Malleable Cast Iron:

- MCI begins as white iron casting, which undergoes heat treatment at around 900 °C (1,650 °F). The slower separation of graphite allows surface tension to create spheroidal particles instead of flakes.
- Owing to their decreased aspect ratio, spheroids are petite and far distant and have a lower propagating fracture or phonon cross section. They feature broad borders, unlike flakes, which reduces stress concentration in grey cast iron. Overall, malleable cast iron behaves like mild steel. Due to its white cast iron composition, malleable iron parts are limited in size.

Ductile Cast Iron:

- Recent developments include nodular or ductile cast iron. Adding small amounts of magnesium or cerium to these alloys slows graphite precipitate formation by attaching to graphite plane edges. Controlling other elements and time enables carbon to segregate into spheroidal particles during solidification. The qualities are like malleable iron, although larger pieces can be cast.

Typical Uses:

- Historic Markers and Plaques
- Hardware (Hinge, Latches)
- Columns, Balusters
- Stairs
- Structural Connectors

- Decorative Features
- Fences
- Tools and Utensils Ordnance
- Stoves and fire backs
- Piping

The cast iron material in all these applications may look the same or comparable, but component size, composition, use, condition, relationship to adjacent materials, exposure, and other characteristics may require distinct treatments to fix identical issues. Any substance should be considered as part of a broader system, and treatment methods should address all relevant elements.

Module-IV Non-Ferrous Metals and Alloys

- Non-ferrous metals- Example: - **aluminum, copper, lead, nickel, tin, titanium and zinc, as well as copper alloys like brass and bronze**.

Properties

No-Fe	High Thermal Conductivity
Corrosion Resistance	Formability and Castability
High Electrical Conductivity	Electric and Magnetic

Copper - its Alloys

Copper is found as native metal and in minerals cuprite, malachite, azurite, chalcopyrite and bornite.

The largest end use for Copper is in the building industry. Within the building industry the use of copper-based materials is broad. Construction industry related applications for Copper include roofing, piping, electrical wiring etc.

Building industry – 47%

Electronic products - 23%

Transportation - 10%

Industrial machinery - 9%

Consumer products - 11%

Copper Applications

In-Power transmission lines
~ Architectural applications
~ Cooking utensils
~ Spark plugs
~ Electrical wiring, cables and busbars
~ High conductivity wires
~ Electrodes
~ Heat exchangers
~ Refrigeration tubing
~ Plumbing
~ Water-cooled Copper crucibles

Structure and Properties

- Copper has a face centered cubic (FCC) crystal structure.
- Copper and its alloys have a range of yellow/gold/red colors and when polished develop a bright metallic luster.
- Around 40% of the annual consumption of Cu alloys is derived from recycled Copper materials.

- tough, ductile malleable
- ~ Excellent heat conductivity
- ~ Excellent electrical conductivity
- ~ Good corrosion resistance
- ~ Good biofouling resistance
- ~ Good machinability
- ~ Retention of mechanical and electrical properties at
- ~ Non-magnetic

Structure and Properties-Brass

Brass is a binary alloy of copper and zinc

Copper – zinc alloys i.e., brasses have two different types of crystal structure.

Alpha brasses are solid solutions of zinc in copper with FCC crystal structure..

The maximum solubility of zinc in the α-phase is about 38%

It has good corrosion resistance, high strength and ductility.

Its electric conductive decreases with increase in zinc content and with higher zinc content, beta phase with BCC structure starts to form.

Brasses with zinc contents near 40% can have a structure of alpha and beta, but at around 50% zinc the structure is entirely beta

Catridge Brass

- Cartridge Brass contains 70% copper and 30% zinc. It is very ductile and has excellent cold working properties.
- It can be easily drawn into wires, rods and tubes and can be formed into intricate shapes by pressing.
- It is used for cartridge cases, locomotive and condenser tubes.

Admiralty Brass

Admiralty brass is an alloy of copper, zinc and tin.

It contains 70% copper , 29% zinc and 1% tin.

It has good resistance to corrosion and is used for condenser tubes and marine parts.

Leaded Brass

Due to high ductility, machining of brass is difficult.

Lead (3% max) is usually added to brass to improve machinability.

Such a brass is called leaded brass or free cutting brass

The usual composition is Cu – 62.5%, Zn – 36% and Pb – 1.5%

Lead is insoluble in solid as well as in liquid phases and appears as globules in the microstructure.

These globules easily break into small chips and increase machinability.

It has low ductility and impact values. It is used for gears, screws and screw machine parts

Naval Brass

- Naval brass is an alloy of Cu – 60%, Zn – 39% and Sn – 1%.
- It has good corrosion resistance against salt water.
- Eg. condenser plates, propeller shafts & marine parts

Name	Composition %			Properties	Uses
	Cu	Zn	Other elements		
Cartridge Brass	70	30		Most ductile and has good tensile strength. Easily cold worked by drawing, pressing and spinning	Cartridge cases, locomotive and condenser tubes. Lamp fixtures and spring
Admiralty brass	70	29	1(Sn)	Resistance to corrosion	Condenser tubes, and marine parts
Muntz metal (Yellow Brass)	60	40		Strong, hard and more ductile	Valves, marine fitting electric equipment, fuses and grill work
Leaded Brass	62.5	36	1.5(Pb)	Good machinability resistance to corrosion, low ductility and impact values	Used for tubes, plates
Naval Brass	60	39	1(Sn)	Suitable for hot-rolled forging and casting. Good corrosion resistance.	Marine parts such as values and fittings

Bronze

Bronze -an alloy of copper and tin is also referred as phosphorus bronze because it contains noticeable amount of phosphorus (upto 0.3%).

It has low coefficient of friction, and it can be rolled into sheets or cast into intricate castings

Bronzes are stronger than brasses, and have better corrosion resistance. The cost of (bronzes) is more than brasses.

The term bronze does not always imply copper-tin alloys. Alloy of copper with other elements (except zinc) are also called bronzes such as aluminum bronze, silicon bronze etc

The properties and applications of important types of bronzes are described below

Phosphorous and other Bronzes

Name	Composition %			Properties	Uses
	Cu	Sn	Other elements		
Phosphor Bronze	93.7	6	0.3(P)	Possess good castability, high fatigue strength	Springs, gears and bearing
Aluminiium Bronze	90 – 95	-	5-10 (Al)	Possess high strength, and resistance to corrosion	Marine engineering, guides, seats, flanges, molding dies for plastics and condenser tubes
Gunmetal	88	10	2 (Zn)	Easily castable, possess high strength, toughness and resistance to sea water corrosion	Casting guns, boiler fittings, bolts, nuts and for many parts in naval constructions
Bell metal	80	20		Hard and resistance to surface wear	Bells gongs and utensils
Silicon Bronze	97.5	-	2.5(Si)	Strength, corrosion resistance	Marine application, High strength fasteners

Nickel Silver

1. Alloy containing 55% of copper, 27% zinc and 18% nickel is called Nickel Silver
2. This alloy do not contain any silver
3. The name is justified because the addition of nickel to brass causes the change of color from yellow to white, resembling that of silver
4. The corrosion resistance of nickel silver is better than the brass. Susceptibility to stress corrosion and dezincification decreases with increasing the nickel content.

5. Its strength can be increased by cold working
6. It is ductile and used for decorative purposes and cutlery.
7. It can also be used for rivets, screws, radio dials and similar applications.

Constantan

1. Constantan is a copper – nickel alloy consisting of 55% copper and 45% nickel.

2. It has the highest electrical resistivity and lowest temperature coefficient of resistance.
3. It is used for electrical resistors and thermo-couples.

Nickel and its Alloys

1. Pure nickel exhibits exceptional corrosion resistance and is both ductile and robust.
2. It is capable of being brazed, welded, and forged. It is employed in the combustion chambers of gas turbines and chemical apparatus.

It functions as a basal coating for the electroplating of chromium. Nickel is a primary component of numerous industrial alloys.

3. Nickel base alloys are composed of over 50% nickel. In the temperature range of 650 to 750 C, a large variety of nickel-based alloys are accessible, and these alloys maintain a significant degree of strength. The following is a description of the properties and applications of significant nickel alloys.
4. Nickel and copper form isomorphous system, and such alloys can be strengthened by cold working.
5. A wide range of properties can be obtained by varying proportions of nickel and copper, and addition of small quantities of other elements.

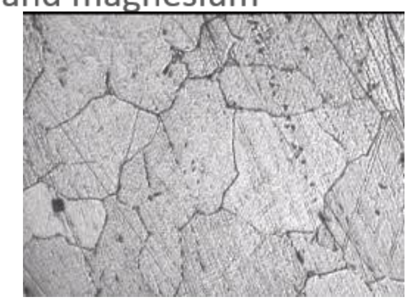
Monel Metal

1. Monel or Monel metal is a nickel –copper alloy with high strength and corrosion resistance.
2. It is harder and stronger than brass and bronze, but weaker than that of alloy steel.
3. It contains about 67% nickel and 30% copper with small quantities of iron, manganese, silicon and carbon
4. Monel is widely used in chemical and textile industries
5. Applications of monel include house hold equipment, heat exchanger tubes, containers, valves, pumps and parts used in food textile and chemical industries

Al and alloys

1. Both groups include non-heat treatable as well as heat treatable alloys.
2. Heat treatable alloys achieve their properties by solid solution strengthening while non-heat treatable alloys are strengthened by cold working.

3. The composition properties and applications of important aluminum alloys are given in the table given below
4. Aluminum alloys are cast in considerable quantity.
5. The main alloying elements in cast alloys are silicon, copper and magnesium.
6. Cast alloys contains enough silicon (11-13%) to form eutectic alloy giving materials low melting point and good fluidity
7. They can be sand cast and die cast into intricate shapes. They are used for engine cylinder blocks, gear box cases, crank cases etc.
8. Wrought alloys are those that are shaped by plastic deformation.
9. They possess good formability characteristics, such as low yield strength, high ductility and good fracture resistance.
10. They can be obtained in the form of sheets, bars and tubes and they can be forged
11. The total alloy content in wrought alloy is about 7% and include copper, manganese and magnesium



Al and its alloys

Type of alloy	Composition % Balance = Al					Properties and applications
	Cu	Mg	Mn	Si	Other elements	
Wrought alloy – work hardened	-	5	-	-	-	High resistance to corrosion (sea water) marine applications
Wrought alloy – Heat treatable (Duralumin)	4	0.5	0.5	0.5	0.5 (Fe)	Non-magnetic, resistance to corrosion; good strength Air craft and automobile industry in the form of forgings, bars, sheets,
Wrought alloy – Heat treatable (magnalium)	1.75	6	-	-	-	Light weight; good mechanical properties Aircraft and automobile components
Wrought alloy – Work hardened (Hindalium)	-	3.5	-	-	0.25 Cr	Strong and corrosion resistance; utensils
Cast alloy – work hardened	3.0	-	0.4	5.0	-	Good casting characteristics with moderate strength manifolds and valve bodies
Heat treatable (Y-alloy]	4	1.5	-	-	2 (Ni)	Retains strength at high temperature, resistance to corrosion
Cast alloy – Heat treatable	1.8	-	-	9.0		High strength; air craft industry

Titanium and its alloys

1. Compared to pure titanium, titanium alloys have a high strength, ductility and corrosion resistance, and retain these properties at elevated temperatures.
2. These merits titanium alloys are used in air craft engineering, marine application, chemical processing and other industries.
3. They may be processed by casting, forming and also by advanced methods such as powder metallurgy and hot –isostatic pressing
4. Depending on stable phases at room temperature, titanium alloys are classified as :

   α – phase titanium alloy

   β – phase titanium alloy

   (α+β) – phase titanium alloy
5. α – phase is stabilized and hardened by adding about 5 percent aluminum and 2.5% percent tin.
6. Addition of tin improves strength without affecting ductility. α – phase alloys are used for gas turbine engine casings and chemical processing equipment.
7. β – phase alloys are produced by adding larger amounts of molybdenum, chromium and vanadium.
8. The usual composition of β – phase alloys is 13% vanadium, 11% chromium and 3% aluminium.
9. They possess good ductility and formability when they are not heat treated
10. Age hardening produce very high strength but ductility and toughness are reducted, β – phase alloys are used for high strength airframe components

11. An alloy composition of 6% aluminum and 4 % vanadium produces (α+β) – phase titanium alloys.

12. This is most popular titanium alloy accounting for nearly 50 – 70% of all titanium alloys used in the entire industries

Alloy	Composition %					Properties and applications
	Al	V	Sn	Mo	Cr	
α – Alloy	5	-	2.5			➢ High Strength and ductility, creep resistance up to 500 C, good formability ➢ Gas turbine engine casings, chemical processing equipment
β – Alloy	3 3	13 8	 -	 4	11 6	▪ High ductility and good formability; low strength to weight ratio ▪ Hight strength air frame components
(α+β) Alloy	6	4	-	-	-	✓ Good strength and formability ✓ Chemical processing equipment and air craft components

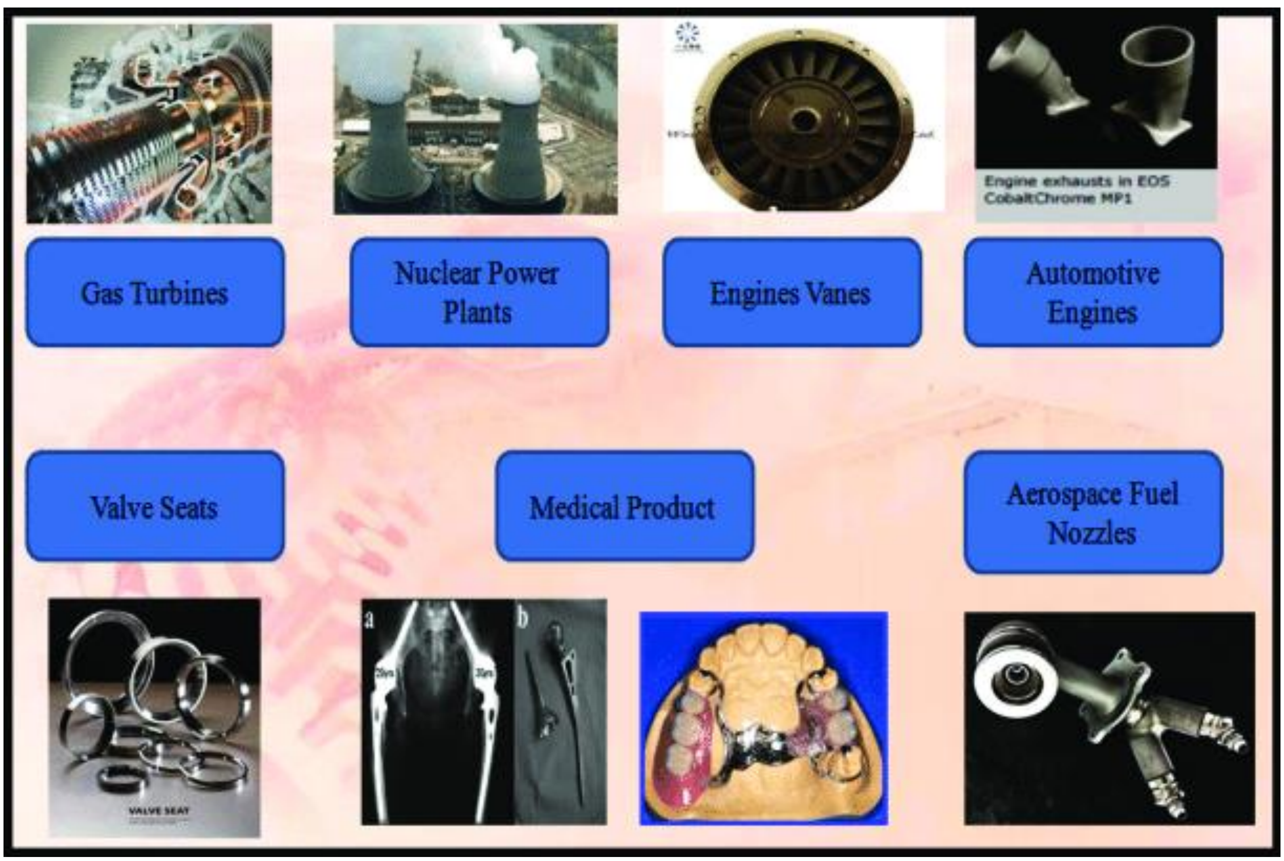
13. Ti – 6Al – 4V alloys have strength and good creep, fatigue and corrosion resistance.

14. They are used for aircraft components such as airframes, turbine compressor blades and rings

Cobalt and its alloys

Around the time of World War II, cobalt alloys were developed for use in adverse conditions, including high temperature exposure, mechanical stress, and contact with chemically aggressive gaseous or molten media. Some of these alloys were derived from cobalt chromium alloys that were already in existence for other purposes.

1. Used as hot components in the first jet engines, including turbine blades
2. Cobalt alloys are classified into two different classes: casting alloys and wrought by (hot) forging alloys.
3. In particular, four cobalt-chromium alloys are commonly used for biomedical applications:
    4. ASTM F75: Co-28Cr-6Mo, casting alloy.
    5. –ASTM F799: Co-28Cr-6Mo, thermodynamically processed alloy.
    6. –ASTM F90: Co-20Cr-15W-10Ni, wrought alloy.
    7. –ASTM F562: Co-35Ni-20Cr-10Mo, wrought alloy.



Mg and its alloys

1. Contains 3 to 10 % Al, 1 to 3.5% Zn and 0.4% manganese.
2. Dow metal : 91 Mg 9 Al / Cu
3. The tensile strength is not high
4. Risk hazards due to burning
5. Weight is 2/3 of AL and Quarter of that of steel.
6. Dow metal cant be forged/ welded/drawn in wires.
7. Mg alloys are called light alloys.

Refractory and precious materials

The term “refractory metals” is gen-erally applied to metals that have melting points greater than 2000^0 C.

Element	Symbol	Melting point, °C	Remarks
Tungsten	W	3410	
Tantalum	Ta	2996	Also used in the chemical industry
Molybdenum	Mo	2610	
Niobium	Nb	2497	Also used in the chemical industry
Zirconium	Zr	1825	Mainly used in the chemical industry
Osmium	Os	3045	Also a member of the platinum group
Iridium	Ir	2410	Also a member of the platinum group
Rhenium	Re	3180	Brittle, difficult to fabricate

Silver, gold, and the six platinum group metals—platinum, palladium, ruthenium, rhodium, osmium, and iridium—are all included in the definition of "precious metals."

The term "fineness" is employed to denote purity in parts per thousand by weight.

For example, 995 fine gold is 99.5% gold, and 925 fine silver (sterling silver) is 92.5% silver.

Throughout history, gold has been exceptionally valuable due to its numerous qualities.

It is highly malleable, durable to the point of virtual indestructibility, and typically found in nature in a comparatively pure form.

Additionally, it is attractive in colour and luminosity.

MODULE -V
CERAMICS, POLYMERS AND COMPOSITES MATERIALS

Introduction:

Heat-resistant, non-metallic, inorganic ceramics are composites of metallic and non-metallic materials. Commonly, ceramics are hard, corrosion-resistant, and brittle. Most ceramics insulate well and resist high temperatures. They are used in almost every facet of modern life due to their qualities. The main ceramic categories are conventional and advanced. Traditional ceramics are comprised of clay and cements that have been hardened through high temperatures. Traditional ceramics are used for plates, kitchenware, flowerpots, roof and wall tiles. Advanced ceramics include carbides like SiC, oxides like Al2O3, nitrides like Si3N4, and many others, including mixed oxide ceramics that can behave as