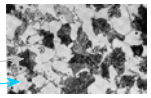
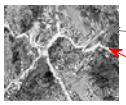
Mechanical prop: Fe-C System (1)

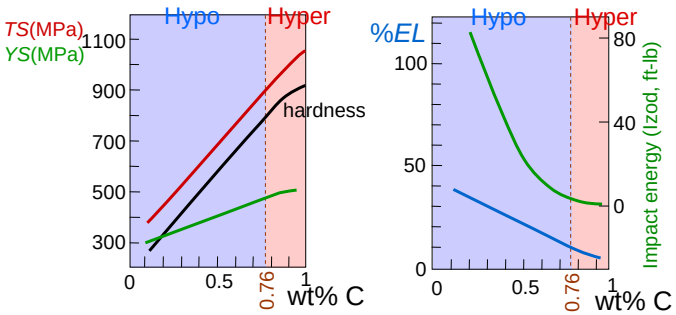
- Effect of wt% C



C_o < 0.76 wt% C
Hypoeutectoid



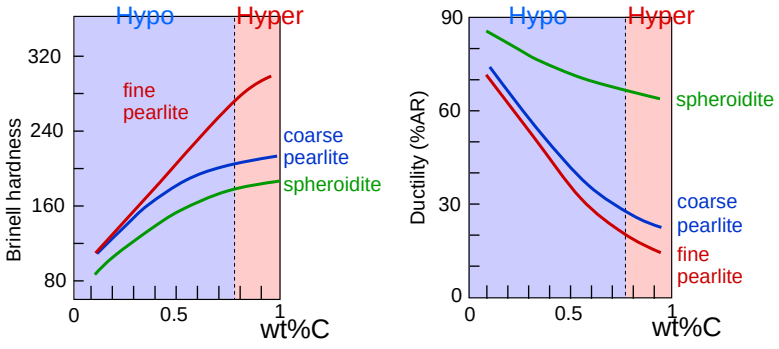
C_o > 0.76 wt% C
Hypereutectoid



- More wt% C: *TS* and *YS* increase, %*EL* decreases.

Mechanical prop: Fe-C system (2)

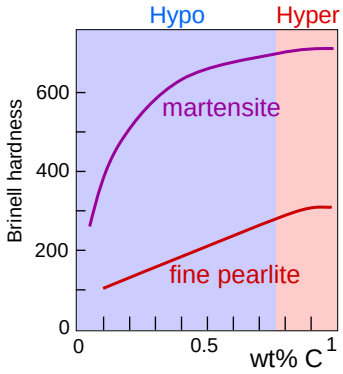
- Fine vs coarse pearlite vs spheroidite



- Hardness: fine > coarse > spheroidite
- %RA: fine < coarse < spheroidite

Mechanical Prop: Fe-C system (3)

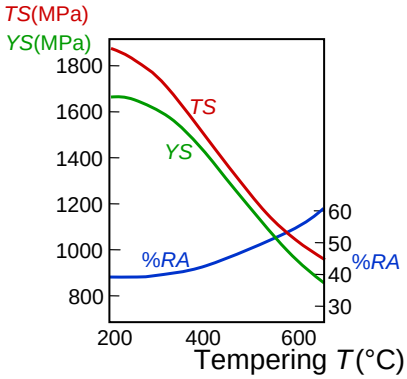
- Fine Pearlite vs Martensite:

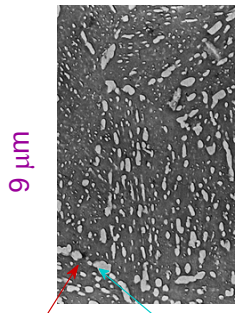


- Hardness: fine pearlite << martensite.

Tempering martensite

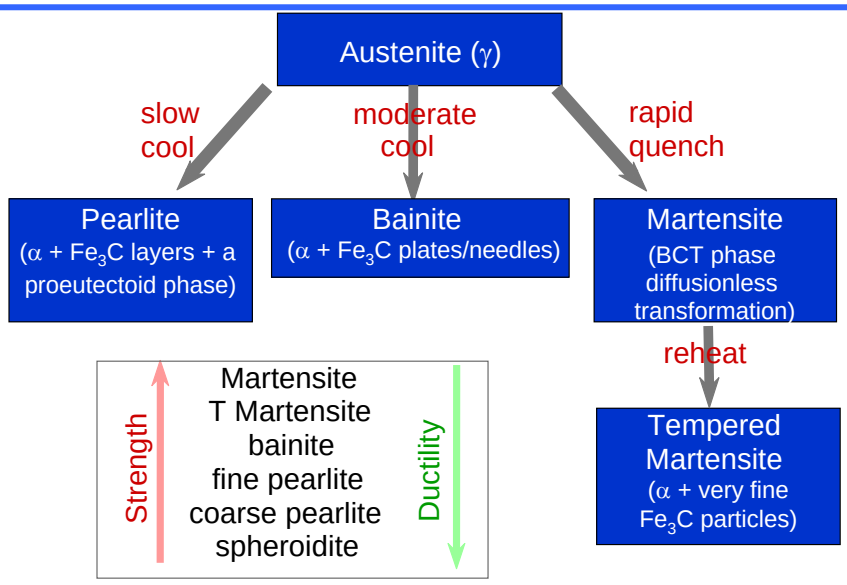
- reduces brittleness of martensite,
- reduces internal stress caused by quenching



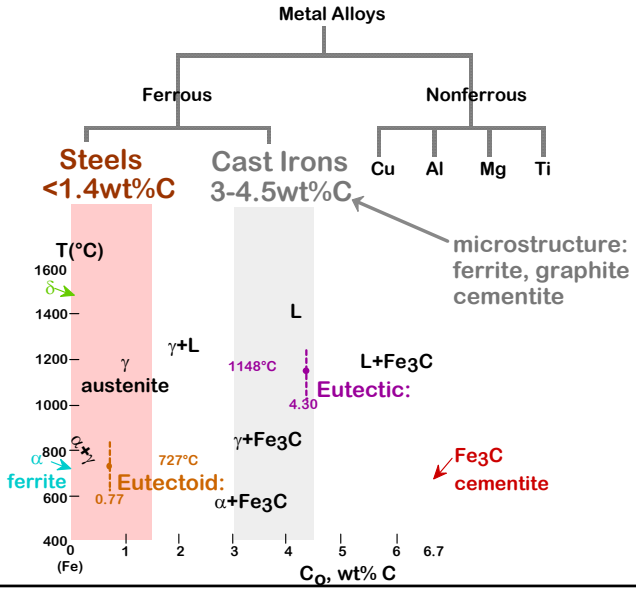


- produces extremely small Fe_3C particles surrounded by α.
- decreases *TS*, *YS* but increases %*RA*

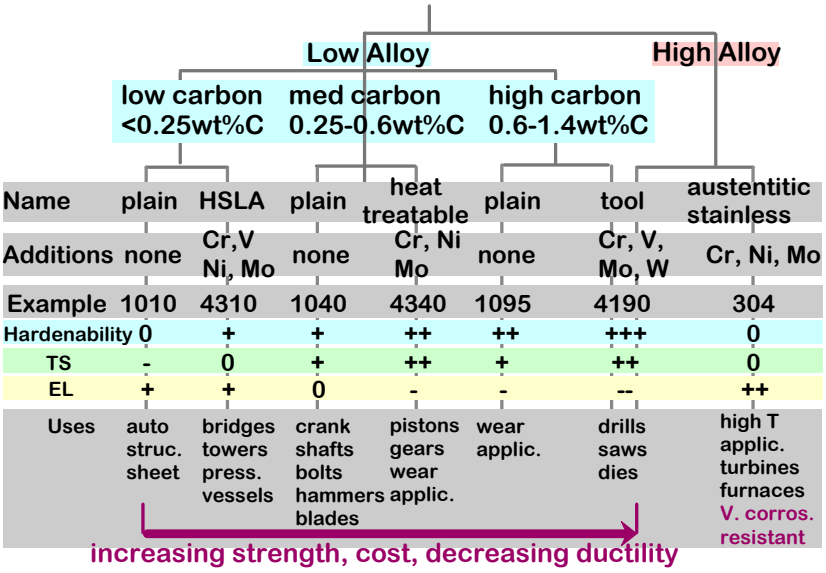
Summary: Processing options



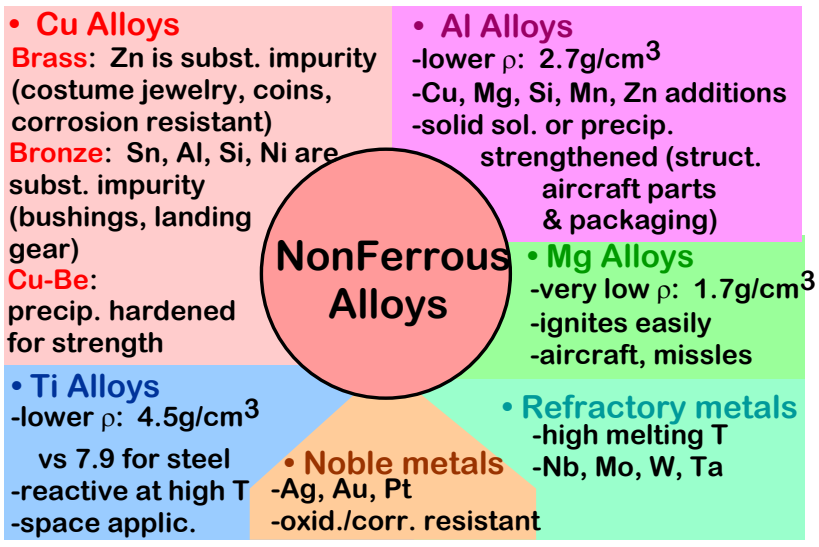
Chap11.Applications and processing of metal alloys



Steels



Nonferrous alloys



Chapter 12 Structures and properties of ceramics

- Bonding in ceramics
- Imperfection in ceramics
- Electric properties of ceramics
- Ceramic phase diagrams
- Brittle fracture of ceramics
- Stress-strain behavior
- Mechanisms of plastic deformation

Ceramic bonding

- **Bonding:**

--Mostly ionic, some covalent.

--% ionic character increases with difference in electronegativity.

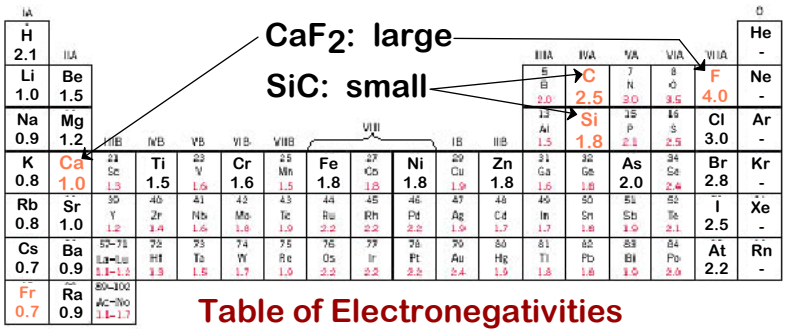
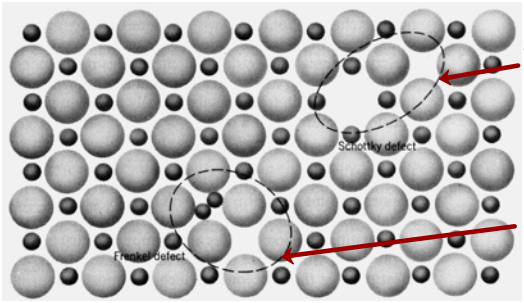


Table of Electronegativities

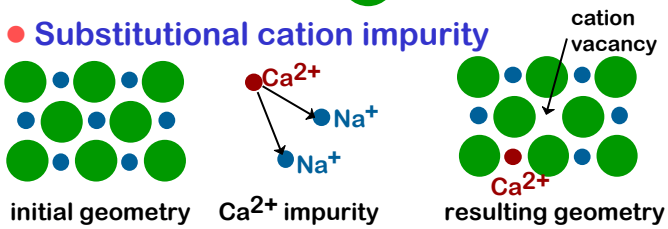
Imperfections in ceramics

- Schottky defects: **--a paired set of cation and anion vacancies.**
- Frenkel defects: an atom from a lattice site to an interstitial position

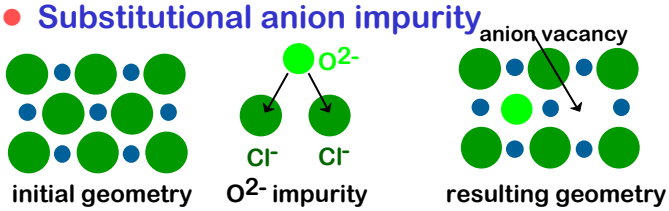


Point defects in ionic crystals

- **Impurities must also satisfy charge balance**
- **Ex: NaCl** Na^+ Cl^-
  - **Substitutional cation impurity**



  - **Substitutional anion impurity**



Point defects in ionic crystals

- Defect examples for other ionic crystal systems
  - ☑ In simple ionic crystals, both Schottky and Frenkel defects occur, but the concentration of one type generally exceeds that of the other
    - Schottky defects dominate in alkali halides
    - Cation Frenkel defects dominate in AgCl and AgBr
    - Anion Frenkel defects dominate in CaF_2 and fluorites

Electric properties

- Electrical conductivity: the mobility of charged point defects

$$\sigma = n(\mu^+ + \mu^-)e$$

$$\approx n\mu^+ e \approx \exp(-\frac{Ea}{KT})$$

Since the cation vacancy is more mobile than anion vacancy

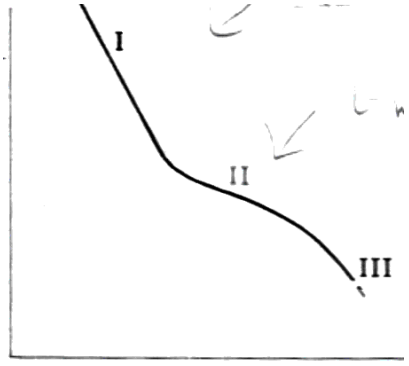
n-- defect concentration

e-- charge

μ-- mobility

Electric properties (continue)

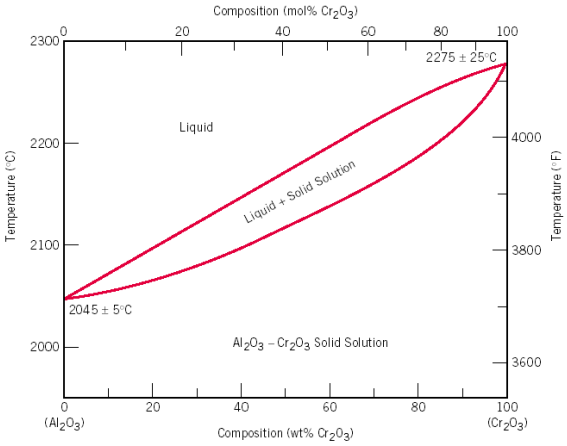
- Electrical conductivity
  - Region I: Schottky defects
    $E_a = E^+_m + 1/2(E_+ + E_-)$
  - Region II: Cation vacancies
    $E_a = E^+_m$
  - Region III: cation vacancies, impurity ions, clustering of defects



Effect of temperature on electrical conductivity of a NaCl crystal containing a small conc. of a divalent cation

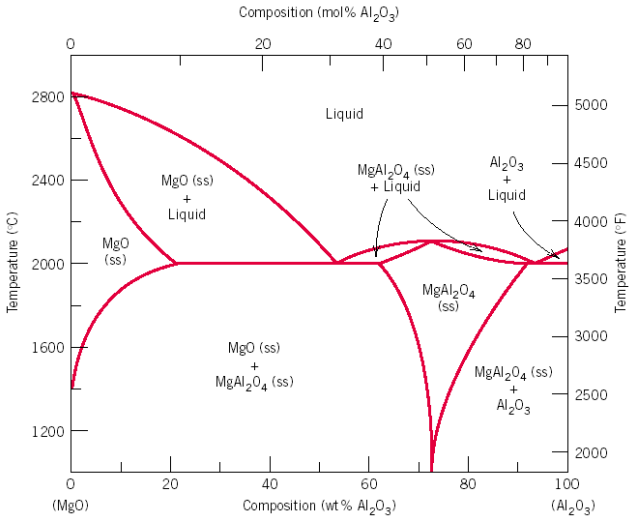
Ceramic phase diagram

- The Al_2O_3-Cr_2O_3 system
  - Isomorphous
  - In solid solution Al^{3+} substitute Cr^{3+}
  - Al and Cr should have have similar radius and same charge
  - Both Al_2O_3 and Cr_2O_3 have the same crystal structure



Ceramic phase diagram

- The Mg_2O-Al_2O_3 system
- Intermediate phase -- spinel compound

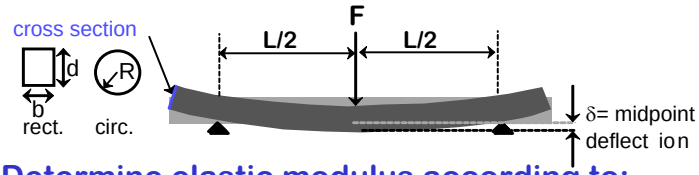


Stress-strain behavior

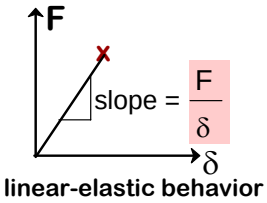
- Flectural testing replace tensile testing
- Reasons for not a standard tension test
  - difficult to prepare and test specimens having a required geometry
  - difficult to grip brittle materials without fracturing them
  - ceramics fail after only about 0.1% strain and samples are difficult to align without experiencing bending stress

Measuring elastic modulus

- Room T behavior is usually elastic, with brittle failure.
  3-Point Bend Testing often used.
- Tensile tests are difficult for brittle materials.



- Determine elastic modulus according to:

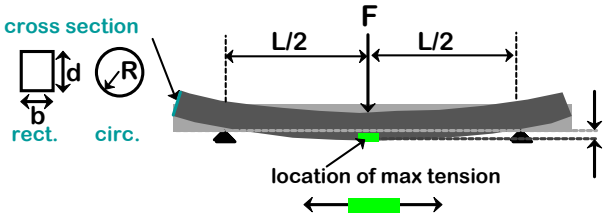


$$E = \frac{F}{\delta}\frac{L^3}{4bd^3} = \frac{F}{\delta}\frac{L^3}{12\pi R^4}$$

rect. cross section | circ. cross section

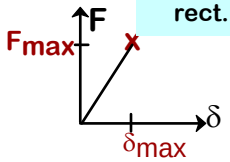
Measuring strength

- 3-point bend test to measure room T strength.



- Flexural strength:

$$\sigma_{fs} = \sigma_m^{fail} = \underbrace{\frac{1.5F_{max}L}{bd^2}}_{\text{rect.}} = \frac{F_{max}L}{\pi R^3}$$



- Typ. values:

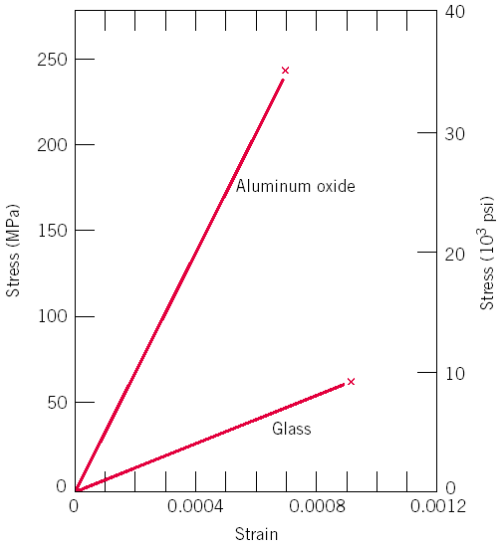
Material	σ_{fs} (MPa)	E(GPa)
Si nitride	700-1000	300
Si carbide	550-860	430
Al oxide	275-550	390
glass (soda)	69	69

Data from Table 12.5, *Callister 6e.*

10

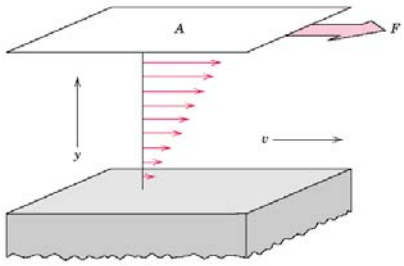
Elastic behavior

- Typical stress-strain behavior to fracture for aluminum oxide and glass



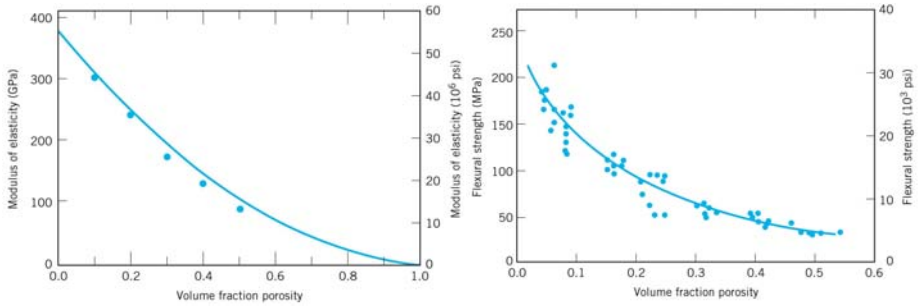
Mechanisms of plastic deformation

- Crystalline ceramics are brittle
  - Covalent bonds are relatively strong
  - There are limited numbers of slip systems
  - Dislocation structures are complex
- Noncrystalline ceramics
  - Plastic deformation does not occur by dislocation motion for noncrystalline ceramics
  - Viscosity is a measure of of non-crystalline material's resistance to deformation



Influence of porosity on mechanical behavior

- $E=E_0(1-1.9P+0.9P^2)$
- $\sigma_{fs}= \sigma_0 \exp(-nP)$



Hardness

Table 13.6 Approximate Knoop Hardness (100 g load) for Seven Ceramic Materials

Material	*Approximate Knoop Hardness*
Diamond (carbon)	7000
Boron carbide (B_4C)	2800
Silicon carbide (SiC)	2500
Tungsten carbide (WC)	2100
Aluminum oxide (Al_2O_3)	2100
Quartz (SiO_2)	800
Glass	550

Summary

- Ceramic materials have mostly ironic bonding& some covalent bonding.
- Defects
  --must preserve charge neutrality
  --have a concentration that varies exponentially w/T.
- Room T mechanical response is elastic, but fracture is brittle, with negligible ductility.
- Elevated T creep properties are generally superior to those of metals (and polymers).