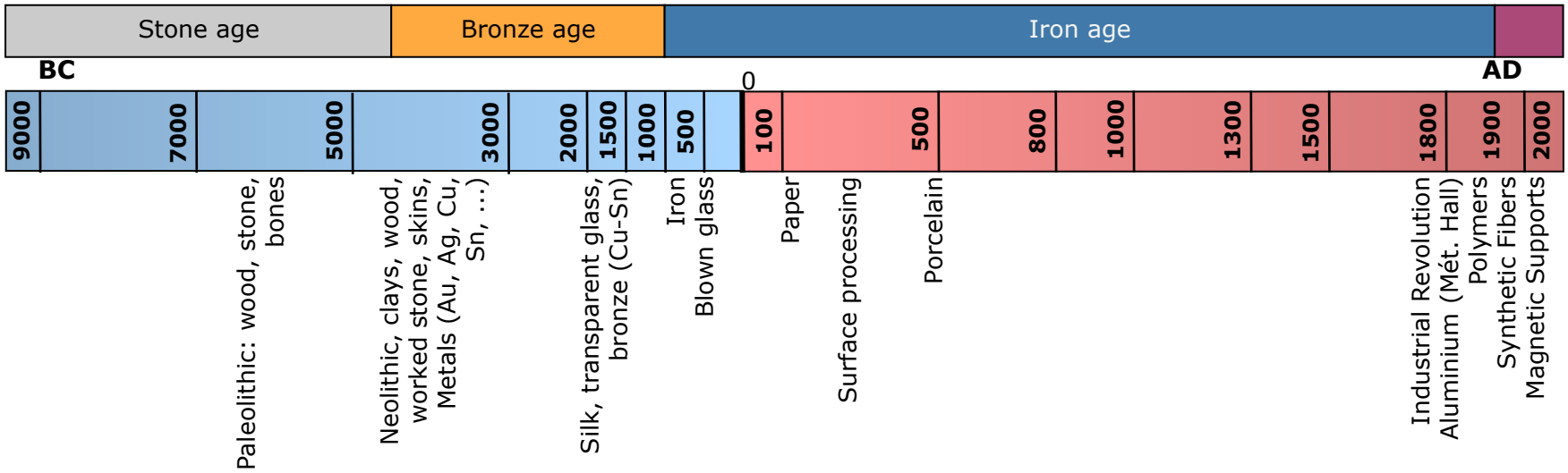
Universidad
Carlos III de Madrid
www.uc3m.es

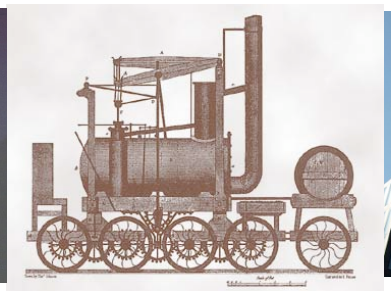
MATERIALS SCIENCE AND ENGINEERING

TOPIC 1.1. FAMILIES OF MATERIALS, PROPERTIES APPLICATIONS AND SELECTION CRITERIA.

- Historic evolution of Materials Science and Engineering
- The Science and Engineering of Materials
- Materials Classification
- General properties of Materials
- Going from Structure to Materials Properties
- Materials Selection

HISTORIC EVOLUTION OF MATERIALS

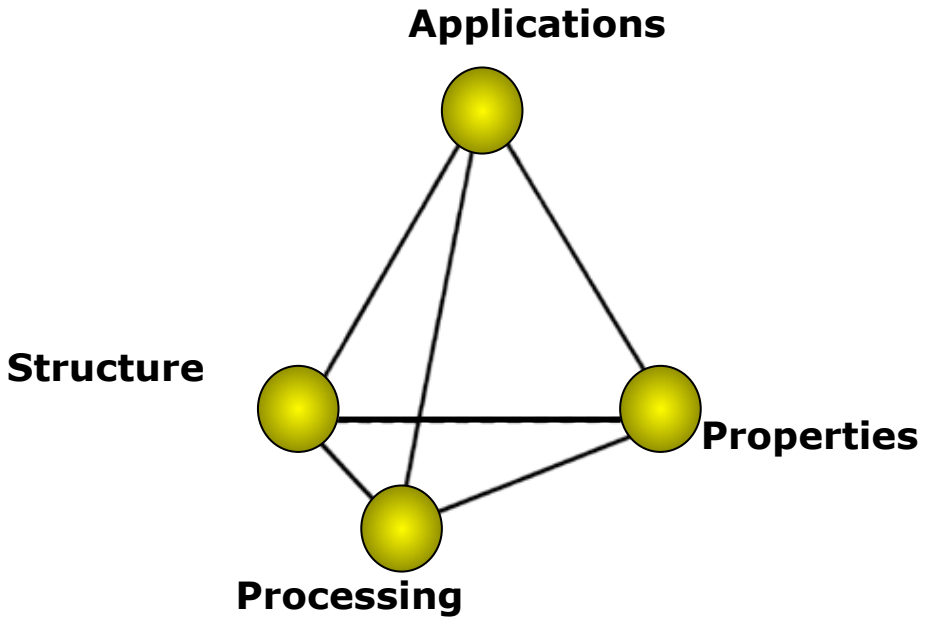




MATERIALS SCIENCE AND ENGINEERING

Materials Science: basic knowledge about the internal structure, properties and processing of materials.

Materials Engineering: fundamental knowledge applied to materials in order to transform them into useful products required by the society.



CLASSIFICATION OF MATERIALS

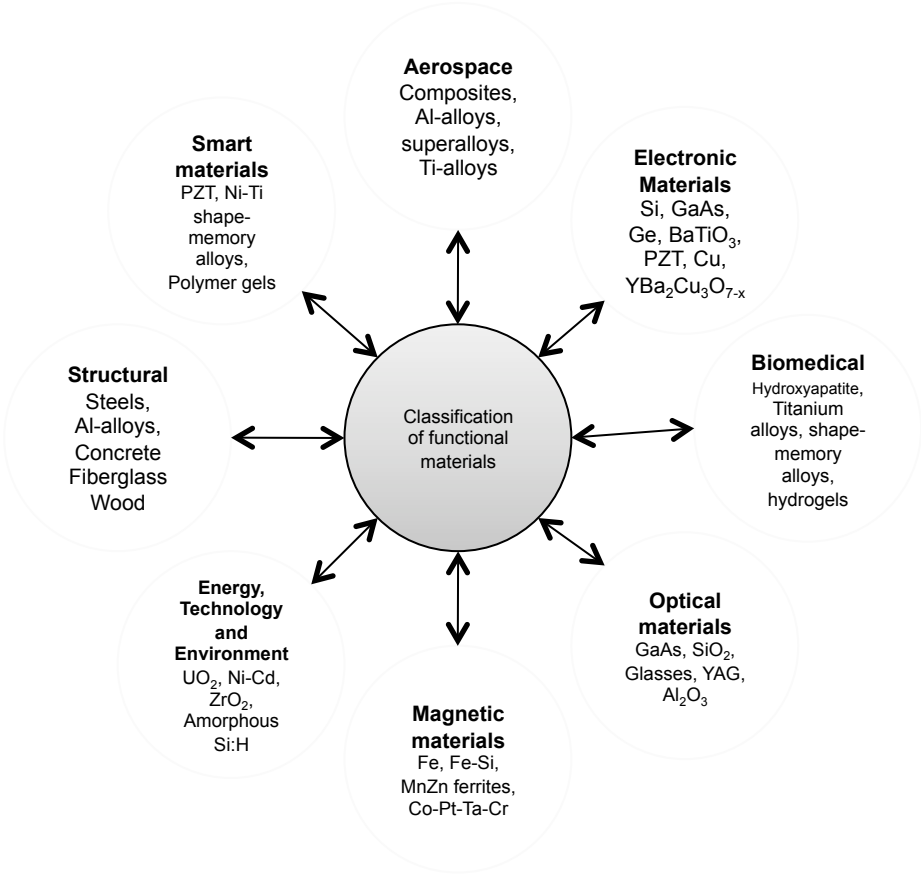
Material	Composition	Structure	Properties
Metals	Metals	Crystalline	$\uparrow\sigma_e$, $\uparrow\sigma_t$, $\uparrow R$
Polymers	Chains of organic molecules	Semi crystalline or amorphous	$\downarrow\sigma_e$,$\downarrow\sigma_t$, $\downarrow\rho$
Ceramics	Metals + no metals	Crystalline or amorphous	↑hardness, ↑brittleness

Composite materials: system or combination of materials that results from the union (not chemical, insoluble between them) of two or more components, creating a new material with specific properties and characteristics, with properties different from the constituent materials .

CLASSIFICATION OF MATERIALS

Functional classification :

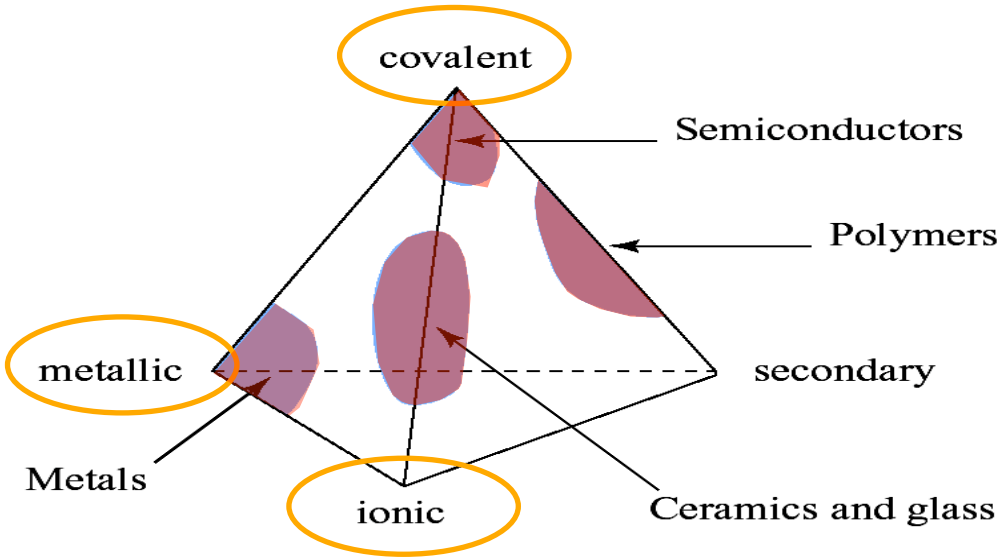
- Aerospace
- Biomedical
- Electronic Materials
- Energy Technology and Environment
- Magnetic Materials
- Optical and Photonic Materials
- "Smart" Materials
- Structural Materials



GENERAL PROPERTIES OF MATERIALS

Nature of bonding ↔ properties ↔ type of materials

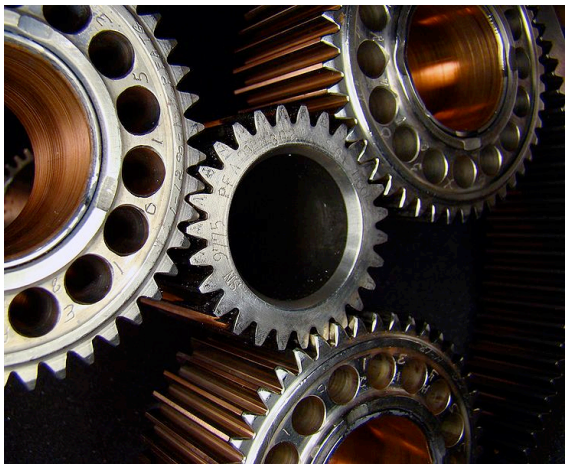
Type of material	Character of bonding	Examples
Metal	Metallic	Fe, steels
Ceramic and glasses	Ionic/ covalent	Silica (SiO_2)
Polymers	Covalent and secondary	Polyethylene $-(CH_2)-$



GENERAL PROPERTIES OF MATERIALS

Metals and Metallic alloys

- Characteristic shine
- Electrical and thermal conductivity
- Workability
- Ductility



http://commons.wikimedia.org/wiki/File:Reduction_Gear.jpg

http://commons.wikimedia.org/wiki/File:Under_the_bridge_-_Oresund_Bridge.jpg

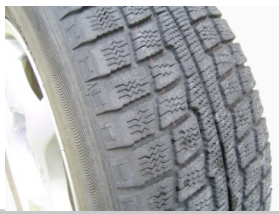
GENERAL PROPERTIES OF MATERIALS

Polymers

- Principally based on chains of carbon atoms joined by covalent bonds.

  - Thermoplastics
  - Thermostable
  - Elastomers

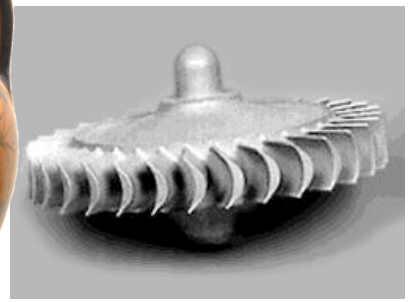
- Thermal and electric insulators
- Good specific properties
- Low working temperature



GENERAL PROPERTIES OF MATERIALS

Ceramics

- High hardness
- Brittleness
- Electric and thermal insulators
- Workability
- Good thermal and chemical stability.



http://perso.wanadoo.es/chyryes/glosario/cer_fun.htm

GENERAL PROPERTIES OF MATERIALS

Composite Materials

- Great range of properties
- Depend on the constituent materials
- General classification as a function of the matrix and the reinforcement
  - Ceramic matrix
  - Metallic matrix
  - Polymeric matrix

FROM STRUCTURE TO PROPERTIES

Structure:

- Distribution of e^- affects the electric , magnetic, thermal , optical behaviour, and the corrosion resistance.
- Bonding determines the type of material
- The positioning of atoms in space ⇒ crystalline structure ⇒ influences mechanical properties

Properties

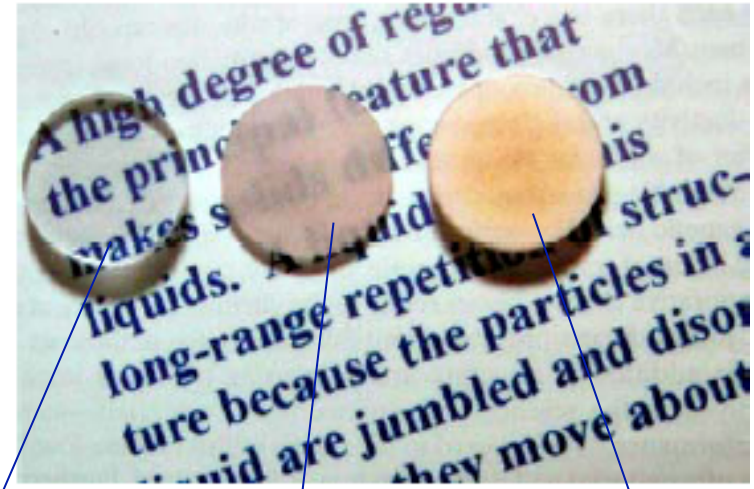
- Mechanical ($R_{mecánica}$, ductility, $R_{impacto}$...)
- Physico-chemical (Corrosion resistance, electrical, magnetic, optical…)

Processing

- Moulding process
- Plastic deformation process
- Joining process
- Mechanical working process

FROM STRUCTURE TO PROPERTIES

Structure, Properties and Processing

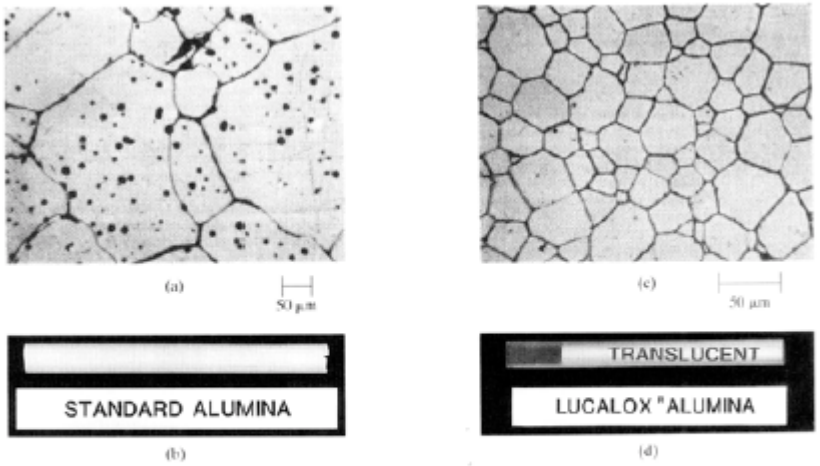


Transparent
Single crystal
without defects

Translucent
Polycrystalline
Grain boundaries

Opaque
Polycrystalline
Grain boundaries + pores

William D. Callister Materials Science and Engineering: An Introduction, John Wiley & Sons



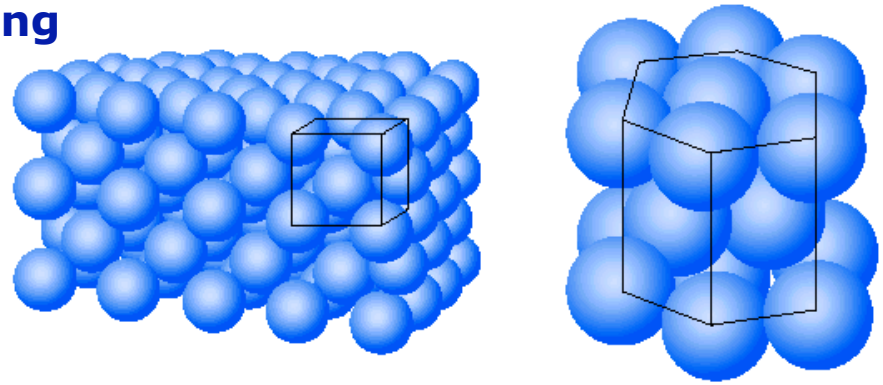
Porous microstructure in polycrystalline Al_2O_3 (a) leads to an opaque material (b). Nearly pore-free microstructure in polycrystalline Al_2O_3 (c) leads to a translucent material.

J.F. Shackelford, Introduction to Materials Science and Engineering for Engineers; Prentice Hall.

FROM STRUCTURE TO PROPERTIES

Structure, Properties and Processing

Atomic Scale
Al alloys: ductile
Mg alloys: relatively brittle



(a) Aluminum (b) Magnesium

J.F. Shackelford, Introduction to Materials Science and Engineering for Engineers; Prentice Hall.

- planes and directions of high atomic density
- easily deformed mechanically
- **Ductility**

http://commons.wikimedia.org/wiki/File:149405.jpeg

Al: 12 planes and directions → major capacity for de deformation
Mg: 3 planes and directions

FROM STRUCTURE TO PROPERTIES

	Example of application	Properties
Metals and alloys Foundry products	Automotive motors	Castable, absorber of vibrations
Ceramics and glasses SiO_2-Na_2O-CaO	Windows	Optically transparent, thermal insulators
Polymers Polyethylene	Packaging and bags	Easily processed in thin layers , flexible and hermetic
Semiconductors Silicon	Transistors and intergraded circuits	Unique electrical properties
Composite Materials WC-Co	Cutting and forming tools	Elevated hardness and relatively good impact resistance

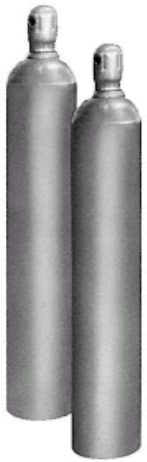
SELECTION OF MATERIALS

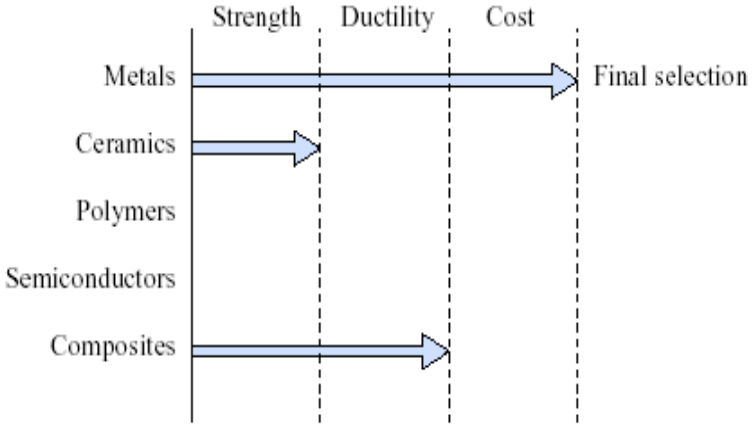
• Practical examples. Preliminary considerations

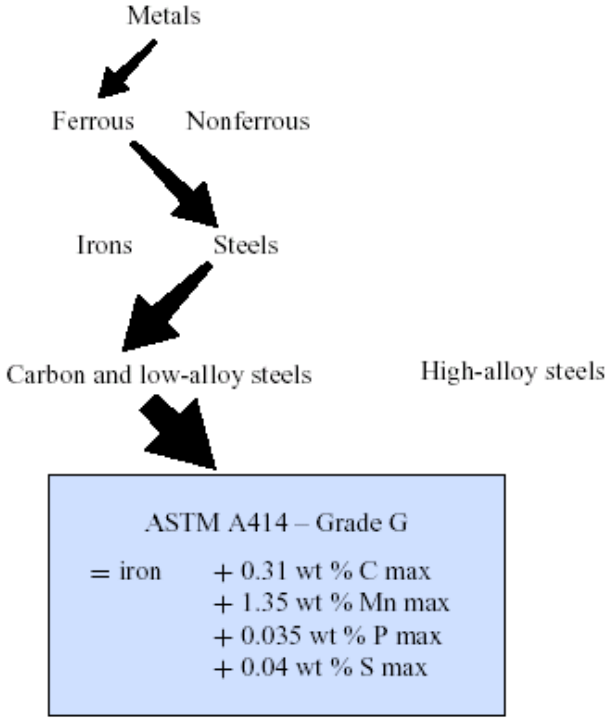
Which material is appropriate? Within a predetermined group, which is the best?

Steps for materials selection: gas cylinder

- Evaluate requirements for storing gases at ↑ P (14 MPa)
- Eliminate materials that do not satisfy the limiting characteristics: ($R_{mehanical}$ and strength): polymers and ceramics
- Choose the one with the lowest cost: metals





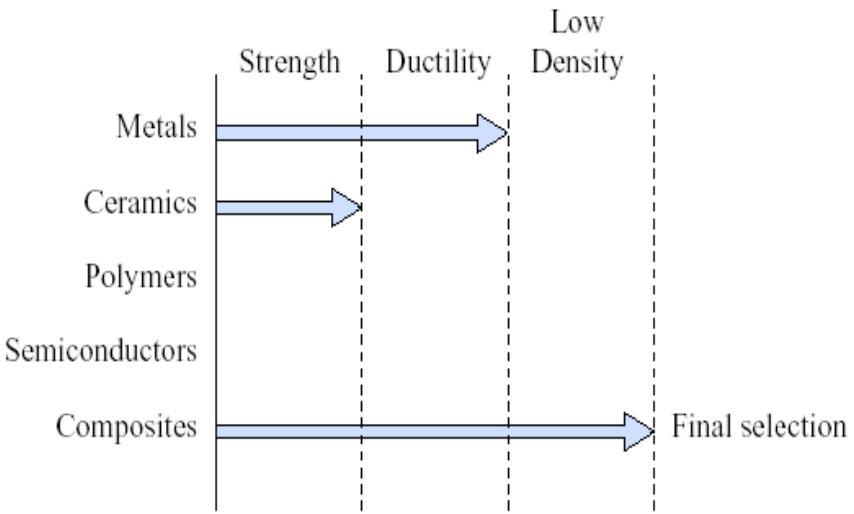


J.F. Shackelford, Introduction to Materials Science and Engineering for Engineers; Prentice Hall

SELECTION OF MATERIALS

- **Practical examples. Preliminary considerations**

Steps for materials selection: Spaceship
Evaluate requirements for a pressure container of a spaceship



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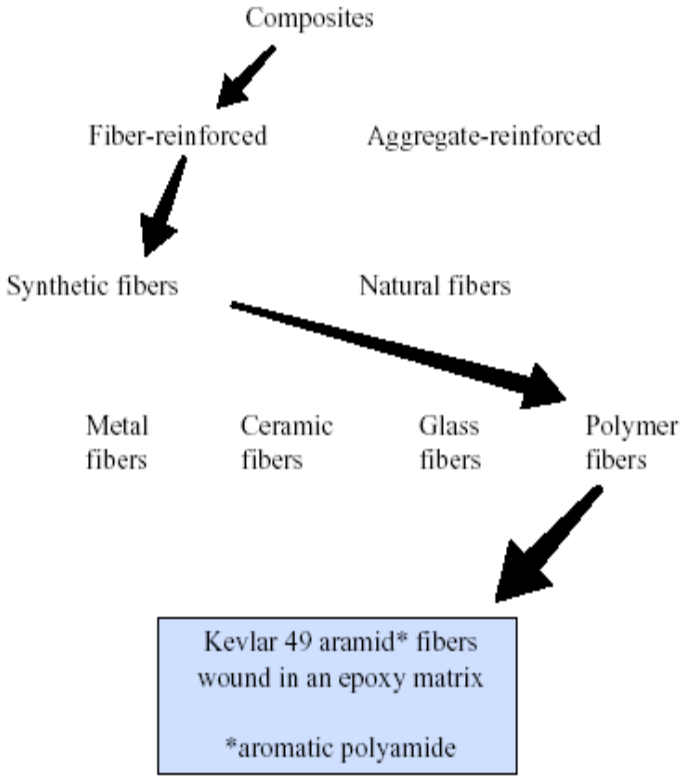
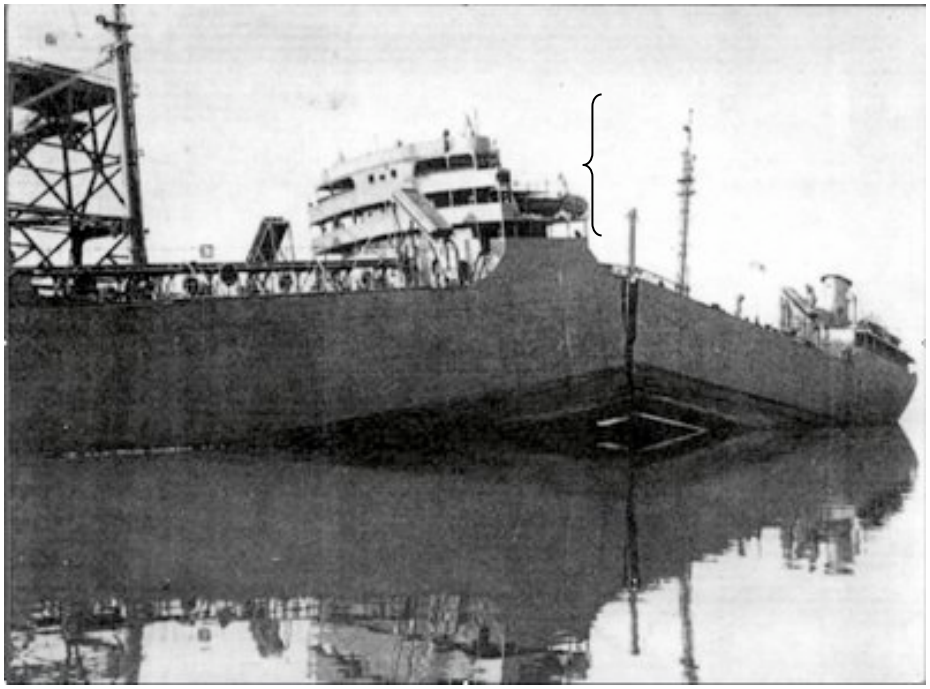


SELECTION OF MATERIALS

- **Practical examples.**

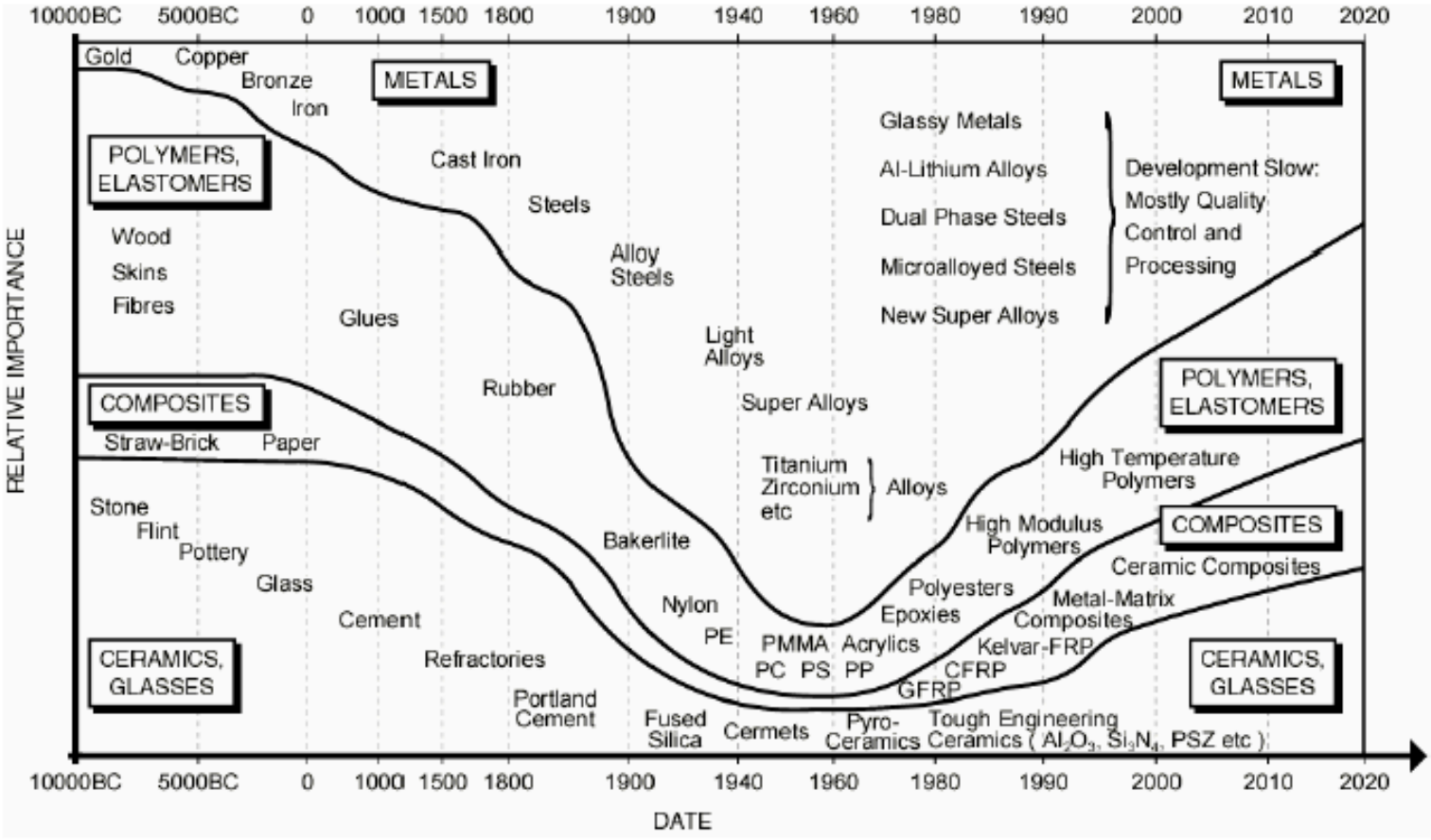


Transport ship of the II World War . Brittle fracture of the steel hull due to low temperatures.

Causes of materials failures :

- Selection and/or inadequate design
- Improper use during service

EVOLUTION AND SUBSTITUTION

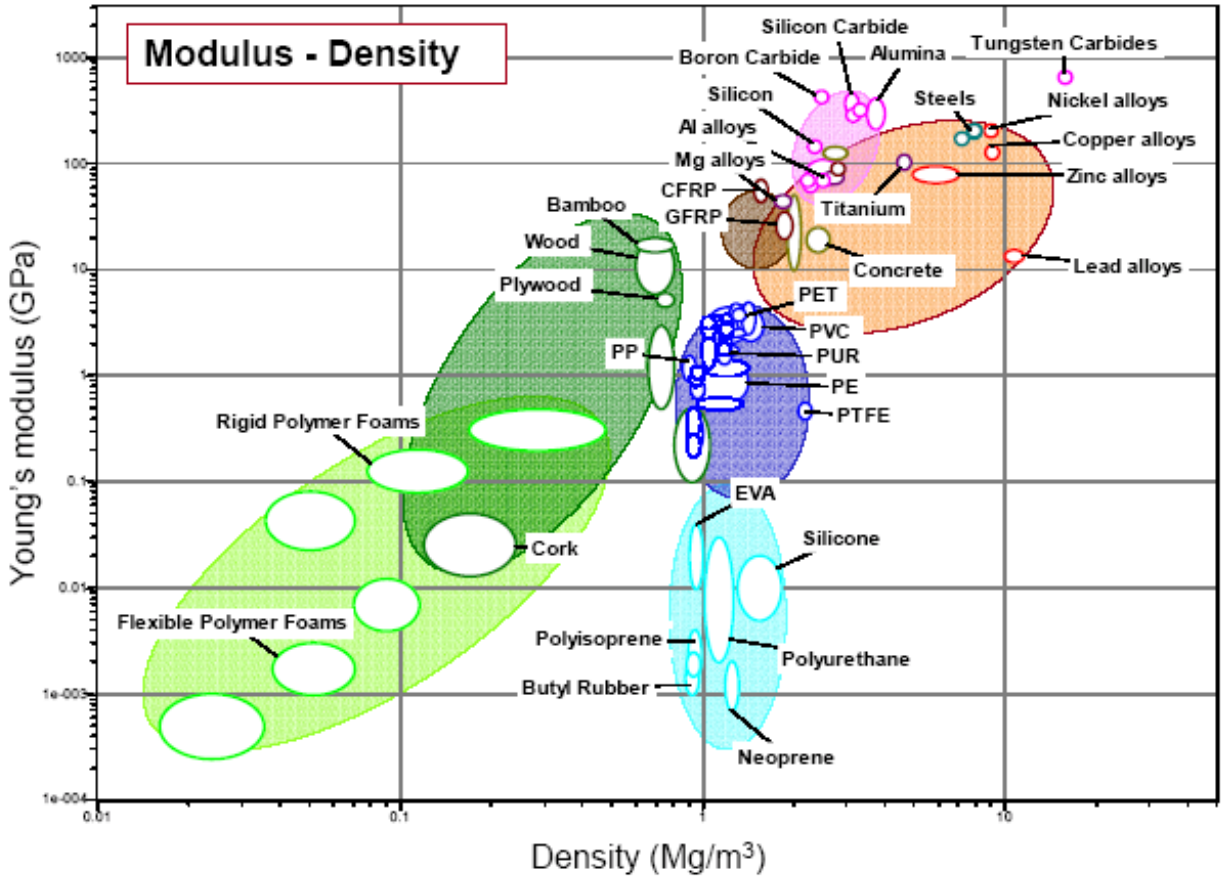


M.F. Ashby, Materials Selection in Mechanical Design, Butterworth-Heinemann

http://ocw.mit.edu/OcwWeb/Materials-Science-and-Engineering/3-080Fall-2005/CourseHome/

SELECTION OF MATERIALS

- **Property Diagrams**



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