Chapter 1

Introduction

The University of Jordan

Chemical Engineering Department

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Outlines

- What is materials science?
- Structure, Processing, & Properties
- Types of Materials
- The Materials Selection Process
- Materials Properties

Materials Science

What is materials science?

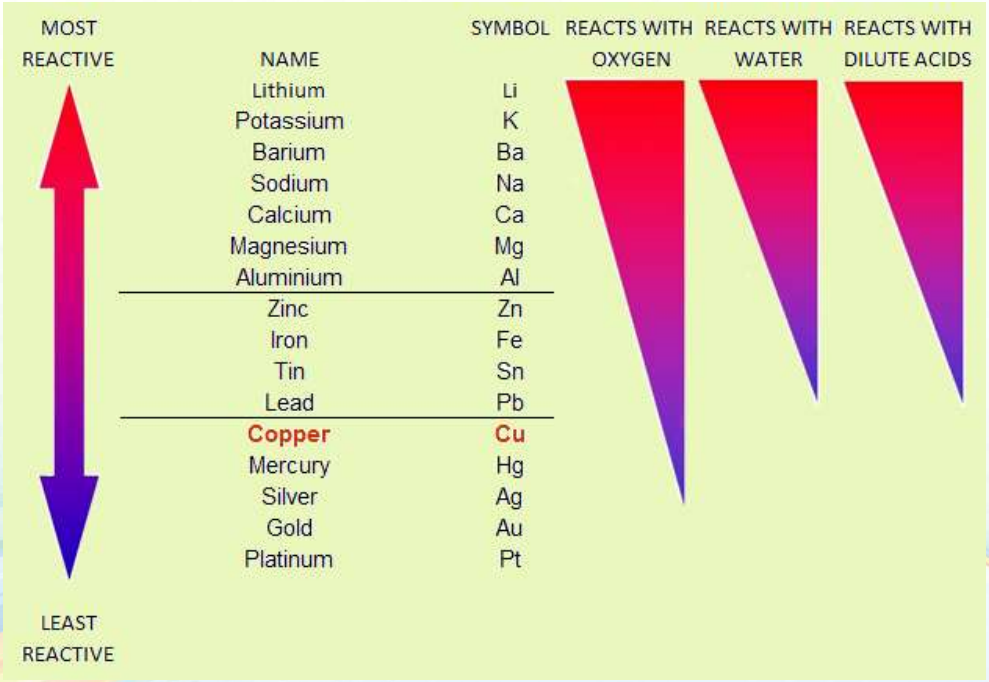
- Materials science or materials engineering is an interdisciplinary field involving the properties of matter and its applications to various areas of science and engineering.
- This science investigates the relationship between the structure of materials at atomic or molecular scales and their macroscopic properties.

Materials drive our society

- Stone Age - Bronze Age - Iron Age
- Now? Silicon Age? Polymer Age?

Metal Reactivity

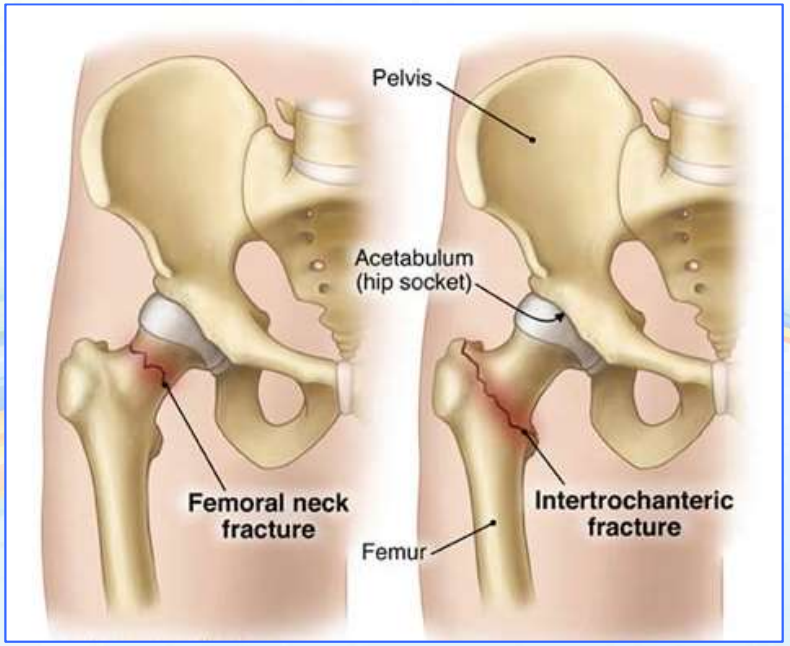
- The reactivity is a measure of the ease of compound formation and stability (i.e., the more reactive the metal, the more readily the metal forms a stable compound as an example with oxygen or sulfur, and therefore, the greater the compound stability, the more difficult it is to reduce the compound to the metal).



- The least reactive metals such as gold, silver and copper have been used for the past 10000 years because the pure metal was found naturally.
- Moderately reactive metals like copper, iron, lead, tin have been extracted using carbon-based smelting for the past 2000-3000 years.
- It is only in the last 200 years that very reactive metals like sodium or aluminum have been extracted by electrolysis.
- Our exploitation of metal mineral resources as developed and expanded as the technology of metal extraction has also developed and improved.

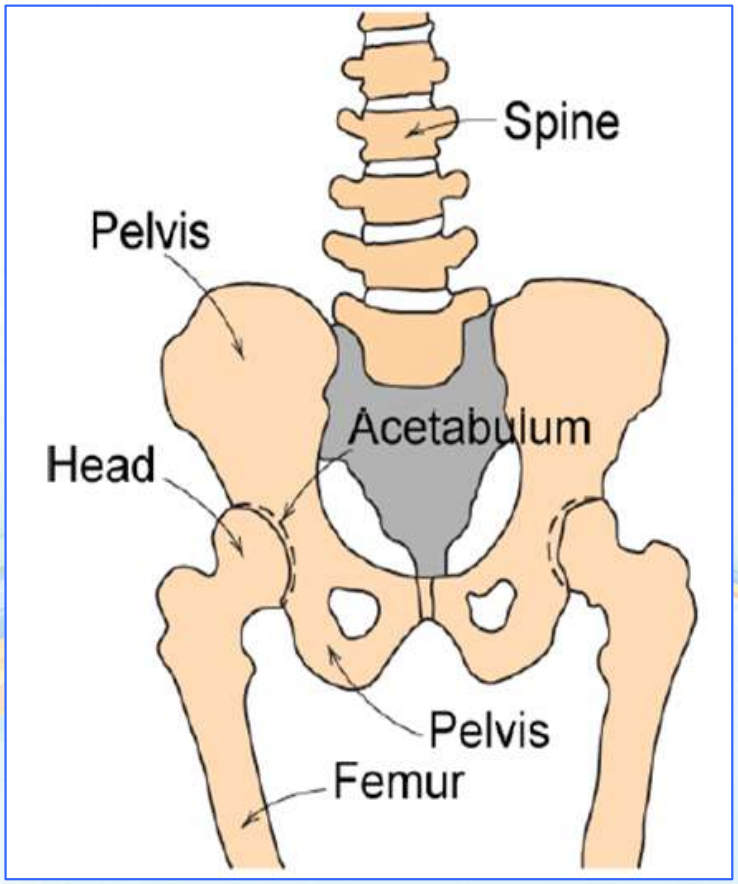
Example – Hip Implant

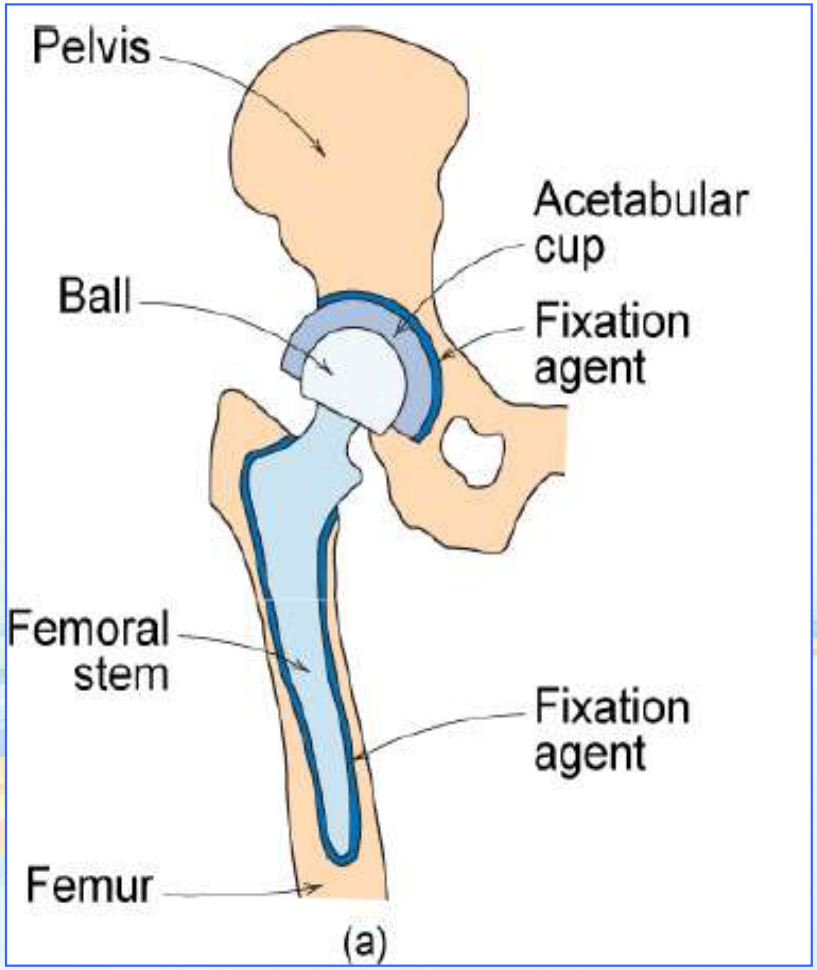
- With age or certain illnesses joints deteriorate.
- Particularly those with large loads (such as hip).



Requirements

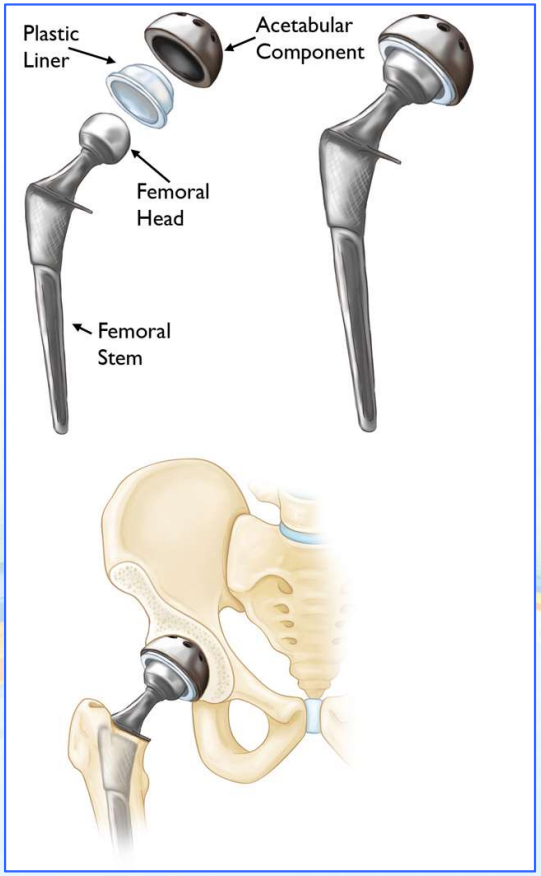
- Mechanical strength (many cycles)
- Good lubricity
- Biocompatibility
- Light weight
- Machinability




Pelvis
Acetabular cup
Ball
Fixation agent
Femoral stem
Fixation agent
Femur
(a)

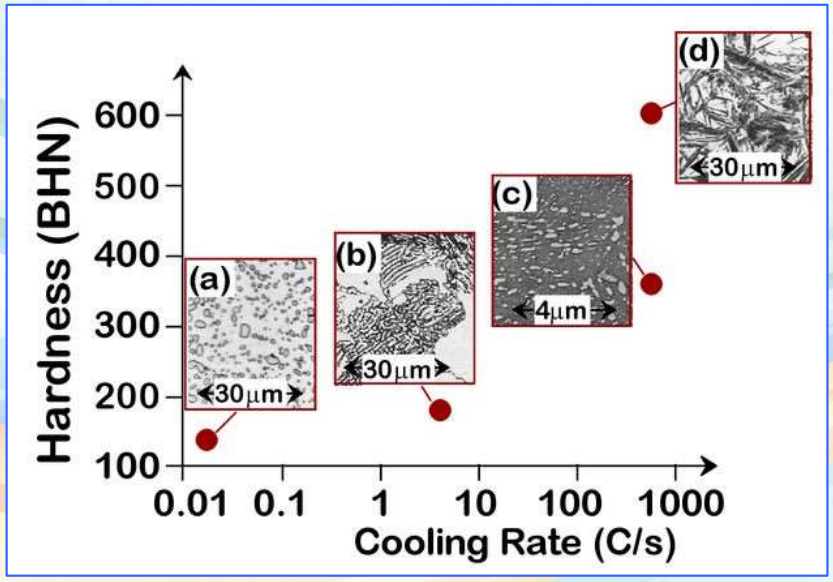
Key problems to overcome

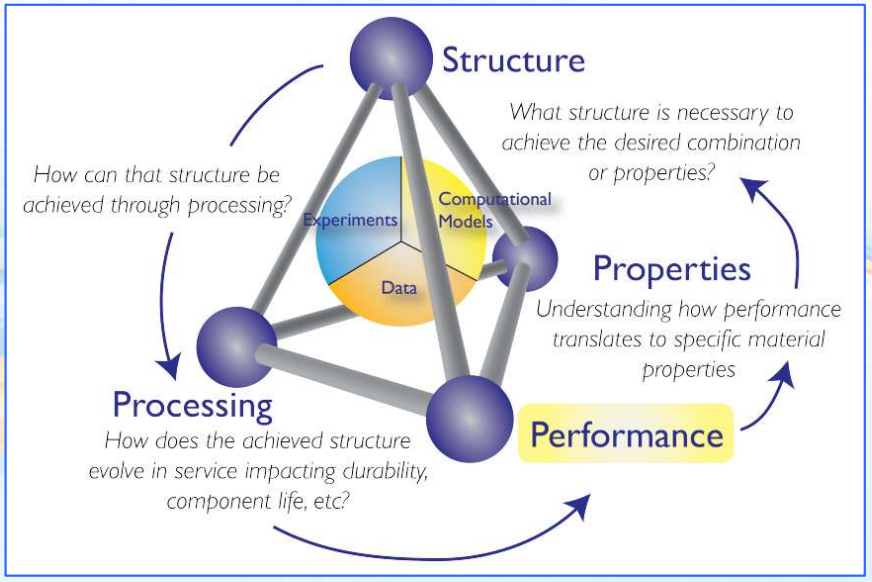
- Fixation agent to hold acetabular cup.
- Cup lubrication material.
- Femoral stem – fixing agent ("glue").
- Must avoid any debris in cup.



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

1. Metals
   - Strong, ductile
   - High thermal & electrical conductivity
   - Opaque, reflective.
2. Polymers/plastics
   - Covalent bonding
   - Soft, ductile, low strength, low density
   - Thermal & electrical insulators
   - Optically translucent or transparent.

3. Ceramics

- Ionic bonding (refractory)
- Compounds of metallic & non-metallic elements (oxides, carbides, nitrides, sulfides)
- Brittle, glassy
- Elastic non-conducting (insulators)

The Materials Selection Process

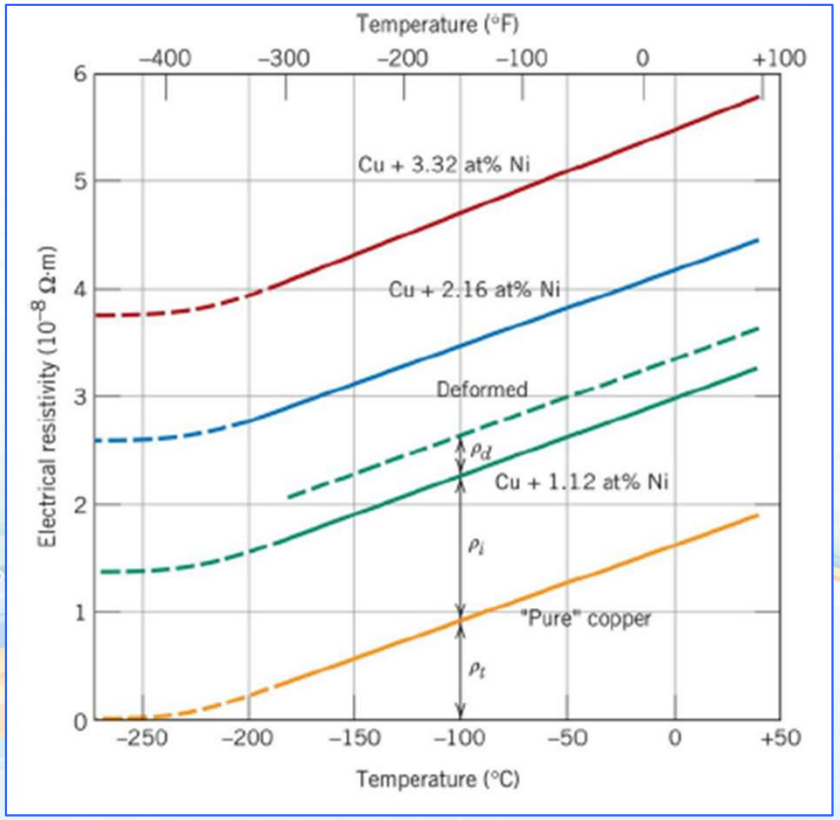
1. **Pick application**
   - Determine required Properties.
   - Properties: mechanical, electrical, thermal, magnetic, optical, and deteriorative.
2. **Properties**
   - Identify candidate materials
   - Material: structure, composition
3. **Material**
   - Identify required Processing
   - Processing: changes structure and overall shape

Ex: casting, sintering, vapor deposition, doping, forming, joining, and annealing.

ELECTRICAL

Electrical Resistivity of Copper:

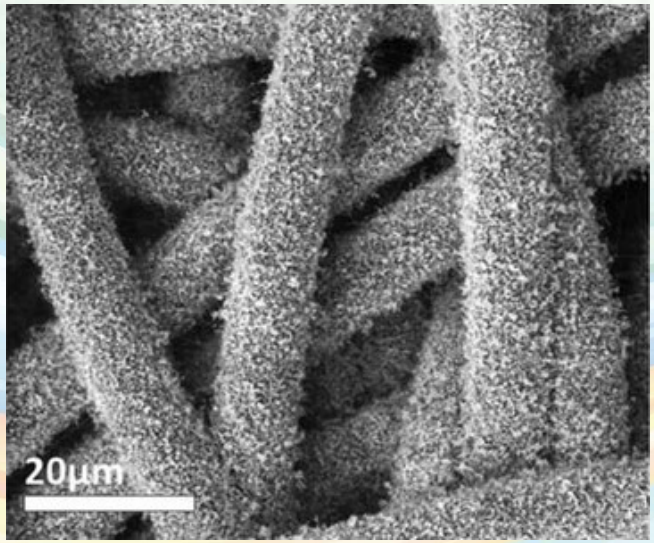
- ✓ Adding "impurity" atoms to Cu increases resistivity.
- ✓ Deforming Cu increases resistivity.

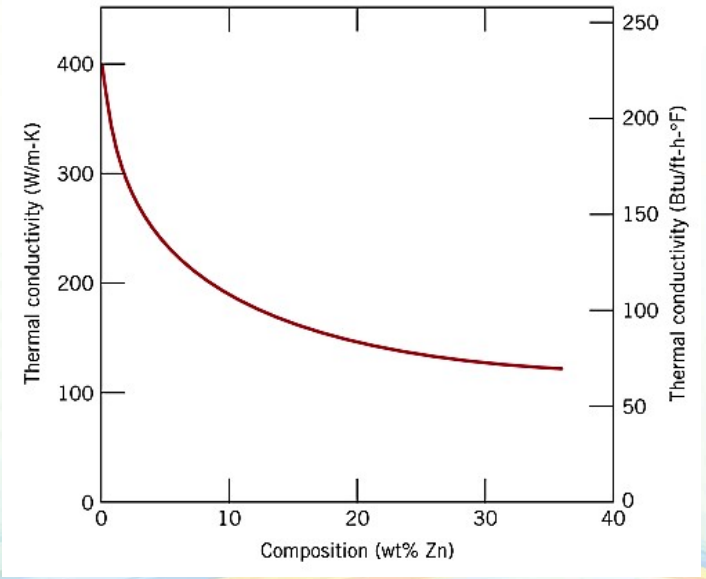


THERMAL

Shuttle Tiles:

- Silica fiber insulation offers low heat conduction.





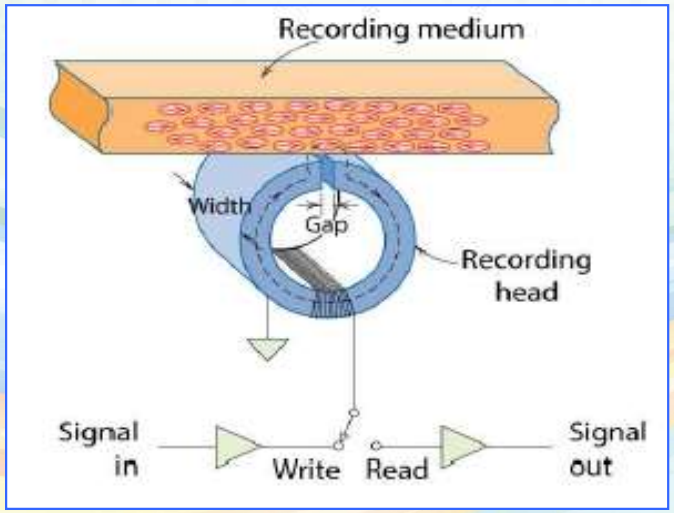
Thermal Conductivity of Copper:

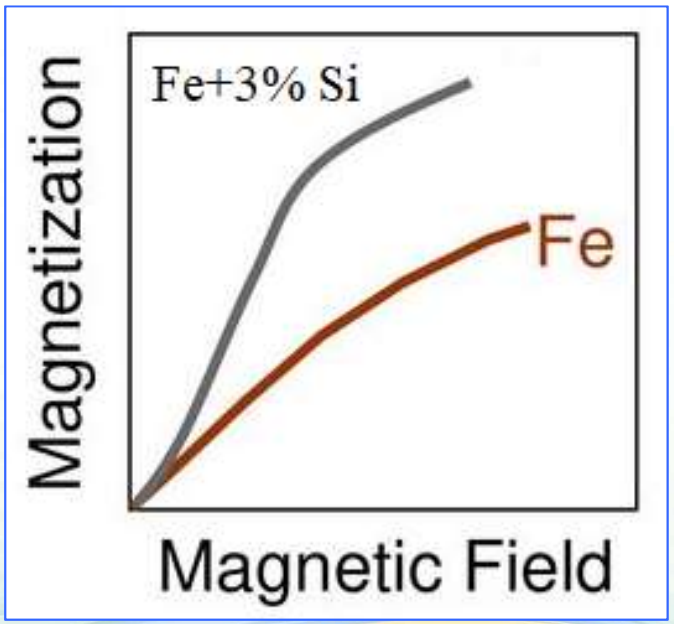
- It decreases when you add zinc.

MAGNETIC

Magnetic Storage:

- Recording medium is magnetized by recording head.





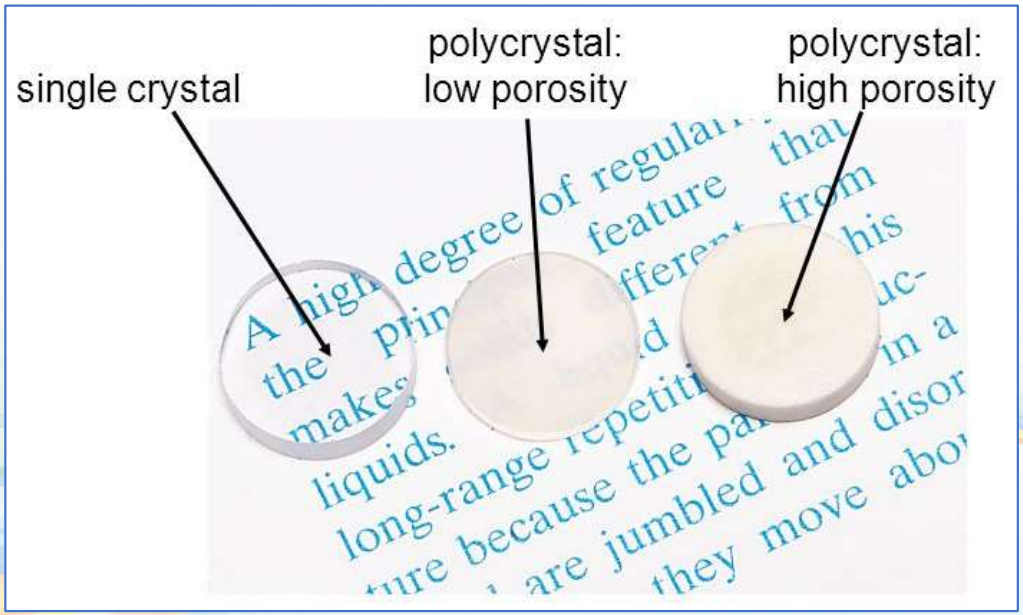
Magnetic Permeability

- Adding 3 % Si makes Fe a better recording medium

OPTICAL

Transmittance:

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



DETERIORATIVE

Stress & Saltwater:

- *causes cracks*

Heat treatment:

- *slows crack speed in salt water.*