Lec. (1)

Prosthetics and orthotics Materials Science

Instructor:

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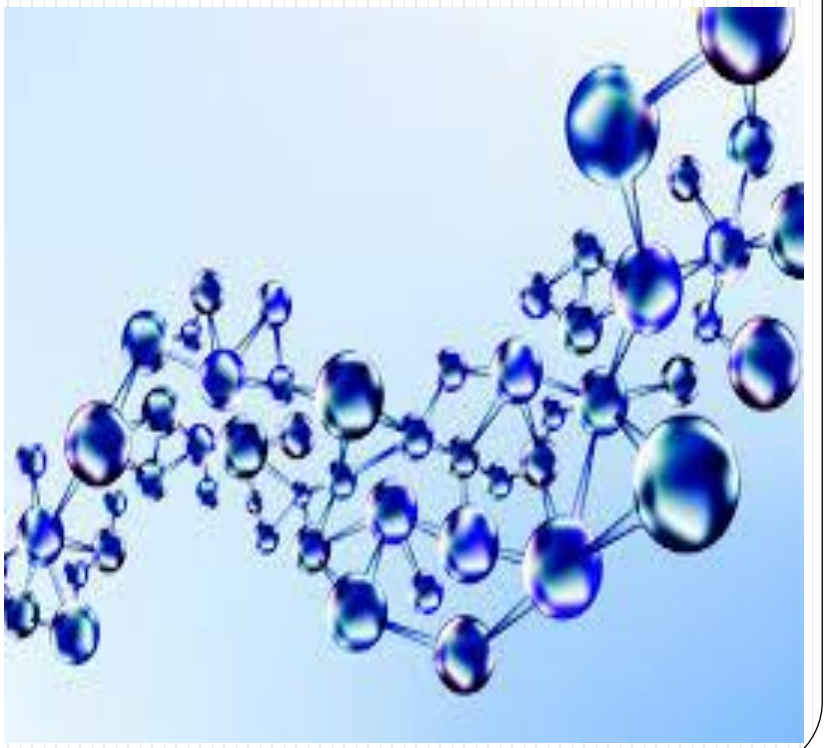


Outlines

- Introduction to the Staff
- Introduction to the Course
  - Textbooks and Course Overview
  - Course Objectives/Contents
  - Evaluation and Grading
- Lecture 1: Introduction to materials science

Introduction to the Staff

• Instructors	Prof.Dr. Ahmed Mohamed Abu-oqail
• E-Mail	Ahmed_abuoqail@yahoo.com
• Office	Mechanical engineering department
• Class Schedule	Wednesday (12:00 pm-2:00 pm)
• Class room	A101

• TAs	Dr. Eng.:

Textbooks

[1] Callister, W. D., “Materials Science and Engineering”, eighth edition, 2010, John Wiley and Sons, Inc.

[2] Milton, O., “Engineering Materials Scienc”,1995, Academic Press, Inc.

Course Overview

- **This course is designed to help orthotics and prosthetics engineers to acquire the basic knowledge and skills about:**

- Basic concepts of materials science; the atomic structure and interatomic bonding; imperfections in solids; basic principles of phase diagrams and phase transformations; strengthening mechanisms; heat treatment processes, and polymers, ceramics and composites characteristics.

Course Objectives

Course Objectives Include:

- Understand the basic concepts of materials science.
- Compare between different types of imperfections in metals.
- Understand the heat treatment processes.
- Evaluate and inspect different microstructures of metals and alloys.
- Know the different strengthening mechanisms.
- Know the different characteristics of polymers, ceramics and composites
- Enable students to work in teams.

Course Contents

Tentative topics of the course include:

- Introduction to materials science
- Atomic structure and materials bonding
- Imperfections in solids
- Strengthening mechanisms
- Phase diagrams and phase transformations
- Heat treatment processes
- Polymers, ceramics and composites characteristics

Evaluation and Grading

	Mark
Mid-term examination (2 exams)	
Work class and experimental	
Final-term examination	
Total	

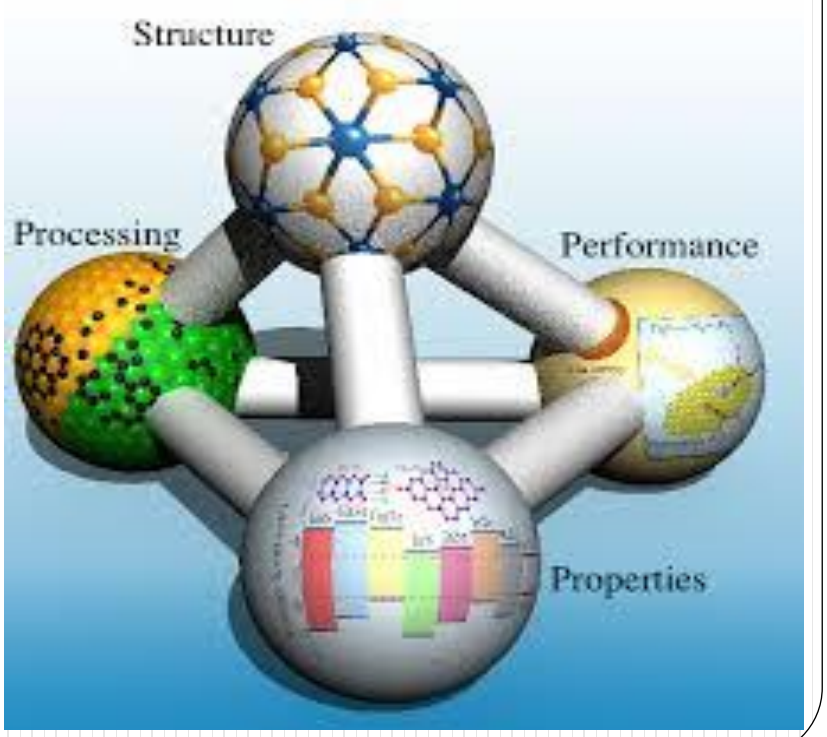
Faculty of engineering
Mechanical Engineering Dept.

Materials science

Chapter 1

Introduction to materials science

Dr. Ahmed Mohamed Abu-oqail



Topics

- Introduction
- What is materials science and engineering?
- Classification of Materials
- Advanced materials and modern material's needs
- How do we test materials?

Introduction

- Every segment of our everyday lives is influenced to one degree or another by materials (i.e. orthotics and prosthetics application, transportation, housing, clothing, communication, recreation, and food production).

- Historically, the development and advancement of societies have been intimately tied to the members' ability to produce and manipulate materials to fill their needs










Materials science and engineering

What is materials science and engineering?

Materials Science

➢The discipline of investigating the relationships that exist between the structures and properties of materials.

Materials Engineering

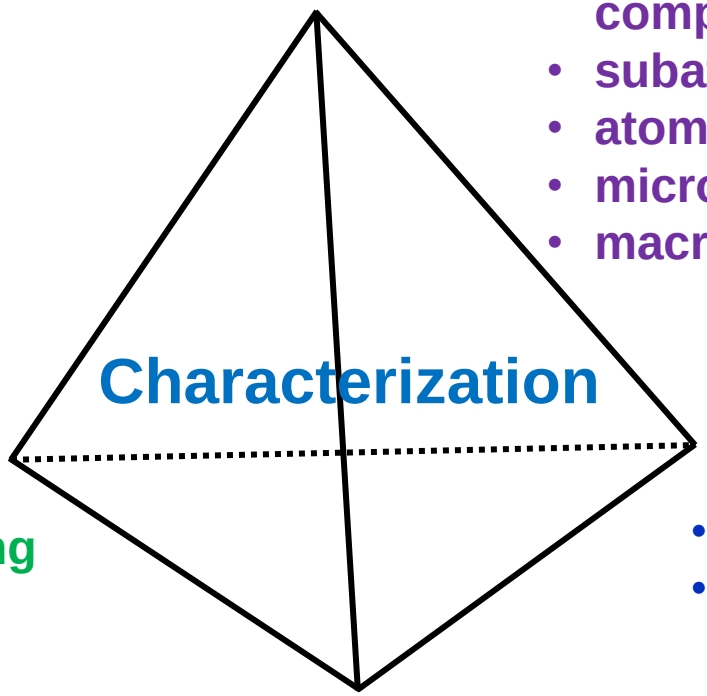
➢The discipline of designing or engineering the structure of a material to produce a predetermined set of properties based on established structure-property correlation.

Materials science and engineering

Components of Material Science and Engineering:

- **Four major components of material science and engineering:**
  - Structure of Materials
  - Properties of Materials
  - Processing of Materials
  - Performance of Materials
- Material science and engineering is the investigation of the relationship among processing, structure, properties, and performance of materials.

Materials science and engineering



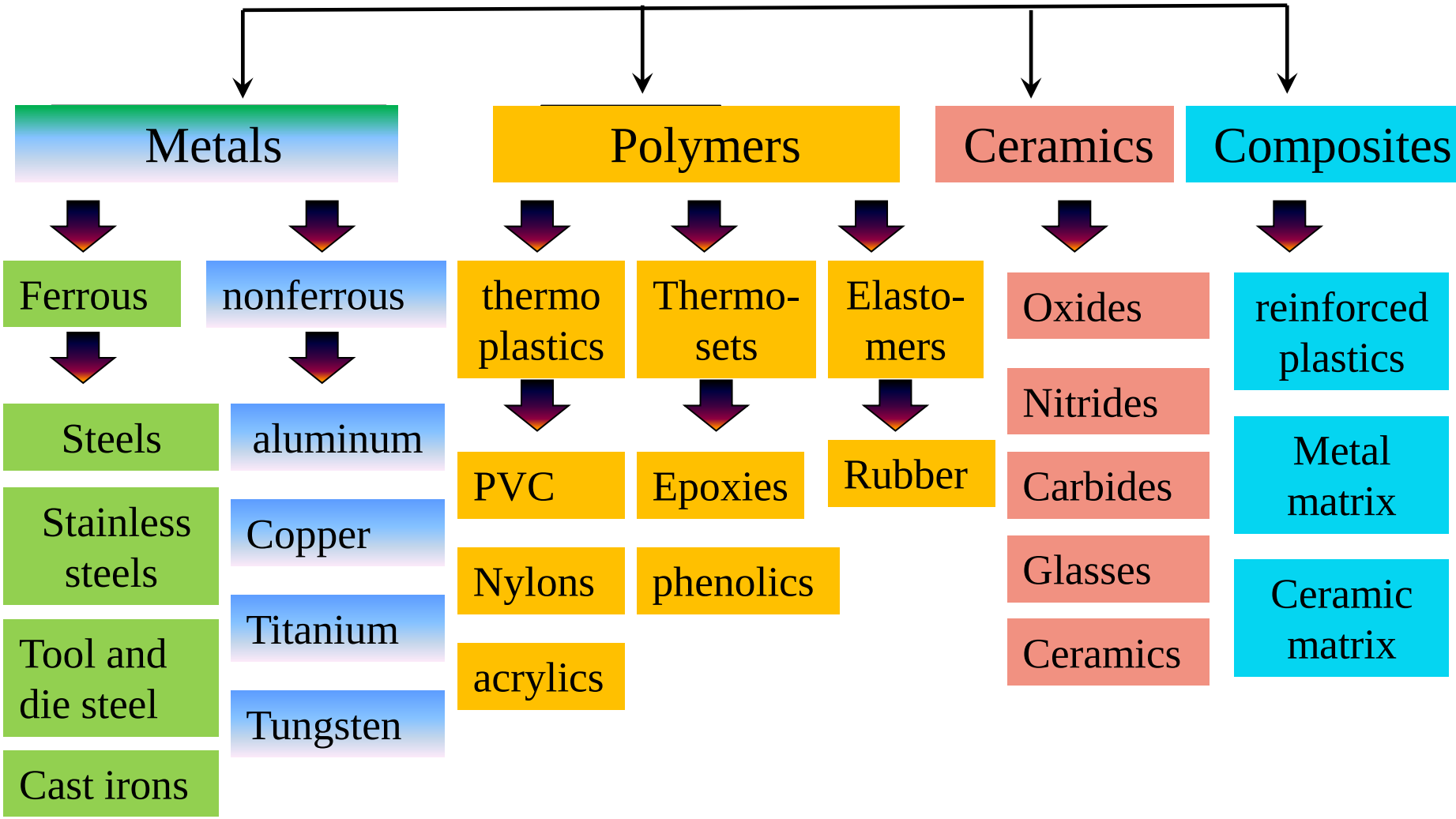
- arrangement of internal components
- subatomic
- atomic
- microscopic
- macroscopic (bulk)

- method of preparing material

- material characteristic
- response to external stimulus
- mechanical, electrical, thermal, magnetic, optical, deteriorative

- behavior in a particular application

Classification of engineering materials



Classification of Materials

Metals

a) Ferrous Metals

- Contain iron as their base metal
- Categories are: carbon and alloy steels, tool and die steels, and cast iron
- Used extensively because of their versatile properties and low cost
- Steels and cast irons are represented by the iron-carbon phase diagram

Classification of Materials

b) Non-Ferrous Metals

- Include wide range of materials such as:

Aluminum – Copper – Nickel – Magnesium – Titanium – Zirconium – Molybdenum

- They are more expensive than the ferrous metals
- Have important properties such as:
- Corrosion resistance, high thermal and electrical conductivity, low density, and ease of fabrication.
- Applications are: aluminum: cooking utensils, aircraft bodies

Copper: wire for electricity

Zinc: for galvanized sheet metal for car bodies

Titanium : for jet-engine turbine blades

Classification of Materials

Metals (ferrous and nonferrous)

Properties:

-Strong, but deformable

- Good conductors of electricity and heat

-Not transparent to visible light

-Some of the metals (i.e., Fe, Co, and Ni) have desirable magnetic properties.

Classification of Materials

Metals (ferrous and nonferrous)

Some applications:

- Electrical wire: aluminum, copper, silver
- Heat transfer fins: aluminum, silver
- Construction beams (bridges, sky scrapers, rebar, etc.): steel (Fe-C alloys)
- Cars: steel (Fe-C alloys)
- Consumer goods:
  - soup cans
  - appliances (stainless steel sheet metal)
  - utensils
  - Tools
  - Many, many, many more…

Classification of Materials

Ceramics:

- Ceramics are compounds between metallic and nonmetallic elements; they are most frequently oxides, nitrides, and carbides.

- For example, common ceramic materials include aluminum oxide (or *alumina,* Al_2O_3), silicon dioxide (or *silica,* SiO_2), silicon carbide (SiC), silicon nitride (Si_3N_4).

- In addition, what some refer to as the *traditional ceramics*—those composed of clay minerals (i.e., porcelain), as well as cement and glass.

Classification of Materials

Ceramics:

Properties:

- Ceramic materials are relatively stiff and strong
- They are typically very hard.
- Exhibited extreme brittleness (lack of ductility).
- Highly susceptible to fracture
- More resistant to high temperatures and harsh environments than metals and polymers.
- Some of the oxide ceramics (e.g., Fe_3O_4) exhibit magnetic behavior.
- Good optical properties
- Thermally and electrically insulating.

Classification of Materials

Ceramics:

Some Applications:

- Window glass: Al_2O_3 – SiO_2 – MgO – CaO
- Aerospace, energy and automotive industry
  - heat shield tiles
  - engine components
  - reactor vessel and furnace linings
- Consumer products:
  - Pottery
  - dishes (fine china, plates, bowls)
  - glassware (cups, mugs, etc.)
  - eye glass lenses

Classification of Materials

Polymers:

- Polymers include the familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements (i.e., O, N, and Si).

- They have very large molecular structures, often chainlike in nature, that often have a backbone of carbon atoms.

- Some of the common and familiar polymers are polyethylene (PE), nylon, poly vinyl chloride (PVC), polycarbonate (PC), polystyrene (PS), and silicone rubber.

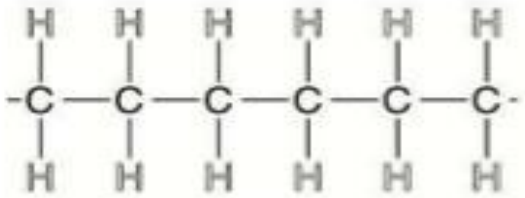
Classification of Materials

What is a Polymer?

Poly **mer**
Many **Units**

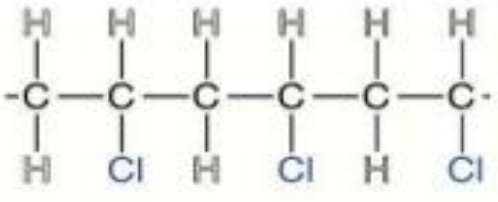
Definition:

repeat unit



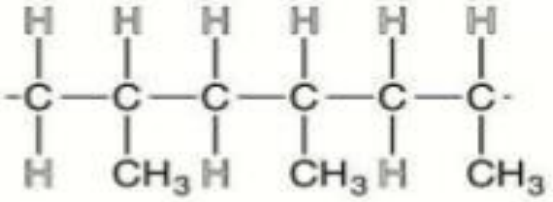
Polyethylene(PE)

repeat unit



Poly(vinyl chloride) (PVC)

repeat unit



Polypropylene (PP)

PE Milk Container

PVC Pipe

PP Rope

Classification of Materials

Polymers:

Properties:

- Ductile: can be stretched up to 1000% of original length
- Lightweight: Low densities
- Medium strength: Depending on additives
- Chemical stability: inert to corrosive environments
- low melting point
- Low electrical conductivities

Classification of Materials

Polymers:

Some Applications:

- Car tires: vulcanized polymer
- Food storage containers
- Aerospace and energy applications: Teflon
- Consumer goods:
  - calculator casings
  - TV consuls
  - shoe soles
  - cell phone casings
  - Elmer’s Glue (adhesives)
  - contact lenses

Classification of Materials

Composites:

- A composite is composed of two (or more) individual materials, which come from the metals, ceramics, and polymers.

- The design goal of a composite is to achieve a combination of properties that is not displayed by any single material, and also to incorporate the best characteristics of each of the component materials.

- One of the most common and familiar composites is fiberglass, in which small glass fibers are embedded within a polymeric material (normally an epoxy or polyester).

Classification of Materials

Composites:

Properties:

Properties depends on composites

- High melting points with improved high temperature strength: (ceramic-ceramic)

- High strength and ductile with improved wear resistance: (metal-ceramic)

- High strength and ductile: (polymer-polymer)

Classification of Materials

Composites:

Some Applications:

- Composites are used in some aircraft and aerospace applications.
- High-tech sporting equipment (e.g., bicycles, golf clubs, and tennis rackets)
- Recently in automobile bumpers.

Classification of Materials

Composites: Some Applications:

✓ Carbon fiber composites with polymer matrices, have become the advanced composite materials for aerospace, due to their high strength, high Modulus and low cost.

✓ Helmet and bullet proof jacket Made Up of Aramide Composite material

✓Fiber-reinforced plastics have reached the stage where they could be used for making wheels.

Advanced materials and modern material's needs

Advanced materials

- Materials that are utilized in high-technology (or high-tech) applications are sometimes termed *advanced materials.*

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

- Advanced materials include semiconductors, biomaterials, and what we may term "materials of the future" (that is, smart materials and nano-materials)

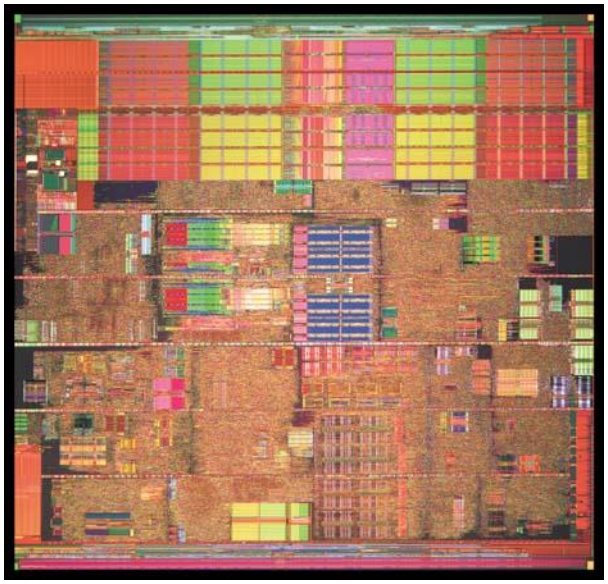
Advanced materials and modern material's needs

Advanced materials

a) Semiconductors

- Semiconductors have electrical properties that are interrmediate between the electrical conductors (i.e., metals and metal alloys) and insulators (i.e., ceramics and polymers).

- Semiconductors have made possible the advent of integrated circuit that has totally revolutionized the electronics and computer industries.



Intel Pentium 4

Advanced materials and modern material's needs

Advanced materials

Applications of Semiconductors

✓Si wafer in photovoltaic cells to convert light energy to electric energy.

✓Semiconductor memory uses semiconductor-based integrated circuits to store information.

✓A transistor is a semiconductor device used to amplify and switch electronic signals

Advanced materials and modern material's needs

Advanced materials

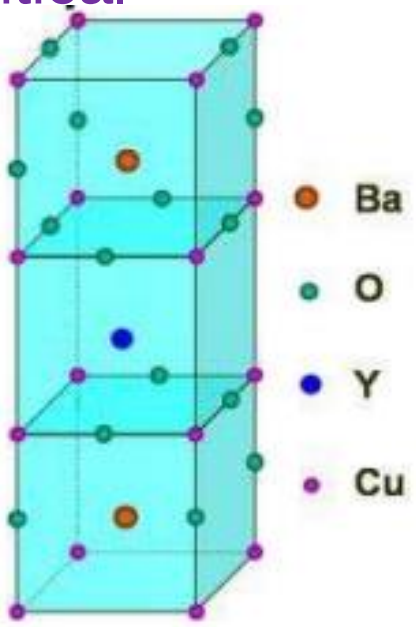
b) Superconductors

What is Superconductivity ?

• Superconductivity is a phenomenon of exactly zero electrical resistance and expulsion of magnetic fields occurring in certain materials when cooled below a characteristic critical temperature.

What is Superconductor ?

• An element, inter-metallic alloy, or compound that will conduct electricity without resistance below a certain temperature.



Example: YBa2Cu3O7(-178°C),Pb(-265.83°C)etc.

Advanced materials and modern material's needs

Advanced materials

b) Superconductors

- The electrical resistivity of a metallic conductor decreases gradually as temperature is lowered. In ordinary conductors, such as **copper or silver**, this decrease is limited by impurities and other defects. Even near absolute zero, a real sample of a normal conductor shows some resistance. In a superconductor, the resistance drops abruptly to zero when the material is cooled below its critical temperature. An electric current flowing in a loop of superconducting wire can persist indefinitely with no power source.

Advanced materials and modern material's needs

Advanced materials

b) Superconductors applications

✓ Based on Meissner effect trains can be made to "float" on strong superconducting magnets, virtually eliminating friction between the train and its tracks.

Speed :581 KPh in shanghai.

Advanced materials and modern material's needs

Advanced materials

c) Biomaterials

- Biomaterials are employed in components implanted into the human body to replace diseased or damaged body parts.

- These materials must not produce toxic substances and must be compatible with body tissues.

- metals, ceramics, polymers, composites, and semiconductors may be used as biomaterials.

Advanced materials and modern material's needs

hip replacement

Advanced materials and modern material's needs

Advanced materials

d) Smart materials

- *Smart* (or *intelligent*) *materials* are a group of new and state-of the-art materials now being developed that will have a significant influence on many of our technologies.

- these materials are able to sense changes in their environment and then respond to these changes in predetermined manners.

Advanced materials and modern material's needs

Advanced materials

e) Nanomaterials

- One new material class that has fascinating properties and tremendous technological promise is the *nanomaterials.*

- Nanomaterials may be any one of the four basic types—metals, ceramics, polymers, and composites.

- The dimensions of these structural entities are on the order of a nanometer (10^{-9} m)—as a rule, less than 100 nanometers

Advanced materials and modern material's needs

Modern material's needs

- Materials for reducing the weight of transportation vehicles (automobiles, aircraft, trains, etc.).

- Materials that have higher-temperature capabilities, for use in engine components.

- Materials for solar cells which use complex and expensive materials.

- Materials for lightweight batteries with high storage densities

How do we test materials?

We use mechanical, chemical and optical methods

- Mechanical testing gives strength, ductility and toughness material information (i.e., tensile tests, bend tests compressive tests, fracture testing)

- Chemical testing tells us about composition and chemical stability (x-ray diffraction and fluorescence – composition testing and corrosion testing)

- Optical testing is more of a way to view atomic, nano and microstructures, and gives us insight to structure property relationships (i.e., light optical microscope – microstructure scanning electron microscope – microstructure and nano structure transmission electron microscope – nanostucture and atomic structure scanning tunneling electron microscope – atomic structures


Thanks