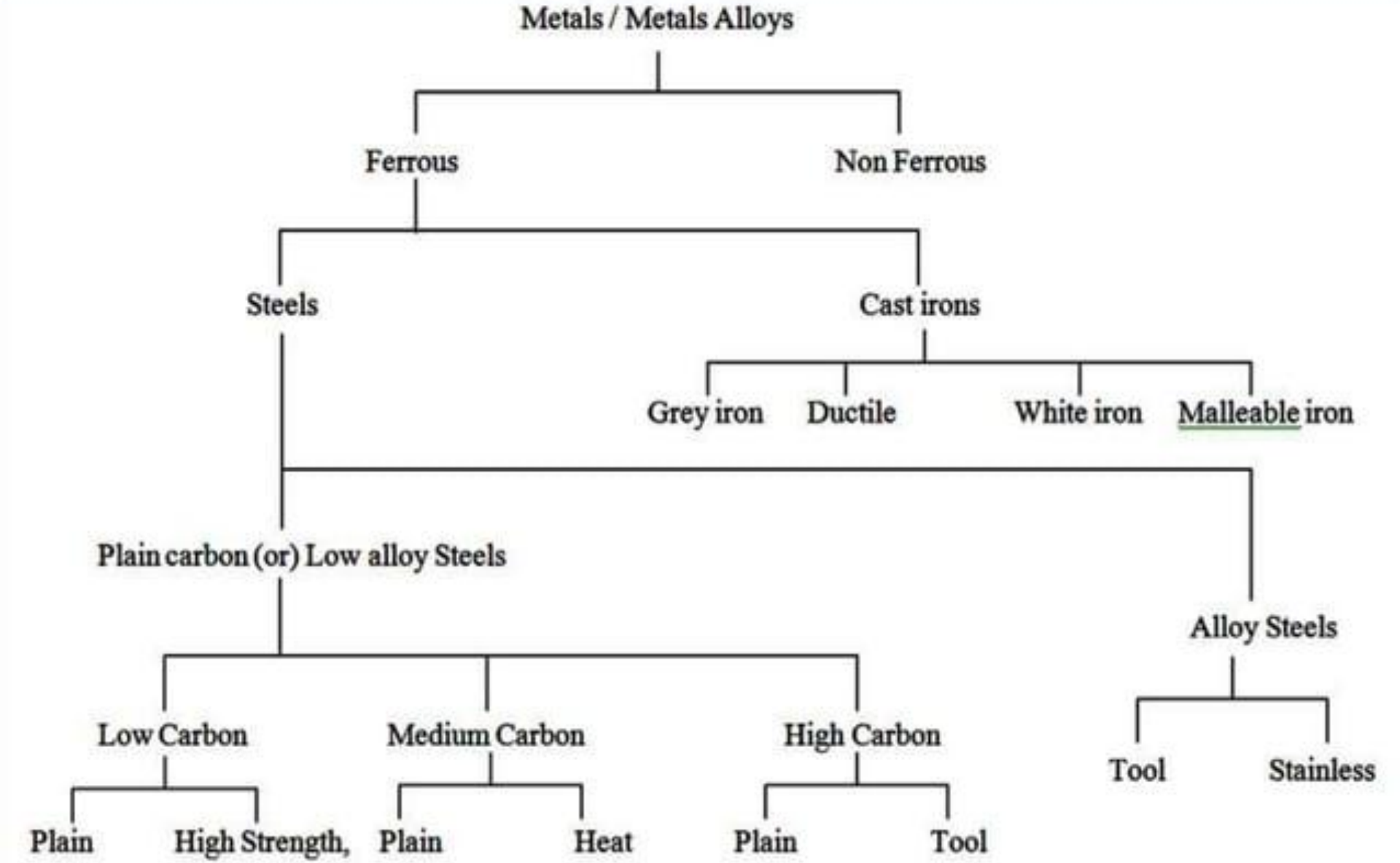
ME3392
ENGINEERING MATERIALS AND METALLURGY

UNIT III

FERROUS AND NON FERROUS ALLOYS

VEERAPANDIAN.K
AP/MECH

CLASSIFICATION OF METALS

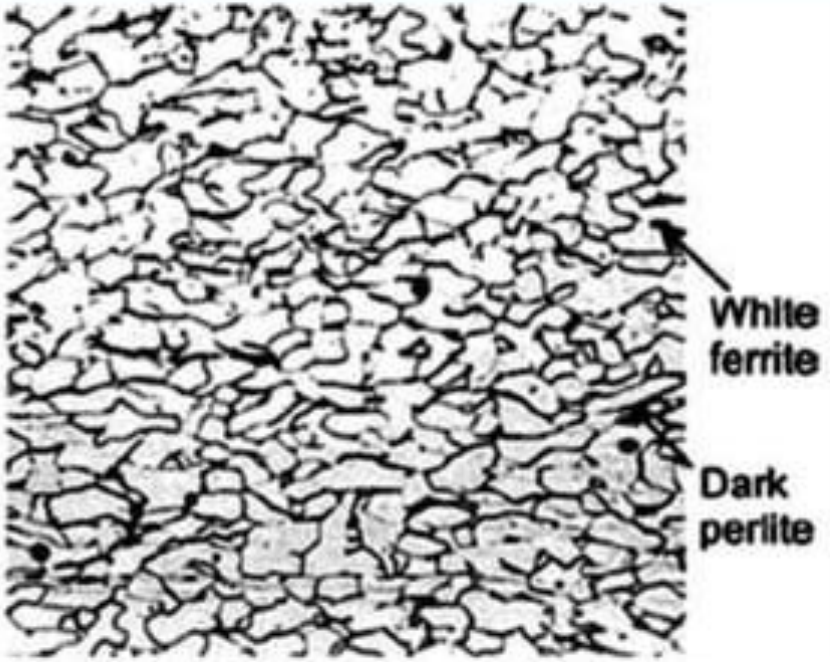


STEELS

- Steels are alloys of iron and carbon.
- It contain other elements like silicon, manganese, sulphur, phosphorus, nickel, etc.
- The alloying elements are either intentionally added or retained during the refining process.

Low Carbon Steel (Mild Steel)

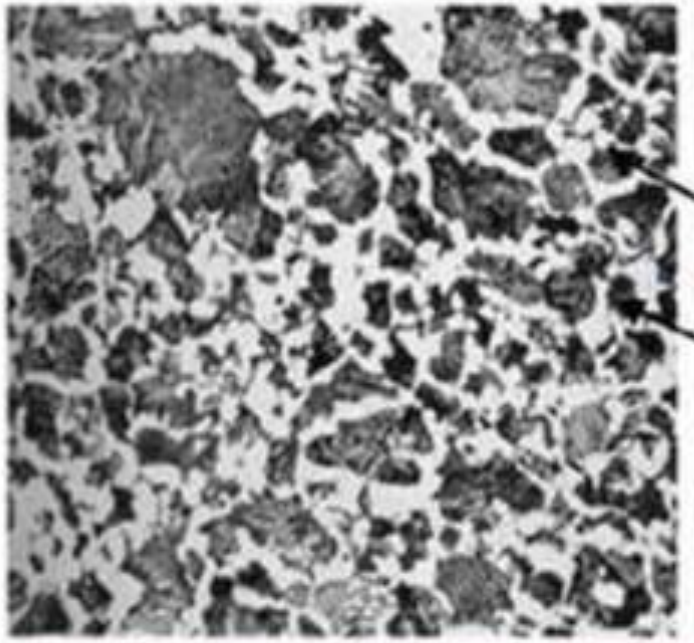
- 0.08% to 0.35% carbon
- It is soft, highly ductile and tough
- Have good machineablity and weldability.



- Used in automobiles, structural fabrication, wires, rivets, nuts, bolts, sheets, tubes and shafts railway axle.

Medium Carbon Steel

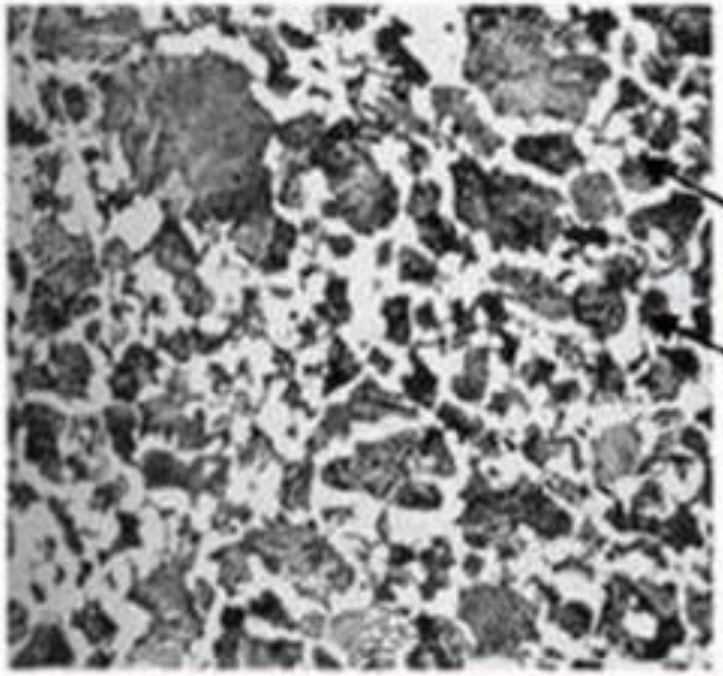
- 0.35% to 0.55% carbon
- It is harder, stronger and less ductile than mild steel



- used in various steel sections, rail steel, springs, wire ropes and hammer.

High Carbon Steel

- 0.55% to 1.55% carbon
- They are hardest, strongest and low ductile
- Respond to hardening and heat treatment



- used in knives, razors, metal-cutting tools, hacksaw blades

Commercial Plain Carbon Steel

Types of Steel	C%	Mn%	Si%	S%	P%
Wrought Iron	0.05	0.05	0.07	0.01	0.01
Low Carbon Steel (Mild Steel)					
(i) Rivet Steel	0.05	0.30	0.07	0.04	0.04
(ii) Structural Steel	0.20	0.08	0.12	0.05	0.05
(iii) Free Cutting Steel	0.13	0.45	0.03	0.12	0.10
(iv) Railway Axle	0.35	0.80	0.20	0.04	0.04
Medium Carbon Steel					
(i) Rail Steel	0.38	1.00	0.08	0.06	0.05
(ii) Railway Spring Steel	0.50	0.85	0.10	0.05	0.05
High Carbon Steel					
(i) Chisel Steel	0.75	0.50	0.08	0.05	0.05
(ii) Carbon Tool Steel	1.30	0.32	0.15	0.02	0.02
(iii) Saws, Razor	1.40	0.50	0.10	0.30	0.05
(iv) Saws for Cutting Steel	1.55	0.40	0.15	0.02	0.02

Alloy Steels

The alloying elements are added in steels to achieve one or more of the following properties.

- Increase resistance to corrosion
- Improve machinability
- Increase resistance to abrasion
- Increase high temperature properties

Classifications of alloy Steel

- If alloying elements **less than 10%** - **low alloy steels**.
- chromium, manganese, nickel, vanadium and boron are the alloying elements
- Has high tensile strength
- Used as machine components in railway, ship, aeroplane, automobile and other engineering industries.
- If alloying elements **more than 10%** - **high alloy steels.**
- used as cutting tools, blades, razors and wear-resistant parts in industry.

Common Types of Alloys

Steel

combination of iron (metal) and carbon (non-metal)

Bronze

combination of copper (metal) and tin (metal)

Brass

mixture of copper (metal) and zinc (metal)

ThoughtCo.

Manganese - Mn

- **0.05 – 0.85%** improves strength and ductility
- **1.5 – 2%** further increases the strength in heat treated condition
- **2 - 10%** along with carbon is responsible for brittleness in steel.
- **11 –16%** along with **1 –1.5%** carbon, the alloy produced is hard and wear resistant.

Used in railroad, rock crusher and dredge buckets in mining.

Nickel (Ni) - Steel

- Small quantity of nickel with steel will improve the toughness and impact resistance.
- **1.5 – 6%** increases the elastic limit, hardness and tensile strength of steel.
- **8 – 22%** improves corrosion resistance and provides additional strength and hardness

These steels are used for bolts, gears, axles, nuts and various machine arts.

Chromium (Cr) - Steel

- It provides hardness and increased elastic limit and tensile strength without affecting the ductility.
- Addition of chromium to plain carbon steel improves the hardenability, strength and wear resistance

It is mainly used in surgical instruments, files, ball and roller bearings, gears and springs.

Stainless Steel

- Nickel and chromium steel are also called as stainless steel
- It has increased strength, surface hardness and resistance to corrosion

Martensitic Stainless Steel

- 11.5 - 18 % Cr + 1.2 % carbon + 1 - 1.2 % nickel.

They are hardenable & moderate corrosion resistance

Used in surgical instruments, wrenches, turbines springs, steam turbine blades and ball bearings.

Ferritic Stainless Steel

10 - 27 % Cr + 0.2 % carbon

They are resistant to corrosion and have great strength

They are used for household steels, surgical instruments, chemical industries and automobile.

Austenitic Stainless Steel

- 16 - 26 % Cr + 35 % nickel.

They have the highest corrosion resistance, not hardenable by heat treatment and are nonmagnetic. .

Used in aircraft, food processing industries, household equipment, heat exchangers and dairy equipment.

High-speed Steel

It containing large amounts of tungsten, chromium, vanadium and cobalt. It withstand in high temperature without loosing hardness

They used in Drills, milling cutters, tool for lathe

Tungsten High-speed Steel

- Tungsten is commonly used as alloying elements in high alloy steels. It varies from 1%–20% in the form of ferrite and also carbide.

High tungsten alloy called as high-speed steel.
Used in high-speed machining operations

EFFECT OF ALLOYING ELEMENTS IN STEELS

- **less than 5 %** - improve strength **or** hardenability.
- **up to 20 %** - gives corrosion resistance or stability at high or low temperatures.

- Ni, Mn, Cu , Co - stabilize austenite .
- Cr, W, Mo, V , Si - stabilize ferrite.
- Cr, W, Ti, Mo, Nb, V, Mn - form carbides.
- Si, Co, Al, Ni destabilize carbides and form graphite.

EFFECT OF ALLOYING ELEMENTS IN STEELS

Manganese (Mn)

- It is used to improve hot ductility.
- At low temperature – it act as austenite stabilizer
- At high temperatures - it will stabilize ferrite

- Manganese increases the solubility of nitrogen and is used to obtain high nitrogen contents in duplex and austenitic stainless steels.

EFFECT OF ALLOYING ELEMENTS IN STEELS

Silicon (Si)

- increases resistance to oxidation, both at high temperatures
- It promotes a ferritic microstructure and increases strength.

Chromium (Cr)

- It gives corrosion resistance.
- Stainless steels - 10.5% Chromium
- It increases the resistance to oxidation at high temperatures and promotes a ferritic microstructure.

EFFECT OF ALLOYING ELEMENTS IN STEELS

Molybdenum (Mo)

- It increases the hardness penetration of steel,
- It slows the critical quenching speed,
- It increases high temperature tensile strength.

Vanadium (V)

- It helps control grain growth during heat treatment.
- It increase the toughness and strength of the steel.

EFFECT OF ALLOYING ELEMENTS IN STEELS

Titanium (Ti)

This element, when used in conjunction with Boron, increases the effectiveness of the Boron in the hardenability of steel.

Aluminum (Al)

- Aluminum - improves oxidation resistance
- In precipitation hardening steels, aluminum is used to form the intermetallic compounds that increase the strength in the aged condition.

EFFECT OF ALLOYING ELEMENTS IN STEELS

Silicon (Si)

- increases resistance to oxidation
- It promotes a ferritic microstructure
- It increases strength.

Copper (Cu)

- **It** enhances corrosion resistance
- It decrease work hardening & improve machinability.
- It improve formability.

Tungsten (W)

- Tungsten added to improve pitting corrosion resistance.

SOME IMPORTANT ALLOY STEELS

- Stainless steels.
- Tool steels
- HSLA steels
- Maraging steels.

Types of steel

Fundamentally, steel is an alloy of iron with low amounts of carbon.

- **Carbon steel** — It contains iron & carbon (Up to 1.5 %) as main constituent
- **Alloy steel** — It contains iron & alloying elements like nickel, copper, chromium, and/or aluminum.
- **Stainless steel** — It contains 10 to 20% chromium as their alloying element and are valued for their high corrosion resistance.
- **Tool steel** — It contains tungsten, molybdenum, cobalt, and vanadium to increase heat resistance and durability.

TOOL STEEL

They are basically high-carbon alloy

Properties

- Good toughness
- Good wear resistance
- Very good machinability
- Resistance to softening on heating

Applications

used in cutting, pressing, extruding, coining, operations.
Used also in injection molding process.

HSLA steels
(High Strength Low Alloy steels)

- They are micro-alloyed steels, having low carbon with small amounts of alloying elements.

Carbon 0.05–0.25% alloying elements include up to 2.0%

Properties

- high yield strength and high corrosion resistance
- They can be welded without becoming brittle
- These are very light i.e., weight savings upto 20 to 30% can be achieved without compromising its Strength.
- ductile, formable and machinable

They are used in cars, trucks, cranes, bridges, roller coasters and other structures that are designed to handle large amounts of stress or need a good strength-to-weight ratio.

Maraging steels

low-carbon, highly alloyed steels

17–19 wt.% nickel,
8–12 wt.% cobalt,
3–5 wt.% molybdenum
0.2–1.6 wt.% titanium.

- .The term maraging is derived from the strengthening mechanism, which is transforming the alloy to martensite with subsequent age hardening. Air cooling the alloy to room temperature from 820°C creates a soft iron nickel martensite, which contains molybdenum and cobalt in supersaturated solid solution.

Maraging steels

Properties

- high tensile strength and impact strength.
- toughness with high strength
- suitable for surface hardening by nitriding.

Applications

- Aerospace,
- Tooling & machinery
- extrusion press rams and mandrels in tube production,
- gears and fasteners

CAST IRON

An alloy of iron that contains 2%–4% carbon along with varying amounts of silicon and manganese and traces of impurities such as sulphur and phosphorus is called cast iron.

GREY CAST IRON

- 2.5%–3.8% carbon,
- 1.1%–2.8% silicon,
- 0.4%–1% manganese
- 0.15% phosphorous
- 0.10% sulphur.

used in water pipes, manhole covers, IC engine blocks, piston rings and machine components.

WHITE CAST IRON

- 1.8%–3.6% carbon,
- 0.5%–2% silicon,
- 0.2%–0.8% manganese,
- 0.18% phosphorus
- 0.10% sulphur.

used for producing malleable cast iron and wear-resistance component machine component.

MALLEABLE CAST IRON

- 2.3% carbon
- 0.6%–1.3% silicon
- 0.2%–0.6% manganese
- 0.15% phosphorous.

used for railroad, agricultural implements and conveyor chain links.

SPHEROIDAL GRAPHITE CAST IRON
(nodular cast iron or 'ductile iron')

- 3.2%–4.2% carbon
- 1.1%–3.5% silicon
- 0.3%–0.8% manganese.

used in internal combustion engine, earth moving machinery, valves and fittings, pipes and flywheels.

ALLOY CAST IRON

- Adding alloying elements like Ni, Cr, Mo, Cu, Si, and Mn with cast iron

- high strength materials,
- hard and abrasion-resistant materials,
- corrosion resistant irons,
- high-temperature service.

Applications

Cylinder blocks, brake drums, clutch, casings, piston rings for Areo, automobile diesel engines , automobile crank shaft.

Effects of Alloying Elements in Cast Iron

S.No	Alloying Element	General Effects
1	Nickel (Ni)	♦ It has graphitizing effect on cementite. So it tends to produce a grey iron. ♦ It has a grain-refining effect, which helps to prevent the formation of coarse grain. ♦ It also toughens thin sections
2	Silicon (Si)	♦ It has same effects as that of nickel
3	Chromium (Cr)	♦ It is a carbide stabilizer, so it is used for hard and wear-resistant irons.
4	Molybdenum (Mo)	♦ It increases the hardness of thick sections. ♦ It also improves toughness.
5	Vanadium (V)	♦ It increases both strength and hardness. ♦ It promotes heat-resistance in cast irons, by stabilizing carbides.
6	Copper (Cu)	♦ It improves resistance to corrosion.

NON - FERROUS MATERIALS

NON - FERROUS MATERIALS

All the metallic elements other than iron are referred to as non ferrous materials.

- Lighter in weight.
- Higher electrical and thermal conductivity.
- Better resistance to corrosion.
- Ease of fabrication (casting, rolling, forging, welding and machining).
- Colour.

COPPER

- Pure copper is **reddish** in colour
- It is highly malleable, ductile and is a good conductor of heat and electricity.
- used in wire and some industrial applications like heat exchanger, bearing, etc.

Principal properties of pure copper

Melting point	1083°C
Crystal structure	FCC
Density	8.93×10^3 kg/m^3
Young's Modulus, E	122.5 Gpa
Tensile strength	220 MPa
Electrical resistivity	$1.67 * 10^{-8}$ Ωm at 20°C
Corrosion resistance	Very good

Brass

- Brass is an alloy of copper and zinc containing at least 50% copper.
- It is bright yellow to golden in colour.
- It is soft and ductile and is stronger than copper.
- It has good casting properties and is resistant to corrosion.
- It is used for making plumbing fittings, bushes, bearings and pumps.

Types of brasses

S.No	Type	Composition	Properties	Uses
1	Yellow brass	65% Copper 35% Zinc	High Ductility, good strength, high resistant to corrosion.	Plumbing, lamp fixtures, grill works, rivets, tubes
2	Red brass or Red metal	85% Copper 15% Zinc	Better corrosion then yellow brass, superior to copper to handling water.	Plumbing lines, Electrical sockets.
3	White brass	10% Copper 90% Zinc	Hard and strong	Used for or namental work
4	Muntz metal (Alpha and Beta brass)	60% Copper 40% Zinc	More brittle, suitable for hot working	condenser tubes, hotworking, rolling, extrusion etc.
5	Naval brass	69% Copper 30.25% Zinc 0.75% Sn	High strength, high resistance to corrosion	Architectural work, condenser tubes, brazing rods etc.
6	Leaded yellow brass	67% Copper 29% Zinc 3% Lead 1% Sn	High strength, high resistance to corrosion	Furniture hardware, radiator, light fittings etc.

BRONZES

- higher strength than copper
- noncorrosive and wear resistant.

S. No	Type	Composition	Properties	Uses
1	**Bell metal**	82% Copper 18% Tin	Hard and brittle. It posses resonance	Making bells
2	**Gun metal**	88% Copper 10% Tin 2% Zinc	Hard, tough and strong. Corrosion resistant to water	Bearings, bolts, nuts, naval applications.
3	**Phosphor bronze**	89% Copper 10% Tin 1% Phosphorous	High endurance limit, hard, strong, corrosion resistant to seawater.	Gears, springs, bearings etc.
4	**Speculum metal**	67% Copper 33% Tin	High reflective surface after surface finishing	Used for telescope
5	**Silicon bronzes**	95% Copper 5% Silicon	Strong, high corrosion resistances	Tanks, presser vessels,
6	**Beryllium bronzes**	88% Copper 1.5 Beryllium 0.2% Cobalt	Good fatigue, creep resistance, high electrical conductivity.	Surgical instruments, bolts, etc.
7	**Aluminum bronzes**	80% Copper 20% Aluminium	Hard, strong, light, malleable.	Corrosion resistant vessels, blades, bearings etc.

SILVER

- Silver is a chemical element with the symbol Ag.
- Its soft, white, lustrous transition metal,
- highest electrical conductivity,
- thermal conductivity,
- High reflectivity of any other metal

Silver Alloys

- Argentium sterling silver
- Britannia silver
- Goloid
- Shibuichi
- Sterling silver

Application areas of silver

- In photography
- In dentistry
- As cutlery and mirrors
- As a catalyst in oxidation reactions
- In high-capacity zinc long-life batteries
- As a precious metal to make coins and jewelry
- In electrical and electronic industries for items such as printed circuits and computer keyboards

Gold

Gold is the first metals used by man

Properties

- It is a bright, yellow, soft,
- Highly malleable and ductile
- corrosion resistance,
- good reflectance,
- resistance to sulfidation and oxidation,
- high electrical and thermal conductivity.

Alloy of Gold

Color of Gold	Alloy Composition
Yellow Gold (22K)	Gold 91.67%, Silver 5%, Copper 2%, Zinc 1.33%
Red Gold (18K)	Gold 75%, Copper 25%
Rose Gold (18K)	Gold 75%, Copper 22.25%, Silver 2.75%
Pink Gold (18K)	Gold 75%, Copper 20%, Silver 5%
White Gold (18K)	Gold 75%, Platinum or Palladium 25%
White Gold (18K)	Gold 75%, Palladium 10%, Nickel 10%, Zinc 5%
Gray-White Gold (18K)	Gold 75%, Iron 17%, Copper 8%
Soft Green Gold (18K)	Gold 75%, Silver 25%
Light Green Gold (18K)	Gold 75%, Copper 23%, Cadmium 2%
Green Gold (18K)	Gold 75%, Silver 20%, Copper 5%
Deep Green Gold (18K)	Gold 75%, Silver 15%, Copper 6%, Cadmium 4%
Blue-White or Blue Gold (18K)	Gold 75%, Iron 25%
Purple Gold	Gold 80%, Aluminum 20%

Applications - Gold

- Gold is used in electronic devices, particularly in **printed circuit boards**, connectors, keyboard contactors, and miniaturized circuitry.
- reflector of infrared radiation in radiant heating and drying devices
- thermal-barrier windows for large buildings and space equipment.

Platinium

- The word Platinum is derived from Platina (Spanish word meaning 'little silver'), because of its grey-white silvery colour.

- soft, lustrous, silver-coloured metal.
- It is highly dense, malleable and ductile
- highcorrosion resistant
- high boiling point
- It's a Noble metal because of its high stability.

Platinium Alloys

- Platinum-Iridium alloys
- Platinum-Cobalt alloys
- Platinum-Palladium alloys
- Platinum-Gold alloys
- Platinum-Tungsten alloys

Platinum-Iridium alloys

- Alloying platinum with iridium (Ir) has a strong hardening effect even at relatively low iridium concentrations.

- This alloy is very malleable and ductile and easy to fabricate.
- Because of its softness the alloy has poorer resistance to scratches.

Platinum-Cobalt alloys

- Alloying platinum with cobalt (Co) results in significant **hardness** **increase due to the grain refining effect of cobalt**

This alloy has excellent Casting properties , high hardness and good scratch resistance.

Platinum-Palladium alloys

popular in Japan and Hong Kong.

- Alloying platinum with Palladium results soft metal ,**hardness increase** by cold.

The alloys have **grey color**.
Rhodium Electroplating is used to improve their appearance

Palladium is actually from the same family of metals as Platinum with very similar characteristics.

Platinum-Gold alloys

- Alloying platinum with Gold
- Its strengthened by precipitation hardening method

Platinum-Tungsten alloys

Strengthen by precipitation hardening (solution treatment-quenching-aging).

Platinum-tungsten alloys are used for fabricating springs

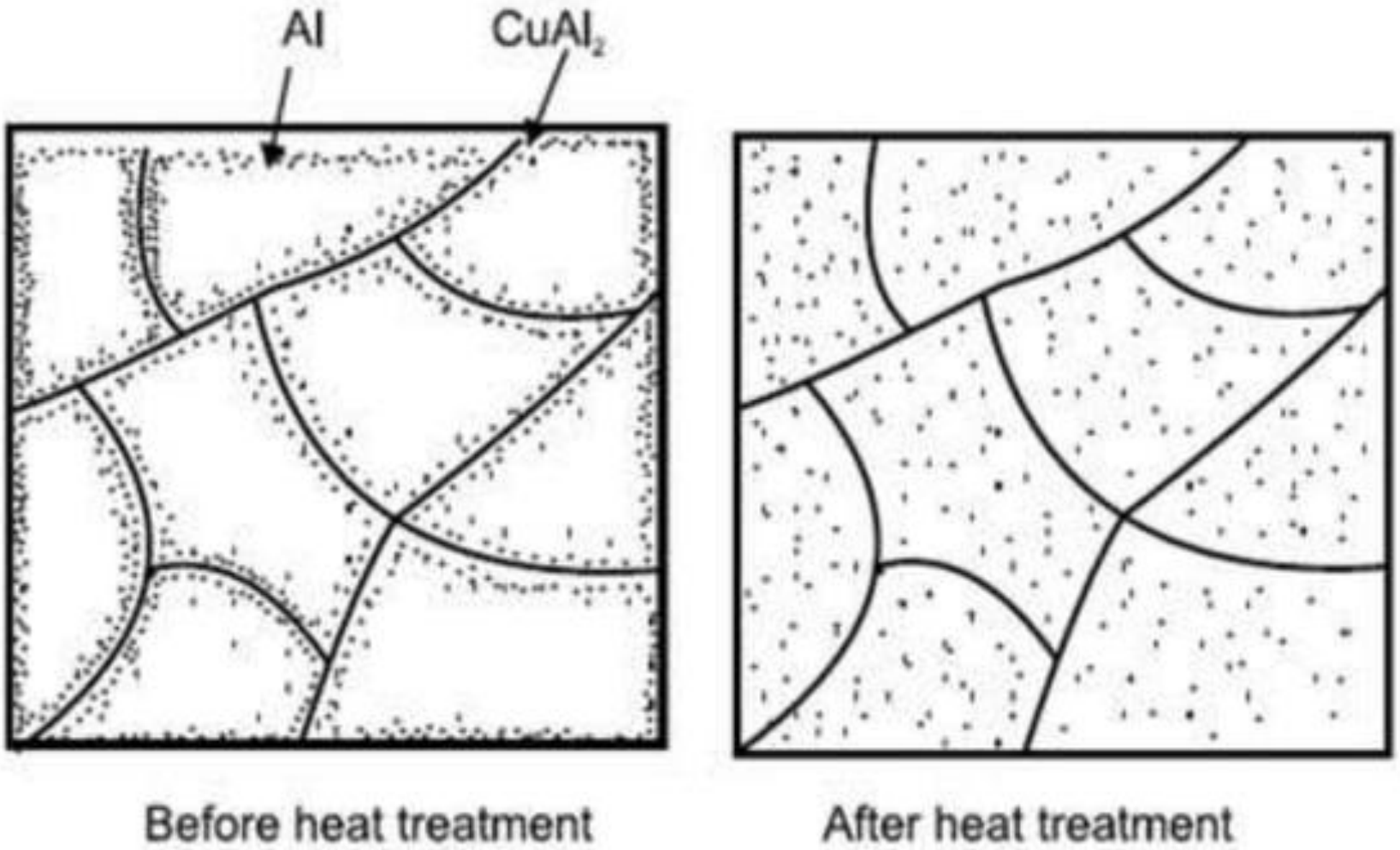
PRECIPITATION STRENGTHENING TREATMENT
(AGE HARDENING)

- To improve physical properties of some of the non-ferrous alloys by solid state reaction.
- It is mostly applicable to the alloys of aluminium, magnesium and nickel,
- It is occasionally used for the alloys of copper and iron.

- By controlling the precipitant from the solid solution, we can achieve varying properties in alloys

1. Solution treatment

2. Ageing treatment (precipitation treatment)


Al
$CuAl_2$
Before heat treatment
After heat treatment

Ageing treatment
(precipitation treatment)

This heat treatment would be used to increase the strength and hardness of a part by precipitating second phase.

Super Saturated Solid Solution

- In the solution treatment, the components of Al–Cu alloys are heated to about 530 °C in a heat treatment furnace and are soaked for a predetermined length of time.
- Then the components are quenched in an oil or water bath at about 60 °C – 80 °C
- On such rapid cooling, there is not enough time for the diffusion of copper atoms to form the precipitate particles. Therefore, a supersaturated solid solution is obtained at room temperature.
- Solid solution in this non equilibrium state is called **supersaturated solid solution**

THANKS AND REGARDS

VEERAPANDIAN.K
AP/MECH
SRVEC