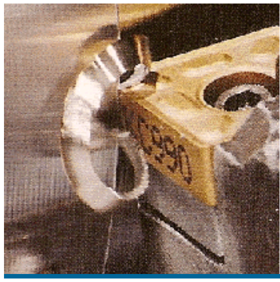

TA202A: Introduction to Manufacturing Processes

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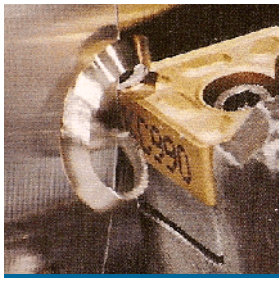
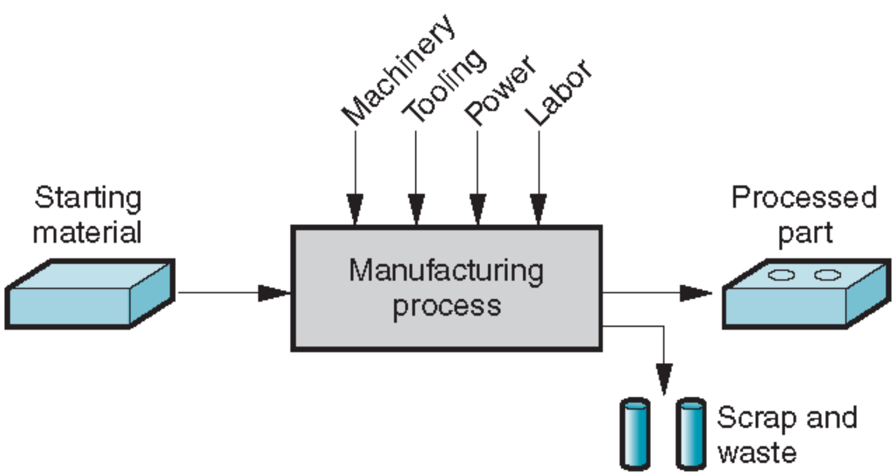


Manufacturing

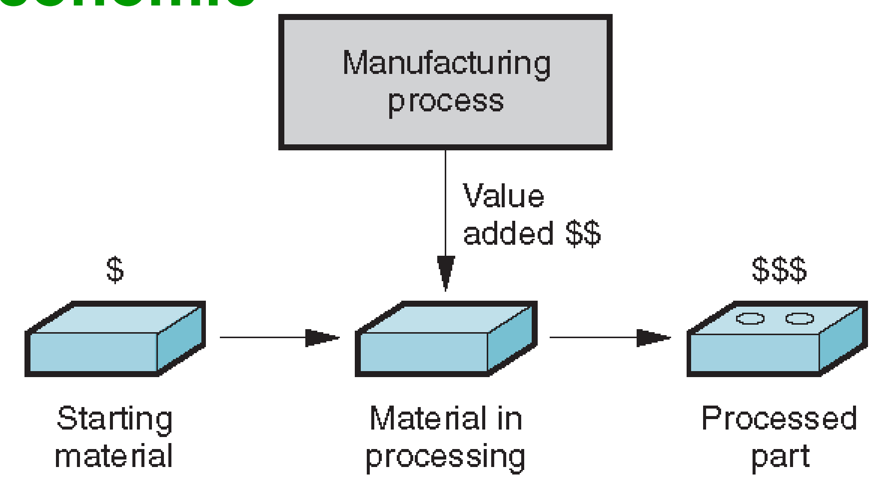
Derived from two latin word *manus* (hand) and *factus* (make); the combination means “made by hand”

Present perspective: involves making products from raw material by various processes, machinery and operations following a well organized plan for each activity required.

Technological



Economic



Manufacturing Activity Should Be Responsive To..

- Meet design requirement(Diameter, length, surface finish, tolerances, etc.).
- Most economic method to minimize cost

- From design to assembly : the quality should be built into the product at each stage.
- Production method should be flexible : meet varying demand (quantity , types, delivery date, etc.).

- **MANUFACTURING ORGANIZATION** : strive for higher productivity and optimum use of all its resources → **material, men, machines, money (4M)**

DESIGN AND MANUFACTURING OF A PRODUCT

1. YOU CAN NOT MAKE IF YOU CAN NOT MEASURE
2. YOU CAN NOT DESIGN IF YOU CAN NOT MANUFACTURE

- **Important issues related to Design and MANUFACTURING.**
- **Ex: Paper clip (clip shape : square or round, wire size: dia, length)**
- **Functional requirement** : to hold papers with sufficient clamping force .

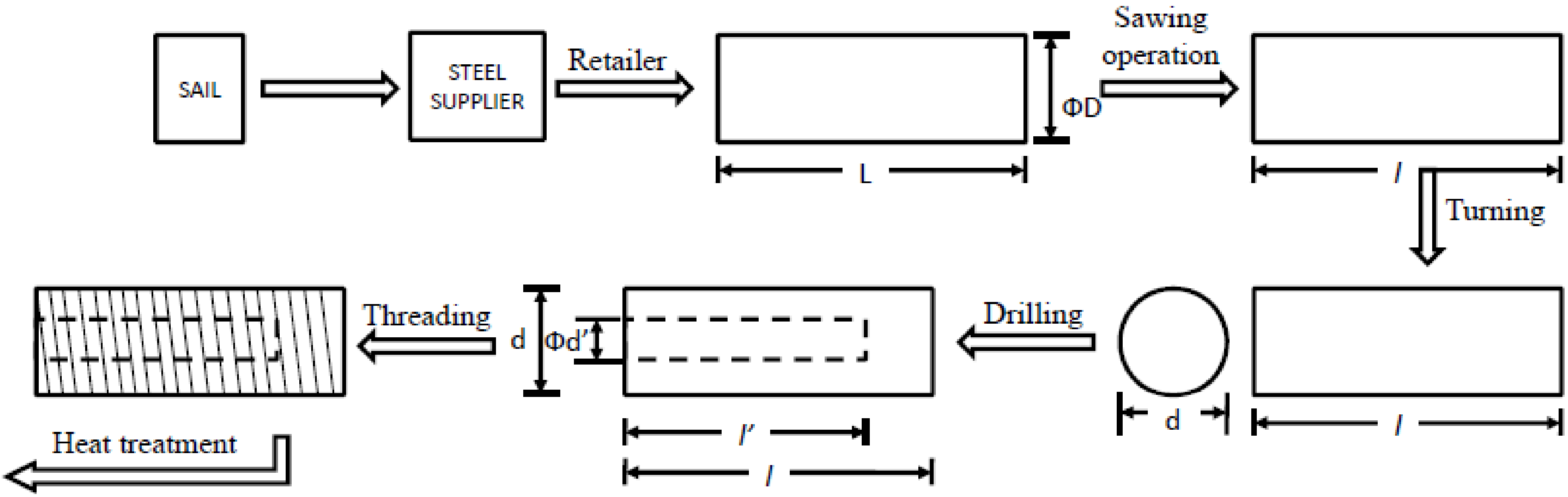
- **Material issues:**
- *Type of material. Stiffness (deflection/ force) & strength (yield stress: stress to cause permanent deformation. If it is too strong, a lot of force will be required but if it is too weak, it may not work in holding the papers etc).*

- **Aesthetic issues:**
- *Style, appearance and surface finish of the clip. Corrosion resistance is also required (subjected to moisture and other environmental attack).*

- **Production issues:**
- *Quantity to be produced: tens , hundreds , ..., millions*
- *Can the wire be bent without cracking/ breaking?*
- *Smooth edge or burr (undesirable): paper finger*

IN CASE OF METALLIC PARTS, STEPS FOLLOWED

ORE → EXTRACT METAL → MELT IN A FURNACE → CASTING → CUT IN PROPER SIZES (LOG) → TRANSPORT TO TRADER



EXPLAIN THE ABOVE STEPS WITH MACHINING CONDITIONS AND TOOLS' DETAILS, IT WILL BE CALLED A PROCESS PLAN.

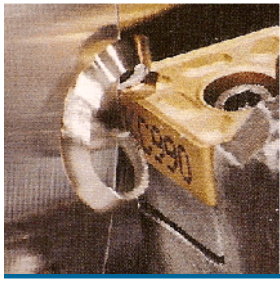
MACHINING CONDITIONS: f , d, v. (cutting fluid / dry cutting)

Tool's Details: Tool material, tool angles.

What has gone into?

- **Value addition**
- **Conversion of raw material into useful product → Manufacturing by performing different operation**

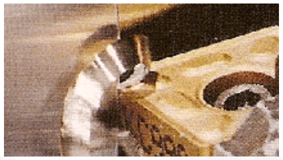
Final product: Weight 3 kg, Cost – Rs 500/. **RAW MATERIAL COST Rs. 60/ PER Kg**



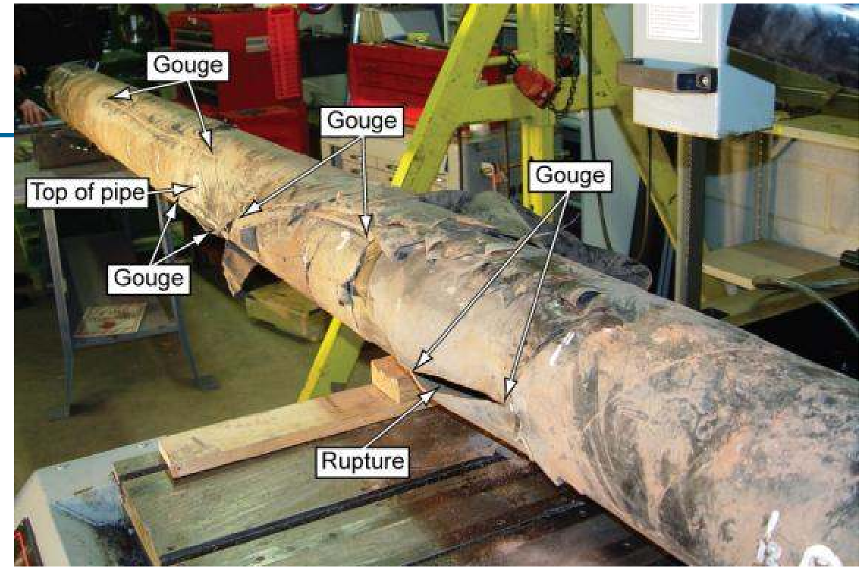
Manufacturing contd.

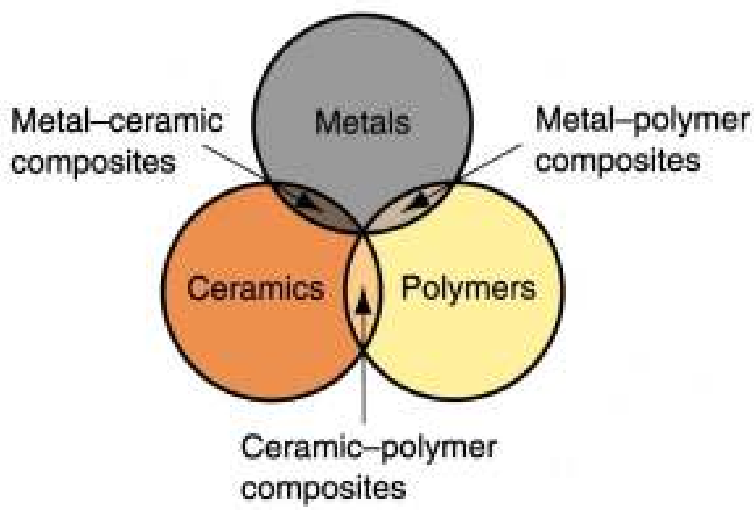
Hence a designer should be well acquainted with

- ✓ Materials and their properties
- ✓ Manufacturing processes and capabilities
  - ➢ Related manufacturing machines and equipments
  - ➢ Assembly and inspection procedures
- ✓ Finishing and surface treatment processes
- ✓ Heat treatment or bulk property enhancing processes

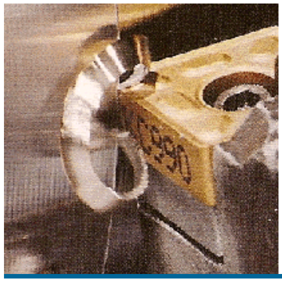


Materials in Manufacturing



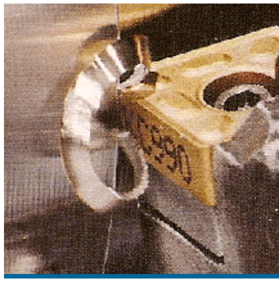


- Their chemistries are different, and their mechanical and physical properties are different.
- These differences affect the manufacturing processes that can be used to produce products from them.



1. Metals

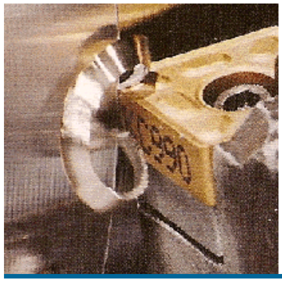
- Usually *alloys*, which are composed of two or more elements, at least one of which is metallic. Two basic groups:
  1. Ferrous metals - based on iron, comprises about 75% of metal tonnage in the world:
     - Steel and cast iron
  2. Nonferrous metals - all other metallic elements and their alloys:
     - Aluminum, copper, nickel, silver, tin, etc.



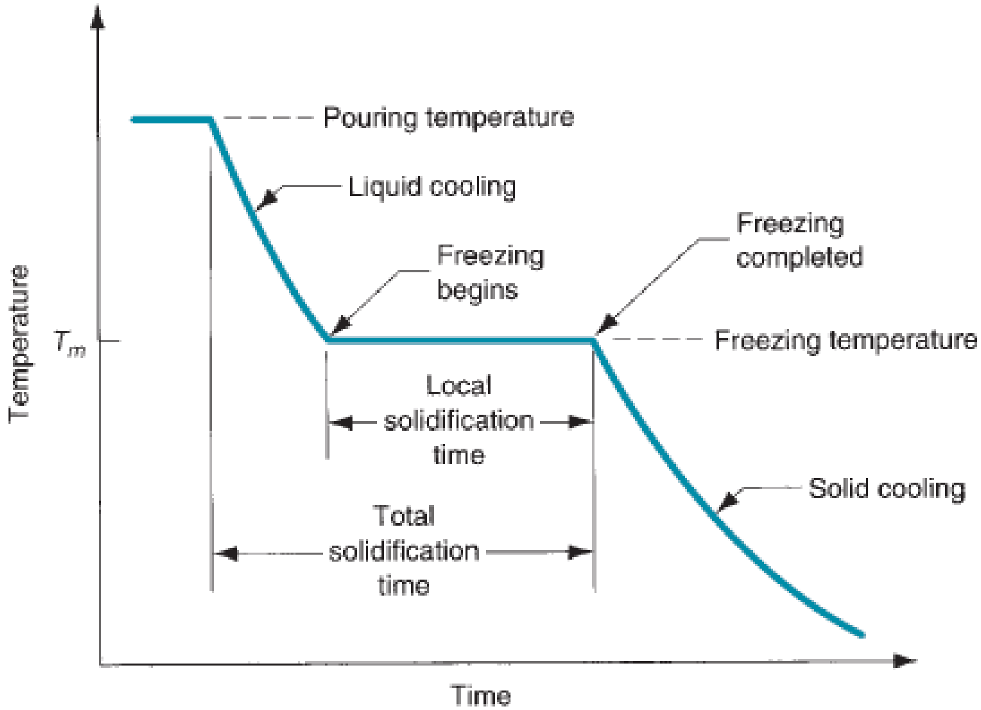
1. Metals

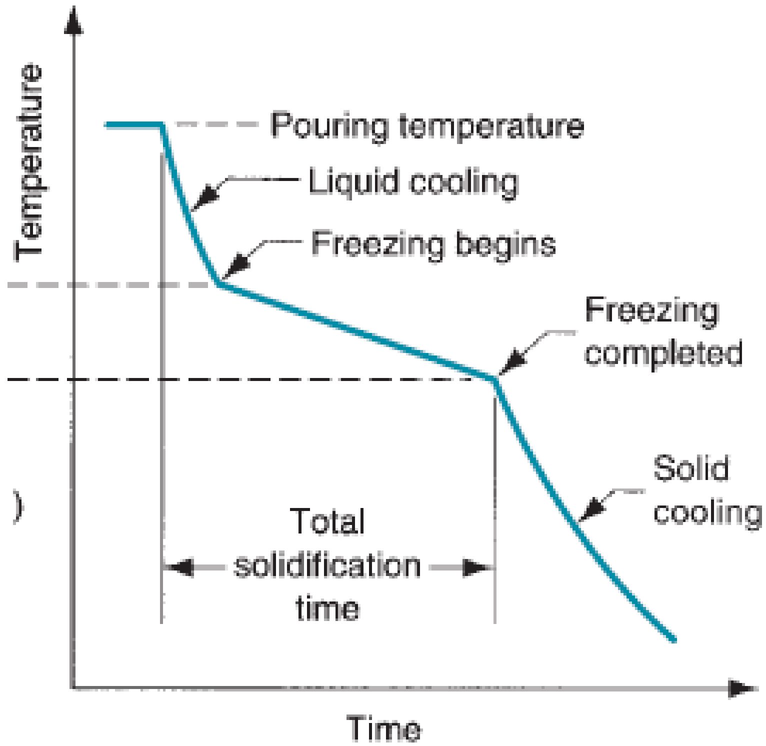
Charging a basic oxygen furnace in steelmaking: molten pig iron is poured. Temperatures are around 1650C (3000F).

Source: 2010 John Wiley & Sons, Inc. M P Groover, ***Fundamentals of Modern Manufacturing*** 4/e



1. Metals





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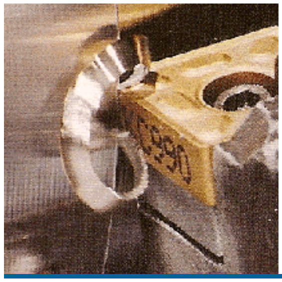


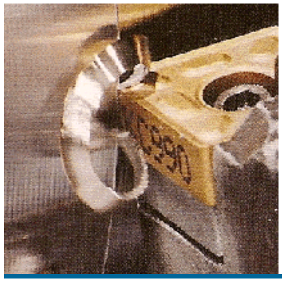
1. Metals

Applications

- Electrical wiring
- Structures: buildings, bridges, etc.
- Automobiles: body, chassis, springs, engine block, etc.
- Airplanes: engine components, fuselage, landing gear assembly, etc.
- Trains: rails, engine components, body, wheels
- Machine tools: drill bits, hammers, screwdrivers, saw blades, etc.
- Magnets

Examples

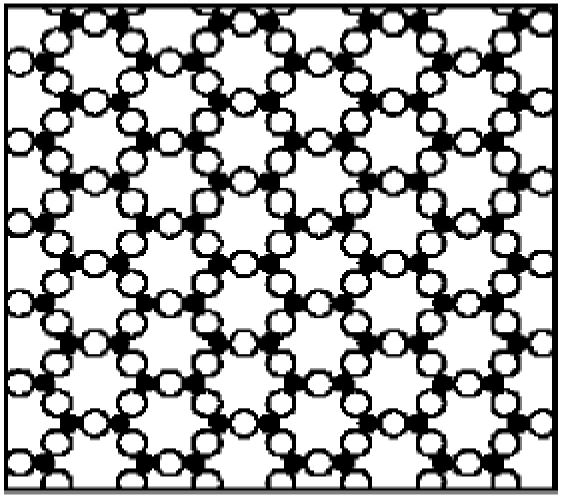
- Pure metal elements (Cu, Fe, Zn, Ag, etc.)
- Alloys (Cu-Sn=bronze, Cu-Zn=brass, Fe-C=steel, Pb-Sn=solder)
- Intermetallic compounds (e.g. Ni_3Al)

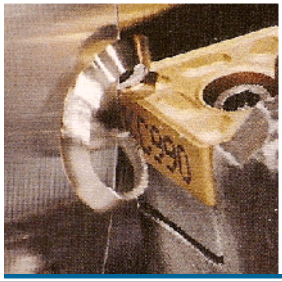


2. Ceramics

Compounds containing metallic (or semi-metallic) and nonmetallic elements.

- Typical nonmetallic elements are oxygen, nitrogen, and carbon
- For processing, ceramics divide into:
  1. Crystalline ceramics – includes:
     - Traditional ceramics, such as clay, and modern ceramics, such as alumina (Al_2O_3)
  2. Glasses – mostly based on silica (SiO_2)



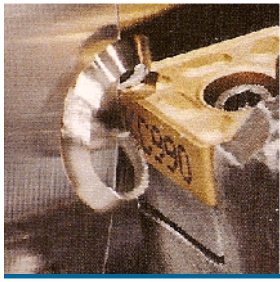


2. Ceramics

Distinguishing features

- Composed of a mixture of metal and nonmetal atoms
- Lower density than most metals
- Stronger than metals
- Low resistance to fracture: low toughness or brittle
- Low ductility or malleability
- High melting point
- Poor conductors of electricity and heat
- Except for glasses, atoms are regularly arranged

- While metals react readily with chemicals in the environment and have low application temperatures in many cases, ceramics do not suffer from these drawbacks.
- Ceramics have high-resistance to environment as they are essentially metals that have already reacted with the environment, e.g. Alumina (Al_2O_3) and Silica (SiO_2, Quartz).
- Ceramics are heat resistant. Ceramics form both crystalline and non-crystalline phases because they can be cooled rapidly from the molten state to form glassy materials.



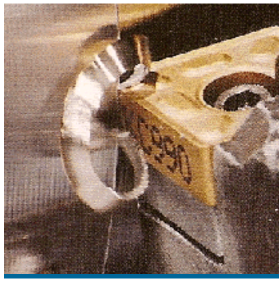
2. Ceramics

Applications

- Electrical insulators
- Abrasives
- Thermal insulation and coatings
- Windows, television screens, optical fibers
- Corrosion resistant applications
- Biocompatible coatings (fusion to bone)
- Magnetic materials (audio/video tapes, hard disks, etc.)
- Night-vision

Examples

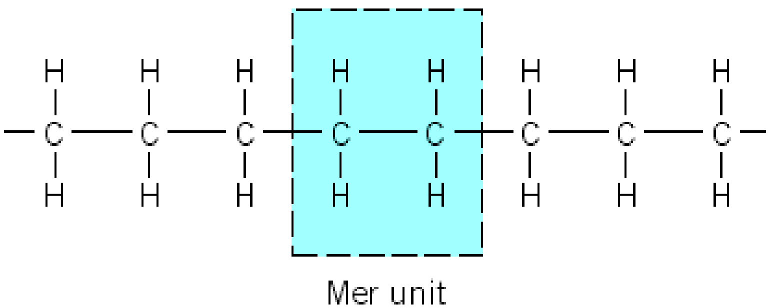
- Simple oxides (SiO_2, Al_2O_3, Fe_2O_3, MgO)
- Mixed-metal oxides ($SrTiO_3$, $MgAl_2O_4$, $YBa_2Cu_3O_{7-x}$)
- Nitrides (Si_3N_4, AlN, GaN, BN, and TiN, which are used for hard coatings)



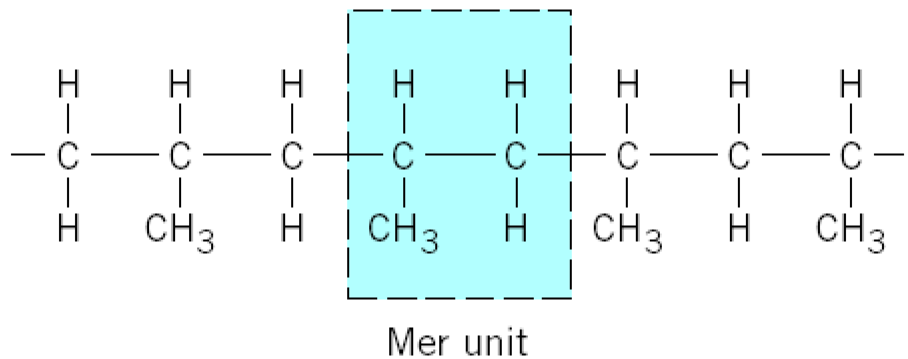
3. Polymers

- Compound formed of repeating structural units called *mers*, whose atoms share electrons to form very large molecules

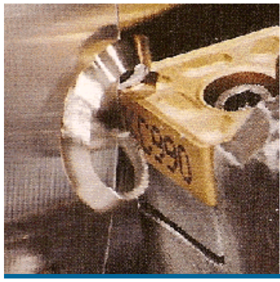
- Polymer usually consists of carbon plus one or more elements such as hydrogen and nitrogen



Polyethylene: (the *mer* unit is C_2H_4)



Polypropylene: (the *mer* unit is C_3H_6)



3. Polymers

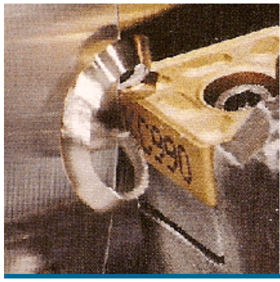
Distinguishing features

• Composed primarily of C and H (hydrocarbons).
• Low melting temperature.
• Most are poor conductors of electricity and heat.
• Many have high plasticity.
• A few have good elasticity.
• Some are transparent, some are opaque.

• Polymers are attractive because they are usually lightweight and inexpensive to make, and usually very easy to process, either in molds, as sheets, or as coatings

• Most are very resistant to the environment

• They are poor conductors of heat and electricity, and tend to be easy to bend, which makes them very useful as insulation for electrical wires.



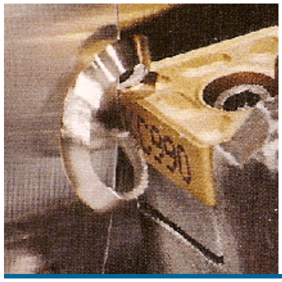
3. Polymers

Three categories:

1. Thermoplastic polymers - can be subjected to multiple heating and cooling cycles without substantially altering molecular structure
2. Thermosetting polymers - molecules chemically transform into a rigid structure – cannot reheat
3. Elastomers - shows significant elastic behavior

Applications and Examples

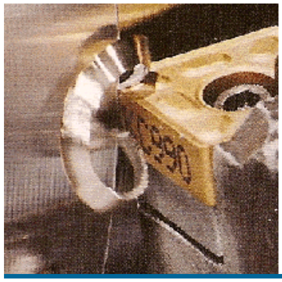
Adhesives and glues, Containers, Moldable products (computer casings, telephone handsets, disposable razors), Clothing and upholstery material (vinyls, polyesters, nylon), Water-resistant coatings (latex), Biodegradable products (corn-starch packing "peanuts"), Biomaterials (organic/inorganic intefaces), Liquid crystals, Low-friction materials (teflon), Synthetic oils and greases, Gaskets and O-rings (rubber), Soaps and surfactants



4. Composites

Material consisting of two or more phases that are processed separately and then bonded together to achieve properties superior to its constituents

- *Phase* - homogeneous mass of material, such as grains of identical unit cell structure in a solid metal
- Usual structure consists of particles or fibers of one phase mixed in a second phase
- Properties depend on components, physical shapes of components, and the way they are combined to form the final material



4. Composites

In two material system, there are two phases : Primary phase & Secondary phase.

 The primary phase forms the matrix within which the secondary phase is imbedded

The imbedded phase is also known as dispersed phase or reinforcing phase

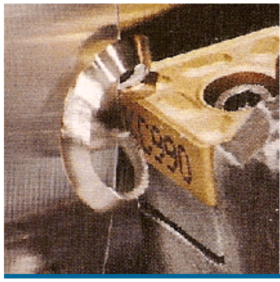
Matrix phase : The continuous phase

Purpose is to

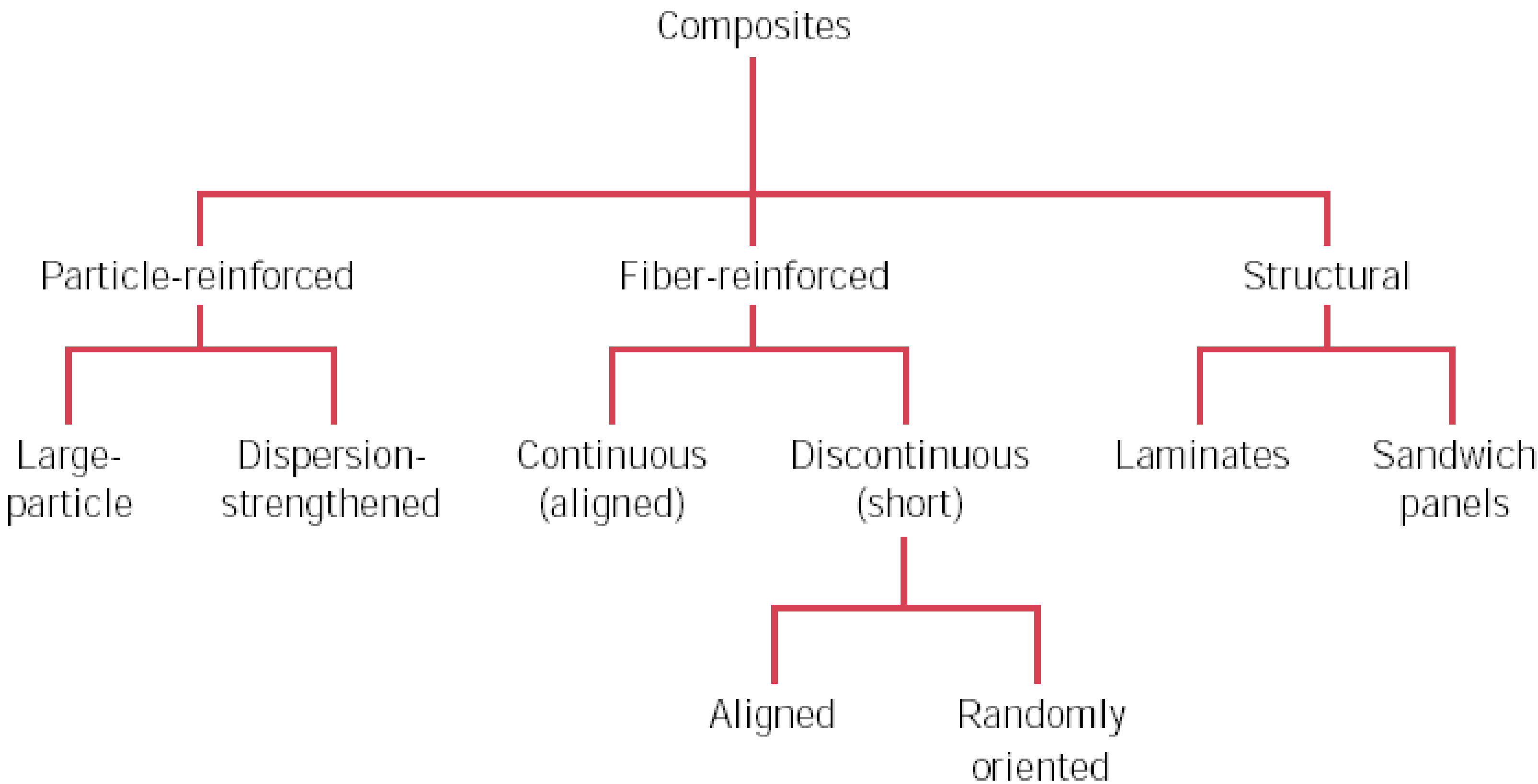
- Transfer stress to other phases
- Protect phases from environment
- Classification: MMC, CMC, PMC

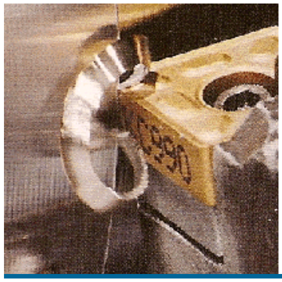
Dispersed phase

- Purpose is to enhance matrix properties
- Classification: Fiber (Diameter 0.0025 to 0.13mm), Particle (25 to 300µm), flake (two dimensional particles, size : 0.01 to 1mm)



4. Composites





4. Composites

Distinguishing features

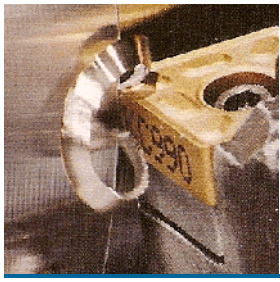
- Composed of two or more different materials (e.g., metal/ceramic, polymer/polymer, etc.)
- Properties depend on amount and distribution of each type of material
- Collective properties more desirable than possible with any individual material

Applications

- Sports equipment (golf club shafts, tennis rackets, bicycle frames)
- Aerospace materials
- Thermal insulation
- Concrete
- "Smart" materials (sensing and responding)
- Brake materials

Examples

Fiberglass (glass fibers in a polymer); space shuttle heat shields (interwoven ceramic fibers); paints (ceramic particles in latex); tank armor (ceramic particles in metal)



4. Composites

Advantages

- Composites can have a unique property (e.g. Specific strength, specific modulus, improved impact resistance) that is significantly higher than their metal, polymer, and ceramic counterparts.

- Composites can be fabricated to a final product from raw materials eliminating many secondary operations such as machining, shaping, joining etc. (Reduce structural weakness and processing costs).

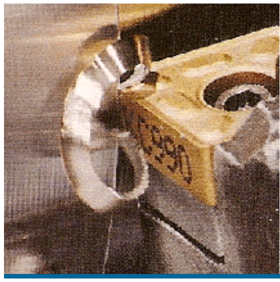
- Composites can be tailored to have both high strengths and high strains.

Disadvantages

- The costs of the materials are generally higher.

- The nature and the amount of reinforcing elements and matrix will limit the usage of that composite.

- Some environmental concerns (e.g. Solvents, chemical fumes, airborne fibers, etc.) can be involved during the processing of composites.



Shape Memory Materials

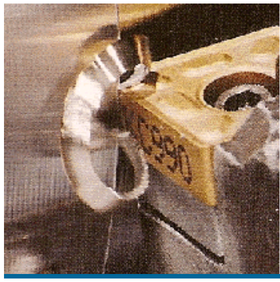
DEFINITION:

Shape Memory Materials (SMM) are those materials which, after being deformed PLASTICALLY (i.e., PERMANENTLY) at the room temperature into various shapes, return to their original shapes upon heating

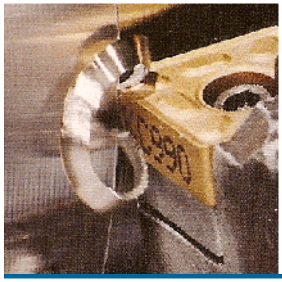
EXAMPLES:

Typical Shape Memory Alloys are

- 55% Ni-45%Ti
- Copper-Aluminum-Nickel
- Copper-Zinc-Aluminum
- Iron-Manganese-Silicon



Shape Memory Materials



Shape Memory Materials

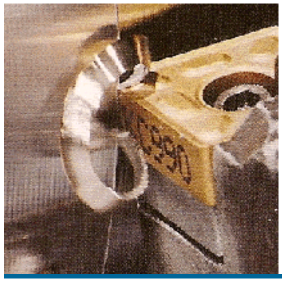
CHARACTERISTICS:

- SMM have good ductility, good corrosion resistance, high electrical conductivity
- Behavior of SMM can also be *reversible*, i.e., shape can switch back and forth upon heating

APPLICATIONS:

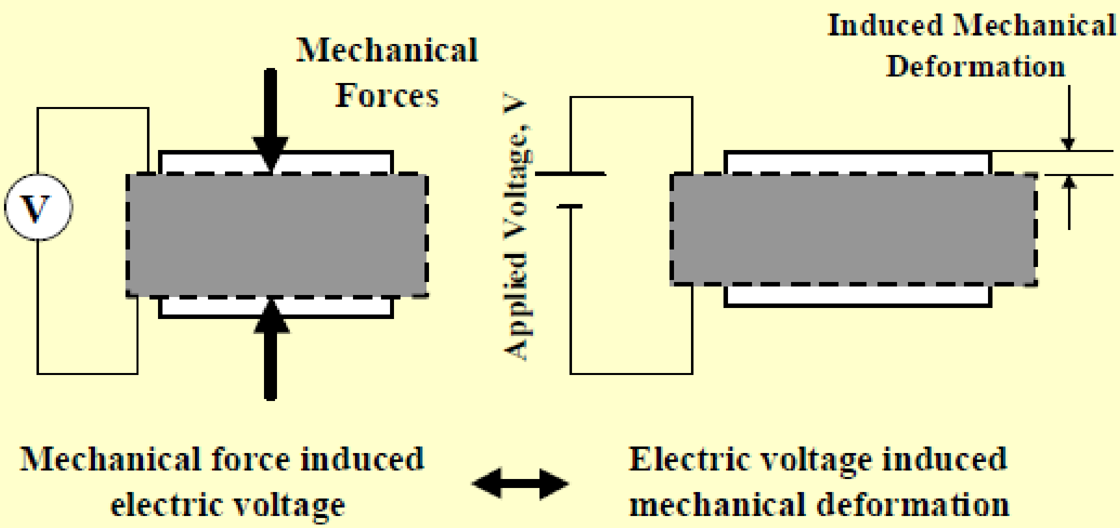
Can be used

- To generate motion and/or force in temperature-sensitive actuators
- Eyeglass frames, connectors, clamps and fasteners



Piezoelectric Materials

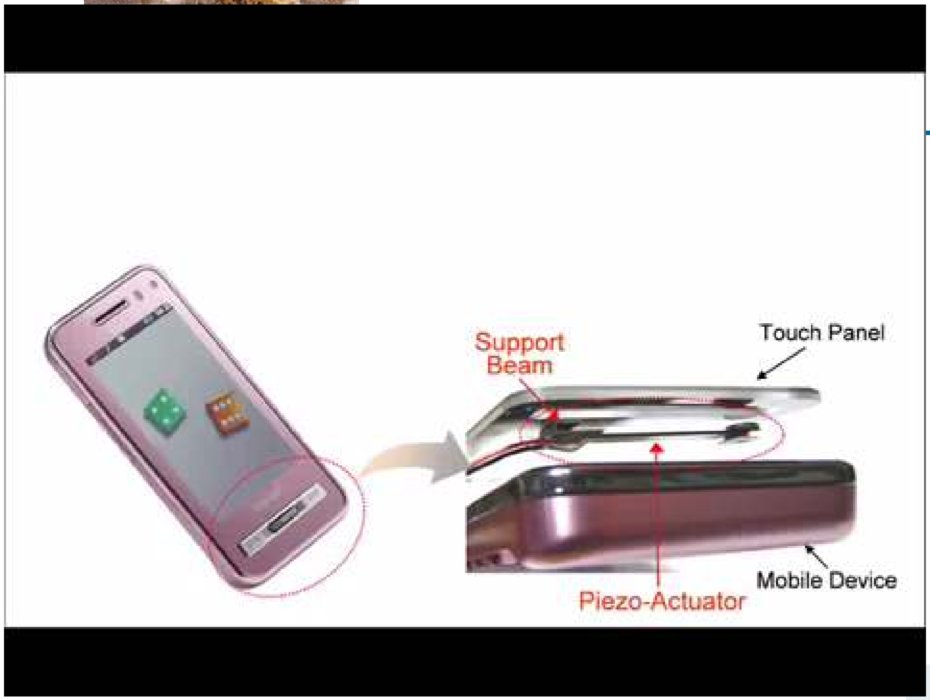
- Piezoelectric crystals are solid ceramic compounds that produce piezoelectric effects:

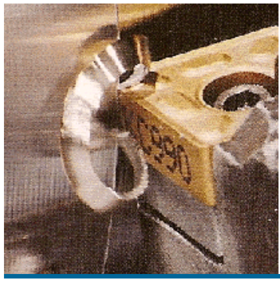


- Natural piezoelectric crystals are: quartz, tourmaline and sodium potassium tartrate.

- Synthesized crystals are: Rochelle salt, barium titanate and lead zirconate.

Piezoelectricity





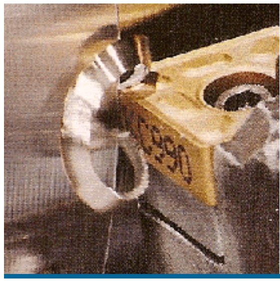
Biomaterials

A biomaterial can be defined as any substance (other than a drug) or combination of substances synthetic or natural in origin, which can be used for any period of time, as a whole or as a part of a system which treats, augments, or replaces any tissue, organ or function of the body.

Theoretically, any material can be a biomaterial as long as it serves the stated medical and surgical purposes.

Example of Biomaterial

Metals	Ceramics	Polymers
316L stainless steel Co-Cr Alloys Titanium Ti6Al4V	Alumina Zirconia Carbon Hydroxyapatite	Ultra high molecular weight polyethylene Polyurethane



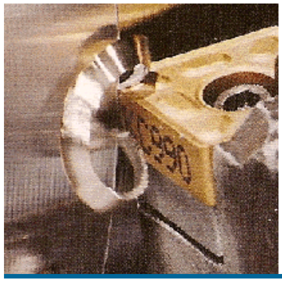
Biomaterials

Orthopaedic Applications

- Metallic materials are normally used for load bearing members such as pins and plates and femoral stems etc.
- Ceramics such as alumina and zirconia are used for wear applications in joint replacements.
- Polymers such as ultra high molecular weight polyethylene are used as articulating surfaces against ceramic components in joint replacements.

Dental Applications

- Metallic biomaterials have been used as pins for anchoring tooth implants and as parts of orthodontic devices.
- Ceramics have found uses as tooth implants including alumina and dental porcelains.
- Polymers, have are also orthodontic devices such as plates and dentures.



Biomaterials

Cardiovascular Applications

- Many different biomaterials are used in cardiovascular applications depending on the specific application and the design. For instance, carbon in heart valves and polyurethanes for pacemaker leads.

Cosmetic Surgery

- Materials such as silicones have been used in cosmetic surgery.