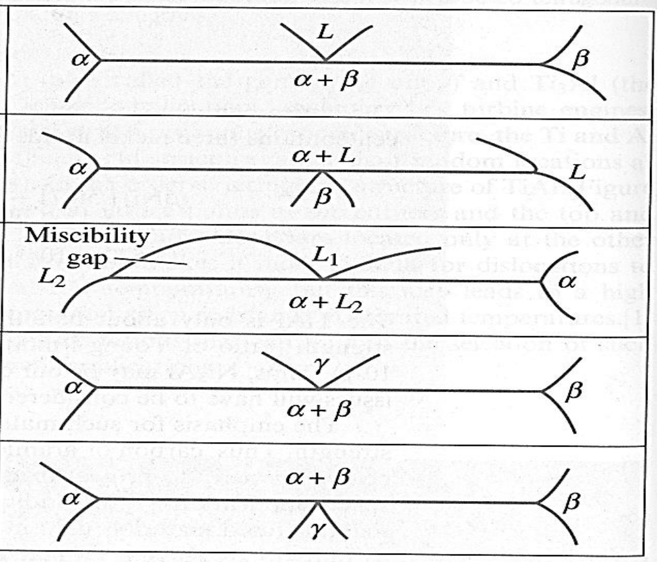
1-9 Three-phase reactions in the phases diagrams:

In addition to the eutectic, other invariant points involving three different phases are found for some alloy systems. One of these occurs for the Iron-Carbon (Fe-C) system.

The five most important three-phase reactions that occur in phases diagrams are:

1- **Eutectic** – a liquid transforms into two solids upon cooling.
2- **Eutectoid** – a solid transforms into two new solids.
3- **Peritectic** – a liquid plus a solid transforms into a new solid.
4- **Peritectoid** – two solids transforms into a new solid.
5- **Monotectic** – a liquid transforms into a new liquid and a solid.

Eutectic	$L \rightarrow \alpha + \beta$
Peritectic	$\alpha + L \rightarrow \beta$
Monotectic	$L_1 \rightarrow L_2 + \alpha$
Eutectoid	$\gamma \rightarrow \alpha + \beta$
Peritectoid	$\alpha + \beta \rightarrow \gamma$



1-10 Iron-Carbon (Fe-C) Phase Diagram

A portion of the iron–carbon phase diagram is presented in fig.(24). The composition axis in fig. (24) extends only to 6.70 wt% C; at this concentration the intermediate compound iron carbide, or **cementite** (Fe3C), is formed, which is represented by a vertical line on the phase diagram. Thus, the iron–carbon system may be divided into two parts: an iron-rich portion, as in fig. (24), and the other (not shown) for compositions between 6.70 and 100 wt% C (pure graphite). In practice, all steels and cast irons have carbon contents less than 6.70 wt% C; therefore, we consider only the iron–iron carbide system. Fig. (24) would be more appropriately labeled the Fe–Fe3C phase diagram, since Fe3C is now considered to be a component. Convention and convenience dictate that composition still be expressed in "wt% C" rather than "wt% Fe3C"; 6.70 wt% C corresponds to 100 wt% Fe3C.

Carbon is an interstitial impurity in iron and forms a solid solution with each of **α** and **δ** ferrites, and also with austenite(γ), as indicated by the **α**, **δ** and **γ** single phase fields in fig. (24).

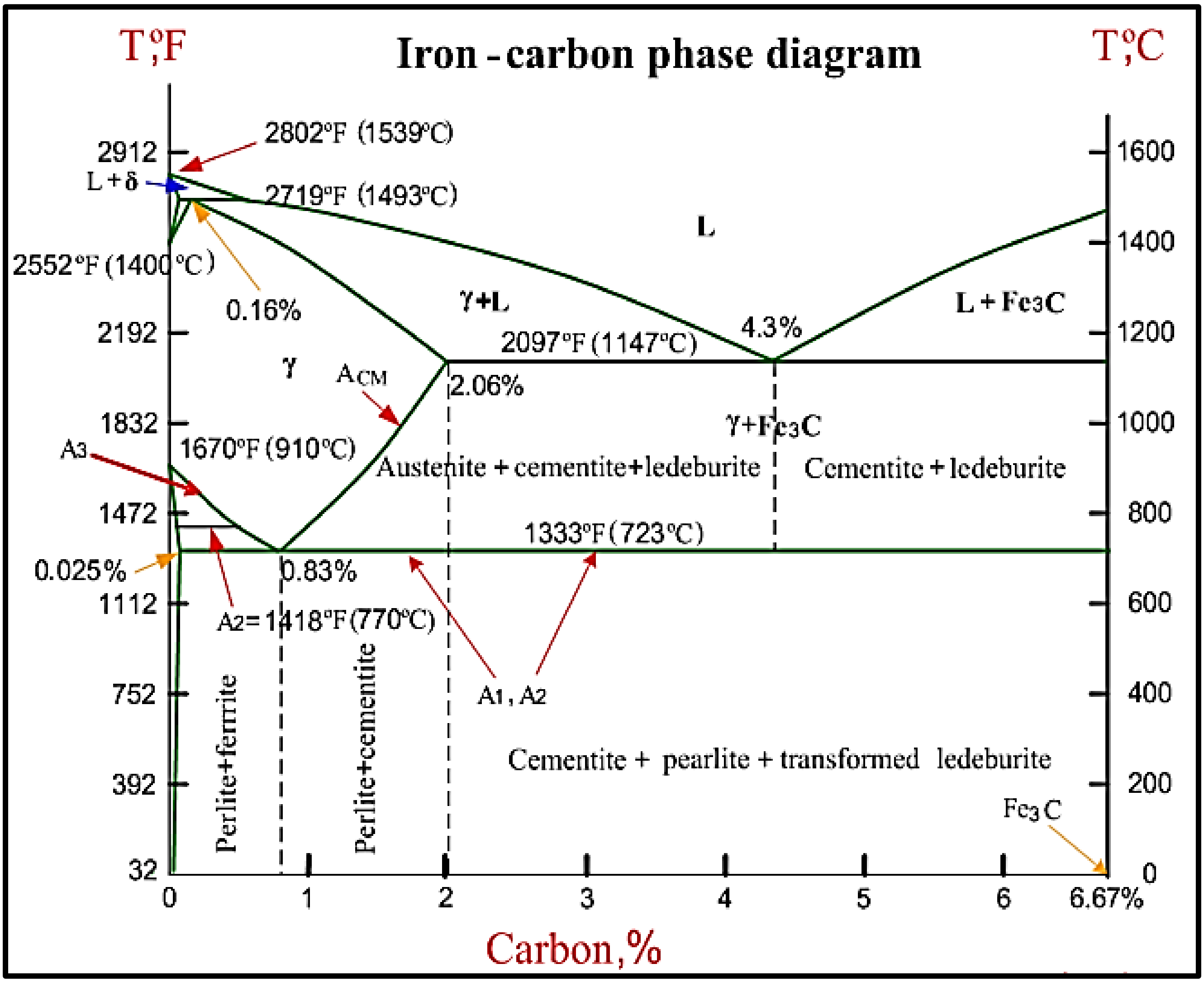


Fig.(24) A portion of the iron–carbon phase diagram which called the Fe–Fe3C phase diagram

The following phases exist on Fe-Fe_3C diagram in fig. (24):

1- **L** - Liquid solution of carbon in iron;
2- **δ-ferrite** – Solid solution of carbon in iron. Maximum concentration of carbon in δ-ferrite is 0.09% at (1493ºC) – temperature of the peritectic transformation. The crystal structure of δ-ferrite is **BCC**.
3- **Austenite(γ)** – Solid solution of carbon in γ-iron. Austenite has **FCC** crystal structure, permitting high solubility of carbon – up to 2.06% at (1147 ºC).
4- **α-ferrite** – Solid solution of carbon in α-iron. α-ferrite has **BCC** crystal structure and low solubility of carbon – up to 0.025% at (723ºC). α-ferrite exists at room temperature.
5- **Cementite** (Fe_3C) – iron carbide, hard and brittle intermetallic compound, the concentration of carbon in Cementite is 6.67%.
6- **Pearlite (α + Fe3C) -** is a mixture of phases which are alternating layers of ferrite and cementite formed simultaneously from the austenite when temperature reaches (723°C) and carbon content (0.83% C) (Eutectoid reaction).
7- **Ledeburite (γ + Fe3C) -** is a mixture of phases which are alternating layers of austenite and cementite formed simultaneously from the liquid when temperature reaches(1147°C) and carbon content(4.3% C) (Eutectic reaction).

Three-phase reactions that occur in Fe-Fe_3C phase diagram are:

1- **Eutectic** – at (1147 ºC) and (4.3 wt% C),

[L ↔ Ledeburite (γ + Fe3C)].

2- **Eutectoid** – at (723 ºC) and (0.83 wt% C),

[γ ↔ Pearlite (α + Fe3C)].

3- **Peritectic** – at (1493 ºC) and (0.16 wt% C),

[L + δ ↔ γ].

Iron-carbon alloys, containing up to 2.06% of carbon, are called **steel**. Iron-carbon alloys, which have carbon content from 2.06% to 4.3%, are called **cast iron**.

-Cooling in a Fe-Fe_3C phase diagram and Microstructure Development:

At cooling the eutectoid, hypoeutectoid and hypereutectoid compositions in Fe-Fe3C phase diagram from the austenite (γ) region, the microstructures develop as shown in fig. (25).

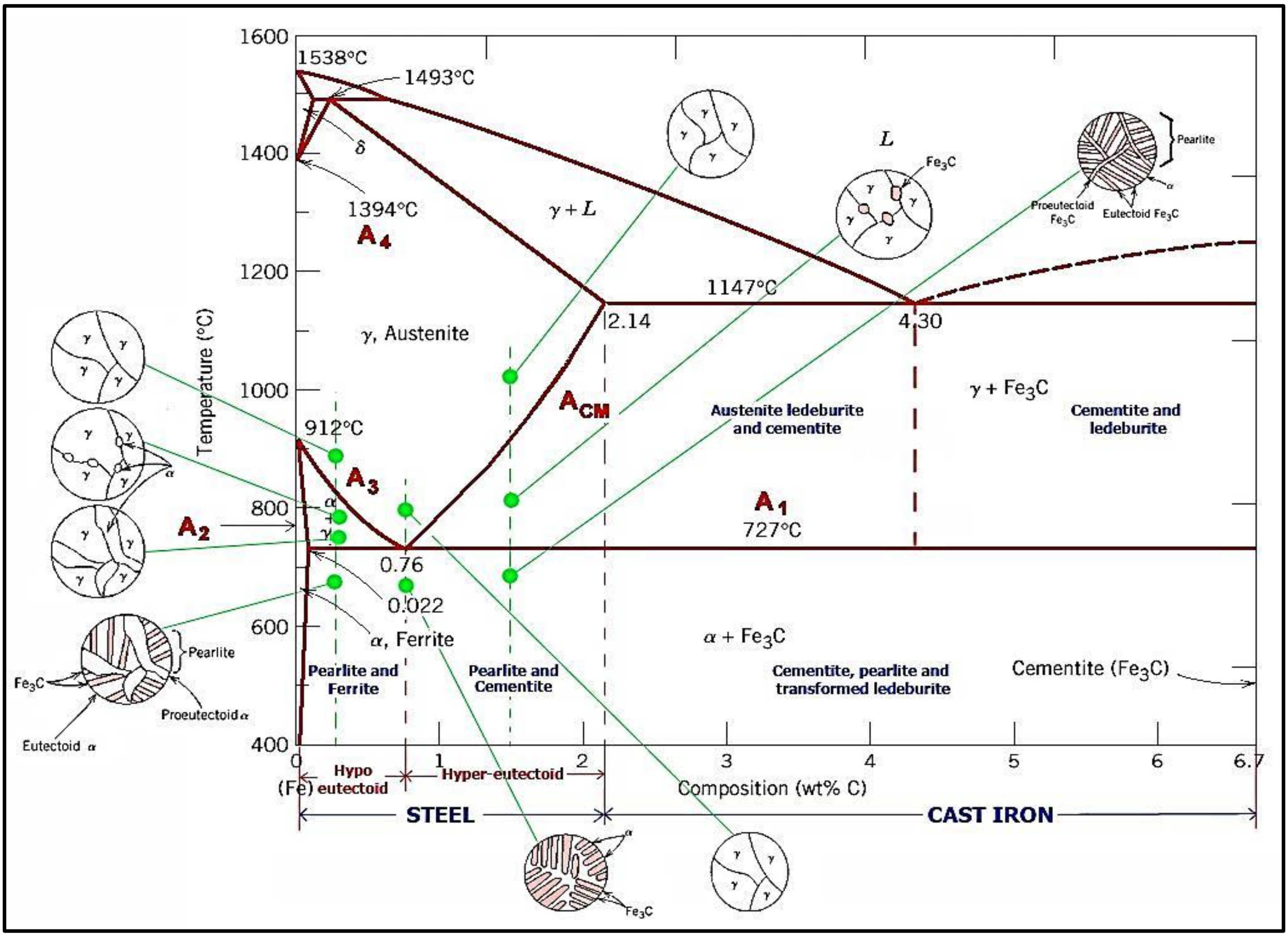


Fig.(25) Microstructure development in Fe-Fe3C phase diagram up to 2.06% C.

Phase diagrams only show stable phases that are formed during slow cooling. If cooling is rapid, the phase diagram becomes invalid and metastable phases may form. Such as **martensite**, which forms when austenite is rapidly cooled (quenched) to room temperature. Martensite is hard and brittle, has distorted BCC lattice and forms plate-like or needle-shaped grains.