ENGINEERING MATERIALS – 21ME32

Presented by,

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Introduction

- Is the study and application of electronic devices that source, control and detect light. It combine electronics and optics.
- Optoelectronic devices are electrical-to-optical or optical-to-electrical transducers.
- Its operation is based on the wave theory and quantum mechanics .

- We can distinguish 3 categories:
  - Light Emitters.
  - Light Receivers.
  - Optocouplers.

LIGHT EMITTERS

Among semiconductor devices, those capable of emitting light belong to the category of the diodes.

- Led (Ligth-emitting diode)
- Laser diode.

LEDs

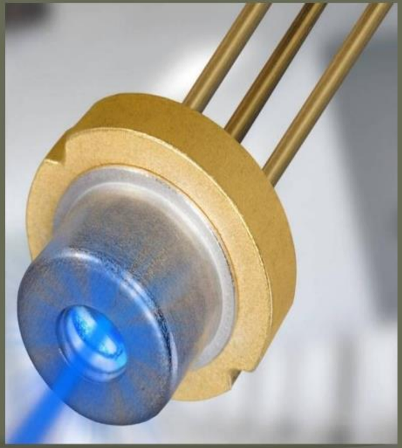
- Is a two-lead semiconductor light source. It is a p–n junction diode, which emits light when activated.
- When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence.

LEDs APPLICATIONS

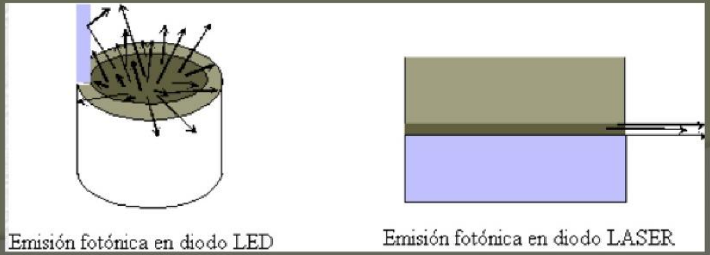
- 3 main types of applications for LEDs:
  - Indicators and signs.
  - Lighting or illumination.
  - Measuring/interacting in processes involving no human vision.

LASER DIODE

- *Light Amplification by Stimulated Emission of Radiation* is an electrically pumped semiconductor laser in which the active laser medium is formed by a p-n junction of a semiconductor diode similar to that found in a LED.



- Advantages over LEDs:
  - Light emission in only one direction.
  - Laser light emission is monochromatic



LASER DIODE APPLICATIONS

- Data communications fiber optics.
- Optical interconnections between integrated circuits.
- Laser printers.
- Scanners and digitizers.
- Sensors.
- Dental laser treatment.
- Body hair removal.
- Laser display
- Odontology

LIGHT RECEPTORS

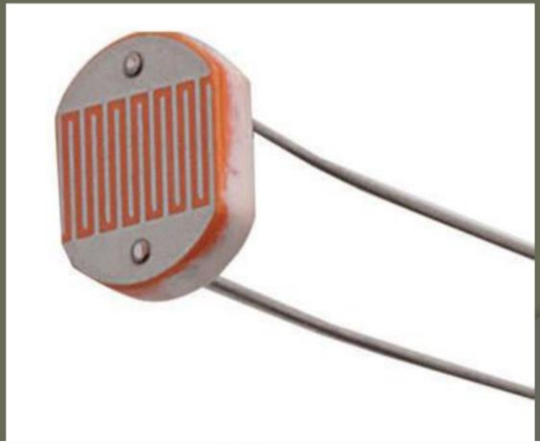
Are those components that vary an electrical parameter depending on the light.

- Three main types:
  - Photoresistor.
  - Photodiode.
  - Phototransistor.

PHOTORESISTOR

Is a light-controlled variable resistor.

The resistance of a photoresistor decreases with increasing incident light intensity.

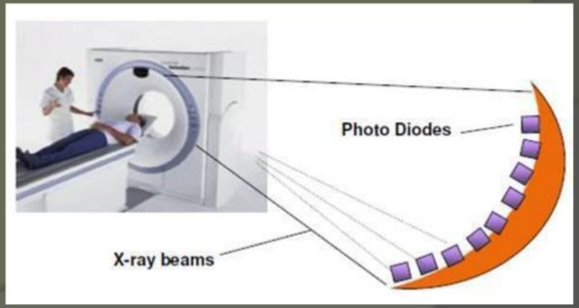


PHOTORESISTORS APPLICATIONS

- Most of the applications are based on photoresistors actuating a relay or a lamp.
- The most popular example is the light activation system in companies when the night falls. When the ambient light drops below a certain level, a relay is actuated, closing the corresponding switch.

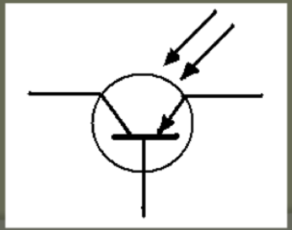
PHOTODIODES APLICATIONS

- Cameras
- Medical devices
- Safety equipment
- Optical communication devices
- Position sensors
- Bar code scanners
- Automotive devices



PHOTOTRANSISTORS

- Is a light-sensitive transistor. A common type of phototransistor, called a photobipolar transistor, is in essence a bipolar transistor encased in a transparent case so that light can reach the base–collector junction.



PHOTOTRANSISTORS

- The operation of a phototransistor is characterized by the following points:
  - A phototransistor operates, generally, without base terminal.
  - The sensitivity of a phototransistor is higher than a photodiode.
  - Operating curves of a phototransistor are analogous curves to BJT transistor, replacing the base intensity for power per unit area incident on the phototransistor.

PHOTOTRANSISTORS APPLICATIONS

- Punch-card readers.
- Security systems
- Electric controls
- Computer logic circuits.
- Relays
- Lighting control
- Level indication
- Counting systems

Semiconductors

- Semiconductors are materials with electrical conductivity between that of conductors (such as metals) and insulators.
- They have a unique property where their electrical conductivity can be controlled and manipulated, making them essential components in electronic devices.
- Silicon is one of the most commonly used semiconductor materials.

Applications of semiconductors

- **Integrated Circuits (ICs) and Microprocessors:**
  - Semiconductors are the foundation of integrated circuits, which are densely packed arrangements of transistors, resistors, capacitors, and other components on a single chip. Microprocessors, the "brains" of computers, use semiconductors extensively.
- **Memory Devices:**
  - Semiconductor-based memory devices, such as RAM (Random Access Memory) and ROM (Read-Only Memory), are used in computers and other electronic devices for temporary and permanent data storage.
- **Transistors:**
  - Transistors are fundamental semiconductor devices that act as amplifiers or switches. They are crucial in electronic circuits, serving roles from signal amplification in audio devices to forming the basis of digital logic circuits in computers.

Applications of semiconductors

- **Diodes:**
  - Semiconductor diodes, such as light-emitting diodes (LEDs) and rectifiers, are used in a wide range of applications. LEDs are employed for lighting, displays, and indicators, while rectifiers convert alternating current (AC) to direct current (DC) in power supplies.
- **Solar Cells:**
  - Photovoltaic cells, or solar cells, use semiconductors to convert sunlight into electrical energy. Silicon-based solar cells are the most common, with the ability to generate electricity in a clean and renewable manner.
- **Semiconductor Lasers:**
  - Semiconductor lasers are used in various applications, including optical communication (fiber optics), laser printers, barcode scanners, and medical equipment. They offer a compact and efficient way to produce coherent light.
- **Sensors:**
  - Semiconductor sensors play a crucial role in detecting and measuring physical quantities. For instance, temperature sensors, pressure sensors, and light sensors in cameras and smartphones often use semiconductor technology.

Applications of semiconductors

- **Radio Frequency (RF) Devices:**
  - Semiconductors are essential in the design of RF devices used in communication systems, such as mobile phones, radios, and wireless networking equipment.
- **Power Electronics:**
  - Semiconductor devices like power transistors and diodes are critical in power electronics applications, including inverters, converters, and motor control systems.
- **Digital and Analog Electronics:**
  - Semiconductors are used in both digital and analog circuits. Digital circuits process information in discrete binary states (0s and 1s), while analog circuits handle continuous signals. Applications include signal processing, amplification, and signal conversion.
- **Microcontrollers:**
  - Microcontrollers are compact integrated circuits that contain a processor, memory, and input/output peripherals. They are widely used in embedded systems, including appliances, automotive electronics, and industrial control systems.

Dielectric Materials and its applications

- Dielectric materials are insulating materials that do not conduct electric current.
- They are characterized by their ability to store and support the transmission of electric charge without conducting it.
- Dielectrics are used in a variety of applications due to their electrical insulating properties.
- Dielectric materials are crucial in a wide range of technologies, from electronics and telecommunications to power systems and medical applications.
- Their insulating properties make them indispensable for managing electric fields and enabling various electrical devices to function efficiently and safely.

Common dielectric materials and their applications

- **Capacitors:**
  - **Dielectric Material:** Various dielectrics such as ceramic, tantalum, aluminum oxide, and polyester.
  - **Application:** Capacitors are electronic components that store and release electrical energy. Dielectrics are used between the capacitor plates to insulate them, allowing the capacitor to store charge.
- **Insulation in Electrical Systems:**
  - **Dielectric Material:** Oil-impregnated paper, polyethylene, polypropylene, and others.
  - **Application:** Dielectric materials are extensively used as insulation in electrical systems, including power cables, transformers, and electrical equipment, to prevent the flow of electric current.
- **Dielectric Resonators:**
  - **Dielectric Material:** Ceramics, quartz, and other high-permittivity materials.
  - **Application:** Dielectric resonators are used in microwave circuits and antennas to tune and control the frequency response.

Common dielectric materials and their applications

- **Microwave Devices:**
  - **Dielectric Material:** Ferrites, barium titanate, and certain ceramics.
  - **Application:** Dielectric materials are used in microwave components such as circulators, isolators, and filters for telecommunications and radar systems.
- **Dielectric Heating:**
  - **Dielectric Material:** Water, certain polymers, and other materials with high dielectric loss.
  - **Application:** Dielectric heating is used in microwave ovens to heat food. The dielectric material (food) absorbs microwaves and gets heated.
- **Dielectric Constant Measurement:**
  - **Dielectric Material:** Liquids with known dielectric properties.
  - **Application:** Dielectric constant measurements are used in various industries to determine the properties of liquids, including moisture content and composition.

Common dielectric materials and their applications

- **Dielectric Elastomers:**
  - **Dielectric Material:** Silicone, acrylic elastomers.
  - **Application:** Dielectric elastomers can deform when an electric field is applied. They are used in soft robotics, artificial muscles, and haptic feedback systems.
- **Dielectric Coatings:**
  - **Dielectric Material:** Polyurethane, epoxy, and other insulating coatings.
  - **Application:** Dielectric coatings are applied to electronic components and devices to provide electrical insulation and protect against environmental factors.
- **Dielectric Spectroscopy:**
  - **Dielectric Material:** Various materials with known dielectric properties.
  - **Application:** Dielectric spectroscopy is used for studying the electrical properties of materials, including biological tissues, polymers, and liquids.

Common dielectric materials and their applications

- **Dielectric Mirrors:**
  - **Dielectric Material:** Multilayer coatings of dielectric materials.
  - **Application:** Dielectric mirrors are used in optics to reflect specific wavelengths of light while allowing others to pass through, commonly employed in lasers and optical instruments.
- **Dielectric Fluids:**
  - **Dielectric Material:** Mineral oil, silicone oil, and synthetic esters.
  - **Application:** Dielectric fluids are used in transformers and high-voltage equipment to provide electrical insulation and dissipate heat.
- **Dielectric Resonator:**
- The dielectric resonator is a ceramic or composite material with a high permittivity (relative dielectric constant). Its shape and dimensions determine the resonant frequency of the antenna.

✓ **Mobile Communications:** DRAs find applications in mobile phones, where space constraints and the need for compact antennas are critical.

✓ **Wireless Communication Systems:** Used in wireless communication systems such as Wi-Fi, Bluetooth, and other short-range communication devices.

✓ **Radar Systems:** DRAs can be used in radar systems where their compact size and efficiency are advantageous.

✓ **Satellite Communication:** In satellite communication systems, where minimizing antenna size and weight is essential.

✓ **Millimeter-Wave Applications:** DRAs are suitable for high-frequency applications, including millimeter-wave communication systems.

Dielectric Waveguides:

- Dielectric waveguides are structures that guide and confine electromagnetic waves within a dielectric material, typically with a lower refractive index than the surrounding medium.
- Dielectric waveguides do not use metal walls to confine the electromagnetic fields.
- These waveguides find applications in various optical and microwave systems.
- **Optical Dielectric Waveguides:**
  - **Material:** Dielectric materials with a high refractive index, such as silicon, silicon nitride, or glass.
  - **Applications:** Optical dielectric waveguides are widely used in integrated photonic devices, such as waveguide-based modulators, splitters, and routers in optical communication systems.

- **Microwave Dielectric Waveguides:**
  - **Material:** Dielectric materials like ceramics or polymers.
  - **Applications:** Dielectric waveguides are employed in microwave and millimeter-wave systems, including antennas, filters, and passive components.
- **Dielectric Optical Fibers:**
  - **Material:** Glass or polymer fibers with a high refractive index.
  - **Applications:** Dielectric optical fibers are used in optical communication systems for transmitting data over long distances with low signal loss. They are also employed in medical applications for endoscopy.
- **Photonic Crystal Waveguides:**
  - **Structure:** Periodic arrangements of dielectric materials.
  - **Applications:** Photonic crystal waveguides are used in creating photonic crystals, which control the flow of light and find applications in optical communications, sensing, and imaging.
- **Dielectric Resonator Waveguides:**
  - **Structure:** Dielectric resonators used to guide and manipulate electromagnetic waves.
  - **Applications:** Dielectric resonator waveguides are employed in microwave circuits, filters, and antennas.

Dielectric Testing Applications

- Dielectric testing involves assessing the electrical properties of insulating materials, including their ability to withstand electrical stress without breakdown.
- **High Voltage Insulation Testing:**
  - **Purpose:** To ensure the integrity of insulation materials in electrical systems.
  - **Methods:** Dielectric strength testing involves applying a high voltage to the insulation and checking for breakdown or flashover.
- **Dielectric Spectroscopy:**
  - **Purpose:** Analyzing the frequency-dependent dielectric properties of materials.
  - **Applications:** Used in material characterization, including the study of polymers, liquids, and biological tissues.
- **Power Cable Testing:**
  - **Purpose:** Ensuring the reliability and safety of power cables.
  - **Methods:** Dielectric testing is performed to assess the insulation quality and detect potential defects in power cables.

Dielectric Testing Applications

- **Transformer Insulation Testing:**
  - **Purpose:** Verifying the insulation integrity of transformers.
  - **Methods:** Dielectric testing assesses the insulation resistance and dielectric strength of transformer components.
- **Capacitor Testing:**
  - **Purpose:** Quality control and reliability testing of capacitors.
  - **Methods:** Dielectric absorption testing and breakdown voltage testing are common methods used in capacitor testing.
- **Insulator Testing in Electronic Devices:**
- **Purpose:** Ensuring proper insulation in electronic components.
- **Methods:** Dielectric testing is essential to verify the insulation properties of components like capacitors, transformers, and integrated circuits.

Optoelectronic materials and its applications

- Optoelectronic materials are substances that can respond to and manipulate light, combining aspects of both optics and electronics.
- These materials exhibit electrical and optical properties that make them valuable in a variety of applications.

- **Semiconductors:**
  - **Material:** Silicon, gallium arsenide, indium phosphide, etc.
  - **Applications:** Semiconductors are fundamental in optoelectronics. They are used in light-emitting diodes (LEDs), laser diodes, photodetectors, solar cells, and integrated circuits for optical communication.
- **Light-Emitting Diodes (LEDs):**
  - **Material:** Gallium nitride (GaN), indium gallium nitride (InGaN), and others.
  - **Applications:** LEDs are used in lighting (including general illumination and display backlighting), electronic displays (TVs, monitors, smartphones), and indicator lights.
- **Laser Diodes:**
  - **Material:** Gallium arsenide (GaAs), indium phosphide (InP), and other compound semiconductors.
  - **Applications:** Laser diodes are used in telecommunications for data transmission (fiber optics), medical devices, barcode scanners, laser printers, and various scientific and industrial applications.

- **Photodetectors:**
  - **Material:** Silicon, germanium, indium gallium arsenide (InGaAs), and others.
  - **Applications:** Photodetectors convert light into electrical signals and are used in optical communication, cameras, sensing applications, and medical imaging.
- **Solar Cells:**
  - **Material:** Silicon, thin-film materials (cadmium telluride, copper indium gallium selenide, organic photovoltaic materials).
  - **Applications:** Solar cells convert sunlight into electricity and are used in photovoltaic panels for renewable energy generation.
- **Liquid Crystal Materials:**
  - **Material:** Liquid crystals (organic molecules with liquid and crystalline properties).
  - **Applications:** Liquid crystal materials are used in displays (LCDs), smart windows, and various optical modulators.

- **Optical Fibers:**
  - **Material:** Glass or plastic fibers.
  - **Applications:** Optical fibers are used in telecommunications for high-speed data transmission, fiber-optic sensors, and medical endoscopy.
- **Optical Modulators:**
  - **Material:** Electro-optic crystals (e.g., lithium niobate), liquid crystals.
  - **Applications:** Optical modulators are used to control the intensity, phase, or polarization of light in optical communication systems and signal processing.
- **Organic Light-Emitting Diodes (OLEDs):**
  - **Material:** Organic compounds.
  - **Applications:** OLEDs are used in display technologies (TVs, smartphones, flexible displays) and lighting applications due to their thin form factor and energy

Optoelectronic materials and its applications

- **Photonic Crystals:**
  - **Material:** Dielectric materials with periodic structures.
  - **Applications:** Photonic crystals are used to control the flow of light and find applications in optical communication, sensors, and lasers.
- **Perovskite Nanomaterials:**
  - **Material:** Perovskite structures.
  - **Applications:** Perovskite materials are being explored for use in solar cells, light-emitting diodes, and other optoelectronic devices due to their excellent optoelectronic properties.
- **Quantum Dots:**
  - **Material:** Semiconductor nanocrystals.
  - **Applications:** Quantum dots are used in displays, imaging technologies, and as fluorescent markers in biological and medical applications.

Structural materials and its applications

- Structural materials are those used to construct various elements of buildings, infrastructure, and other engineering projects.
- The selection of these materials is crucial for ensuring the structural integrity, durability, and safety of the constructed components.

- **Steel:**
  - **Applications:** Widely used in construction for beams, columns, and structural frames. Also used in bridges, automotive structures, and industrial machinery.
- **Concrete:**
  - **Applications:** Used in construction for foundations, pillars, beams, and slabs. Also employed in bridges, dams, and other infrastructure projects.
- **Wood:**
  - **Applications:** Used in residential construction for framing, flooring, and siding. Also used in the construction of bridges, decks, and other outdoor structures.

Structural materials and its applications

- **Aluminum:**
  - **Applications:** Used in the aerospace industry for aircraft frames and components. Also used in the construction of lightweight structures, such as curtain walls and architectural features.
- **Masonry (Brick and Stone):**
  - **Applications:** Used in the construction of walls, facades, and partitions. Stone is used for decorative and structural purposes in buildings and monuments.
- **Reinforced Concrete:**
  - **Applications:** Combines concrete with reinforcing materials (usually steel) to enhance tensile strength. Commonly used in high-rise buildings, bridges, and infrastructure projects.
- **Fiber-Reinforced Polymers (FRP):**
- **Applications:** Used as a substitute for steel in some applications, such as strengthening of concrete structures, and in the construction of lightweight and corrosion-resistant components.

Structural materials and its applications

- **Glass:**
  - **Applications:** Used in buildings for windows, facades, and decorative features. Also employed in the construction of certain bridges and as a structural material in the form of laminated glass.
- **Composites:**
  - **Applications:** Materials like fiberglass, carbon fiber, and aramid fibers are used in the construction of lightweight and high-strength components in aerospace, automotive, and marine industries.
- **Pre-stressed Concrete:**
  - **Applications:** Concrete in which internal stresses are introduced before loading to improve its ability to resist tension. Used in bridges, parking structures, and buildings with large spans.
- **Engineered Wood Products:**
- **Applications:** Includes materials like laminated veneer lumber (LVL), particleboard, and plywood, used in construction for beams, columns, and sheathing.

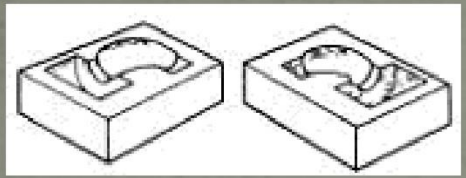
Structural materials and its applications

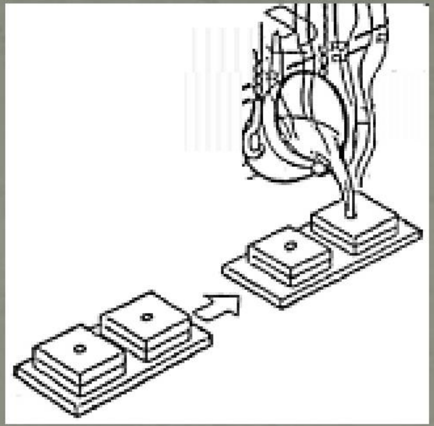
- **Titanium:**
  - **Applications:** Used in the aerospace industry for aircraft components, as well as in medical implants and certain high-performance structures.
- **Ceramics:**
  - **Applications:** Used in specialized applications such as the construction of heat-resistant components, refractory linings, and certain structural elements in electronic devices.
- **Geosynthetics:**
  - **Applications:** Materials like geotextiles, geogrids, and geomembranes used in civil engineering for soil stabilization, erosion control, and reinforcement of slopes and embankments.
- **Bamboo:**
- **Applications:** Used in traditional construction and increasingly in modern building for its sustainability and strength-to-weight ratio.

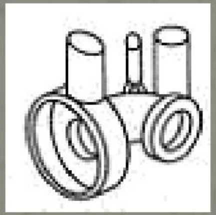
Processing of Structural Materials.

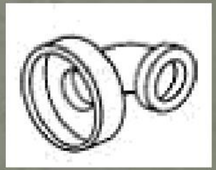
- Casting
- Joining
- Forming

Casting









Refractory mold → pour liquid metal → solidify, remove → finish

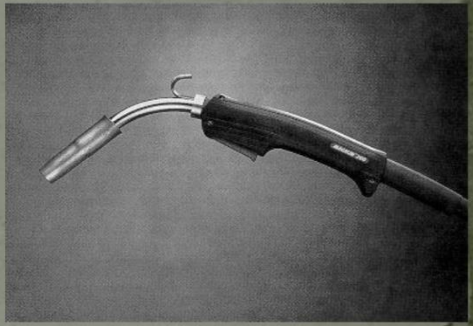
Different Casting Processes

Process	Advantages	Disadvantages	Examples
Sand	many metals, sizes, shapes, cheap	poor finish & tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, few shapes	pipes, boilers, flywheels

Joining Processes

Consumable Electrode

- SMAW – Shielded Metal Arc Welding
- GMAW – Gas Metal Arc Welding
- SAW – Submerged Arc Welding



Non-Consumable Electrode

- GTAW – Gas Tungsten Arc Welding
- PAW – Plasma Arc Welding

High Energy Beam

- Electron Beam Welding
- Laser Beam Welding

SMAW – Shielded Metal Arc Welding

Welding Processes

- Consumable electrode
- Flux coated rod
- Flux produces protective gas around weld pool
- Slag keeps oxygen off weld bead during cooling

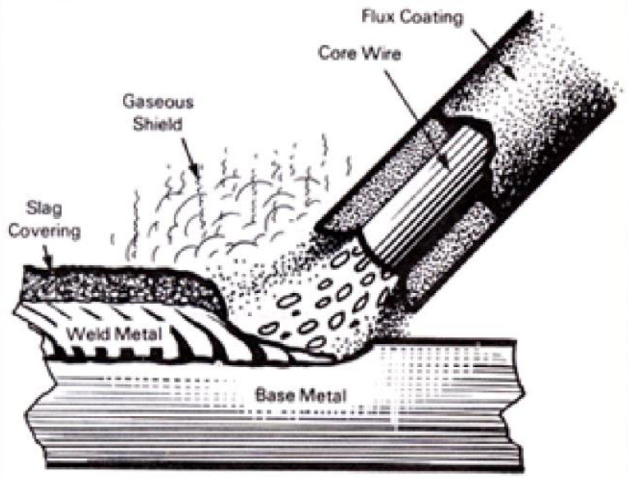


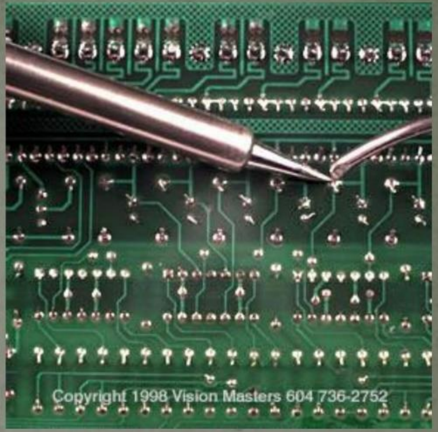
Fig. 6

- General purpose welding—widely used
- Thicknesses 1/8” – 3/4”
- Portable

Power... Current I (50 - 300 amps)
Voltage V (15 - 45 volts)

Power = VI ≈ 10 kW

Soldering & Brazing



- Only filler metal is melted, not base metal
- Lower temperatures than welding
- Filler metal distributed by capillary action
- Metallurgical bond formed between filler & base metals

- Strength of joint typically
  - stronger than filler metal itself
  - weaker than base metal
  - gap at joint important (0.001 – 0.010")
- Pros & Cons
  - Can join dissimilar metals
  - Less heat - can join thinner sections (relative to welding)
  - Excessive heat during service can weaken joint

Soldering

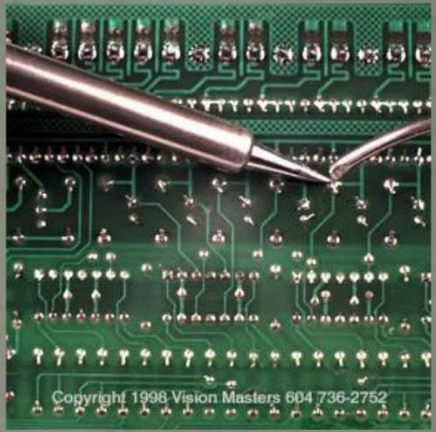
Solder = Filler metal

- Alloys of Tin (silver, bismuth, lead)
- Melt point typically below 840 F

Flux used to clean joint & prevent oxidation

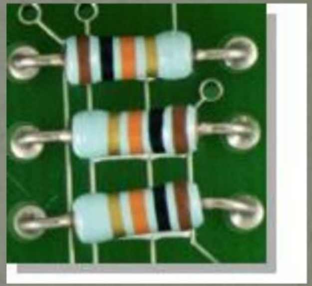
- separate or in core of wire (rosin-core)

Tinning = pre-coating with thin layer of solder



Applications:

- Printed Circuit Board (PCB) manufacture
- Pipe joining (copper pipe)
- Jewelry manufacture
- Typically non-load bearing



Easy to solder: copper, silver, gold

Difficult to solder: aluminum, stainless steels

(can pre-plate difficult to solder metals to aid process)

Brazing

Use of low melt point filler metal to fill thin gap between mating surfaces to be joined utilizing capillary action

- Filler metals include Al, Mg & Cu alloys (melt point typically above 840 F)
- Flux also used
- Types of brazing classified by heating method:
  - – Torch, Furnace, Resistance

Applications:

- Automotive - joining tubes
- Pipe/Tubing joining (HVAC)
- Electrical equipment - joining wires
- Jewelry Making
- Joint can possess significant strength

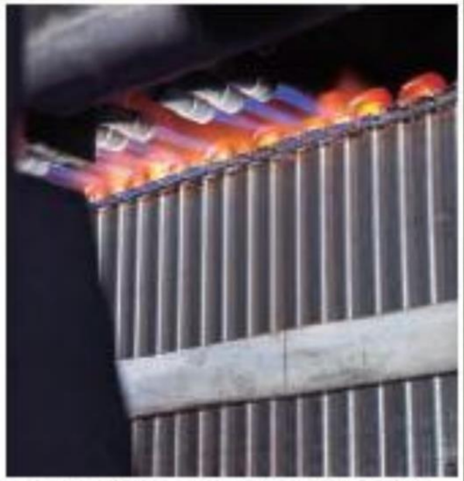


Figure 7. Typical brazed pipe/tube applications. (Photo courtesy of Handy & Harman)

Figure 11. Typical brazing filler metal preforms. (Photo courtesy of Handy & Harman)

Deformation Processes

Forming

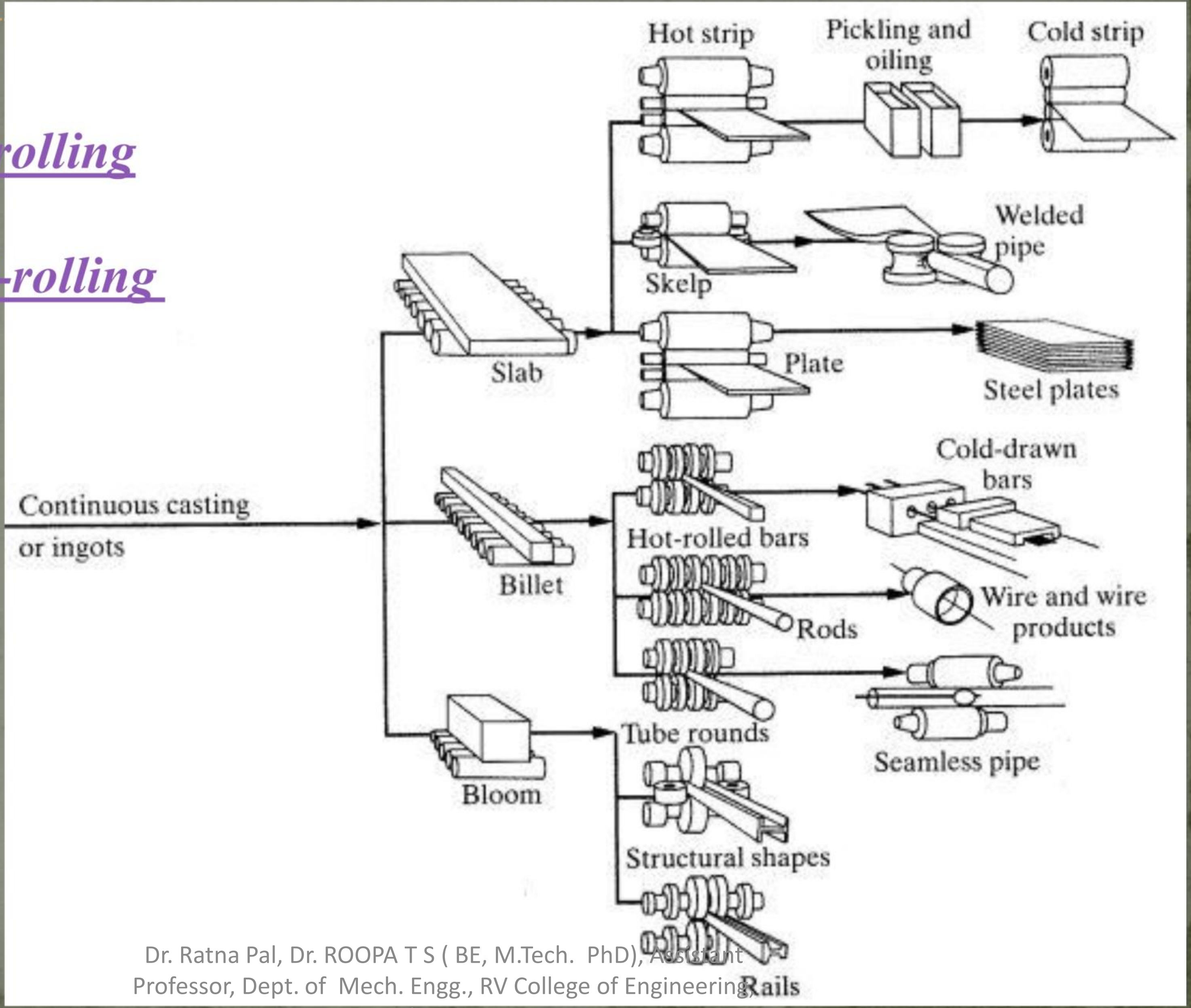
Any process that changes the shape of a raw stock without changing its phase

Example products:
Al/Steel frame of doors and windows, coins, springs,
Elevator doors, cables and wires, sheet-metal, sheet-metal parts…

Rolling

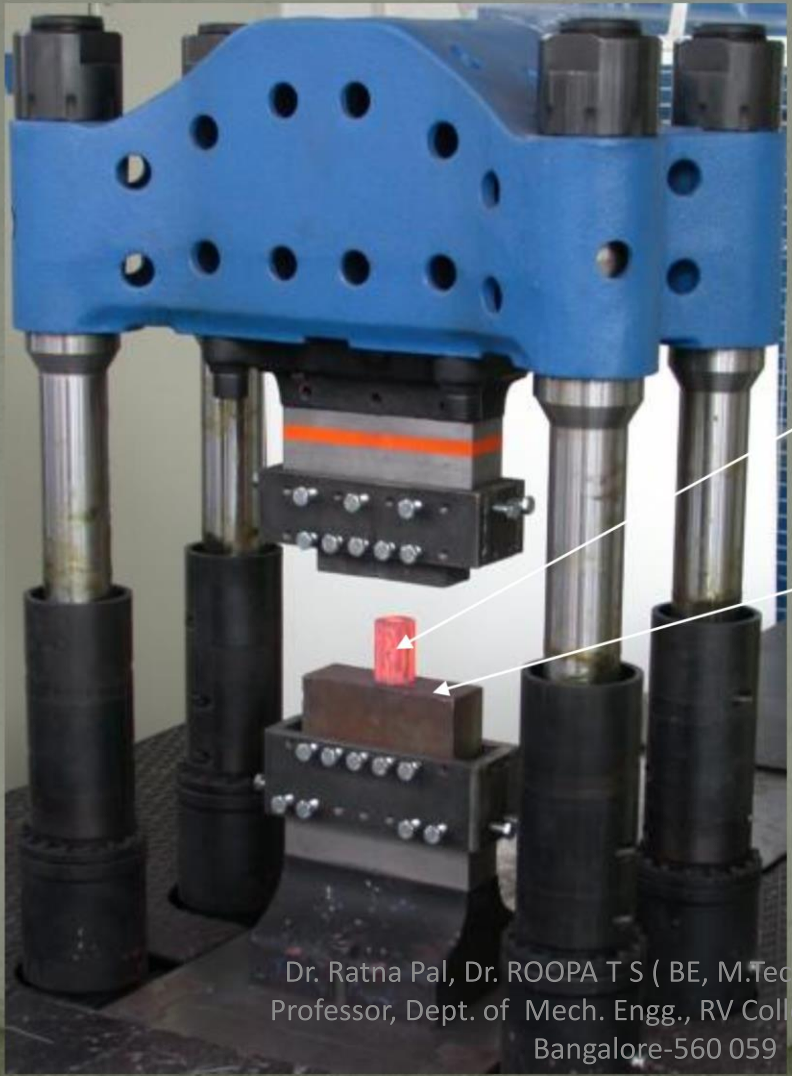
→ *Hot-rolling*

→ *Cold-rolling*



Forging

[Heated] metal is beaten with a heavy hammer to give it the required shape



Hot forging,

open-die

Extrusion

Metal forced/squeezed out through a hole (die)

[source:www.magnode.com]

Typical use: ductile metals (Cu, Steel, Al, Mg), Plastics, Rubbers

Common products:

Al frames of white-boards, doors, windows, …

Sheet Metal Processes

Raw material: sheets of metal, rectangular, large

Raw material Processing: Rolling (anisotropic properties)

Processes:
- Shearing
- Punching
- Bending
- Deep drawing

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Powder Metallurgy

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Basic Steps In Powder Metallurgy (P/M)

- Powder Production
- Blending or Mixing
- Compaction
- Sintering
- Finishing

Advantages of P/M

- Virtually unlimited choice of alloys, composites, and associated properties
  - Refractory materials are popular by this process
- Controlled porosity for self lubrication or filtration uses
- Can be very economical at large run sizes (100,000 parts)
- Long term reliability through close control of dimensions and physical properties
- Wide latitude of shape and design
- Very good material utilization

Disadvantages of P/M

- Limited in size capability due to large forces
- Specialty machines
- Need to control the environment – corrosion concern
- Will not typically produce part as strong as wrought product. (Can repress items to overcome that)
- Cost of die – typical to that of forging, except that design can be more – specialty
- Less well known process

Ferrous Alloys

Strengths

1) Inexpensive
2) Abundant supply of iron ore
3) Many applications due to wide range of material properties.

Limitations

1) Relatively high densities
2) Relatively low electrical conductivities
3) Generally poor corrosion resistance

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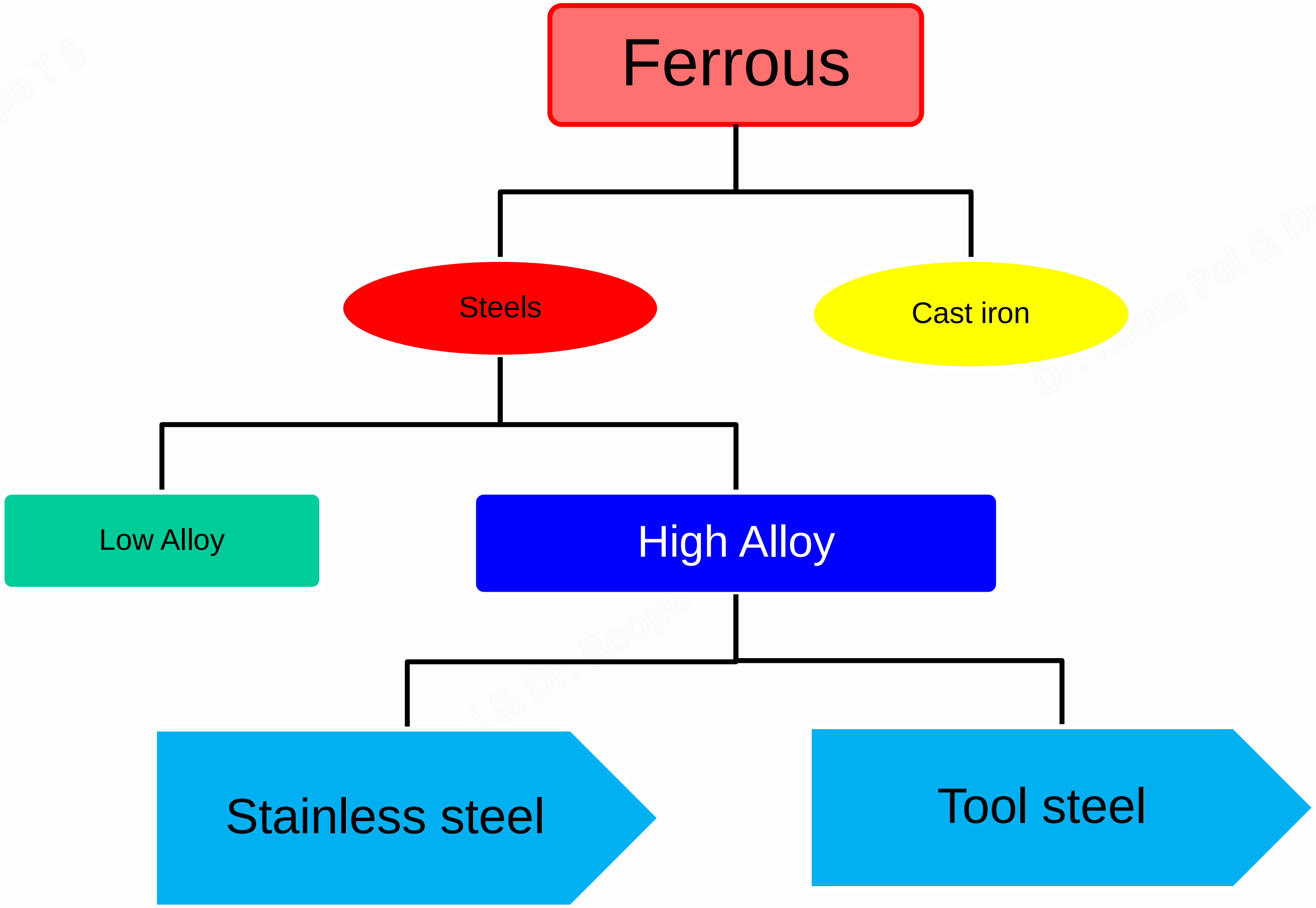
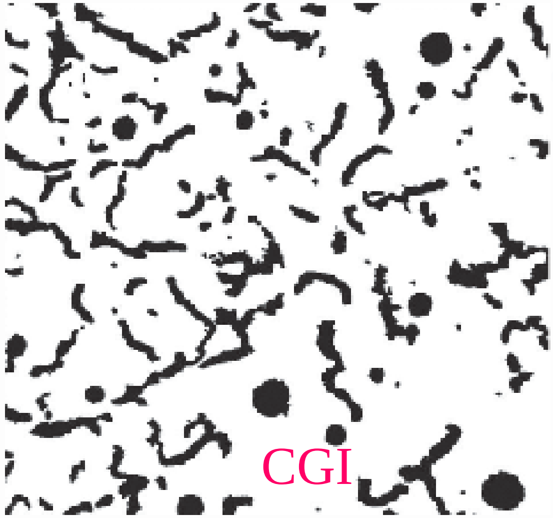
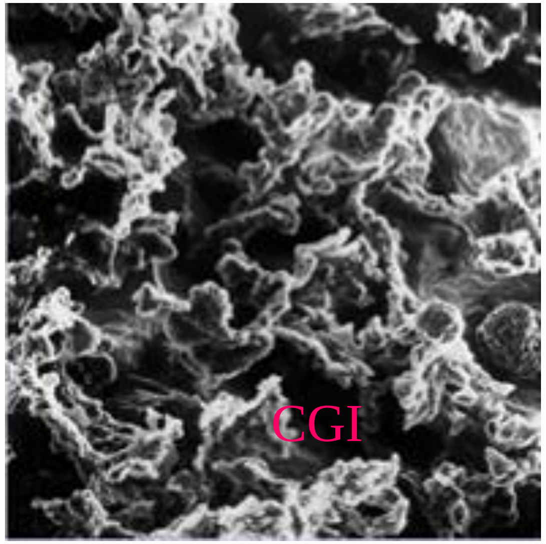
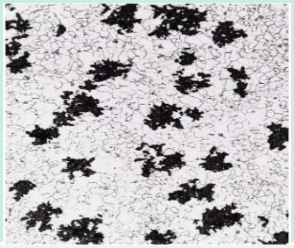
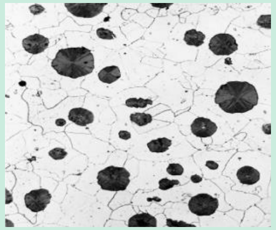
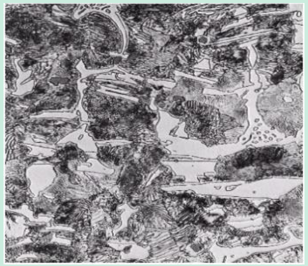

Ferrous
Steels
Cast iron
Low Alloy
High Alloy
Stainless steel
Tool steel

Compact Graphite Iron (CGI)

- CGI graphite occurs as blunt flakes or with a worm-like shape (vermicular).
- Microstructure and properties are a cross between gray and ductile iron.
- Production requires other alloying elements to minimize the sharp edges and formation of spheroidal graphite.
- CGI retains much of the castability of gray iron, but has a higher tensile strength and some ductility.
- Its matrix structure can be adjusted by alloying or heat treatment.
- relatively high thermal conductivity
- good resistance to thermal shock
- lower oxidation at elevated temperatures
- Carbon content: 3.1 – 4.0 wt%
- Silicon content: 1.7 – 3.00 wt %

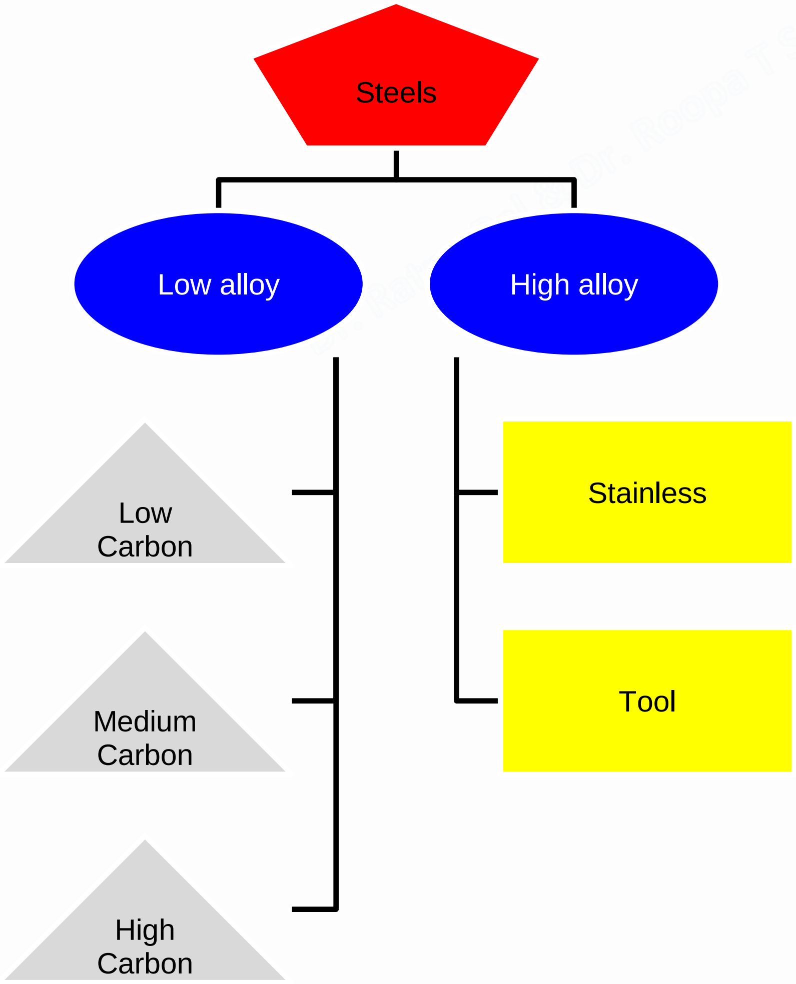




Grey Cast Iron	Malleable Cast Iron	Ductile Cast Iron	White Cast Iron
Flakes of graphite in pearlite/ferrite matrix leading to grey sooty appearance 	Obtained by heat treatment of white cast iron. Contains carbon as irregular round particles known as temper carbon 	Also called nodular cast iron- graphite exists as round particles/spheroid form in ferrite/pearlite matrix 	Freshly broken surface shows a bright white fracture 
Composition: 2.5- 3.8 % C; 1.1 – 2.8% Si; 0.15%P; 0.4 – 1% Mn;0.1%S	**Composition**: 2- 3%C; 0.6 – 1.3% Si; 0.15%P; 0.2 – 0.6% Mn;0.1%S	**Composition**: 3.5- 3.8%C; 1.1 – 3.5% Si; 0.08%P; 0.3 – 0.8% Mn;0.2%S	**Composition**: 1.8 – 3.6%C; 0.5 – 2% Si; 0.18%P; 0.2 – 0.8% Mn;0.1%S
Properties: Lowest melting point-1200ºC, High fluidity, Better machinability, High resistant to wear, Good damping capacity, High compressive strength	**Properties:** High tensile strength, good machinability, high toughness, high wear resistance and damping capacity	**Properties:** High tensile strength, high machinability, high wear and corrosion resistance and good thermal shock resistance	**Properties:** Brittle-not machinable under normal conditions, excellent abrasive wear resistance
Applications: Machine tool structures, Under ground gas/water pipes, Machine covers, IC engine cylinder block heads, Piston rings furnace parts Frames of electric motors	**Applications:** Automobile industry, agricultural implements, electrical line hardware, conveyor chain links, machine parts, hand tools	**Applications:** Paper industries machinery, IC engines and automobiles, power transmission equipment, farm implements and tractors, earth moving machinery, pumps compressors and	**Applications:** for producing malleable iron castings, hard and abrasion resistance requirements

Ferrous Materials → Steels

- Steels are iron-carbon alloys that may contain other alloying elements.
- There are 1000s of alloys with different compositions and/or heat treatments.
- Low Alloy (<10 wt%)
  - Low Carbon (<0.25 wt%)
  - Medium Carbon (0.25 to 0.60 wt%)
  - High Carbon (0.60 to 1.4 wt%)
- High Alloy
  - Stainless Steel (> 11 wt% Cr)
  - Tool Steel



Low Carbon Steel

- Plain carbon steels have very little additives (alloying elements) and small amounts of manganese.
- Most prevalent type of steel is low carbon steel (greatest quantity produced; least expensive).
- Low carbon not responsive to heat treatment; have to cold work.
- Weldable and machinable.
- High Strength, Low Alloy (HSLA) steel contains alloying elements (copper, vanadium, nickel and molybdenum) up to 10 wt %; they have higher strengths (than plain LC steels) and may be heat treated.
- **Applications:** Wired rod, thin sheets, tubes, corrugated sheets, automobile stampings, boiler plates, draw forgings

Medium Carbon Steel

- These alloys may be (heat treated) austenitized, quenched and then tempered to improve mechanical properties (tempered martensite).
- Cr, Ni, Mo improve the heat treating capacity of plain medium carbon steels.
- **Applications:** rails, wheels, axels, springs, hammers, shear blades, wood chisel.

High Carbon Steel: These steels alloyed with Cr, V, W, Mo.

Applications: are used in blade applications, cutting tools (hammers, chisels, milling cutters) ball bearings, files, lathe tools.

Alloy steels

- Tool steels
- Stainless steels
- Structural steels
- High temperature steels

Tool steels: Used in machining and forming operations

Capable to work in high temperature

Properties: High strength and toughness, high wear and abrasion resistance, high dimensional and thermal stability.

Types:

- HSS:
- Hot worked
- Cold worked
- Water hardening
- Shock resisting

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HSS – High Speed Steels

	HSS-Mb based	HSS-W based
Composition	0.7-1%C, 9%Mo, 5%W	0.7-1 %C, 18%W, 4%Cr, 1%V
Properties	High strength and toughness, high resistance to wear and abrasion, high dimensional and thermal stability	High strength and toughness, high resistance to wear and abrasion
Applications	Cutting tools, drill bits, reamers, dies	High temperature dies, tools for hard materials

- ***Hot work steels***
- Alloying elements-W, Mo, V and Cr
- Used for high temperature applications like in hot working tools and dies
- ***Cold work steels***
- Oil or air hardening types
- Used in cold working operations
- ***Shock resisting steels***
- Have high shock and impact resistance
- Used in header dies, punches, chisels
- ***Water hardening steels***
- Plain carbon steels with high carbon content
- Used in most common machine tools for cutting operations like in drill bits, shear blades, dies, hammers

Table 13.3 Designations, Compositions, and Applications for Six Tool Steels

AISI Number	UNS Number	Composition (wt%)[a] C	Cr	Ni	Mo	W	V	Typical Applications
M1	T11301	0.85	3.75	0.30 max	8.70	1.75	1.20	Drills, saws; lathe and planer tools
A2	T30102	1.00	5.15	0.30 max	1.15	—	0.35	Punches, embossing dies
D2	T30402	1.50	12	0.30 max	0.95	—	1.10 max	Cutlery, drawing dies
O1	T31501	0.95	0.50	0.30 max	—	0.50	0.30 max	Shear blades, cutting tools
S1	T41901	0.50	1.40	0.30 max	0.50 max	2.25	0.25	Pipe cutters, concrete drills
W1	T72301	1.10	0.15 max	0.20 max	0.10 max	0.15 max	0.10 max	Blacksmith tools, wood-working tools

[a] The balance of the composition is iron. Manganese concentrations range between 0.10 and 1.4 wt%, depending on alloy; silicon concentrations between 0.20 and 1.2 wt% depending on alloy.

Source: Adapted from *ASM Handbook*, Vol. 1, *Properties and Selection: Irons, Steels, and High-Performance Alloys*, 1990. Reprinted by permission of ASM International, Materials Park, OH.

Stainless steels

- Basically Cr, Ni, Fe based alloys
- Used mainly for corrosion and heat resistance applications
- Corrosion resistance is because of the thin adherent ,stable chromium oxide layer
- >10% Cr
- ***Classification: Based on microstructure***
- ***Austenitic, Ferritic, Martensitic***

- ***Austenitic:***
- Composition: 18%Cr, 8%Ni, <0.1% C
- Temperature resistant (Ni stabilises austenitic structure)
- Can be hardened only by cold working
- High resistant to corrosion
- Non magnetic
- It can undergo intergranular corrosion, addition of titanium and niobium avoids this.
- Stronger, more ductile, have better fabrication characteristics.

- ***Ferritic:***
- Composition: 18 - 30%Cr, No Nickel
- magnetic
- Has BCC structure
- Can be hardened by cold working but can not be hardened by heat treatment
- Less corrosion resistance compared to austenitic steels
- It can undergo intergranular corrosion, addition of titanium and niobium avoids this.
- Stronger, more ductile, have better fabrication characteristics.

- ***Martensitic:***
- Composition: 12 - 17%Cr, No Ni
- Magnetic
- Have Body cantered tetragonal structure
- Can be hardened by heat treatment
- Corrosion resistance under mild conditions

Table 13.4 Designations, Compositions, Mechanical Properties, and Typical Applications for Austenitic, Ferritic, Martensitic, and Precipitation-Hardenable Stainless Steels

AISI Number	UNS Number	Composition (wt%)[a]	Condition[b]	Mechanical Properties: Tensile Strength [MPa (ksi)]	Mechanical Properties: Yield Strength [MPa (ksi)]	Mechanical Properties: Ductility [%EL in 50 mm (2 in.)]	Typical Applications
			Ferritic				
409	S40900	0.08 C, 11.0 Cr, 1.0 Mn, 0.50 Ni, 0.75 Ti	Annealed	380 (55)	205 (30)	20	Automotive exhaust components, tanks for agricultural sprays
446	S44600	0.20 C, 25 Cr, 1.5 Mn	Annealed	515 (75)	275 (40)	20	Valves (high temperature), glass molds, combustion chambers
			Austenitic				
304	S30400	0.08 C, 19 Cr, 9 Ni, 2.0 Mn	Annealed	515 (75)	205 (30)	40	Chemical and food processing equipment, cryogenic vessels
316L	S31603	0.03 C, 17 Cr, 12 Ni, 2.5 Mo, 2.0 Mn	Annealed	485 (70)	170 (25)	40	Welding construction
			Martensitic				
410	S41000	0.15 C, 12.5 Cr, 1.0 Mn	Annealed Q & T	485 (70) 825 (120)	275 (40) 620 (90)	20 12	Rifle barrels, cutlery, jet engine parts
440A	S44002	0.70 C, 17 Cr, 0.75 Mo, 1.0 Mn	Annealed Q & T	725 (105) 1790 (260)	415 (60) 1650 (240)	20 5	Cutlery, bearings, surgical tools
			Precipitation Hardenable				
17-7PH	S17700	0.09 C, 17 Cr, 7 Ni, 1.0 Al, 1.0 Mn	Precipitation hardened	1450 (210)	1310 (190)	1–6	Springs, knives, pressure vessels

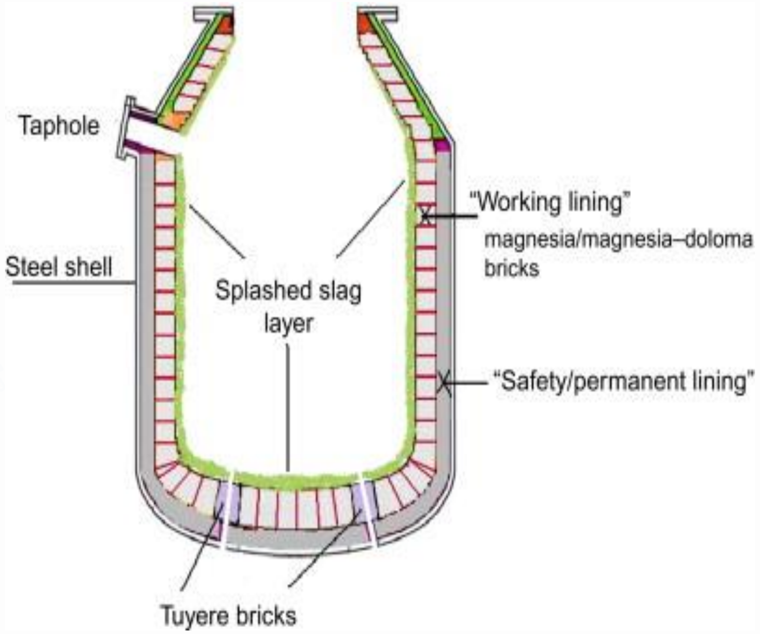
[a] The balance of the composition is iron.

[b] Q & T denotes quenched and tempered.

Source: Adapted from *ASM Handbook*, Vol. 1, *Properties and Selection: Irons, Steels, and High-Performance Alloys*, 1990. Reprinted by permission of ASM International, Materials Park, OH.

High temperature steels

- Perform satisfactorily at high temperature
- Ex: 1. Mo and V alloys: up to 450 and up to 550ºC with 2% Cr
  2. Austenitic steels: up to 900ºC
  3. Ferritic steels: up to 800ºC
  4. Martensitic steels: up to 650ºC
  5. Super alloys (Ni and Co based): up to 1000ºC
- Applications: Pressure vessels, Super heater tubes, aircraft parts, Furnace linings, Exhaust systems



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Structural steels

	High strength low alloy steels (HSLA UTS - 600-1000MPa)	Ultra high strength low alloy steel [Maraging steel – (martensitic + aging) UTS- >1000 MPa]
Composition	0.15-0.25%C, 1.25%Mn, 0.3%Si, 0.02%V	0.03%C, 18-25% Ni, 8%Co
Properties	Yield strength: 600MPa Tensile strength: 750MPa % elongation 25%	Yield strength: 2000MPa % elongation 12%
Applications	Automobiles, bridges, trains and buildings	

Effects of Alloying Elements on Steel

- Manganese contributes to **strength and hardness**; dependent upon the carbon content. Increasing the manganese content decreases ductility and weldability. Manganese has a significant effect on the hardenability of steel.
- Phosphorus **increases strength and hardness and decreases ductility** and notch impact toughness of steel. The adverse effects on ductility and toughness are greater in quenched and tempered higher-carbon steels.
- Sulfur **decreases ductility** and notch impact toughness especially in the transverse direction. Weldability decreases with increasing sulfur content. Sulfur is found primarily in the form of sulfide inclusions.
- Silicon is one of the principal **deoxidizers** used in steelmaking. Silicon is less effective than manganese in increasing as-rolled strength and hardness. In low-carbon steels, silicon is generally detrimental to surface quality.
- Copper in significant amounts is detrimental to hot-working steels. Copper can be detrimental to surface quality. Copper is beneficial to **atmospheric corrosion resistance** when present in amounts exceeding 0.20%.
- Nickel is a ferrite strengthener. Nickel does not form carbides in steel. It remains in solution in ferrite, strengthening and toughening the ferrite phase. Nickel increases the hardenability and impact strength of steels.
- Molybdenum increases the hardenability of steel. It enhances the creep strength of low-alloy steels at elevated temperatures.

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Nonferrous Metals

NonFerrous Alloys

- Cu Alloys

Brass: Zn is a substitutional impurity (costume jewelry, coins, corrosion resistant)

Bronze : Sn, Al, Si, Ni are substitutional impurities

Cu-Be : precipitation hardened for strength (bushings, landing gear)

- Al Alloys

-low ρ: 2.7 g/cm^3

-Cu, Mg, Si, Mn, Zn additions

-solid solution or precipitation strengthened (structural aircraft parts & packaging)

- Mg Alloys

-very low ρ: 1.7g/cm^3

-ignites easily

-aircraft, missiles

- Ti Alloys

-relatively low ρ: 4.5 g/cm^3 (7.9 g/cm^3 for steel)

-reactive at high *T's*

-space application

- Noble metals

-Ag, Au, Pt

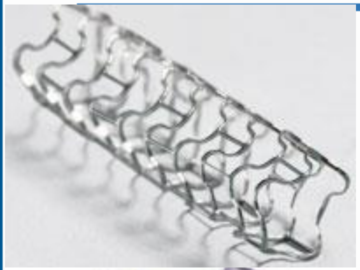
-oxidation/corrosion resistant

- Refractory metals

-high melting *T's*

-Nb, Mo, W, Ta

Magnesium




- Magnesium is the ***lightest*** of the commonly used metals (density is 1.7 g/cm3). Versatile and abundant, magnesium alloys are frequently used in industry because of strength, easy machining, and stability.
- Magnesium alloys are also impact and dent resistant, and have the capacity for damping and low inertia, which makes them effective in high-speed applications.
- Magnesium is too soft to be used as a structural metal and is most commonly alloyed with aluminum.
- Due to its light weight, superior machinability and ease of casting, magnesium has many applications in auto parts (gearboxes, valve covers, wheels, clutch housings, and brake pedal brackets, sporting goods, power tools, aerospace equipment, and fixtures). Wrought alloys are available in rod, bar, sheet, plate, forgings and extrusions.
- A biodegradable magnesium drug-eluting stent for treating vascular disease has been successfully implanted, reports Biotronik. The Biotronik DREAMS (Drug Eluting Absorbable Metal Scaffold) is made of a biodegradable magnesium alloy combined with a slow-release drug and is intended to open vessels and to keep them from re-clogging, while avoiding the longer-term disadvantages associated with permanent metal stents.

MAGNESIUM AND ITS ALLOYS

- Perhaps the most outstanding characteristic of magnesium is its density, 1.7 g/cm, which is the lowest of all the structural metals; therefore, its alloys are used where light weight is an important consideration (e.g., in aircraft components).
- Magnesium has an HCP crystal structure, is relatively soft, and has a low elastic modulus: 45 GPa (6.5 10 psi). At room temperature, magnesium and its alloys are difficult to deform; in fact, only small degrees of cold work may be imposed without annealing. Consequently, most fabrication is by casting or hot working at temperatures between 200°C and 350°C (400F and 650F).
- Magnesium, like aluminum, has a moderately low melting temperature [651°C (1204F)]. Chemically, magnesium alloys are relatively unstable and especially susceptible to corrosion in marine environments. However, corrosion or oxidation resistance is reasonably good in the normal atmosphere; it is believed that this behavior is due to impurities rather than being an inherent characteristic of Mg alloys. Fine magnesium powder ignites easily when heated in air; consequently, care should be exercised when handling it in this state.

Magnesium

ASTM Number	UNS Number	Composition (wt%)[a]	Condition	Mechanical Properties: Tensile Strength [MPa (ksi)]	Mechanical Properties: Yield Strength [MPa (ksi)]	Mechanical Properties: Ductility [%EL in 50 mm (2 in.)]	Typical Applications
			Wrought Alloys				
AZ31B	M11311	3.0 Al, 1.0 Zn, 0.2 Mn	As extruded	262 (38)	200 (29)	15	Structures and tubing, cathodic protection
HK31A	M13310	3.0 Th, 0.6 Zr	Strain hardened, partially annealed	255 (37)	200 (29)	9	High strength to 315°C (600°F)
ZK60A	M16600	5.5 Zn, 0.45 Zr	Artificially aged	350 (51)	285 (41)	11	Forgings of maximum strength for aircraft
			Cast Alloys				
AZ91D	M11916	9.0 Al, 0.15 Mn, 0.7 Zn	As cast	230 (33)	150 (22)	3	Die-cast parts for automobiles, luggage, and electronic devices
AM60A	M10600	6.0 Al, 0.13 Mn	As cast	220 (32)	130 (19)	6	Automotive wheels
AS41A	M10410	4.3 Al, 1.0 Si, 0.35 Mn	As cast	210 (31)	140 (20)	6	Die castings requiring good creep resistance

TITANIUM AND ITS ALLOYS

GENERAL PROPERTIES OF TITANIUM ALLOYS

PHYSICAL PROPERTIES

- Low density
- high strength and ductility
- lustrous
- corrosion resistant and high melting point
- low thermal & electrical conductivity
- Paramagnetic

MECHANICAL PROPERTIES

Young's modulus	116 Gpa
Shear modulus	44 Gpa
Bulk modulus	110 Gpa
Poisson ratio	0.32
Thermal conductivity	21.9 W/m/K

- It is stronger than steel, but 45% lighter
- It is not easily corroded
- resistance to high temperatures
- low thermal conductivity
- low electrical conductivity
- heat has no or negligible effect on dimension but it hardens on heating
- higher resistance towards metal fatigue
- no harm to biological tissues

TITANIUM ALLOYS

- The crystal structure of titanium at ambient temperature and pressure is close-packed hexagonal α phase . At about 890°C, the titanium undergoes an allotropic transformation to a body-centred cubic β phase which remains stable to the melting temperature.
- Some alloying elements raise the alpha-to-beta transition temperature (i.e. alpha stabilizers) while others lower the transition temperature (i.e. beta stabilizers).
- Aluminium, gallium, germanium, carbon, oxygen and nitrogen are alpha stabilizers.
- Molybdenum, vanadium, tantalum, niobium, manganese, iron, chromium, cobalt, nickel ,copper and silicon are beta stabilizers.

CATEGORIES

- **Alpha alloys** which contain neutral alloying elements (such as tin) and/ or alpha stabilisers (such as aluminium or oxygen) only. These are not heat treatable.
- **Alpha & Beta Alloys**, which are metastable and generally include some combination of both alpha and beta stabilisers, and which can be heat treated.
- **Beta Alloys**, which are metastable and which contain sufficient beta stabilisers (such as molybdenum, silicon and vanadium to allow them to maintain the beta phase when quenched, and which can also be solution treated and aged to improve strength.

APPLICATIONS

- ALLOYING
- PAINTS,PAPER,TOOTHPASTE,PLASTICS
- CORROSION RESISTANT TOOLS
- SURGICAL INSTRUMENTS
- AIRCRAFT PARTS AND GEARS
- MARINE VEHICLE PARTS
- PLUMBING EQUIPENTS
- $TiCl_4$ IS USED TO PRODUCE MANY CATALYSTS.
- SPORTS GOODS
- DEGIGNER JEWELLERY
- ORTHOPAEDIC IMPLANTS

Aerospace and Industrial Applications

- turbines
- shafts
- sheet metal work

- Increased life of articles.
- Reliability of machine parts
- Pipings

AUTOMOTIVE Computer Industry Human Implants

- Engine parts such as connecting rods, wrist pins, valves, valve retainers and springs, rocker arms and camshafts, to name a few, lend themselves to fabrication from titanium, because it is durable, strong, lightweight and resists heat and corrosion.

- Modern Hard disks
- Modern pen drives

- Surgical instruments
- Implants to repair facture of bones...

Nickel

Nickel-containing materials are used in buildings and infrastructure, chemical production, communications, energy supply (batteries: Ni-Cd, Ni-metal hydrides), environmental protection, food preparation, water treatment and travel.

Nickel Catalyst for Fuel Cells: Nickel-cobalt is seen as a low-cost substitute for platinum catalysts.

Shape Memory Alloys: Stainless steel may soon provide a low-cost alternative to alloys that snap back to original form but are too expensive for widespread use.

Two-thirds of all nickel produced goes into stainless steel, to promote a stable, ductile, austenitic structure as well as contribute to corrosion resistance.

Key attributes: high melting point of 1453°C , forms an adherent oxide film

resists corrosion by alkalis

forms alloys readily, both as solute and solvent

readily deposited by electroplating

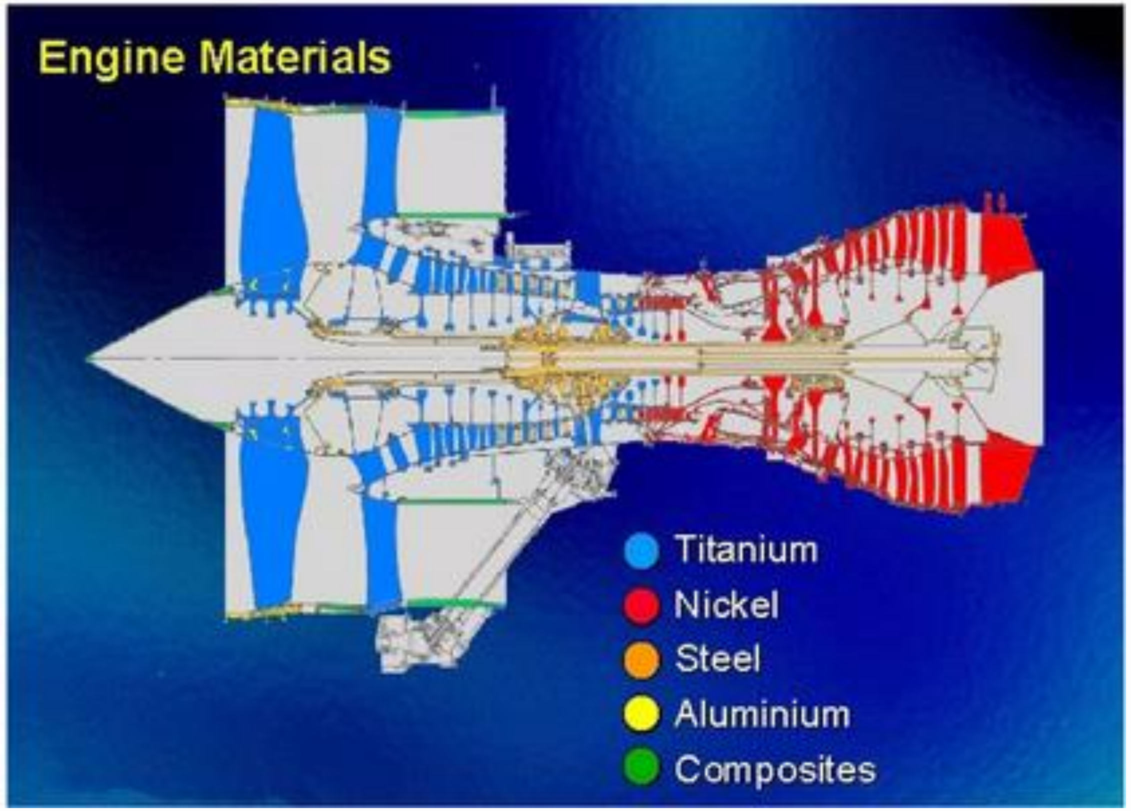
Nickel

SUPERALLOYS

Applications:

- Aerospace Gas Turbine Engines
- Space vehicles - Rocket engines,
- Nuclear reactors
- Power Generation Turbines
- Submarines.
- Petrochemical equipment.
- High-Temperature Fasteners
- Combustion Engine Exhaust Valves
- Hot Working Tooling and Dies,

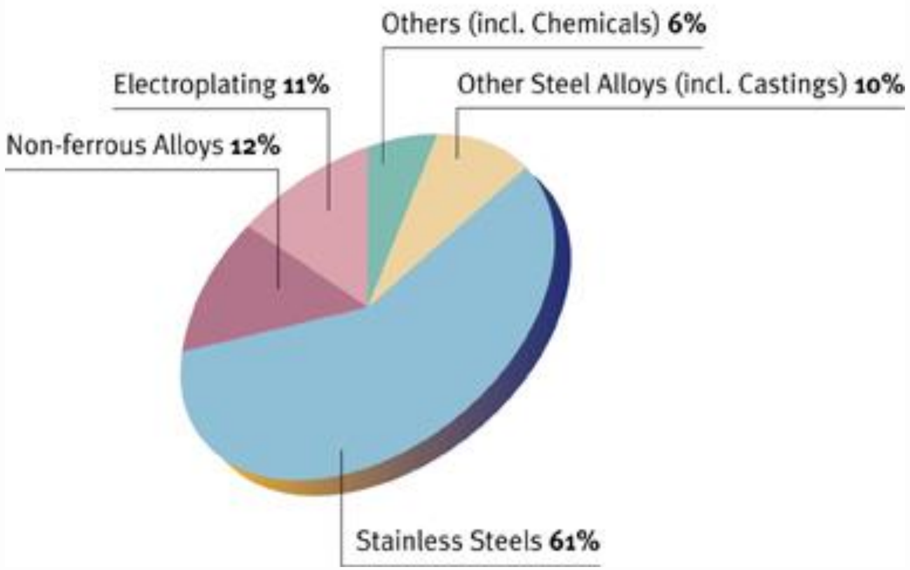
SUPERALLOYS



Nickel

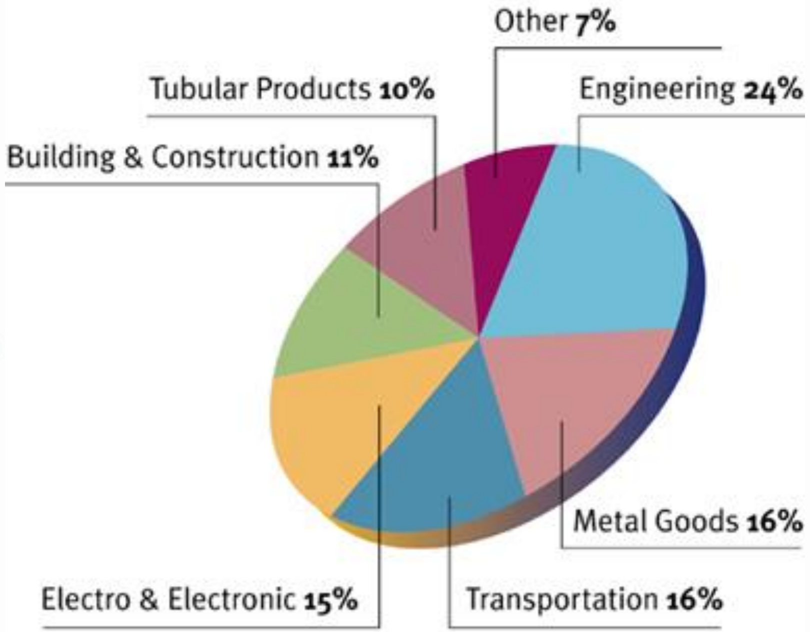
http://www.nickelinstitute.org/8/index1.shtml

Nickel First Use



Stainless steel roofing on the Thames Barrier

Who uses nickel alloys and stainless steels?



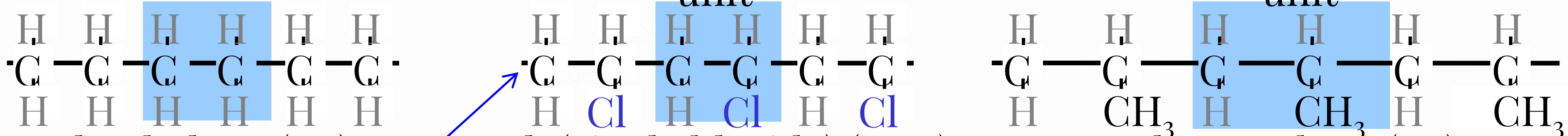
Polymers

- A compound consisting of long-chain molecules, each molecule made up of repeating units connected together
- There may be thousands, even millions of units in a single polymer molecule
- The word polymer is derived from the Greek words poly, meaning many, and **meros** (reduced to mer), meaning **part**
- Most polymers are based on carbon and are therefore considered organic chemicals

Poly mer

many repeat unit (building blocks)

repeat unit repeat unit repeat unit



Polyethylene (PE) Poly(vinyl chloride) (PVC) Polypropylene (PP)

Carbon chain backbone

Classification of Polymers

- **Polymers can be separated into plastics and rubbers**
- As engineering materials, it is appropriate to divide them into the following three categories:

1. Thermoplastic polymers
2. Thermosetting polymers
3. Elastomers

where (1) and (2) are plastics and (3) are rubbers

Properties of Polymers

Polymers

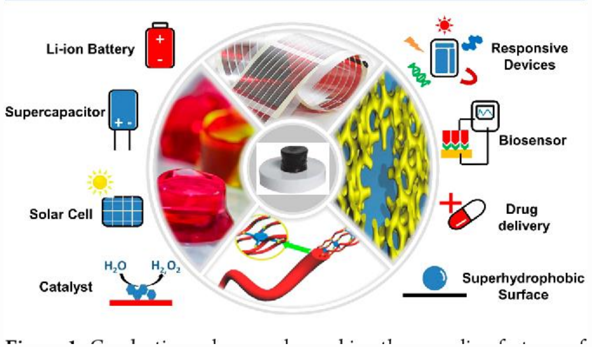
- ❖ Can be very resistant to chemicals.
- ❖ Can be both thermal and electrical insulators.
- ❖ Generally, polymers are very light in weight with significant degrees of strength.
- ❖ Can be processed in various ways.
- ❖ Are materials with a seemingly limitless range of characteristics and colors.
- ❖ Are usually made of petroleum, but not always.
- ❖ Can be used to make items that have no alternatives from other materials.

Difference between Thermoset and Thermoplastic Polymers

SI No.	Thermosetting Plastics	Thermoplastics
1	Three dimensional network of primary covalent bonds with cross linking between chains	Linear polymers without cross linking and branching
2	Upon heating they retain their strength and prolonged heating causes roasting of polymers and ultimately depolymerisation	Upon heating the secondary bonds between individual chains break, the polymers become soft and on cooling hard and rigid because secondary bonds re-establish themselves
3	Harder, stronger and more brittle	strong and less brittle
5	It is difficult to fill an intricate mold with such plastics	They can fill the complicated mold quite easily
6	can not be recycled	can be recycled
7	Ex: polyesters, silicones, Bakelite etc.	PVC, Nylons, polyethylene
8	Applications: manufacture of telephones, electrical outlets, appliance handles etc.	Applications: Plastic walls, floor tiles, reflectors, plastic lenses etc.

Applications of Polymers

- While plastics are used as a common example of polymers, there are many other materials which are also polymers.
- Proteins, such as hair, nails, tortoise shell
- Cellulose in paper and trees
- DNA
- Rubber



Polymers

- Domestic household
- Packaging
- Automobiles
- Building construction
- Electronics

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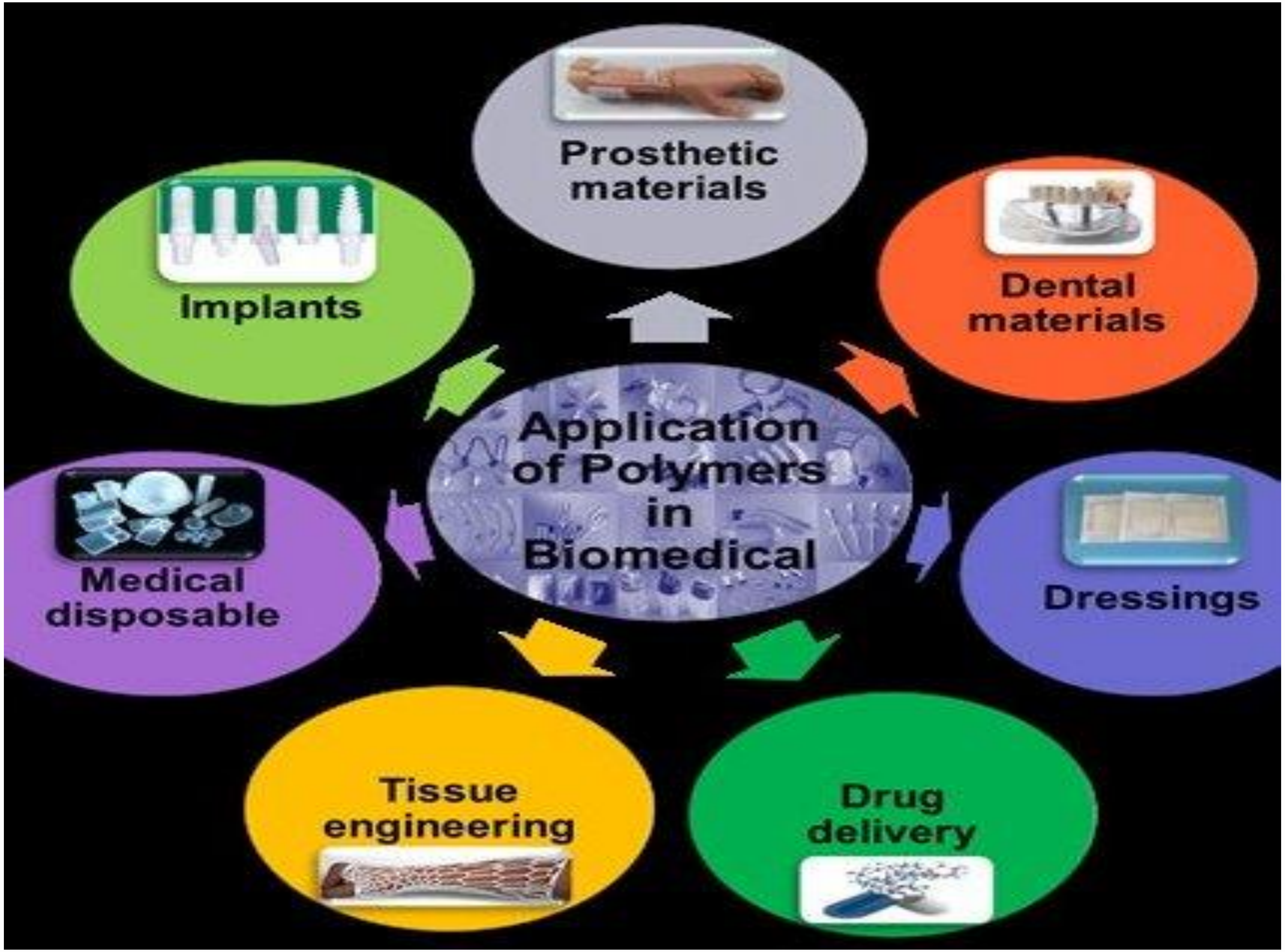
Applications of Polymers

Applications of Polymers



Ceramics

- **Ceramic materials are inorganic, non-metallic materials made from compounds of a metal and a non metal. They are formed by the action of heat and subsequent cooling.**
  - Are of 2 types : Crystalline & Non-crystalline-glass

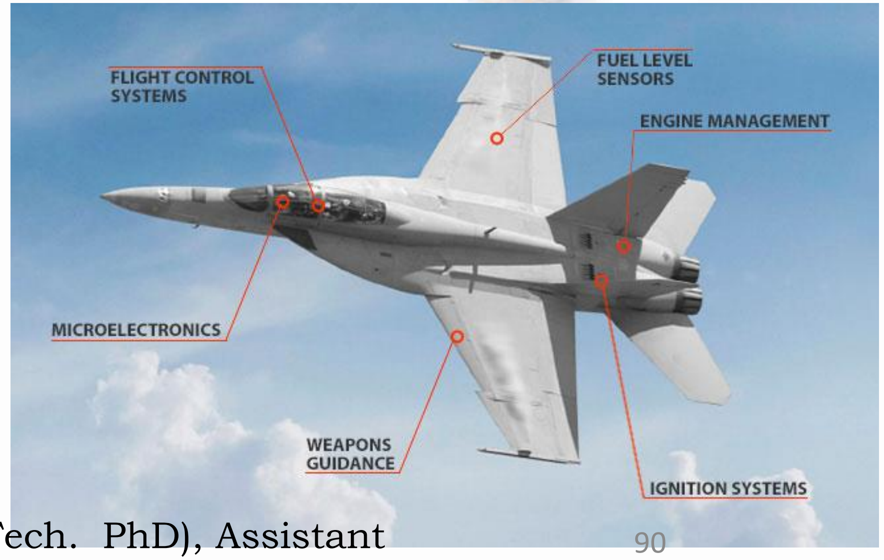
- Some ceramics are semiconductors. Most of these are transition metal oxides that are II-VI semiconductors, such as zinc oxide.
- Under some conditions, such as extremely low temperature, some ceramics exhibit high temperature superconductivity.

Properties of Ceramics

- Hard, Brittle
- Wear-resistant
- Refractory
- Thermal and Electrical Insulators
- Nonmagnetic
- Oxidation Resistant
- Prone To Thermal Shock And
- Chemically Stable

Applications of Ceramics

- **Aerospace:** space shuttle tiles, thermal barriers, high temperature glass windows, fuel cells
- **Consumer Uses:** glassware, windows, pottery, Corning¨ ware, magnets, dinnerware, ceramic tiles, lenses, home electronics, microwave transducers
- **Automotive:** catalytic converters, ceramic filters, airbag sensors, ceramic rotors, valves, spark plugs,
- **Medical (Bio ceramics):** orthopedic joint replacement, prosthesis, dental restoration, bone implants
- **Military:** structural components for ground, air and naval vehicles, missiles, sensors
- **Computers:** insulators, resistors, superconductors, capacitors, ferroelectric components, microelectronic packaging
- **Other Industries:** bricks, cement, membranes and filters, lab equipment
- **Communications:** fiber optic/laser communications, TV and radio components, microphones



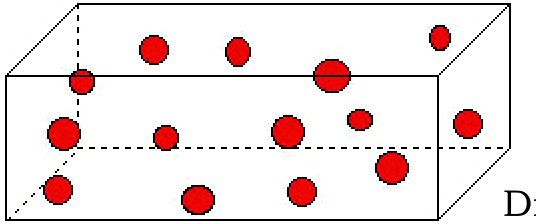
Composites

- **Composite materials** are **materials** made from two or more constituent **materials** with significantly different physical or chemical properties, that when combined, produce a **material** with characteristics different from the individual components

Typical engineered composite materials include:
- Composite building materials such as cements, concrete
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites

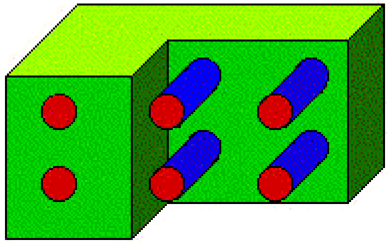
Particulate composite

materials contain a large number of randomly oriented particles. Ex: ceramic particles dispersed in a metallic matrix.



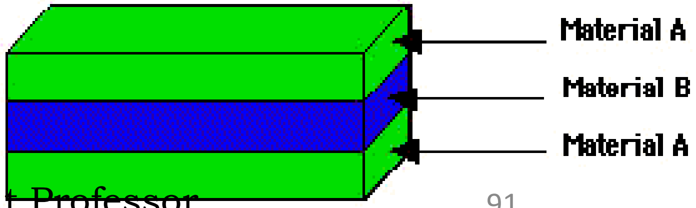
Fiber-reinforced composites

are composed of strong and stiff brittle fibers which are incorporated into a softer, more ductile matrix.



Laminar composites

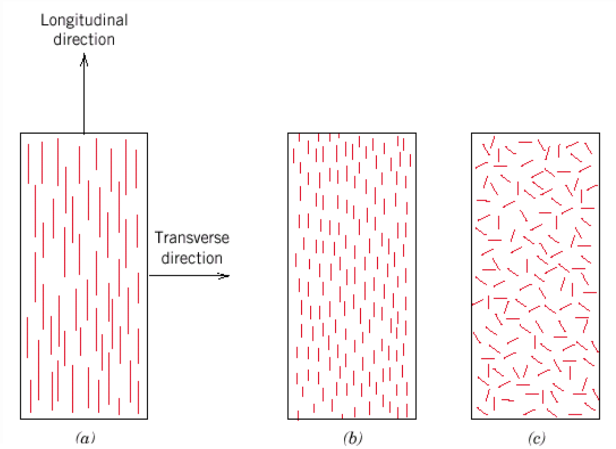
are Composed of layers of different materials, called laminates



Classification of Composites

Classification - Based on type of reinforcement

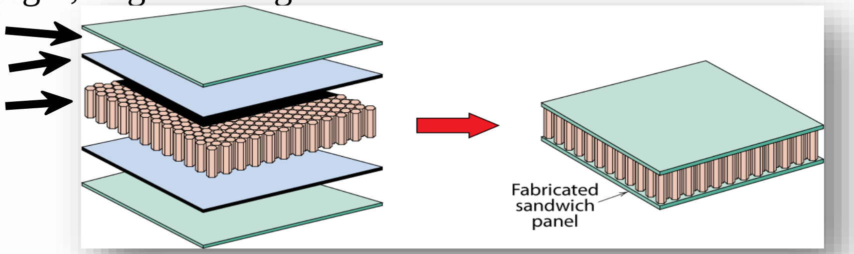
- Composites
  - Particle-reinforced
    - Large-particle
    - Dispersion-strengthened
  - Fiber-reinforced
    - Continuous (aligned)
    - Discontinuous (short)
      - Aligned
      - Randomly oriented
  - Structural
    - Laminates
    - Sandwich panels



aligned continuous

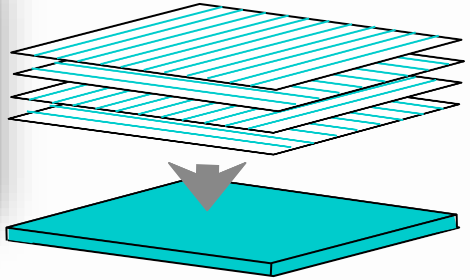
aligned discontinuous random

- Sandwich panels
  - -- low density, honeycomb core
  - -- benefit: light weight, large bending stiffness



Adapted from Fig. 16.18, *Callister 7e*. (Fig. 16.18 is from *Engineered Materials Handbook*, Vol. 1, *Composites*, ASM International, Materials Park, OH, 1987.)

- Laminate
  - Stacked and bonded fiber-reinforced sheets
    - -- stacking sequence: e.g., 0º/90º or 0°/45º/90º
    - -- benefit: balanced, in-plane stiffness



Adapted from Fig. 16.16, *Callister 7e*.

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Properties of Composites

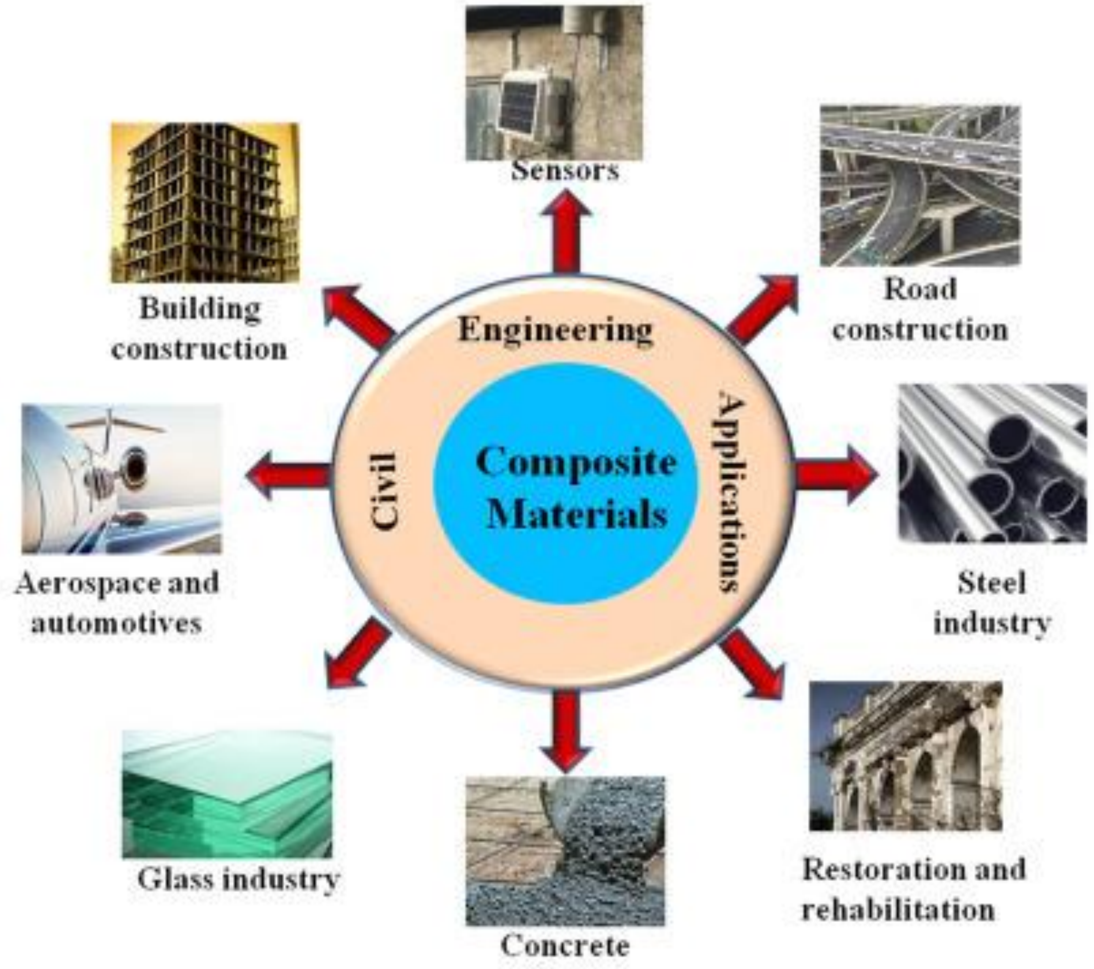
- **High Strength to Weight Ratio:** Fibre composites are extremely strong for their weight
- Fire Resistance
- **Chemical & Weathering Resistance:** Composite products have good weathering properties and resist the attack of a wide range of chemicals.
- **Translucency:** Polyester resins are widely used to manufacture translucent mouldings and sheets.
- **Manufacturing Economy:** due to their easy of production composite materials are economically easy to produce

Applications of Composites

- Light weight and strong - buildings, bridges and structures such as boat hulls,
- Carbon composite is a key material in today's launch vehicles and heat shields for the re-entry phase of spacecraft race car bodies,
- Used in storage tanks, imitation granite and cultured marble sinks and counter tops.
- Wood is a naturally occurring composite comprising cellulose fibers in a lignin and hemicellulose matrix.

❖ Applications:
  - ❖ Aerospace industry
  - ❖ Sporting Goods Industry
  - ❖ Automotive Industry
  - ❖ Home Appliance Industry

Applications of Composites



- Applications:
  - Aerospace industry
  - Sporting Goods Industry
  - Automotive Industry
  - Home Appliance Industry

(FRPs)

1.pipes, roofing's, storage containers, industrial floorings and automotive bodies

2.sports and recreational equipment's, pressure vessels and aircraft structural components.

3.military aircraft components, helicopter rotor blades and in some sporting goods.

4.Sic and Al_2O_3 fibre reinforced composites are used in tennis rackets, circuit boards and rocket cone noses.

Aggregate Composites

Aggregate composites, commonly known as composite materials, are materials composed of two or more distinct phases (typically a matrix and reinforcement) with different properties that, when combined, produce a material with enhanced performance characteristics. Here are various applications of aggregate composites across different industries:

Concrete with Aggregate – Building Construction

Fiberglass Composite- Boat Hulls

Carbon Fiber Reinforced Polymer (CFRP) – Aerospace Components

Concrete with Aggregate – Building Construction

Carbon Nanotube Reinforced Composites – Sports Equipment

Epoxy Resin Matrix Composites – Printed Circuit Boards (PCBs)

Wood-Plastic Composite (WPC) –Decking Material

Aluminum Matrix Composites – Aerospace Components

Natural Fiber Composites – Automotive Interiors

Biocomposite Bone Implants- Medical Implants

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Biomaterials - definition

- A BIOMATERIAL, is any *synthetic material that is used to* replace or restore function to a body tissue and is continuously or intermittently in contact with body fluids
- First and foremost, a biomaterial must be biocompatible — it should not elicit an adverse response from the body, and vice versa.
- Additionally, it should be nontoxic and noncarcinogenic.
- The biomaterial should possess adequate physical and mechanical properties to serve as augmentation or replacement of body tissues

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PROPERTIES OF BIOMATERIALS

- A biocompatible chemical composition to avoid adverse tissue reactions
- Excellent resistance to degradation (e.g., corrosion resistance for metals or resistance to biological degradation in polymers)
- Acceptable strength to sustain cyclic loading endured by the joint
- A low modulus to minimize bone resorption
- High wear resistance to minimize wear debris generation

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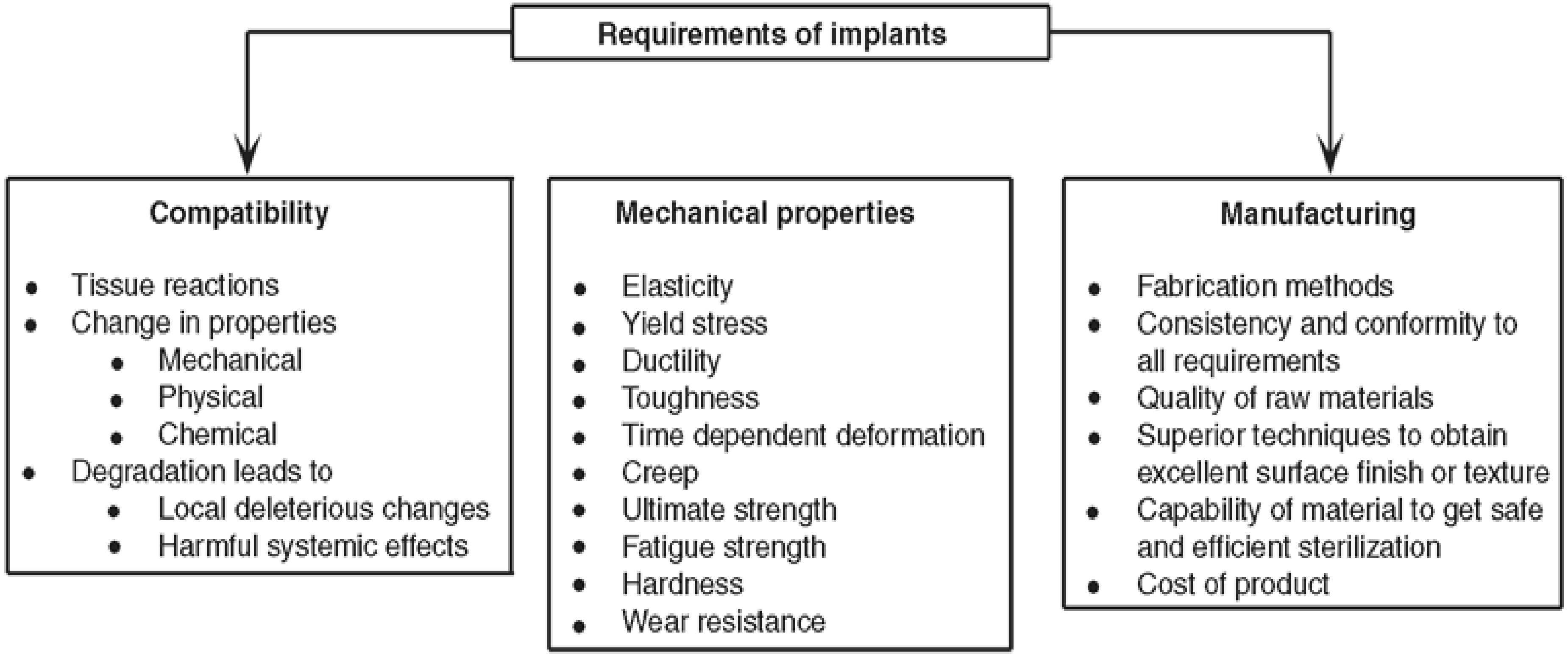
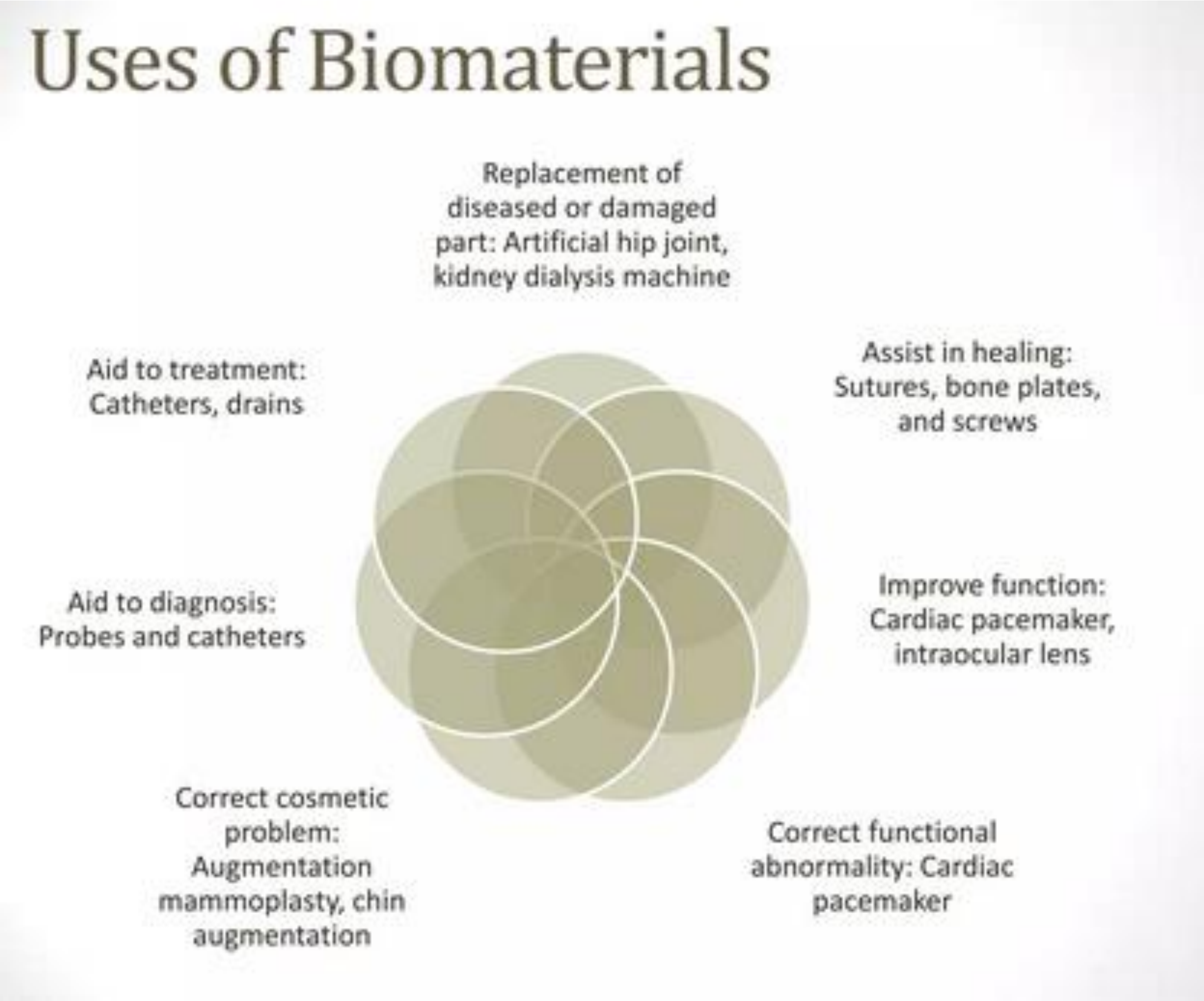
REQUIREMENTS OF IMPLANTS



USES FOR BIOMATERIALS



- One of the primary reasons that biomaterials are used is to physically replace hard or soft tissues that have become damaged or destroyed through some pathological process

1. **Orthopedics**
2. Cardiovascular Applications
3. **Ophthalmics**
4. **Dental Applications**

Main features for medical applications

- **Biofunctionality**
- Playing a specific function in physical and mechanical terms

- **Biocompatibility**
- Concept that refers to a set of properties that a material must have to be used
- safely in a biological organism

Characteristics of Biomaterials

Physical Requirements

- Hard Materials.
- Flexible Material.

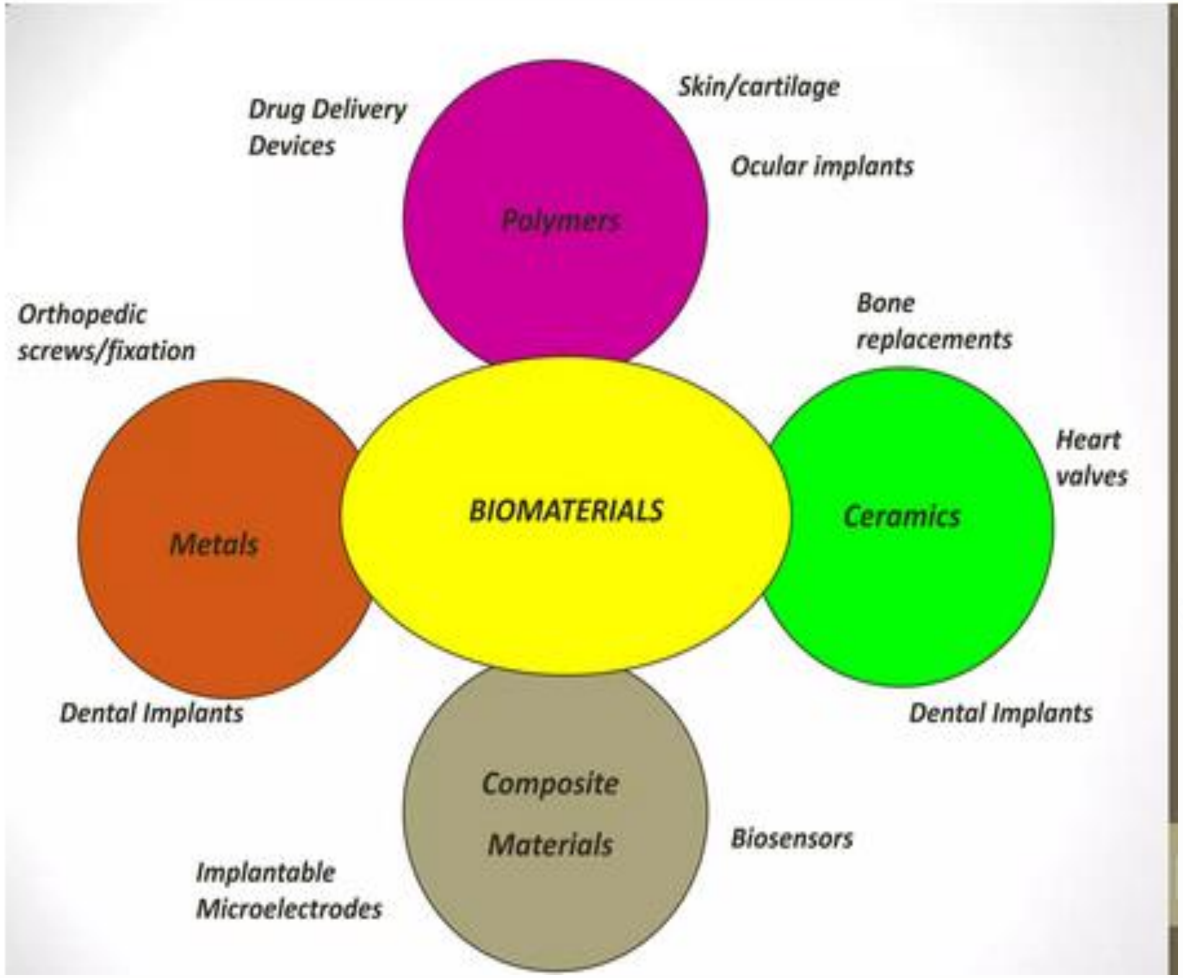
Chemical Requirements

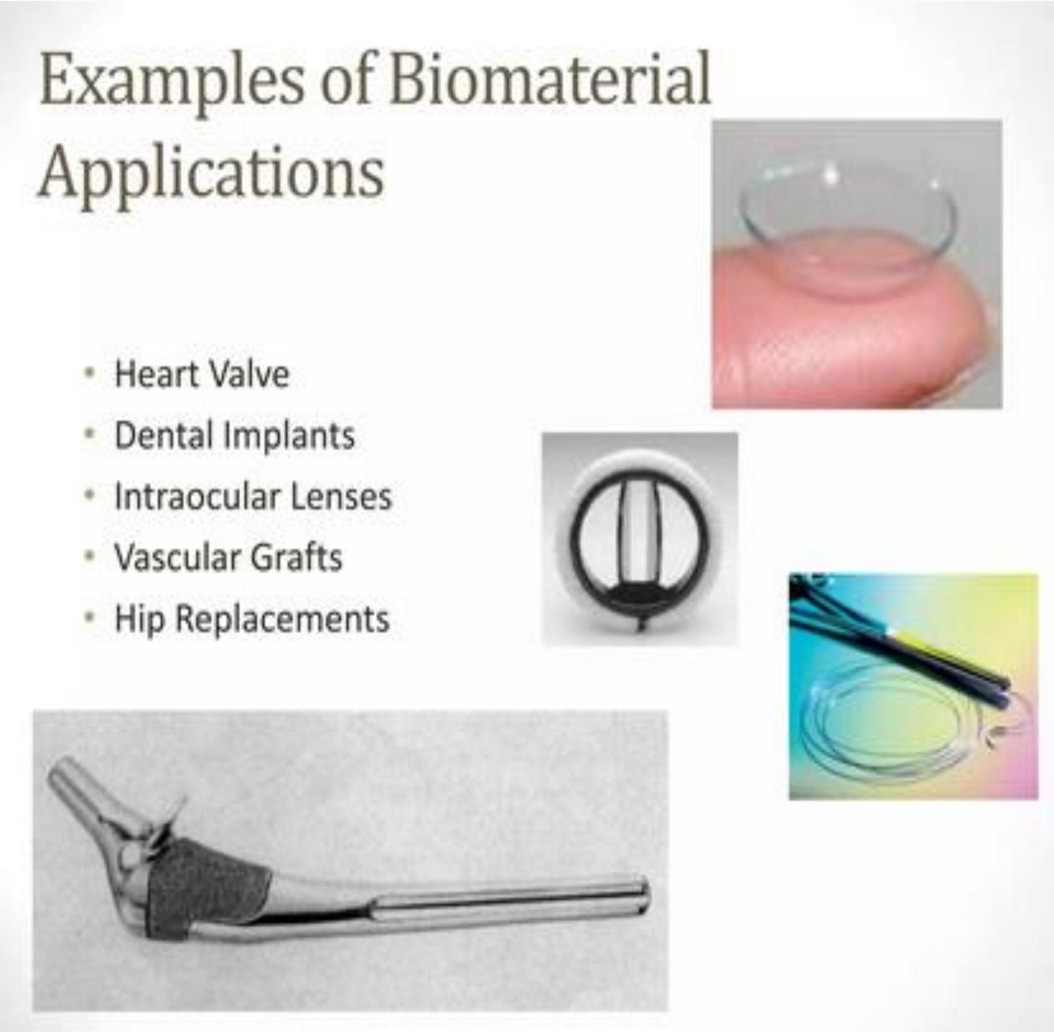
- Must not react with any tissue in the body.
- Must be non-toxic to the body.

Biocompatible material features

- Absence of carcinogenicity (the ability or tendency to produce cancer)
- Absence of immunogenicity (absence of a recognition of an external factor which could create rejection)
- Absence of teratogenicity (ability to cause birth defects)
- Absence of toxicity

Biomaterials





Thank You

PHOTODIODES

- Semi-conductor device, with a p-n junction and an intrinsic layer between p and n layers.
- Produces photocurrent by generating electron-hole pairs, due to the absorption of light in the intrinsic or depletion region.

PHOTODIODES

- Photodiodes can operate in 3 different modes:
  - photovoltaic mode
  - photoconductive mode
  - avalanche mode