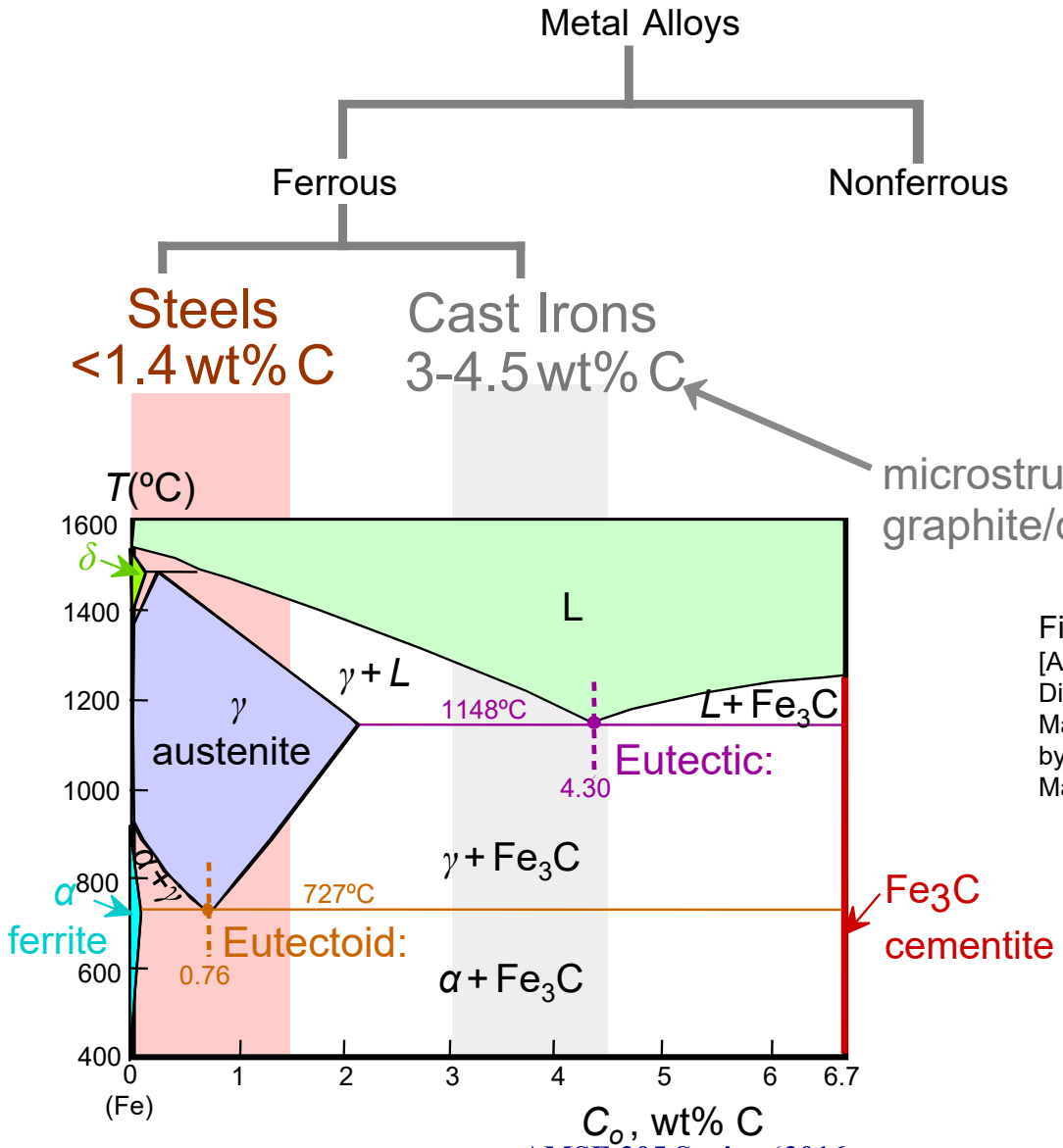
Chapter 13: Properties and Applications of Metals

ISSUES TO ADDRESS...

- How are metal alloys classified and what are their common applications?
- What are the microstructure and general characteristics of cast irons?
- What are the distinctive physical and mechanical properties of nonferrous alloys?

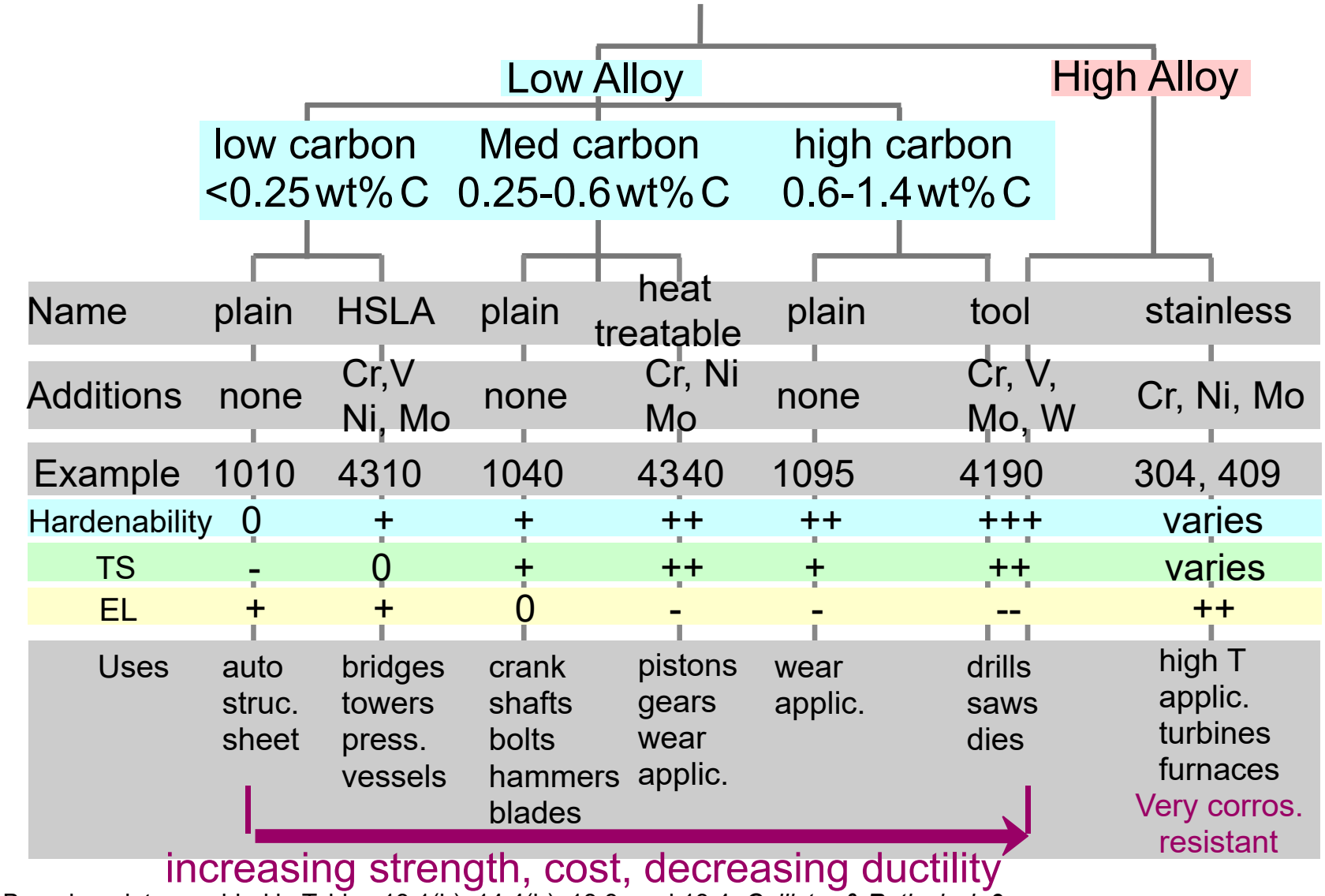
Classification of Metal Alloys



Adapted from Fig. 13.1, *Callister & Rethwisch 9e.*

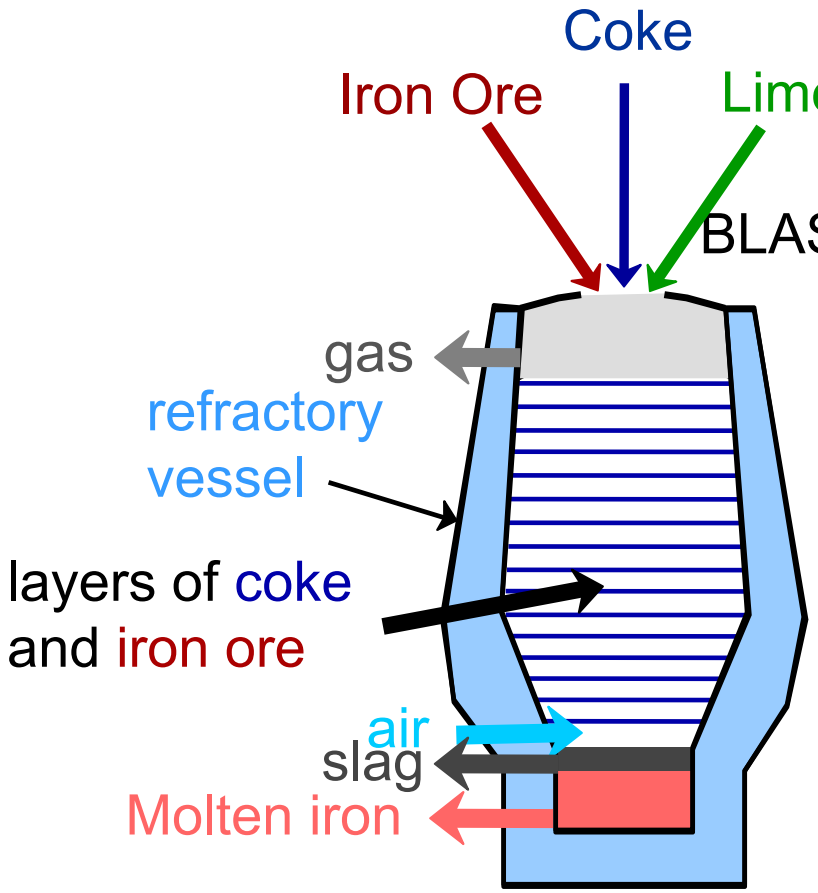
Fig. 11.23, *Callister & Rethwisch 9e.* [Adapted from Binary Alloy Phase Diagrams, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

Steels



Based on data provided in Tables 13.1(b), 14.4(b), 13.3, and 13.4, *Callister & Rethwisch 9e.*

Refinement of Steel from Ore



heat generation

$$C + O_2 \rightarrow CO_2$$

reduction of iron ore to metal

$$CO_2 + C \rightarrow 2CO$$

$$3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$$

purification

$$CaCO_3 \rightarrow CaO + CO_2$$

$$CaO + SiO_2 + Al_2O_3 \rightarrow \text{slag}$$

Ferrous Alloys

Iron-based alloys

- Steels
- Cast Irons

Nomenclature for steels (AISI/SAE)

10xx Plain Carbon Steels
11xx Plain Carbon Steels (resulfurized for machinability)
15xx Mn (1.00 - 1.65%)
40xx Mo (0.20 ~ 0.30%)
43xx Ni (1.65 - 2.00%), Cr (0.40 - 0.90%), Mo (0.20 - 0.30%)
44xx Mo (0.5%)

where xx is wt% C x 100

example: 1060 steel – plain carbon steel with 0.60 wt% C

Stainless Steel >11% Cr

Cast Irons

- Ferrous alloys with > 2.1 wt% C
  - more commonly 3 - 4.5 wt% C
- Low melting – relatively easy to cast
- Generally brittle

- Cementite decomposes to ferrite + graphite

$$Fe_3C \rightarrow 3\ Fe\ (\alpha) + C\ (graphite)$$

  - generally a slow process

Fe-C True Equilibrium Diagram

Graphite formation promoted by

- Si > 1 wt%
- slow cooling

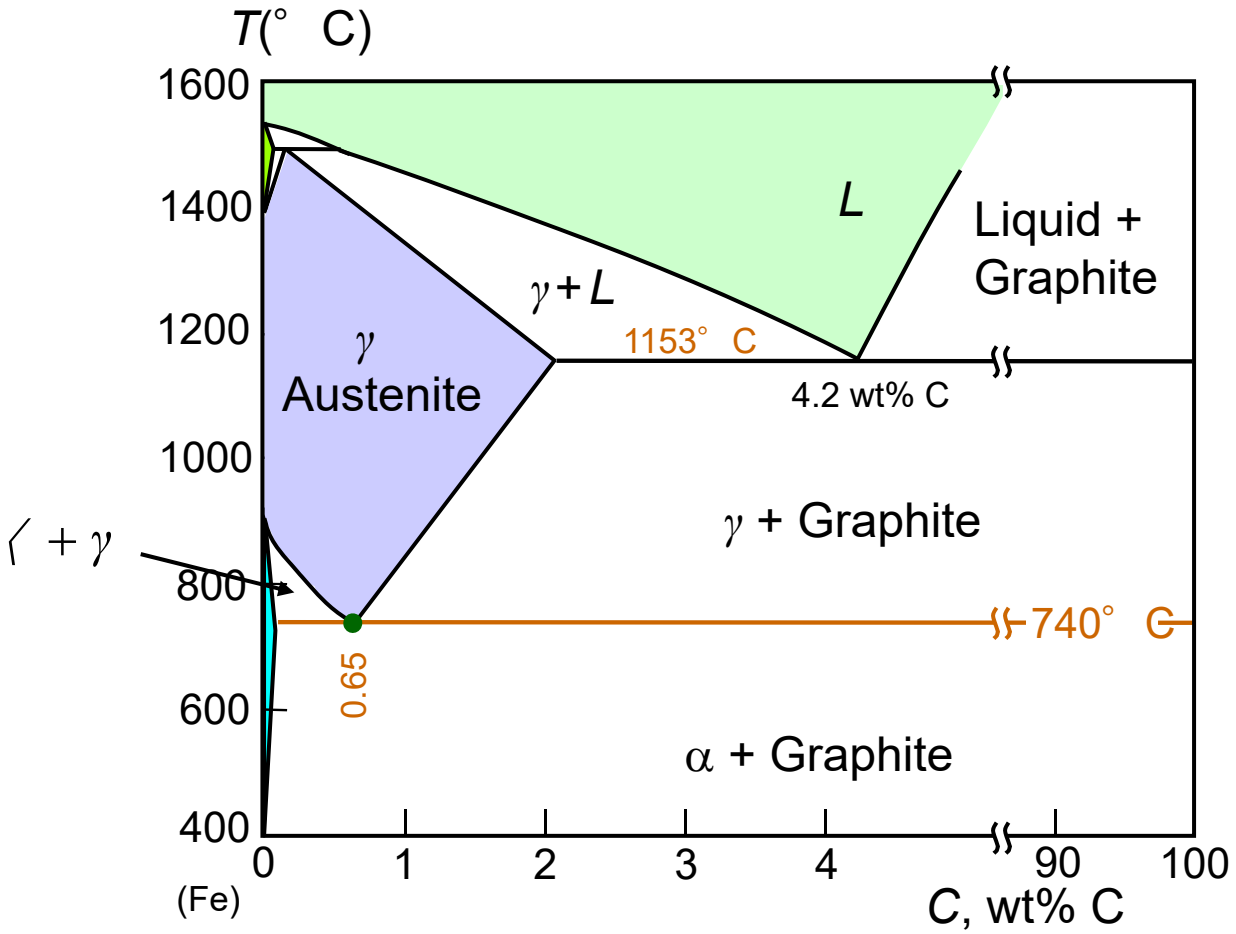


Fig. 13.2, *Callister & Rethwisch 9e.* [Adapted from *Binary Alloy Phase Diagrams*, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

Types of Cast Iron

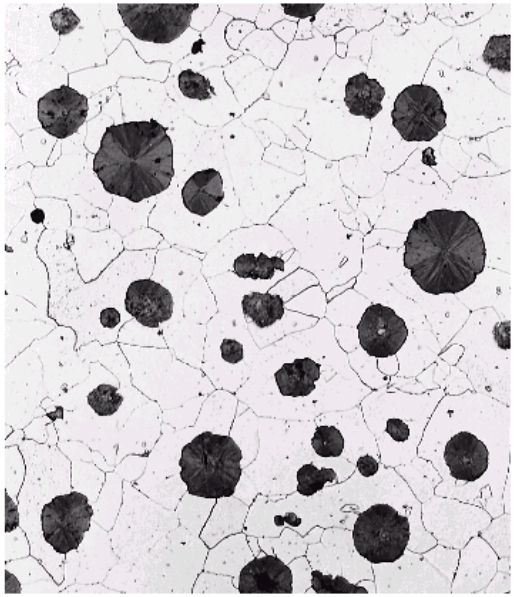
Gray iron

- graphite flakes
- weak & brittle in tension
- stronger in compression
- excellent vibrational dampening
- wear resistant

Figs. 13.3(a) & (b), *Callister & Rethwisch 9e.* [Courtesy of C. H. Brady and L. C. Smith, National Bureau of Standards, Washington, DC (now the National Institute of Standards and Technology, Gaithersburg, MD]

Ductile iron

- add Mg and/or Ce
- graphite as nodules not flakes
- matrix often pearlite – stronger but less ductile



Types of Cast Iron (cont.)

White iron

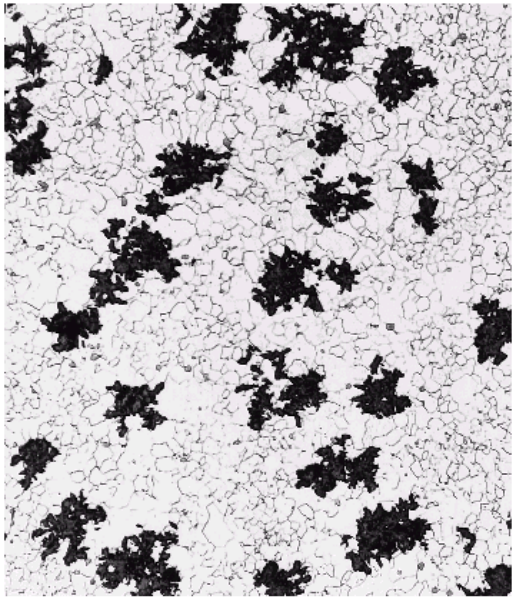
- < 1 wt% Si
- pearlite + cementite
- very hard and brittle

Figs. 13.3(c) & (d), *Callister & Rethwisch 9e.*

Courtesy of Amcast Industrial Corporation

Malleable iron

- heat treat white iron at 800-900°C
- graphite in rosettes
- reasonably strong and ductile



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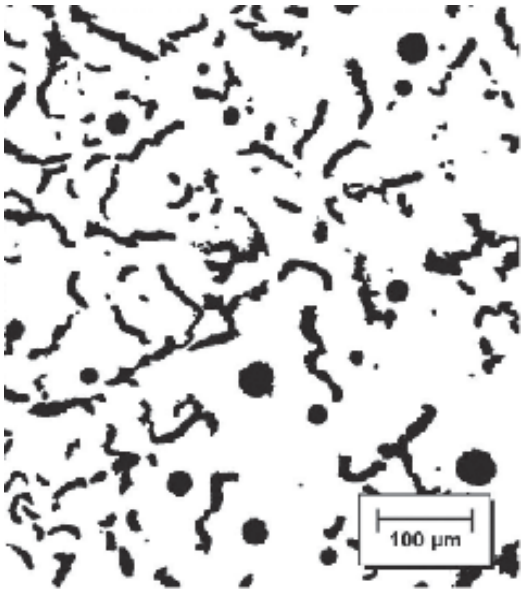
Types of Cast Iron (cont.)

Compacted graphite iron

- relatively high thermal conductivity
- good resistance to thermal shock
- lower oxidation at elevated temperatures



Courtesy of Sinter-Cast, Ltd.

Fig. 13.3(e), *Callister & Rethwisch 9e.*

Production of Cast Irons

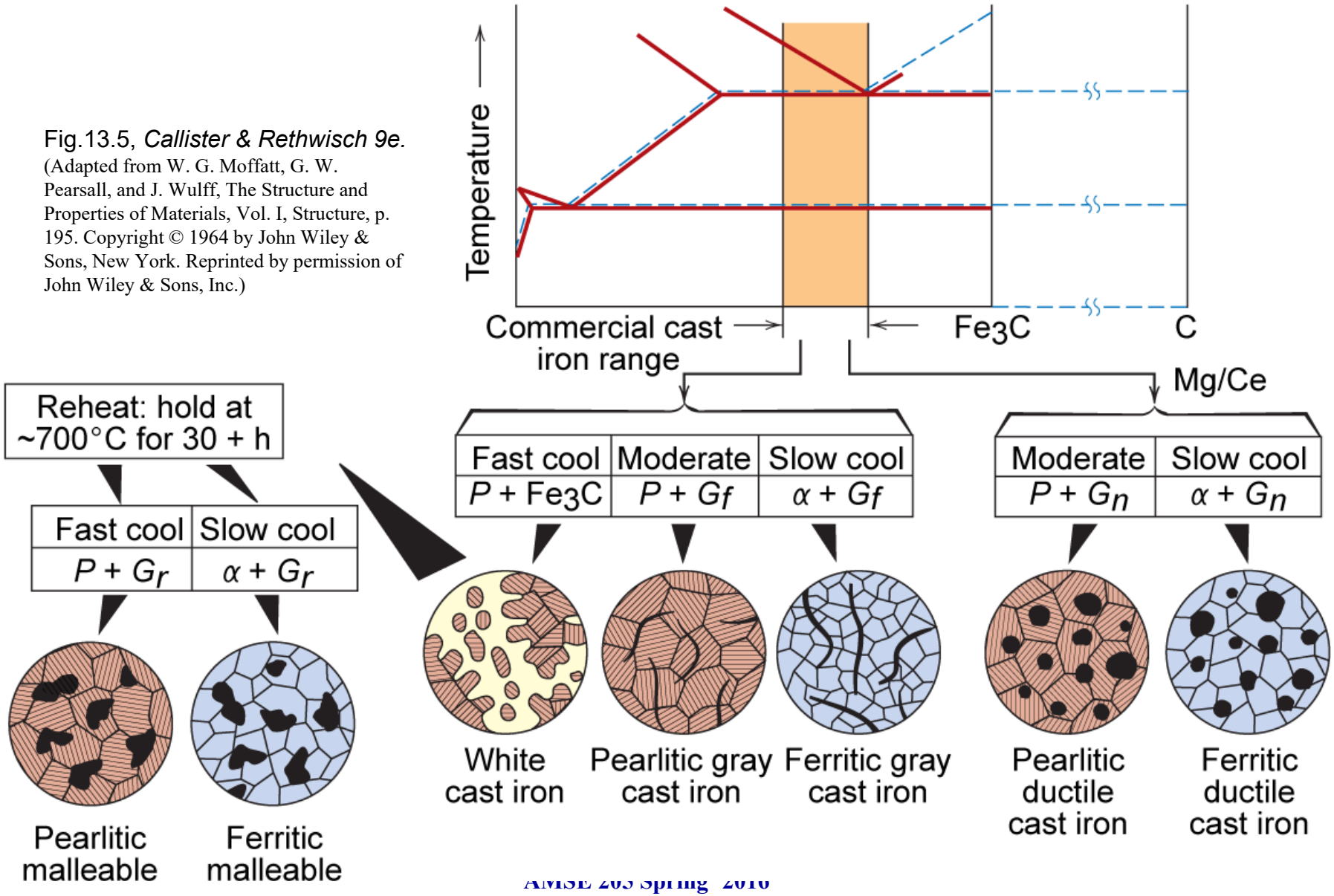
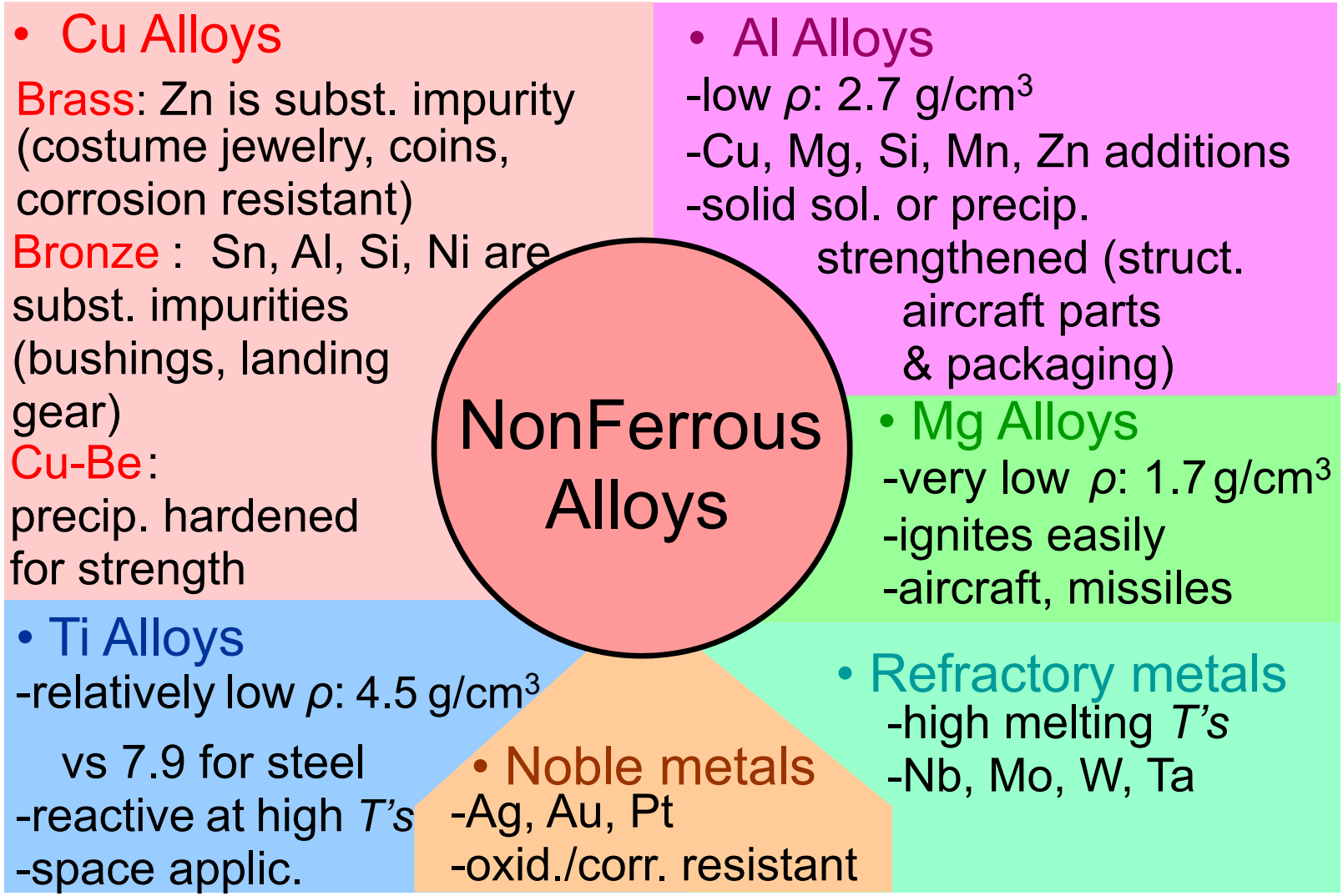


Fig.13.5, *Callister & Rethwisch 9e.*
(Adapted from W. G. Moffatt, G. W. Pearsall, and J. Wulff, The Structure and Properties of Materials, Vol. I, Structure, p. 195. Copyright © 1964 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)

Limitations of Ferrous Alloys

1) Relatively high densities
2) Relatively low electrical conductivities
3) Generally poor corrosion resistance

Nonferrous Alloys



Based on discussion and data provided in Chapter 13, *Callister & Rethwisch 9e.*

Summary

- Ferrous alloys:
  -- steels
  -- cast irons
- Non-ferrous alloys:
  -- Cu, Al, Ti, and Mg alloys; refractory alloys; and noble metals