Introduction to Materials Science & Engineering

Course Objective...

Introduce fundamental concepts in Materials Science

You will learn about:

- material structure
- how structure dictates properties
- how processing can change structure

This course will help you to:

- use materials properly
- realize new design opportunities with materials

Chapter 1 - Introduction

- **What is materials science?**

  The discipline of *materials science* involves investigating the relationships that exist between the structures and properties of materials

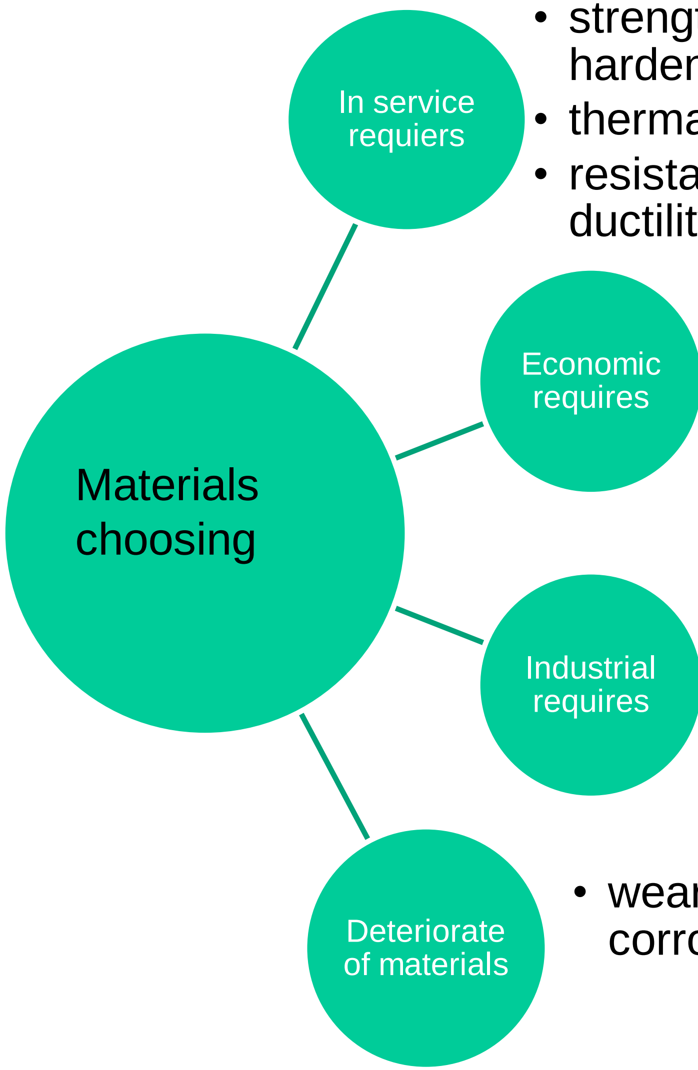
- **What is materials engineering ?**

  Designing or engineering the structure of a material to produce a predetermined set of properties

- **Microscopic: a larger structural realm, which contains large groups of atoms, that are normally agglomerated together**

- **Macroscopic: structural elements that may be viewed with the naked eye.**

Materials choosing



- strength, hardeness,
- thermal,
- resistant, ductility

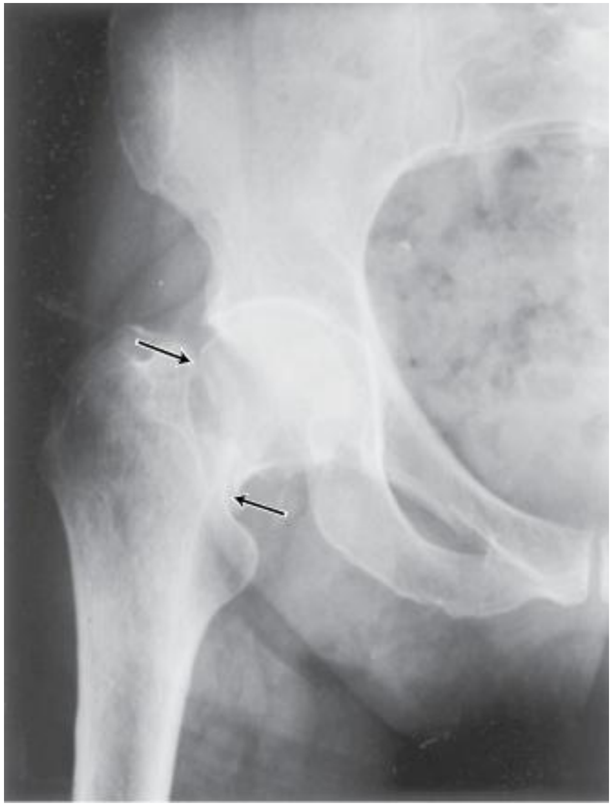
- materials cost, machine cost, process time

Easily parts assemble, machine ability of runing, cast properties

- wear, oxidation, corrosion

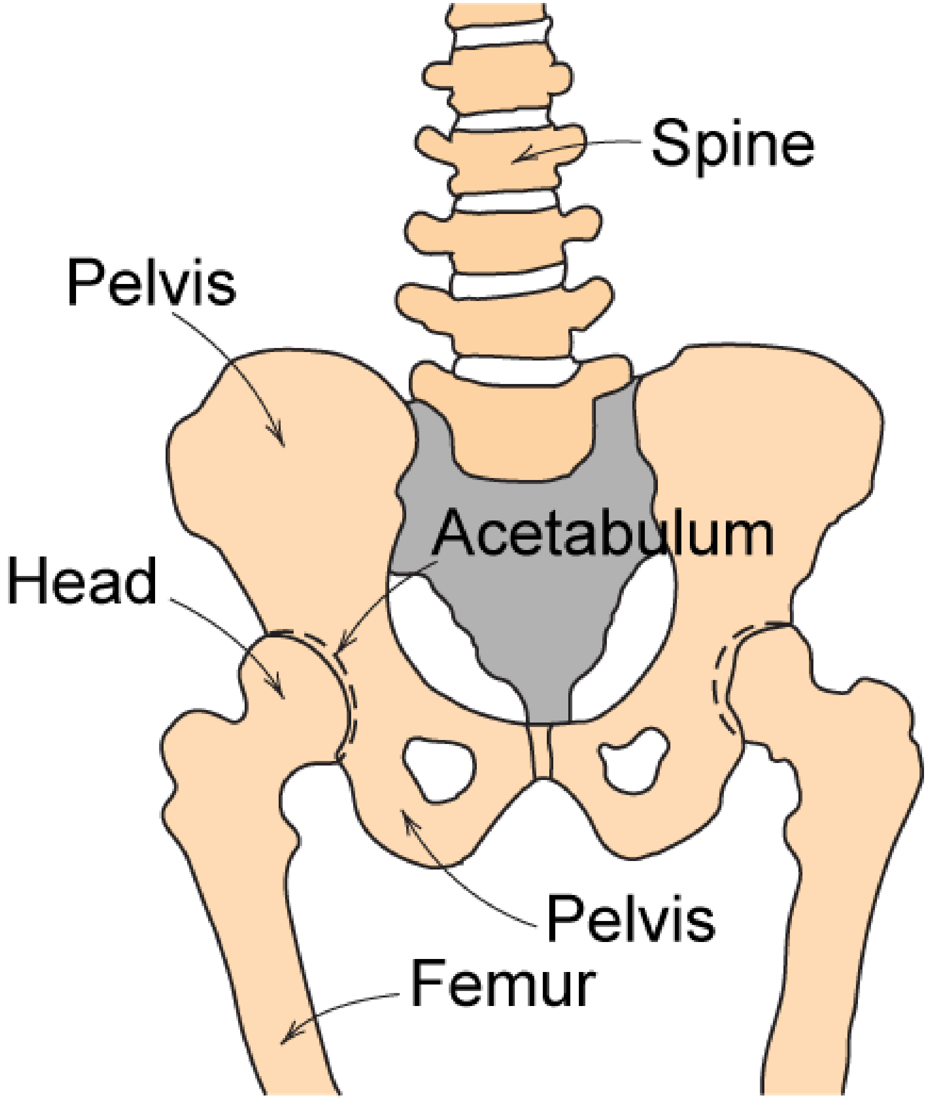
Example – Hip Implant

- With age or certain illnesses joints deteriorate. Particularly those with large loads (such as hip).

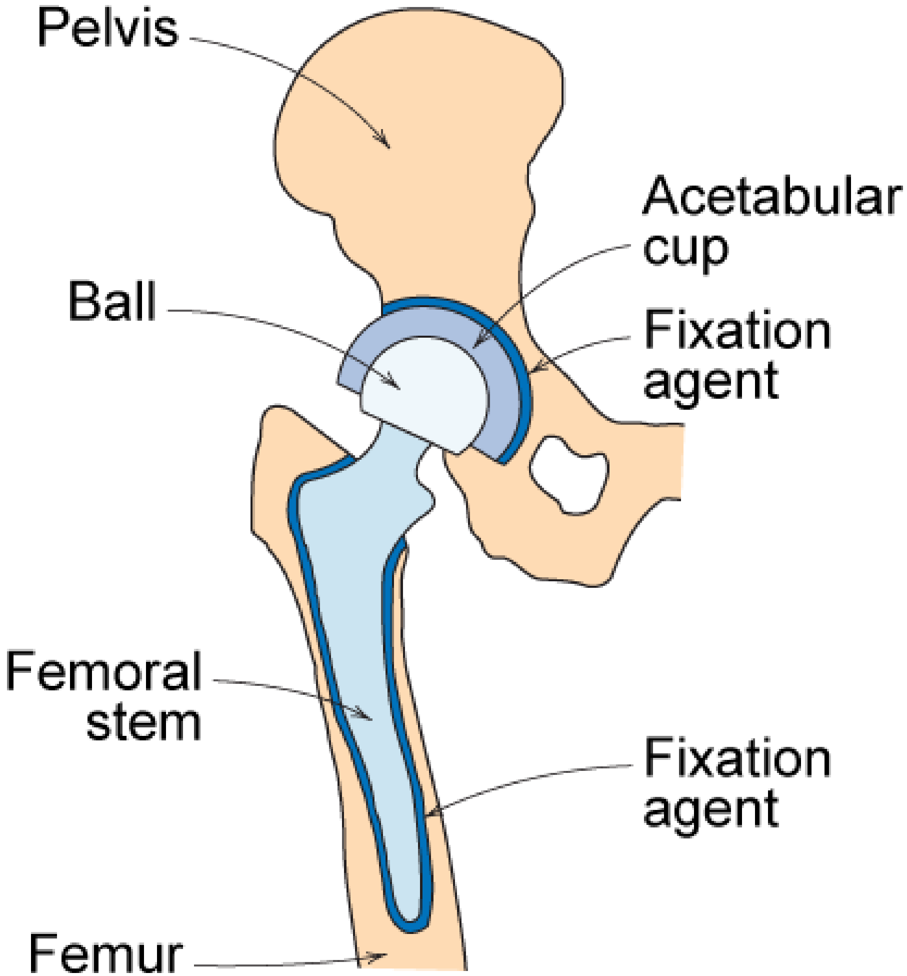


Example – Hip Implant

- Requirements
  - mechanical strength (many cycles)
  - good lubricity
  - biocompatibility



Example – Hip Implant

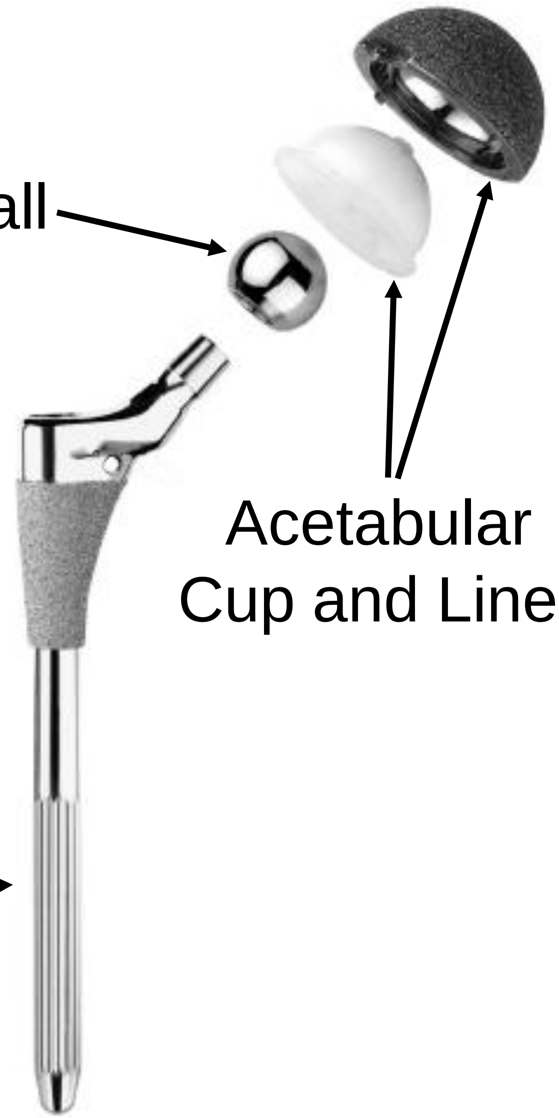


(a)

(b)

Hip Implant

- Key problems to overcome
  - fixation agent to hold acetabular cup
  - cup lubrication material
  - femoral stem – fixing agent (“glue”)
  - must avoid any debris in cup



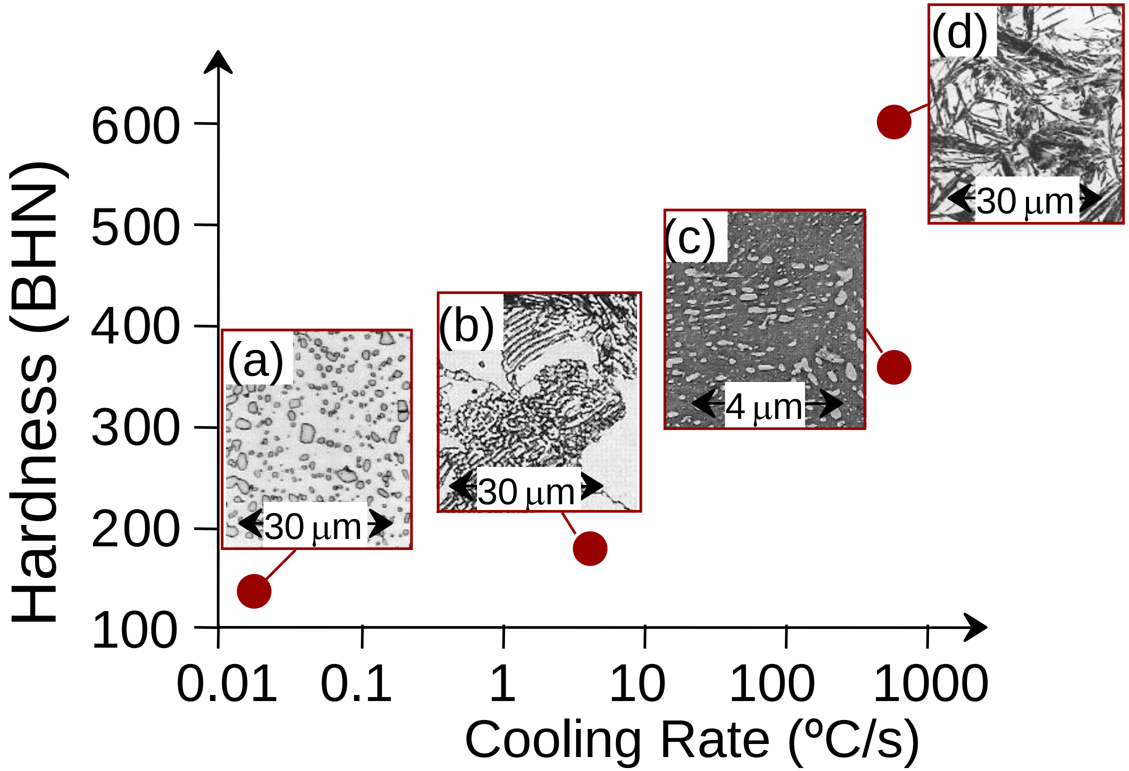
The four components of the discipline of materials science and engineering and their linear interrelationship:

processing--> structure ---> properties --> performance

With regard to the relationships of these four components, the structure
of a material will depend on how it is processed. Furthermore, a material’s performance will be a function of its properties. Thus, the interrelationship between processing, structure, properties, and performance is linear

Structure, Processing, & Properties

- Properties depend on structure
  ex: hardness vs structure of steel



- Processing can change structure
  ex: structure vs cooling rate of steel

Types of Materials

- Metals:
  - Strong, ductile
  - high thermal & electrical conductivity
  - opaque, reflective.

- Polymers/plastics:
  - include the familiar plastic and rubber materials
  - covalent bonding → sharing of electrons
  - soft, ductile, low strength, low density
  - thermal & electrical insulators
  - optically translucent or transparent.
  - many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements

Ceramics:

- ionic bonding (refractory)
– compounds of metallic & non-metallic elements (oxides, carbides, nitrides, sulfides)
- Brittle, glassy, elastic
- non-conducting (insulators)
- ex. Aluminium oxide(Al_2O_3), silicon dioxide (SiO_2)

Composites :

- is composed of two (or more) individual materials, which come from the categories discussed above.
- composite is designed to display a combination of the best characteristics of each of the component materials
-ex.Fiberglass is a familiar example, in which glass fibers are embedded within a polymeric material. Fiberglass acquires strength from the glass and flexibility from the polymer

The Materials Selection Process

1. Pick Application ⟶ Determine required Properties

   Properties: mechanical, electrical, thermal, magnetic, optical, deteriorative.

2. Properties ⟶ Identify candidate Material(s)

   Material: structure, composition.

3. Material ⟶ Identify required Processing

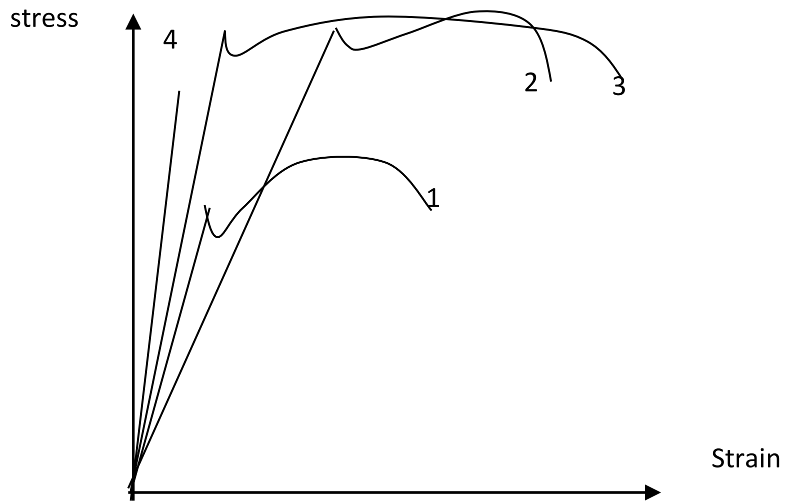
   Processing: changes *structure* and overall *shape*
   ex: casting, forming, joining, annealing.

important properties of solid materials may be grouped into six catagories

- **Mechanical properties relate deformation to an applied load or force; examples include elastic modulus and strength**
- **Electrical properties, such as electrical.**

- **Thermal properties** of solids can be represented in terms of heat capacity and thermal conductivity
- **Magnetic properties** demonstrate the response of a material to the application of a magnetic field
- **Optical properties**, the stimulus is electromagnetic or light radiation; index of refraction
- **Deteriorative properties** indicate the chemical reactivity of materials

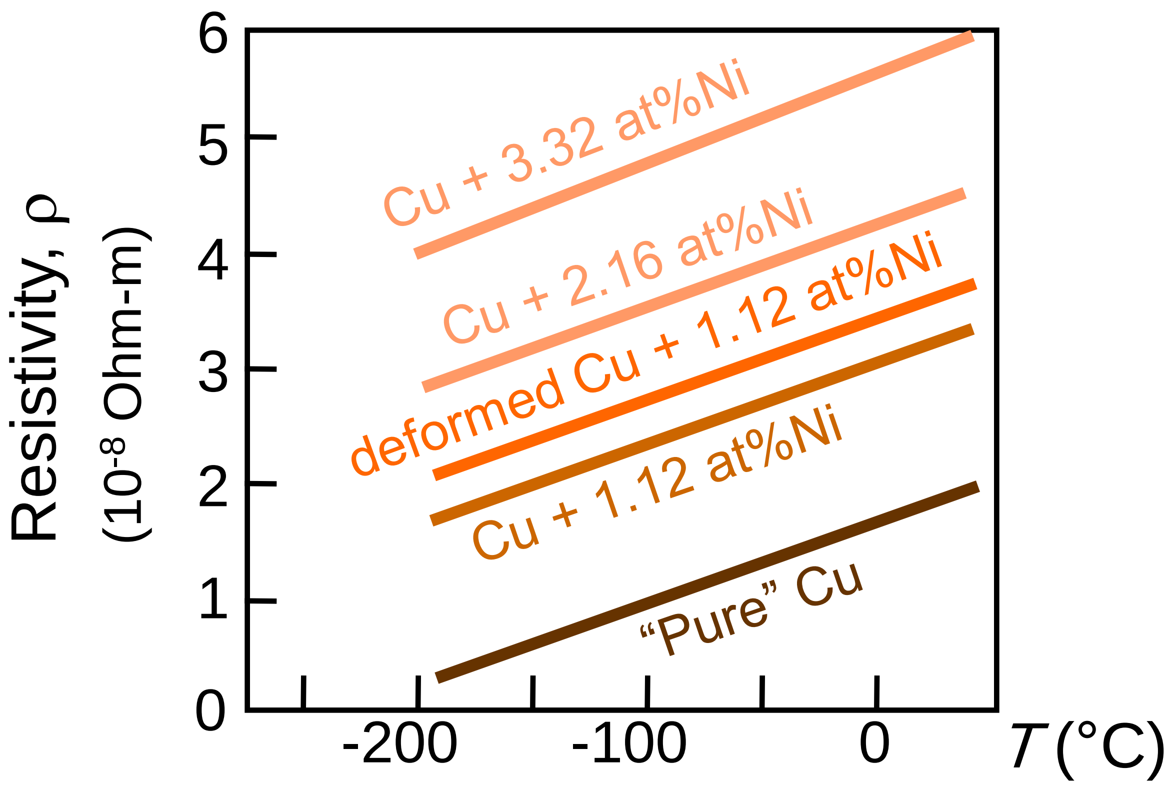
Mechanical



Type of loading
Strength, toughness, ductility

ELECTRICAL

- Electrical Resistivity of Copper:



- Adding "impurity" atoms to Cu increases resistivity.
- Deforming Cu increases resistivity.

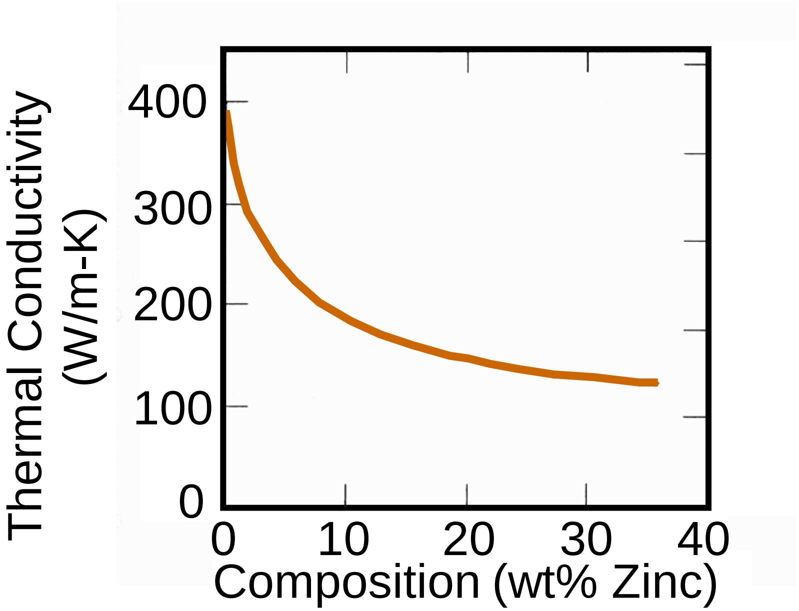
THERMAL

- Thermal Conductivity

  of Copper:

  --It decreases when

  you add zinc!



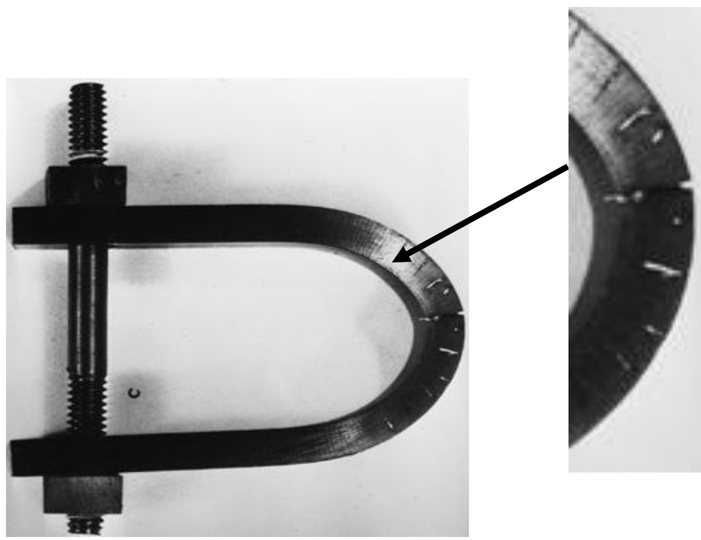
OPTICAL

- Transmittance:

  --Aluminum oxide may be transparent, translucent, or opaque depending on the material structure.

DETERIORATIVE

- Stress & Saltwater...
  --causes cracks!



Advanced Materials

- Materials that are utilized in high-technology (or high-tech) applications
- By high technology we mean a device or product that operates or functions using relatively Complicat and sophisticated principles

Examples include electronic equipment CD players, computers, spacecraft, aircraft, and military rocketry.

- They may be of all material types (e.g., metals, ceramics, polymers), and are normally relatively expensive

ex. Semiconductors materials, Biomaterials, materials of the future (smart materials, nano-engineered materials)

1. Semiconductors material :

- **Semiconductors have electrical properties that are intermediate between the electrical conductors (metals) and insulators (ceramics and polymers)**
- **The electrical characteristics of these materials are extremely sensitive to the presence of minute concentrations of impurity atom**
- **The semiconductors have made possible the advent of integrated circuitry that has totally revolutionized the electronics and computer industries**

2. Biomaterials :

- **are employed in components implanted into the human body for replacement of diseased or damaged body parts**
- **These materials must not produce toxic substances and must be compatible with body tissues**
- **all of the above materials—metals, ceramics, polymers, composites, and semiconductors—may be used as biomaterials**

Materials of The Future

a) Smart materials:

a) These materials are able to sense changes in their environment and then respond to these changes in predetermined manner (sensors)

b) Ex. One type of smart materials is used in helicopter to reduce aerodynamic noise that is created by the rotating rotor blades

c) Ex. Piezoelectric sensors inserted into blades monitoring blades

stresses and deformations

b) Nano engineered materials:

a) The dimensions of these structures are on the order of a nanometer

b) They are materials which are built from simple atomic level constituents (i.e., materials by design)

c) This ability to carefully arrange atoms provide opportunities to develop mechanical, electrical, magnetic, and other properties that are not otherwise possible (ex. Carbon nanotube)

SUMMARY

Course Goals:

- Use the right material for the job.
- Understand the relation between properties, structure, and processing.
- Recognize new design opportunities offered by materials selection.