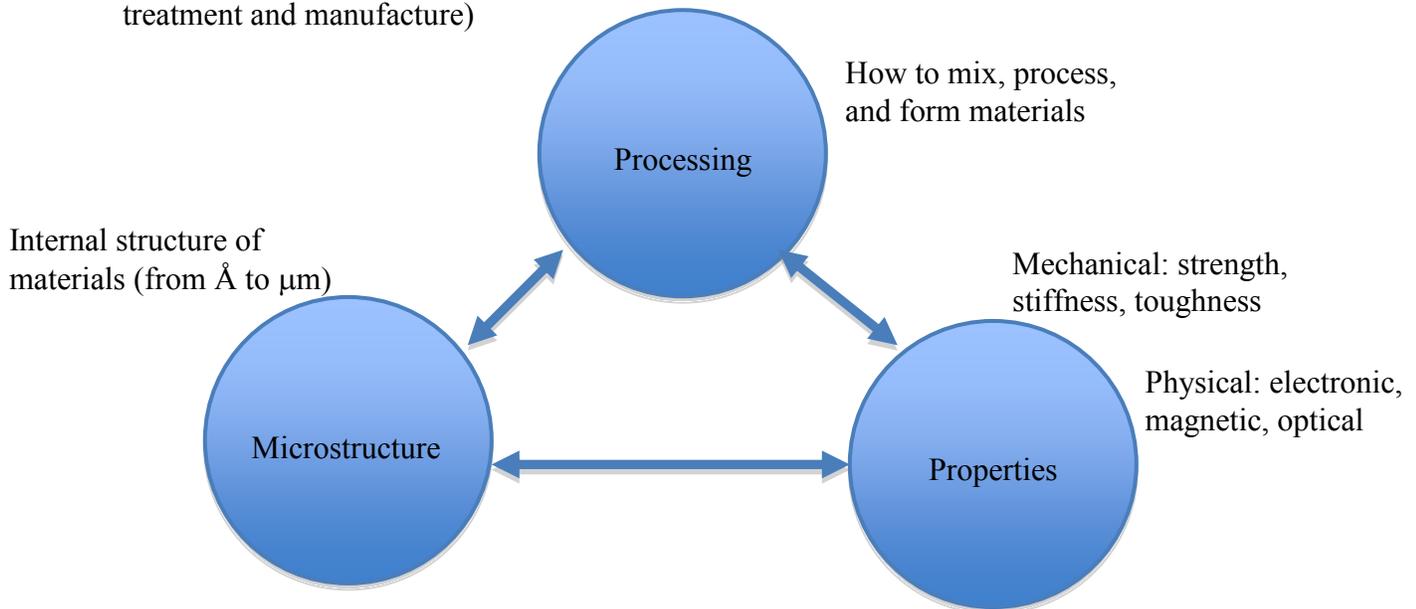


**“Understanding the underlying physical basis for the connection between microstructure and the mechanical behavior of materials”**

There are some 40,000-80,000 different types of materials in use today! However, most are derived from a few generic materials – we seek to understand the fundamental properties of these material systems and their relationship to microstructure.

**Design Process**

- All mechanical properties of materials depend on composition (including alloying)
- Many mechanical properties of materials depend on processing (including heat treatment and manufacture)



- Both composition and processing must be specified

## Classes of Materials

### Metal & Alloys

#### *Iron based alloys (ferrous alloys):*

- Cast iron: Fe + >2% C + 1-3% Si
- Plain carbon steel: Fe + <1% C
- Low-alloy steel: Fe + C + other metals (up to 5%)
- Stainless steel: Fe + > 10% Cr
- Tool steel: Fe + (e.g., 0.85% C, 1.5%W, 8.5% Mo, 4% Cr, 1%V)

#### *Non-ferrous metals*

##### Light alloys

- Aluminum and alloys: Al + Mg, Cu, Ni, etc.
- Titanium and alloy: Ti + Al, V, etc.
- Magnesium and alloys: Mg + Al, Mn, Zn, Zr, etc.

##### Copper & alloys

- Pure Cu - good conductor, used ubiquitously in microelectronics
- Brass: Cu + Zn
- Bronze: Cu + Sn

##### Superalloys

- Nickel-based: 48% Ni + 19% Cr + 19% Co
- Cobalt-based: 37% Co + 22%Cr + 22%Ni + 14%W

##### Metallic Glasses: amorphous metallic alloys with extraordinary mechanical properties

- Zr-based: e.g.  $Zr_{57}Ti_5Cu_{20}Ni_8Al_{10}$ ,  $Cu_{60}Zr_{30}Ti_{10}$
- Pd-based: e.g.  $Pd_{40}Cu_{30}Ni_{10}P_{20}$
- Pt-based: e.g.  $Pt_{60}Ni_{15}P_{25}$

### Polymers

#### Thermoplastics

- E.g., PE (HDPE, LDPE); Polyethylene Terephthalate (PET); PMMA (“plexiglass”); PS; PVC; PP; PC; Nylon (gears)

Thermosets

- *E.g.*, epoxy resins, polyesters

Elastomers

- *E.g.*, SBR - Styrene-butadiene (tires & hoses), Natural rubber (tires), Neoprene (wet suits & gaskets)

**Ceramics (inorganic, non-metallic)**

- $\text{Al}_2\text{O}_3$  polycrystalline alumina (spark plugs, cutting tool inserts)  
Single crystals form basis of many gems: sapphire, etc.
- Silicon Carbide (SiC) - high-temperature engine parts
- Silicon Nitride (e.g.  $\text{Si}_3\text{N}_4$ ) – diffusion barrier in microelectronics
- Zirconia - coatings for turbine blades
- Diamond – microelectronics, cutting tools
- Silicon – the King of microelectronics
- Cement – nearly all construction

Glasses (non-crystalline forms)

- $\text{SiO}_2$  (silica, quartz, amorphous - )high quality lenses, high-temperature windows, abrasives, in microelectronics low-K dielectric
- Soda-lime glass: silica with Na ions - used in window glass

**Composites**

Combination of two or more materials as distinct macroscopic entities

- Wood
- Fiberglass (GFRP)
- Carbon-fiber reinforced polymers (CFRP)
- Concretes (Cement & Aggregate)
- Cermets (WC/W)
- Steel-belted tires
- Wire-reinforced concrete

⇒ **PROCESSING:** mixing, forming, sintering

