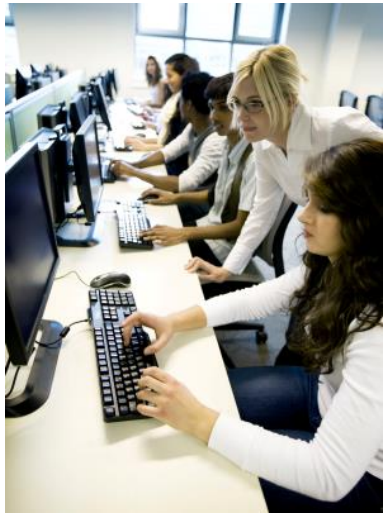
Introduction to Materials

What Are Materials?

Substances out of which all things are made

Currently the MatWeb Material Property Data website lists over 76,000 individually unique materials http://www.matweb.com

What materials are present in the classroom?



Material History

Throughout history cultures have been defined by their ability to select and modify materials.

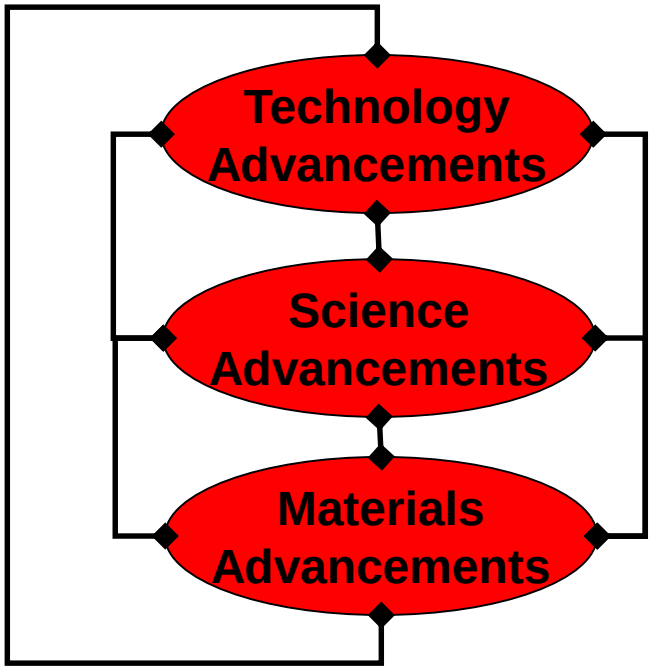
Can you think of a time in America when material availability played a critical role in defining culture?

Is American culture currently being defined by availability and demand for materials?

Material History

Materials continue to change the world.

Advancements in materials, technology, and science create continued advancement possibilities for each sector.



Material Composition

What makes a material?

Elements

Consist of **only one** type of particle or atom

Cannot be broken down

Criteria for element classification

Based on individual properties

Grouped according to shared properties

Amount of substance is irrelevant

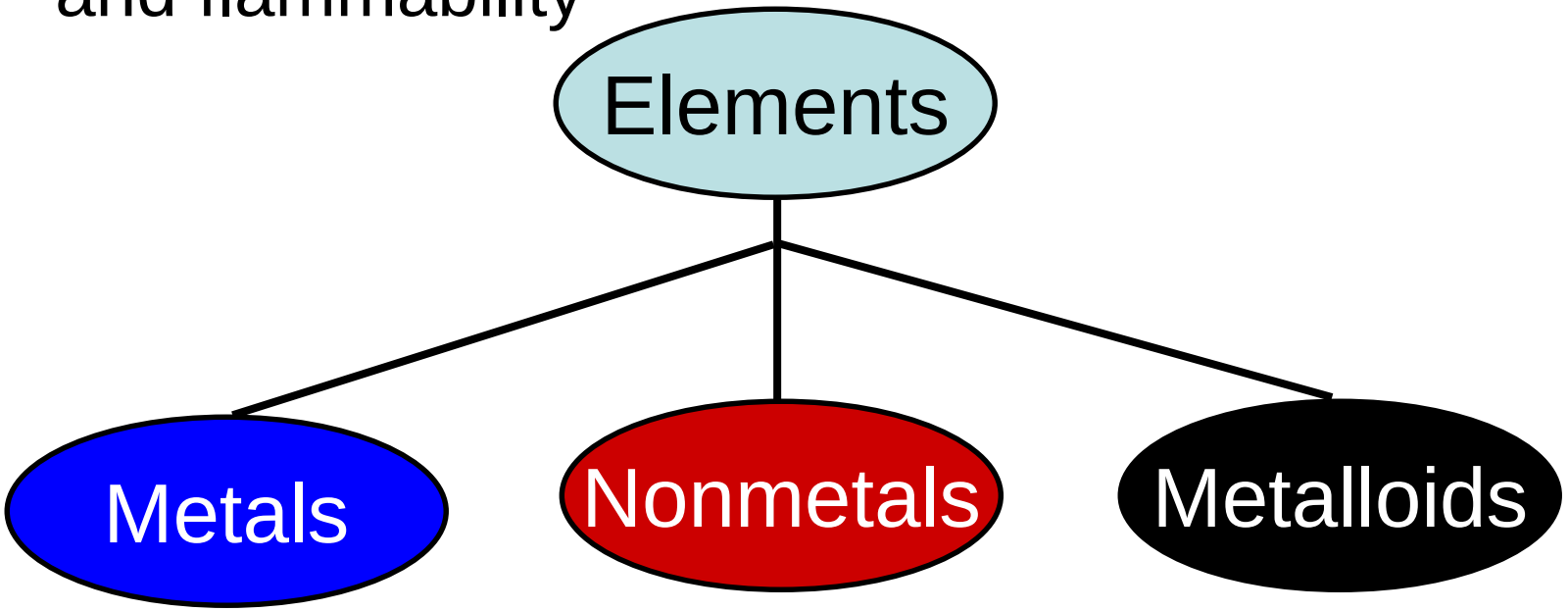
Material Composition

Classification of Elements

Divided into three categories based on

Physical Properties – Boiling point, melting point, density, color, hardness, and texture

Chemical Properties – Reactivity to acid, oxygen, and flammability



Material Composition

Metal Elements

Distinguishing Characteristics

Good conductors of heat and electricity, hard, shiny, reflect light, malleable, ductile, typically have one to three valence electrons

Material Composition

Nonmetal Elements

Distinguishing Characteristics

Most are gases at room temperature

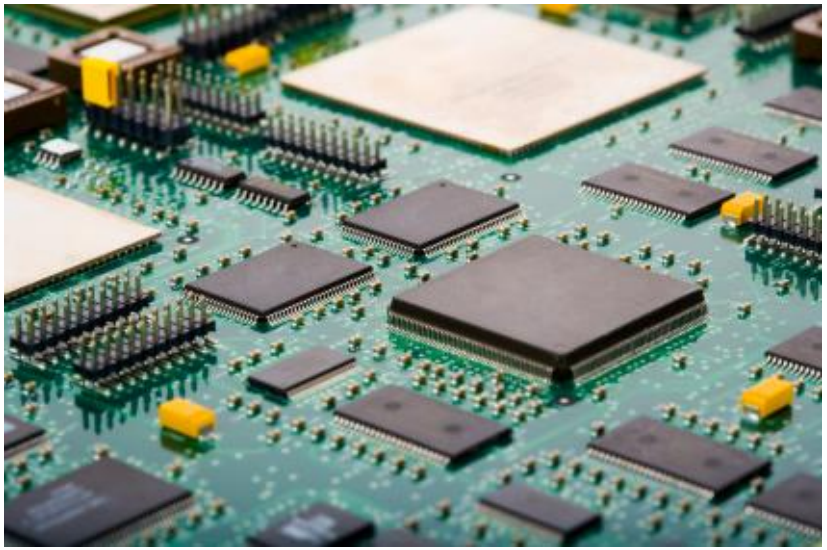
Solids are dull, brittle, and powdery; electrons are tightly attracted and restricted to one atom; poor conductors of heat and electricity

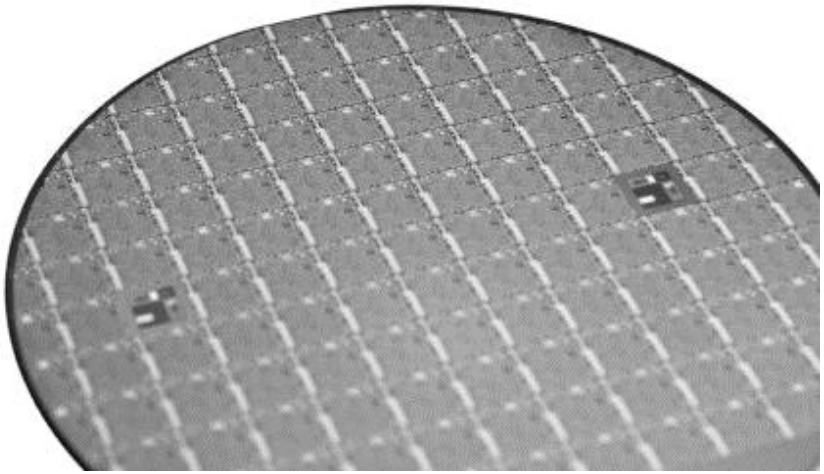
Material Composition

Metalloids

Distinguishing Characteristics

Possess both metallic and nonmetallic properties





Material Composition

Compounds

Most substances are compounds

Compounds are created when two or more elements are chemically combined

Properties are different than the elements from which the compound was created

Material Composition

Compounds

Element combinations are not random but based upon specific mass ratios, such as

H_2O = 1 g of hydrogen to 8 g of oxygen

Compounds can **only** be broken down through chemical processes, **not** physical processes

Material Composition

Mixtures

- Non-chemical combination of any two or more substances
- Elements within the mixture retain their identity
- Mixtures do not have a definite ratio
- Mixtures can be physically separated

Material Classification

Based upon material composition and distinguishable properties

Common material classification categories:

Metallic Materials

Ceramic Materials

Organic Materials

Polymeric Materials

Composite Materials

Metallic Materials

Distinguishing Characteristics

Pure metal elements

(Not commonly found or used)

Metal element compounds (alloy)

(Commonly used due to the engineered properties of the compound)

Thermal and electrical conductors

Mechanical properties include strength and plasticity

Ceramic Materials

Distinguishing Characteristics

Compounds consisting of metal and nonmetal elements

Thermal and electrical insulators

Mechanical properties include high strength at high temperatures and brittleness

Ceramic Materials

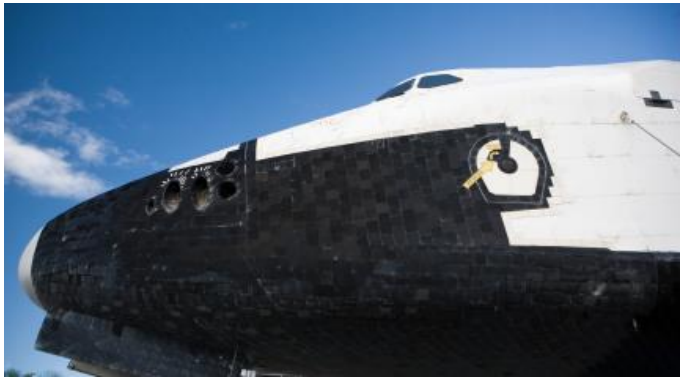
Applications

Clay—Shaped, dried, and fired inorganic material

Examples: Brick, tile, sewer pipe, chimney flue, china, porcelain, etc.

Refractory—Designed to provide acceptable mechanical or chemical properties while at high temperatures

Example: Space shuttle all-silica insulating tiles



Ceramic Materials

Applications

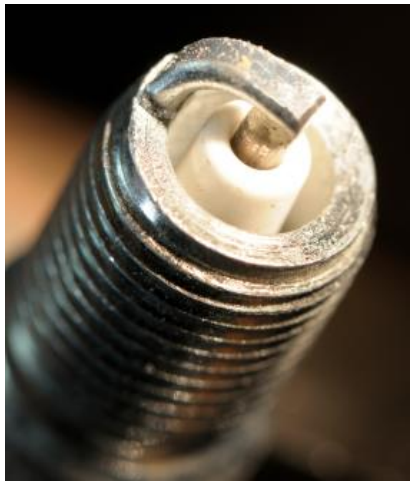
Electrical

Resistors—Create desired voltage drops and limit current

Thermistors—Application of heat regulates current flow

Rectifiers—Allow current to flow in one direction

Heating elements for furnaces



Organic Materials

Distinguishing Characteristics

Are or were once living organisms

Consist of mostly carbon and hydrogen

Genetically alterable

Renewable

Sustainable

Polymeric Materials

Distinguishing Characteristics

Compounds consist of mostly organic elements

Low density

Mechanical properties include flexibility and elasticity

Polymeric Subgroups

Plastics

Elastomers

Polymeric Materials

Plastics

Thermoplastic

- Formed into a desired shape by applying heat and pressure and being cooled
- May be heated and remolded

Thermosetting

- Formed into a desired shape by applying heat and pressure and being cooled
- May not be heated and remolded

Polymeric Materials

Elastomers

Natural or synthetic material

Can be stretched 200 percent of their length at room temperature and can return quickly to original length after force is released

Vulcanization

Chemical process used to form strong bonds between adjacent polymers to produce a tough, strong, hard rubber (automobile tires)

Composite Materials

Distinguishing Characteristics

Composed of more than one material

Designed to obtain desirable properties from each individual material

Composite Materials

Layer Composites—Alternate layers of materials bonded together

Particulate Composites—Discrete particles of one material surrounded by a matrix of another material

Fiber-Reinforced Composites—Composed of continuous or discontinuous fibers embedded in a matrix of another material

Material Selection

Material selection is based upon application, required material properties, and budget.

Applications can vary from electrical components to construction of large-scale civil engineering projects.

Initial material property considerations consist of product function, environmental conditions, and material degradation.

Material Selection

Refined material selection based upon:

Technical and structural analysis

Examination of known and desired properties, such as:

- Mechanical
- Thermal
- Electromagnetic
- Chemical

Material Selection

Mechanical Properties

Deformation and fracture as a response to applied mechanical forces

- Strength
- Hardness
- Ductility
- Stiffness

Material Selection

Thermal Properties

Affected by heat fluxes and temperature changes

Thermal Capacity—Heat storage capacity of a material

Thermal Conductivity—Capacity of a material to transport heat

Thermal Expansion—How a material expands or contracts if the temperature is raised or lowered

Material Selection

Electrical Properties

Material response to electromagnetic fields

Electrical Conductivity—Insulators, dielectrics, semiconductors, semimetals, conductors, superconductors

Thermoelectric—Electrical stimuli provoke thermo responses; thermo stimuli provoke electrical responses

Material Selection

Chemical Properties

Response and impact of environment on material structures

Oxidation and Reduction—Occur in corrosion and combustion

Toxicity—The damaging effect a material has on other materials

Flammability—The ability of a material to ignite and combust

Material Selection—Alternative

Material selection and development is currently focused on alternative materials.

Alternative materials are being designed to solve socioeconomic problems such as sustained economic development and depletion of natural resources.

Alternative materials include

- Fullerenes
- Liquid Crystals
- Biocompatible Materials
- Microelectronics