Materials Science

ME 274

Dr Yehia M. Youssef

- Textbook:

Callister, W. D., “Materials Science and Engineering An Introduction”, 7th ed., John Wiley & Sons, Inc, 2007.

- Other References:

Shackelford, J. F., Introduction to Materials Science for Engineers, 6th ed., Prentice Hall, 2005.

Aims & Objectives

- The aim of the course is to give the students a good background knowledge about the Science of Engineering Materials.
- The objectives of the course include the following:
  - To illustrate the relationship between the structure and properties of different engineering materials.
  - To explain how the structures can be modified in order to achieve specific properties with emphasis on some typical applications.

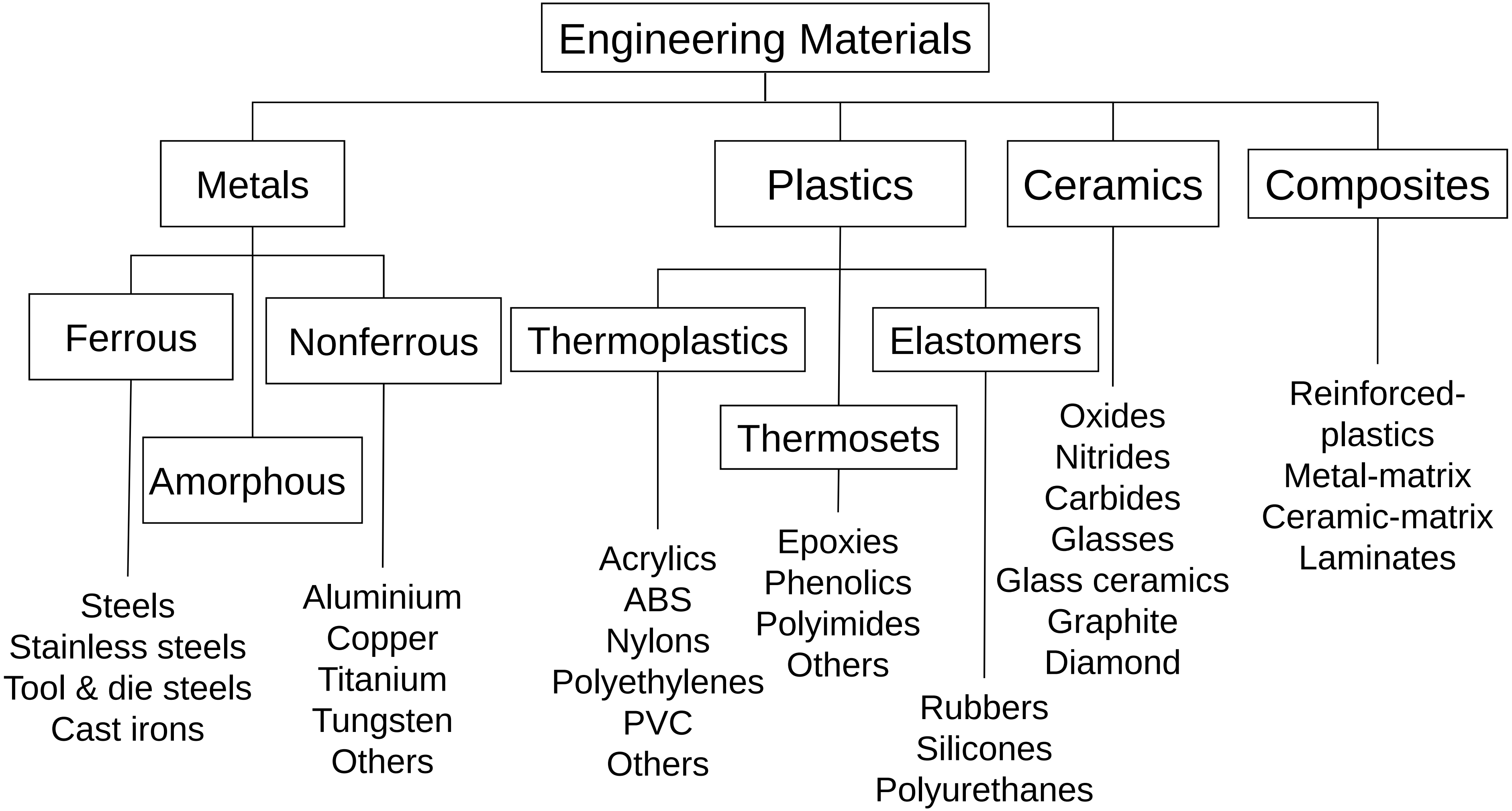
Outlines

- W1: General Introduction
  Classification of Engineering Materials
- W2: Atomic Bonding in Solids
- W3: The Structure of Crystalline Solids
- W4: Imperfections in Solids- Crystal Defects
- W5: Diffusion
- W6: Mechanical Properties of Materials
- W7: Exam
- W8: Mechanical Properties of Materials - Testing
- W9: Dislocations and strengthening Mechanisms

Outlines

- W10: Introduction to Phase Diagrams
- W11: Phase Transformations in Metals
- W12: Exam
- W13: The Iron-carbon System
- W14: Heat Treatment of Metals
- W15: Review
- W16: Final Exam

Classification of Engineering Materials



Evolution of Engineering Materials with Time

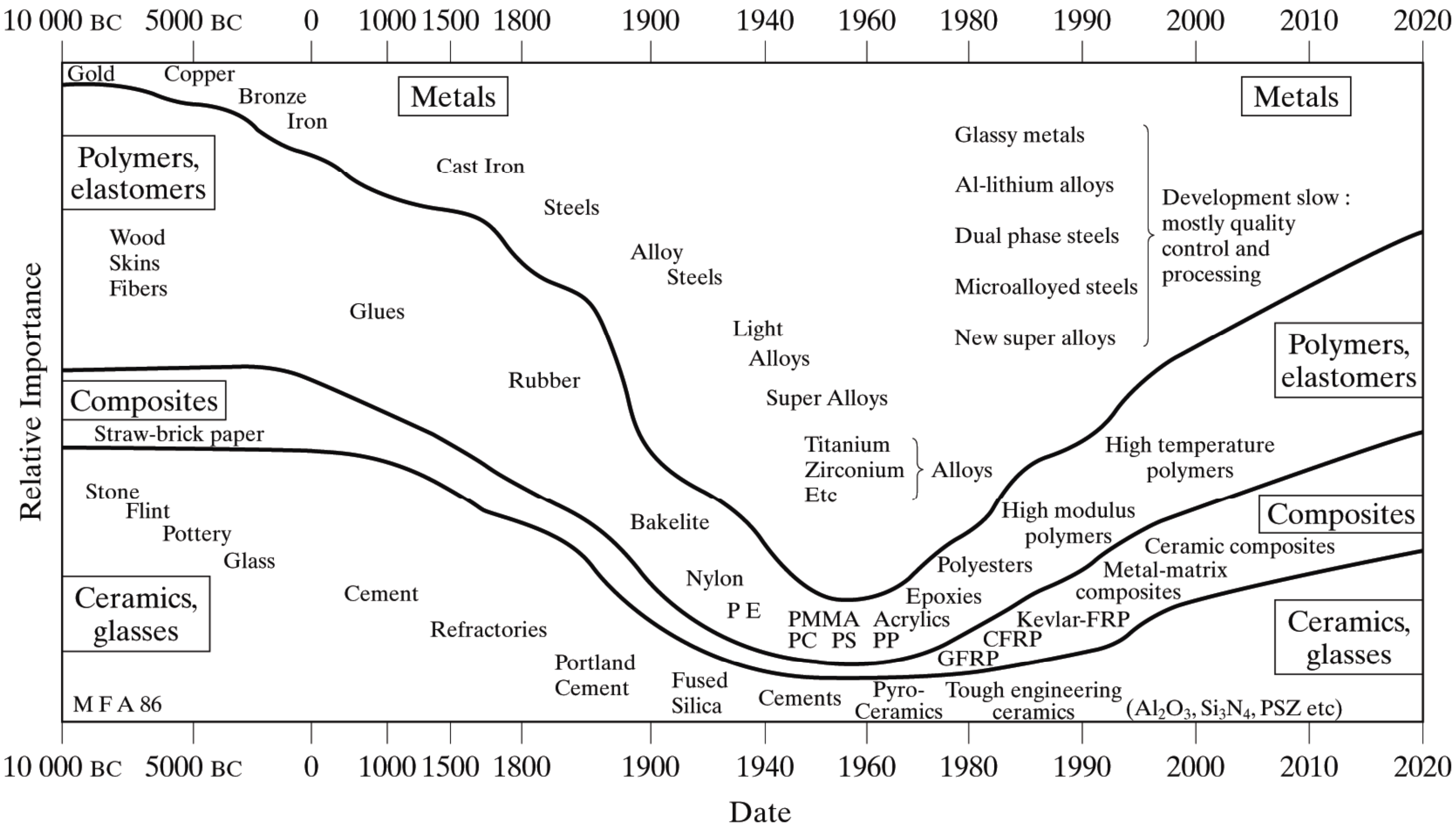


Figure 1.1

The evolution of engineering materials with time. Note the highly nonlinear scale. (From M. F. Ashby, Materials Selection in Mechanical Design, *2nd ed., Butterworth-Heinemann, Oxford, 1999.)*

The Periodic Table of The Elements

I A	II A	III B	IV B	V B	VI B	VII B	VIII			I B	II B	III A	IV A	V A	VI A	VII A	O
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg												

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw

Figure 1.3

Periodic table of the elements. Those elements that are inherently metallic in nature are shown in color.

Types of Engineering Materials

The different types of materials include:

- **Metals**; shaded elements in the periodic table; a large family which includes
  - Irons and Steels (based on Fe),
  - Aluminium alloys (based on Al),
  - Magnesium alloys (based on Mg),
  - Titanium alloys (based on Ti),
  - Nickel alloys (based on Ni),
  - Zinc alloys (based on Zn), and
  - Copper alloys (based on Cu), including brasses.
- **Ceramics and glasses**; one of the common oxide ceramics is alumina; Al_2O_3. Ceramics have superior chemical and temperature-resistant properties compared with metals, however, they are brittle.

Types of Engineering Materials

- Magnesium oxide (MgO), and silica (SiO_2) are other examples of ceramics. In addition SiO_2 is the basis of a large complex family of silicates which includes clays and clay-like minerals.
- The general term for noncrystalline solids with composition comparable to those of crystalline ceramics is **Glass**. Most common glasses are silicates; ordinary window glass is ~ 72% silica by weight, with the balance being sodium oxide (Na_2O) and calcium oxide (CaO). The third class is glass-ceramics.

- **Polymers** (or plastics); polymers are long-chain molecules composed of many mers bonded together. The most common commercial polymer is polyethylene $-(C_2H_4)-_n$ where n can range from 100 to 1000. Many important polymers are simply compounds of H and C.

Types of Engineering Materials

  - Other polymers contain Oxygen (e.g. acrylics), nitrogen (nylons), fluorine (fluoroplastics) and silicon (silicones).
- **Composites**; this set of materials is made up of some combinations of individual materials from the previous categories. An example is fibreglass. The high strength of the small-diameter glass fibres is combined with the ductility of the polymer matrix to produce a strong material capable of withstanding the normal loading required of a structural material.
  - Different classes of composites may include:
    - Polymer-matrix composites
    - Metal-matrix composites
    - Ceramic-matrix composites

Types of Engineering Materials

- **Semiconductors**; a relatively small group of elements and compounds has an important electrical property, semiconduction, in which they are neither good electrical conductors nor good electrical insulators. Instead their ability to conduct electricity is intermediate. The three elements; silicon (Si), germanium (Ge), and tin (Sn) serve as kind of boundary between metallic and non-metallic elements. Si and Ge are widely used elemental semiconductors. Precise control of their chemical purity allows precise control of electronic properties.