Materials Science
The Iron- Iron Carbide Phase Equilibrium Diagram (Part 2) (Weeks 10) Presented by

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Hypoeutectoid Alloys

Microstructures for iron–iron carbide alloys having other than the eutectoid composition are now explored.

Consider a composition C_0 to the left of the eutectoid, between 0.022 and 0.76 wt% C; this is termed a **hypoeutectoid** ("less than eutectoid") **alloy**. Cooling an alloy of this composition is represented by moving down the vertical line yy' in Figure 9.29. At about 875°C, point c, the microstructure consists entirely of grains of the γ phase, as shown schematically in the figure. In cooling to point d, about 775°C, which is within the $\alpha + \gamma$ phase region, both these phases coexist as in the schematic microstructure. Most of the small α particles form along the original γ grain boundaries. The compositions of both α and γ phases may be determined using the appropriate tie line; these compositions correspond, respectively, to about 0.020 and 0.40 wt% C.

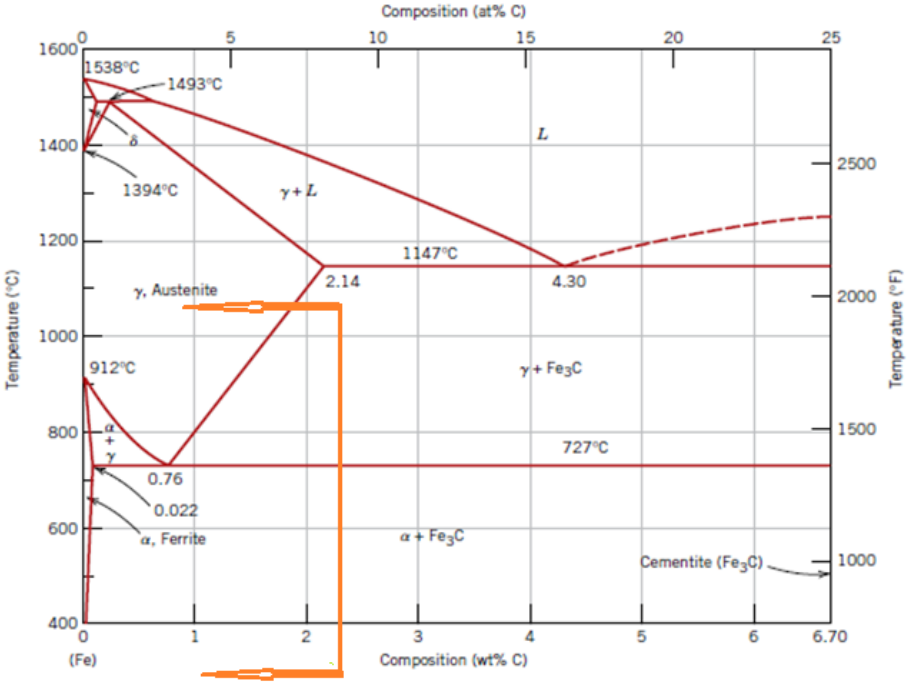
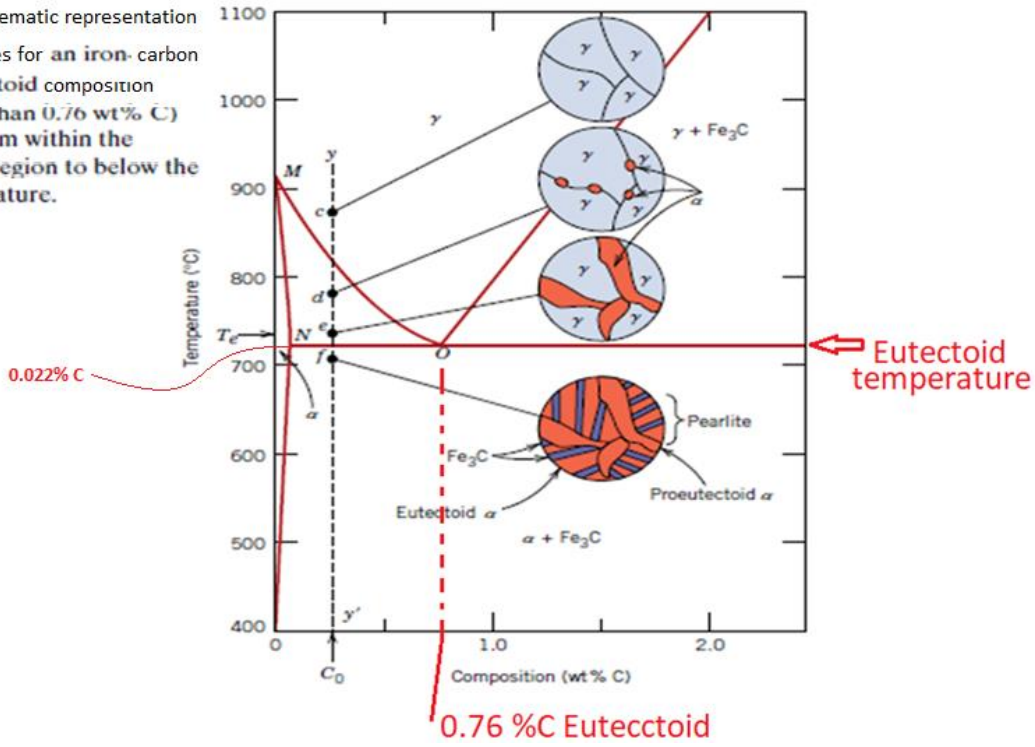


Figure 9.24 The iron–iron carbide phase diagram.



Cooling from point *d* to *e*, just above the eutectoid but still in the $\alpha + \gamma$ region, produces an increased fraction of the α phase and a microstructure similar to that also shown: the α particles will have grown larger. At this point, the compositions of the α and γ phases are determined by constructing a tie line at the temperature T_e; the α phase contains 0.022 wt% C, whereas the γ phase is of the eutectoid composition, 0.76 wt% C.

As the temperature is lowered just below the eutectoid, to point *f*, all of the γ phase that was present at temperature T_e (and having the eutectoid composition) transforms into pearlite, according to the reaction in Equation 9.19. There is virtually no change in the α phase that existed at point *e* in crossing the eutectoid temperature—it is normally present as a continuous matrix phase surrounding the isolated pearlite colonies. The microstructure at point *f* appears as the corresponding schematic inset of Figure 9.29. Thus the ferrite phase is present both in the pearlite and as the phase that formed while cooling through the $\alpha + \gamma$ phase region. The ferrite present in the pearlite is called *eutectoid ferrite,* whereas the other, which formed above T_e, is termed **proeutectoid** (meaning "pre- or before eutectoid") **ferrite,** as labeled in Figure 9.29.

Figure 9.30 is a photomicrograph of a 0.38-wt% C steel; large, white regions correspond to the proeutectoid ferrite. For pearlite, the spacing between the α and Fe_3C layers varies from grain to grain; some of the pearlite appears dark because the many close-spaced layers are unresolved at the magnification of the photomicrograph. Note that two microconstituents are present in this micrograph—proeutectoid ferrite and pearlite—which appear in all hypoeutectoid iron–carbon alloys that are slowly cooled to a temperature below the eutectoid.

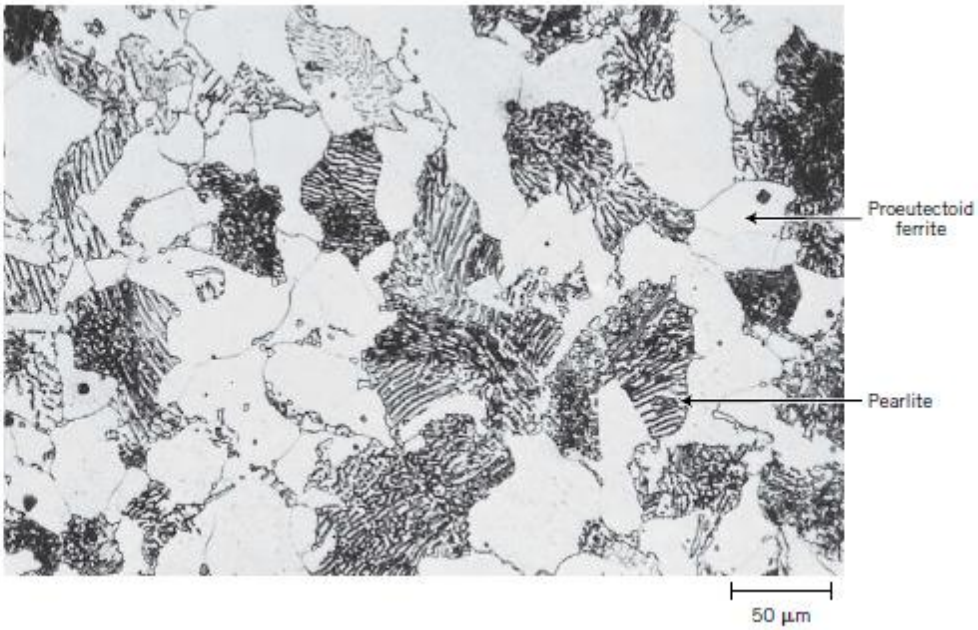


Figure 9.30 Photomicrograph of a 0.38 wt% C steel having a microstructure consisting of pearlite and proeutectoid ferrite. 635×. (Photomicrograph courtesy of Republic Steel Corporation.)

The relative amounts of the proeutectoid α and pearlite may be determined in a manner used for primary and eutectic microconstituents.
We use the lever rule in conjunction with a tie line that extends from the $\alpha - (\alpha + Fe_3C)$ phase boundary (0.022-wt% C) to the eutectoid composition (0.76-wt% C) inasmuch as pearlite is the transformation product of austenite having this composition. For example, let us consider an alloy of composition C_0' in Figure 9.31. The fraction of pearlite, W_p, may be determined according to

Lever rule expression for computation of pearlite mass fraction (composition C_0', Figure 9.31)

$$W_p = \frac{T}{T+U} = \frac{C_0' - 0.022}{0.76 - 0.022} = \frac{C_0' - 0.022}{0.74} \tag{9.20}$$

The fraction of proeutectoid α, $W_{\alpha'}$, is computed as follows:

Lever rule expression for computation of proeutectoid ferrite mass fraction

$$W_{\alpha'} = \frac{U}{T+U} = \frac{0.76 - C_0'}{0.76 - 0.022} = \frac{0.76 - C_0'}{0.74} \tag{9.21}$$

Fractions of both total α (eutectoid and proeutectoid) and cementite are determined using the lever rule and a tie line that extends across the entirety of the $\alpha + Fe_3C$ phase region, from 0.022 to 6.70 wt% C.

Figure 9.31 A portion of the Fe–Fe_3C phase diagram used in computing the relative amounts of proeutectoid and pearlite microconstituents for hypoeutectoid C_0' and hypereutectoid C_1' compositions.

