

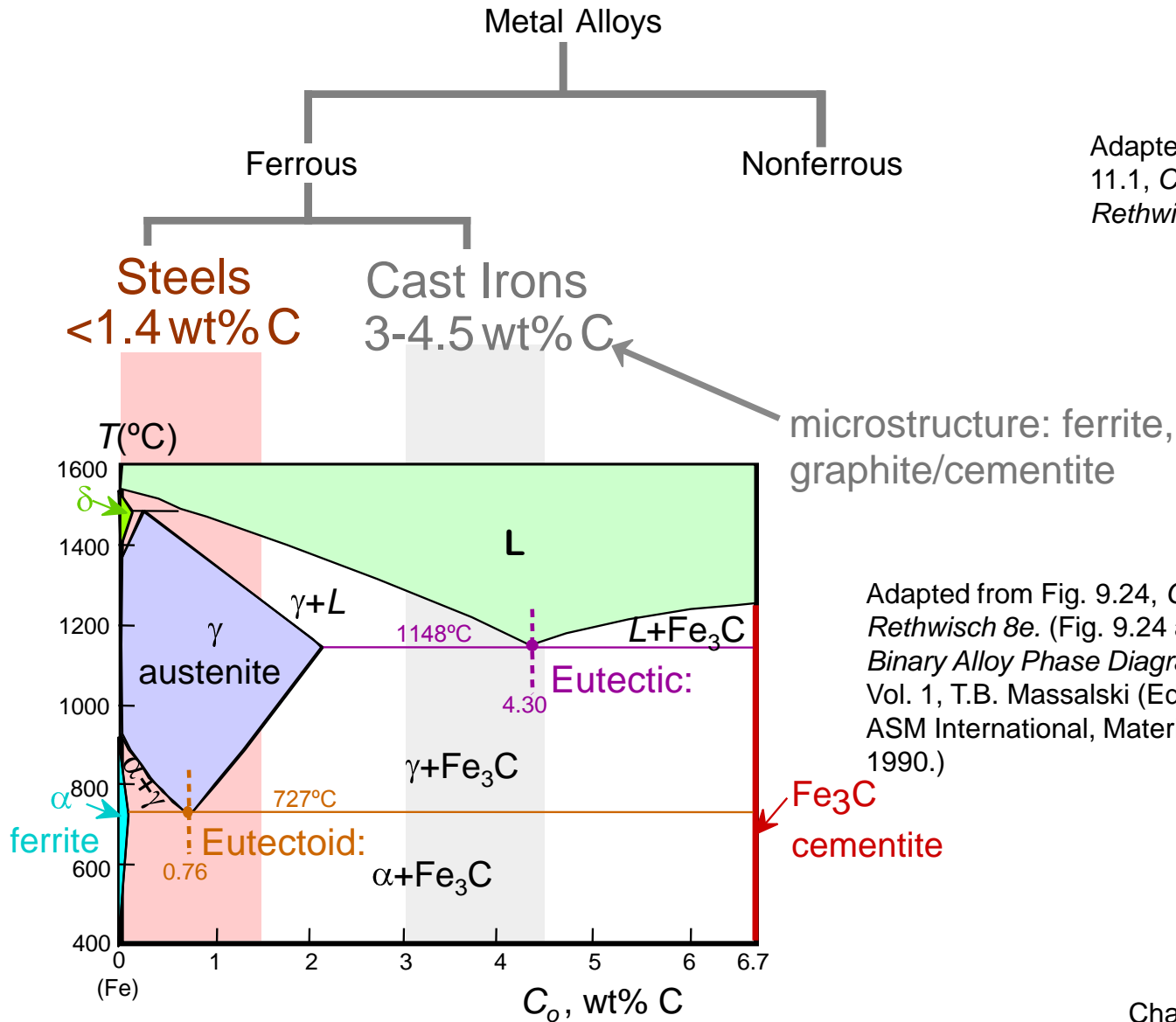
# Chapter 11: Applications and Processing of Metal Alloys

## ISSUES TO ADDRESS...

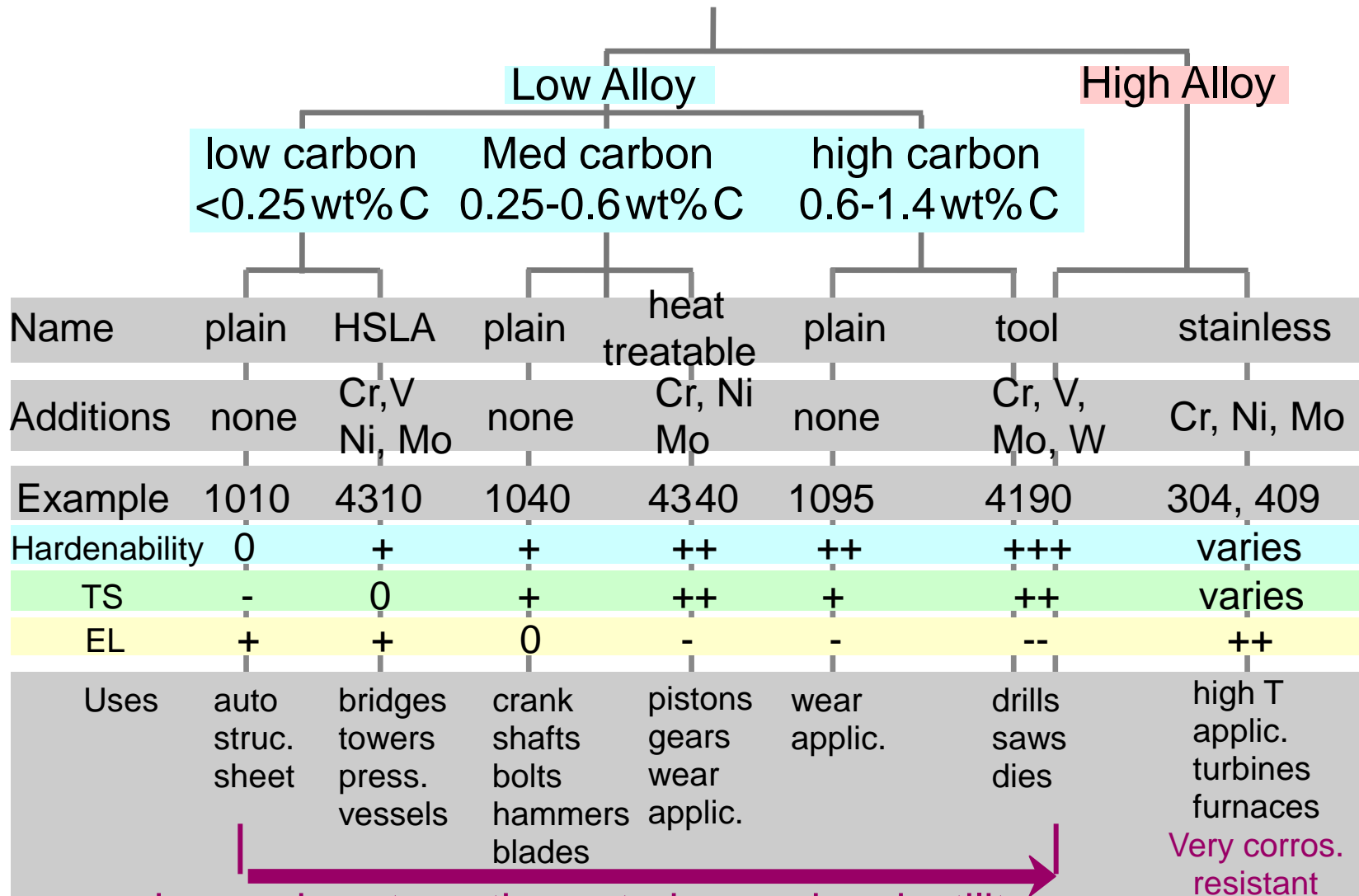
- ✓• How are metal alloys classified and what are their common applications?
- What are some of the common fabrication techniques for metals?
- What heat treatment procedures are used to improve the mechanical properties of both ferrous and nonferrous alloys?



# Classification of Metal Alloys



# Steels



increasing strength, cost, decreasing ductility

Based on data provided in Tables 11.1(b), 11.2(b), 11.3, and 11.4, Callister & Rethwisch 8e.



# 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
$$\text{Fe}_3\text{C} \rightarrow 3 \text{Fe} (\alpha) + \text{C} (\text{graphite})$$
  - generally a slow process



# Types of Cast Iron

## Gray iron

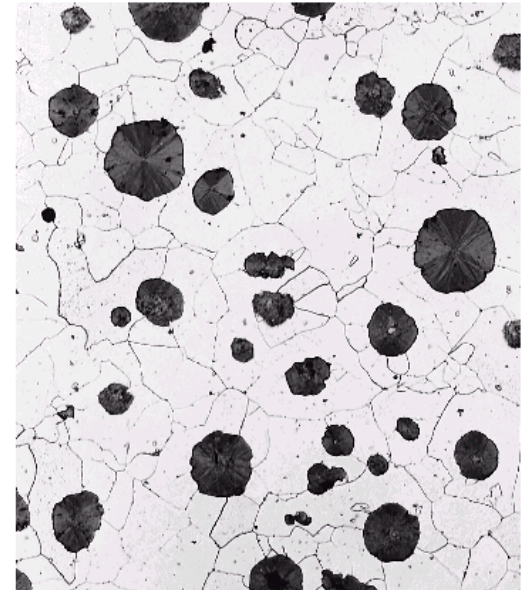
- graphite flakes
- weak & brittle in tension
- stronger in compression
- excellent vibrational dampening
- wear resistant

Adapted from Fig.  
11.3(a) & (b),  
*Callister &  
Rethwisch 8e.*



## 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

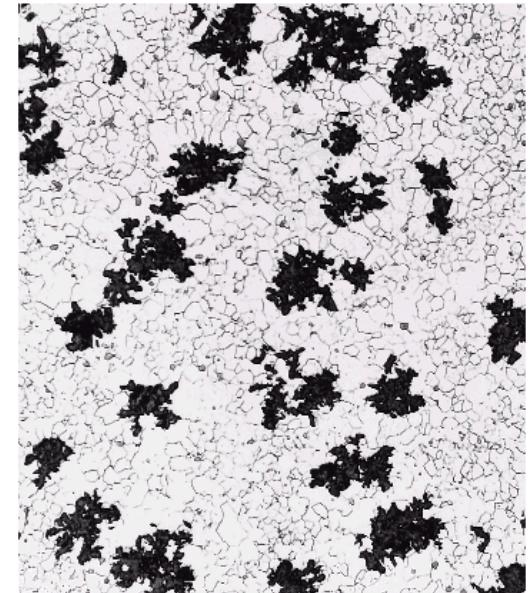
- $< 1$  wt% Si
- pearlite + cementite
- very hard and brittle

Adapted from Fig.  
11.3(c) & (d),  
*Callister &  
Rethwisch 8e.*



## Malleable iron

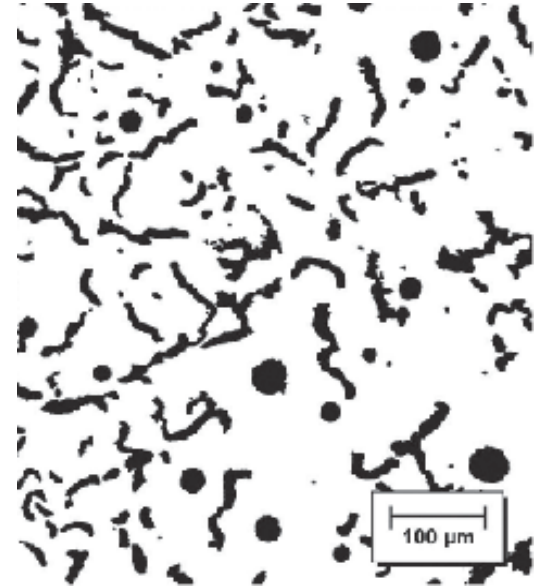
- heat treat white iron at 800-900°C
- graphite in rosettes
- reasonably strong and ductile



# Types of Cast Iron (cont.)

## Compacted graphite iron

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

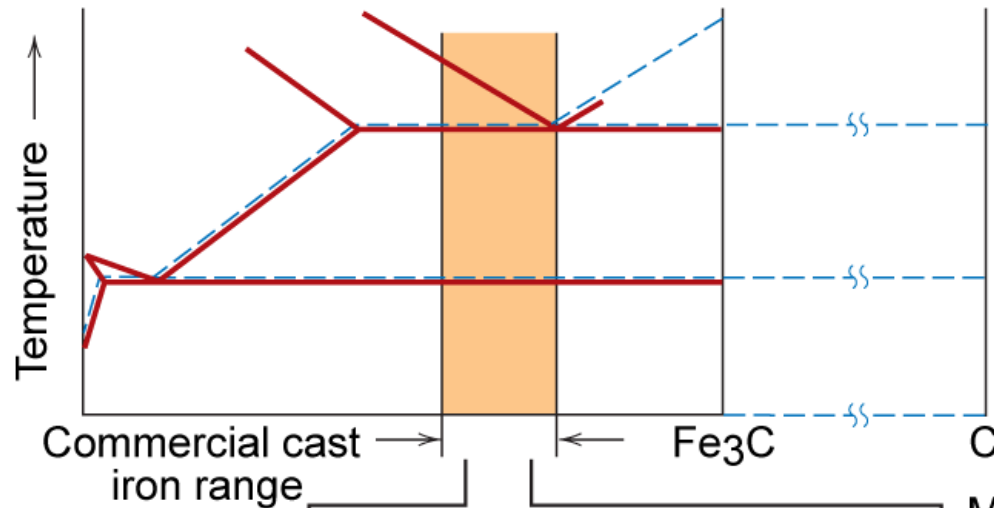


Adapted from Fig. 11.3(e),  
*Callister & Rethwisch 8e.*



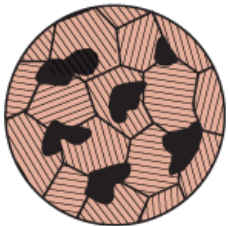
# Production of Cast Irons

Adapted from Fig. 11.5,  
Callister & Rethwisch 8e.

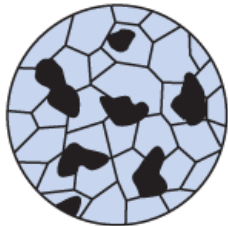


Reheat: hold at  
 $\sim 700^\circ\text{C}$  for 30 + h

Fast cool	Slow cool
$P + G_r$	$\alpha + G_r$



Pearlitic malleable

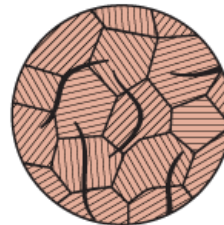


Ferritic malleable

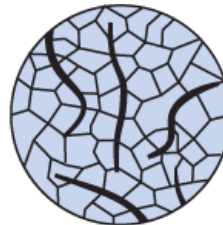
Fast cool	Moderate	Slow cool
$P + \text{Fe}_3\text{C}$	$P + G_f$	$\alpha + G_f$



White cast iron

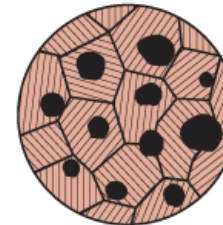


Pearlitic gray cast iron

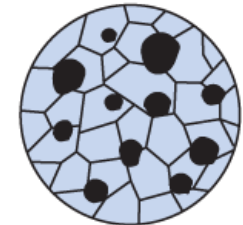


Ferritic gray cast iron

Moderate	Slow cool
$P + G_n$	$\alpha + G_n$



Pearlitic ductile cast iron



Ferritic ductile cast iron

# Limitations of Ferrous Alloys

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



# Nonferrous Alloys

## • Cu Alloys

**Brass:** Zn is subst. impurity (costume jewelry, coins, corrosion resistant)

**Bronze:** Sn, Al, Si, Ni are subst. impurities (bushings, landing gear)

**Cu-Be:** precip. hardened for strength

## • Ti Alloys

-relatively low  $\rho$ : 4.5 g/cm<sup>3</sup>

vs 7.9 for steel

-reactive at high  $T$ 's

-space applic.

## • Al Alloys

-low  $\rho$ : 2.7 g/cm<sup>3</sup>

-Cu, Mg, Si, Mn, Zn additions

-solid sol. or precip.

strengthened (struct. aircraft parts & packaging)

## • Mg Alloys

-very low  $\rho$ : 1.7g/cm<sup>3</sup>

-ignites easily

-aircraft, missiles

## • Refractory metals

-high melting  $T$ 's

-Nb, Mo, W, Ta

NonFerrous Alloys

## • Noble metals

-Ag, Au, Pt

-oxid./corr. resistant

