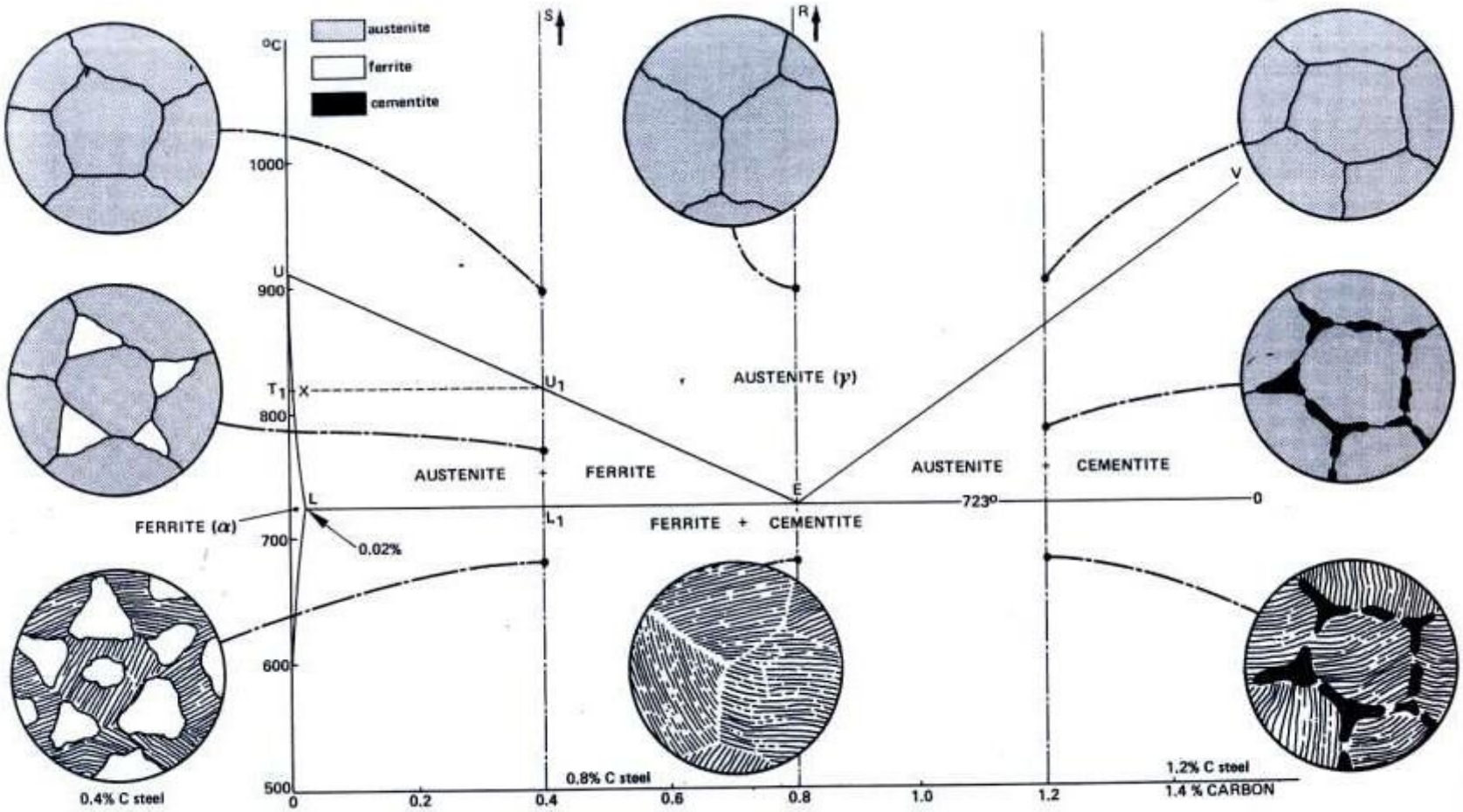


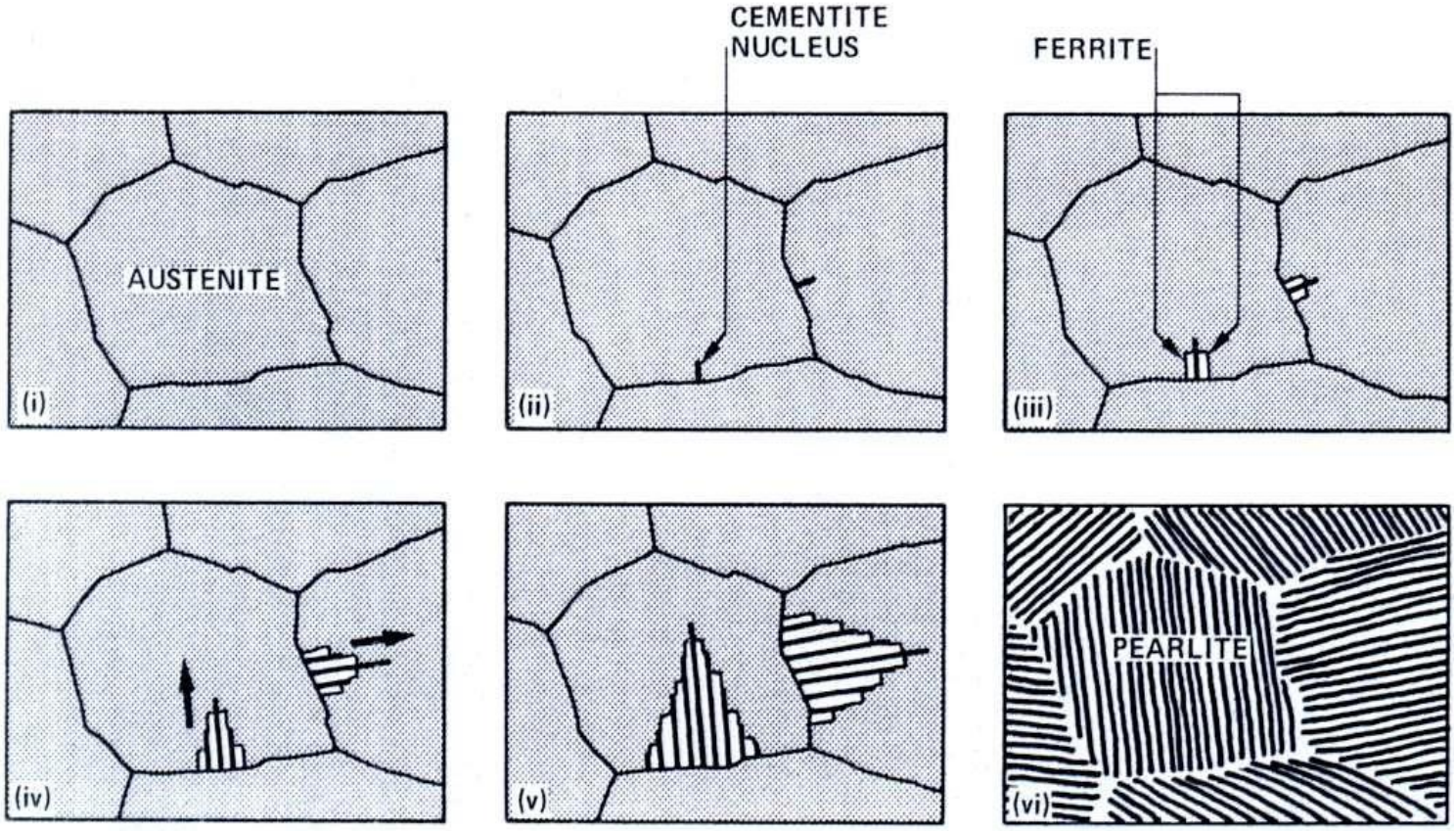
Fig. 9.3—The austenite → ferrite/cementite transformation in relation to the iron–carbon diagram.

Transformation in relation to Fe-C diagram

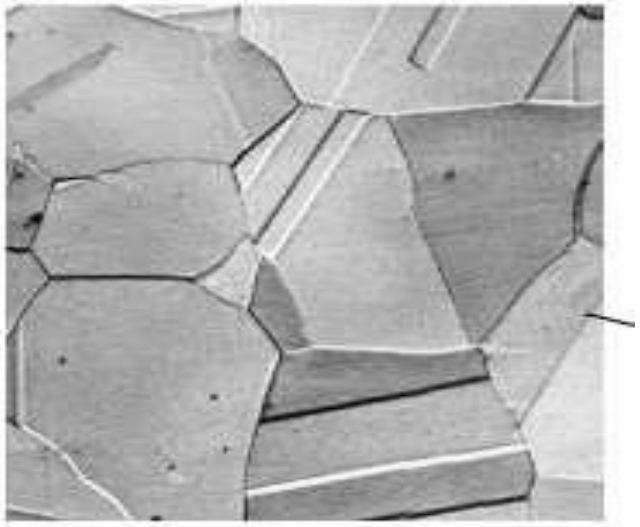
In order to understand the transformation processes, consider a steel of the eutectoid composition. 0.8% carbon, being slow cooled along line *x-x'.*

- At the upper temperatures, only austenite is present, with the 0.8% carbon being dissolved in solid solution within the FCC. When the steel cools through 723°C, several changes occur simultaneously.
- The iron wants to change crystal structure from the FCC austenite to the BCC ferrite, but the ferrite can only contain 0.02% carbon in solid solution.
- The excess carbon is rejected and forms the carbon-rich intermetallic known as cementite.

Nucleation & growth of pearlite

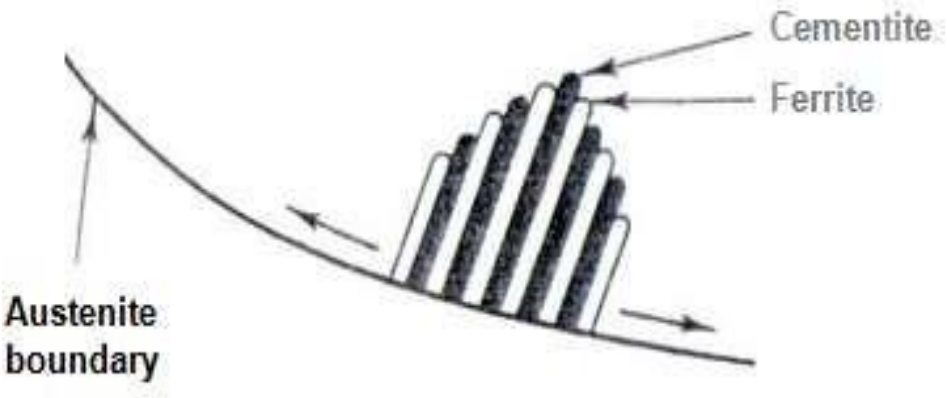


Austenite Microstructure for Steel



austenite

Schematic picture of the formation and growth of pearlite



Cementite Structure

CEMENTITE

Martensite Structure:

NEEDLE LIKE STRUCTURE

Principal phases of steel and their Characteristics

Phase	Crystal structure	Characteristics
Ferrite	BCC	Soft, ductile, magnetic
Austenite	FCC	Soft, moderate strength, non-magnetic
Cementite	Compound of Iron & Carbon Fe_3C	Hard &brittle

Cast Iron

-Iron-Carbon alloys of 2.00%C or more are cast irons.

-Typical composition: 2.0-4.0%C,0.5-3.0% Si, less than 1.0% Mn and less than 0.2% S.

-Si-substitutes partially for C and promotes formation of graphite as the carbon rich component instead Fe_3C

SUMMARY

1). Phase diagrams are useful tools to determine:-the number and types of phases, the wt% of each phase and the composition of each phase for a given T and composition of the system.

2). Binary eutectics and binary eutectoids allow for a range of microstructures with different properties

THANK YOU