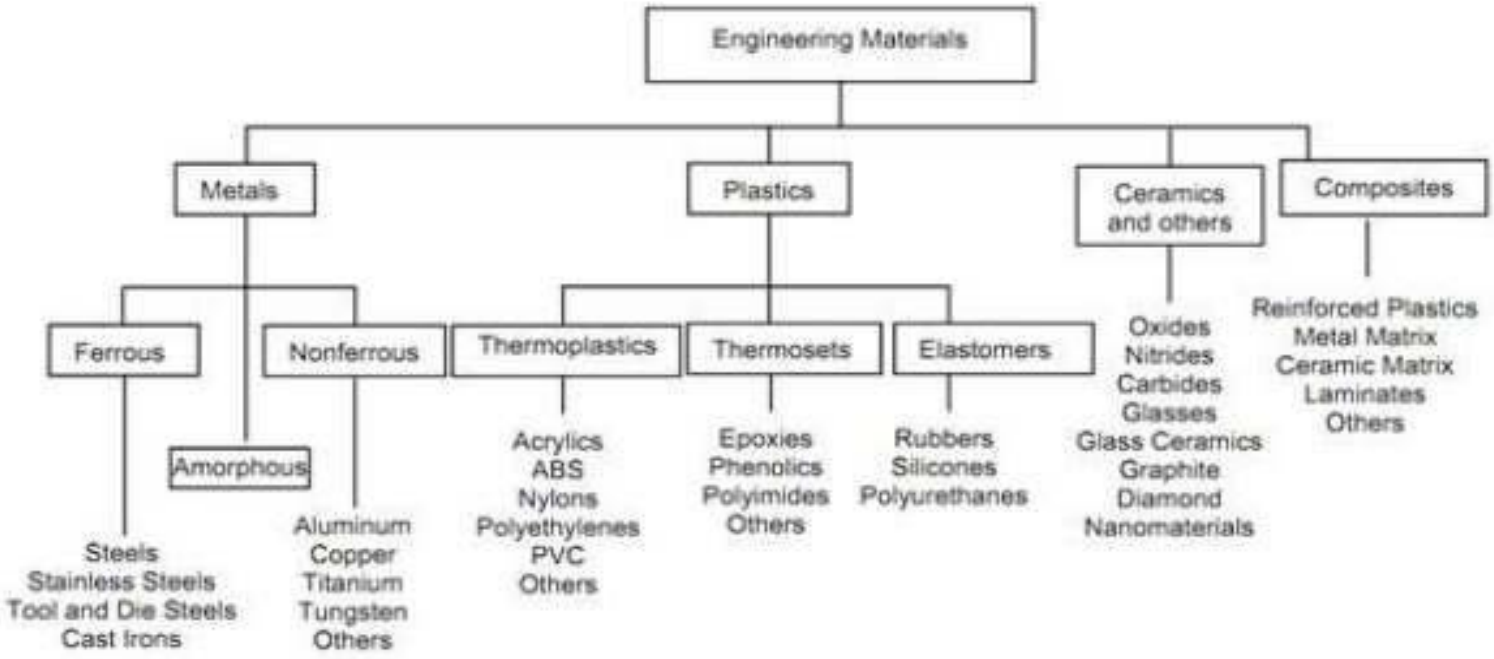
UNIT-IV

FERROUS AND NON-FERROUS METALS

CLASSIFICATION OF ENGINEERING MATERIALS



Copper

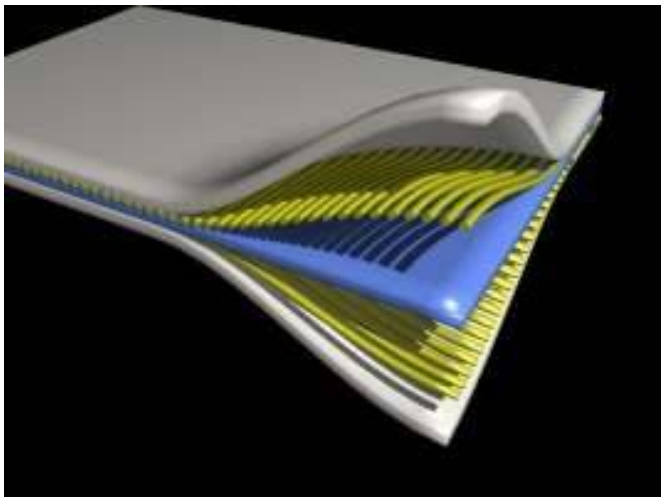
Lead

Tin

Nickel

Steel

Zinc



Metals

- Metals are composed of elements which readily give up electrons and provide a metallic bond and electric conductivity

Types of Metals

- Ferrous metals – The metals, which contain iron as their main constituent
- EX: Steel, Cast Iron, Wrought Iron.

- Non-Ferrous metals – the metals, which contain a metal other than iron as their main constituent
- EX: Aluminium, Copper, Zinc, Lead, Brass

Ferrous Metals

- 90% by weight of the metallic materials used by human being are ferrous metals
- Ferrous metals are widely used in engineering due to the following factors

- ✓ Iron-Based component are relatively plentiful and are widely distributed throughout the world
- ✓ Ferrous metals can be provided very economically
- ✓ Ferrous metals are versatile. Therefore wide range of mechanical and physical properties of ferrous materials can be achieved

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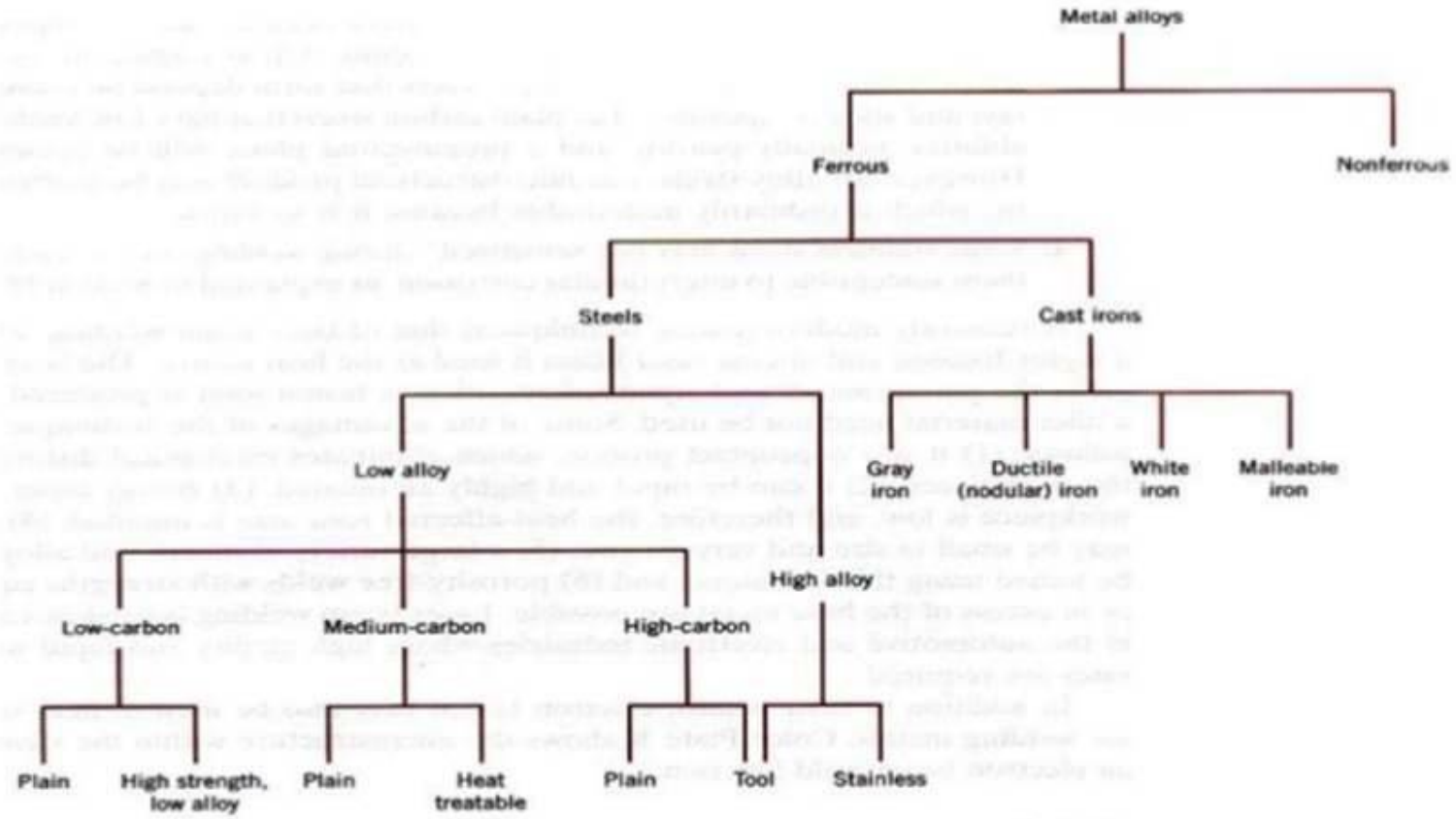
- Principal Disadvantage of many ferrous alloys is their weakness to Corrosion

Classification scheme for ferrous alloys



Steels

- Steels are alloys of iron and carbon .
- However steels contain other elements like silicon, manganese, sulphur, phosphorus, nickel etc.

- ***Classification of steels:***
- 1. Plain carbon steels.
    - (i) Low carbon steels
    - (ii) Medium carbon steels
    - (iii) High Carbon steels
- 2. Alloy Steels
    - (i) Low alloy steels
    - (ii) High alloy steels

Plain carbon Steels

- **Composition:**

Carbon upto 1.5%

Copper upto 0.6%

Manganese upto 1.65%

Silicon upto 0.6%

Types

1.Low Carbon steels (Carbon- Less than 0.25%)

2.Medium Carbon steels (Carbon- 0.25% to 0.60%)

3. High Carbon steels (Carbon- more than 0.60%)

Low carbon Steels (Carbon- Less than 0.25%)

- **Characteristics:**

✓ Its Relatively soft and week

✓ The possess formability and Weldability

✓ They have outstanding ductility and toughness

✓ the microstructure of low-carbon steel consists of ferrite & pearlite

✓ Of all the steels , the low –carbon steels are least expensive to produce

- **Applications:**

✓ Automobile body components

✓ Sheets that are used in pipelines , buildings, bridges and tin cans

Medium carbon Steels (Carbon- 0.25%to 0.60%)

- **Characteristics:**

✓ Low hardenabilities

✓ High strength and hardness properties are achieved at the sacrifice of ductility and toughness

- **Applications:**

✓ Railway wheels

✓ Railway tracks

✓ Gears

✓ Cranks shafts

High carbon Steels (Carbon- More then 0.60%)

- **Characteristics:**

✓ Hardest and strongest of carbon steels

✓ They are the least ductile

✓ They have more wear resistant

✓ They are capable of holding a sharp cutting edge

- **Applications:**

✓ Cutting tools and dies

✓ Razors

✓ Hacksaw blades

✓ High strength wire

Alloy Steels

- Any steels other than carbon steels
- The steels products manual defines alloy steels as steels that exceed one or more of the following limits

✓ Manganese – 1.65%

✓ Silicon- 0.60%

✓ Copper- 0.60%

- **<u>Other alloying elements of steels :-</u>** Chromium, nickel, tungsten , boron and others

Alloy Steels

- **Classifications of alloy steels**
  - Low alloy steels- 3 to 4 % of alloying elements
  - High alloy steels – more than 5% of alloying elements

Low Alloy Steels

1) AISI Steels
2) HSLA Steels

- **AISI Steels (American Iron and Steel Institute steels)**
- Its an addition of elements Cr, Ni,Cu, Mn etc
- Generally used for Machine construction
- Also called **Construction steels** or **structural steels**
- **HSLA Steels (High strength low alloy steels)**
- They have different microstructure and require different heat treatments than that of plain carbon steels

High Alloy Steels

1) Tool and die Steels
2) Stainless Steels

- **Tool and die steels**
- It’s used for making tools and dies
- Special characteristics of hardenability, wear resistance,
- **Stainless steels**
- Its used for improving corrosion resistance

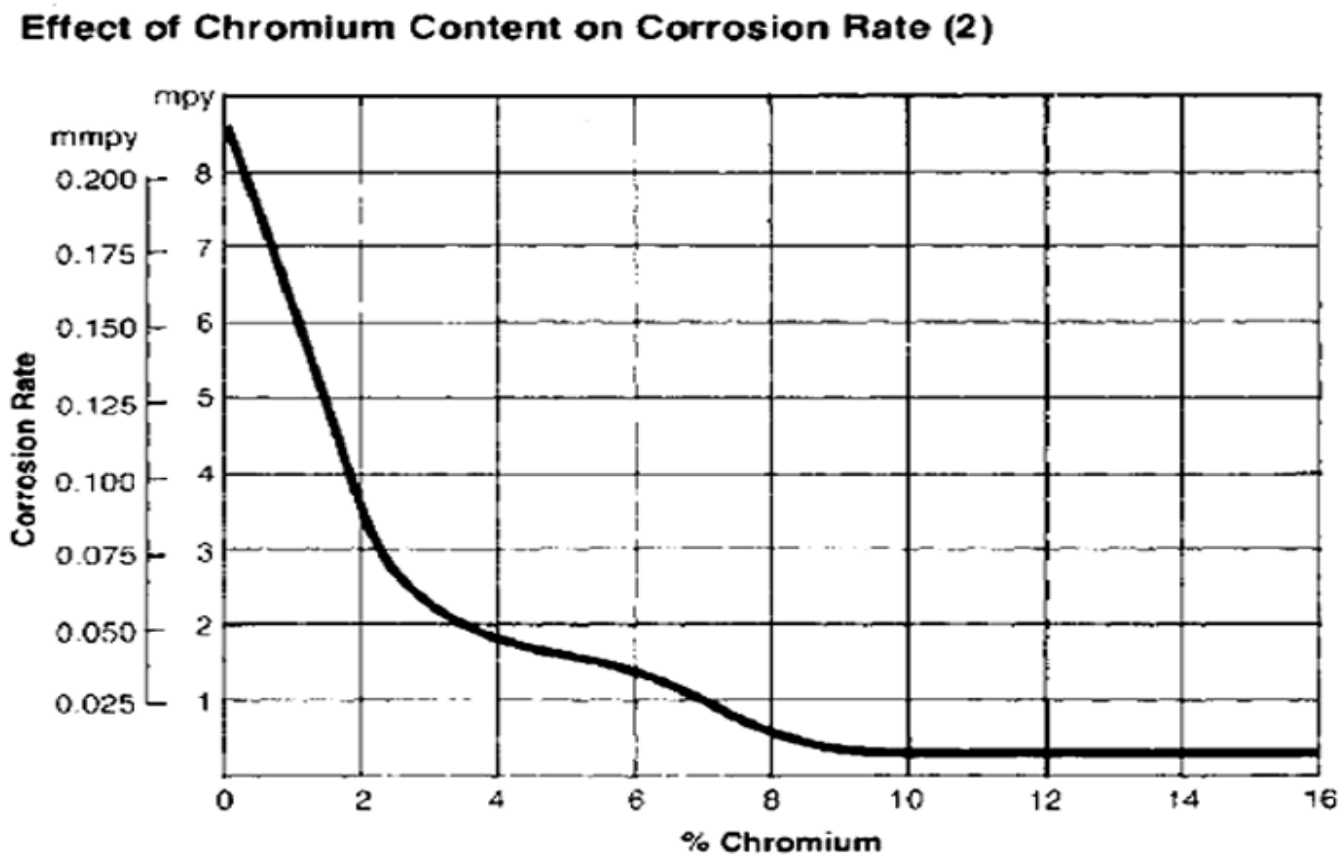
Important alloy steels

- Stainless steels
- Tools steels
- HSLA steels
- Maraging steels

Stainless steels

- Stainless steels are alloys of iron, chromium and other elements that resist corrosion from many environments
- It is also called as Corrosion – resistant steels or chromium – behavior steels
- All true stainless steel contain minimum of about 12%Cr.
- This 12%Cr permits thin protective surface layer of chromium oxide to form when the steel is exposed to oxygen

Effect of Chromium on Stainless steels



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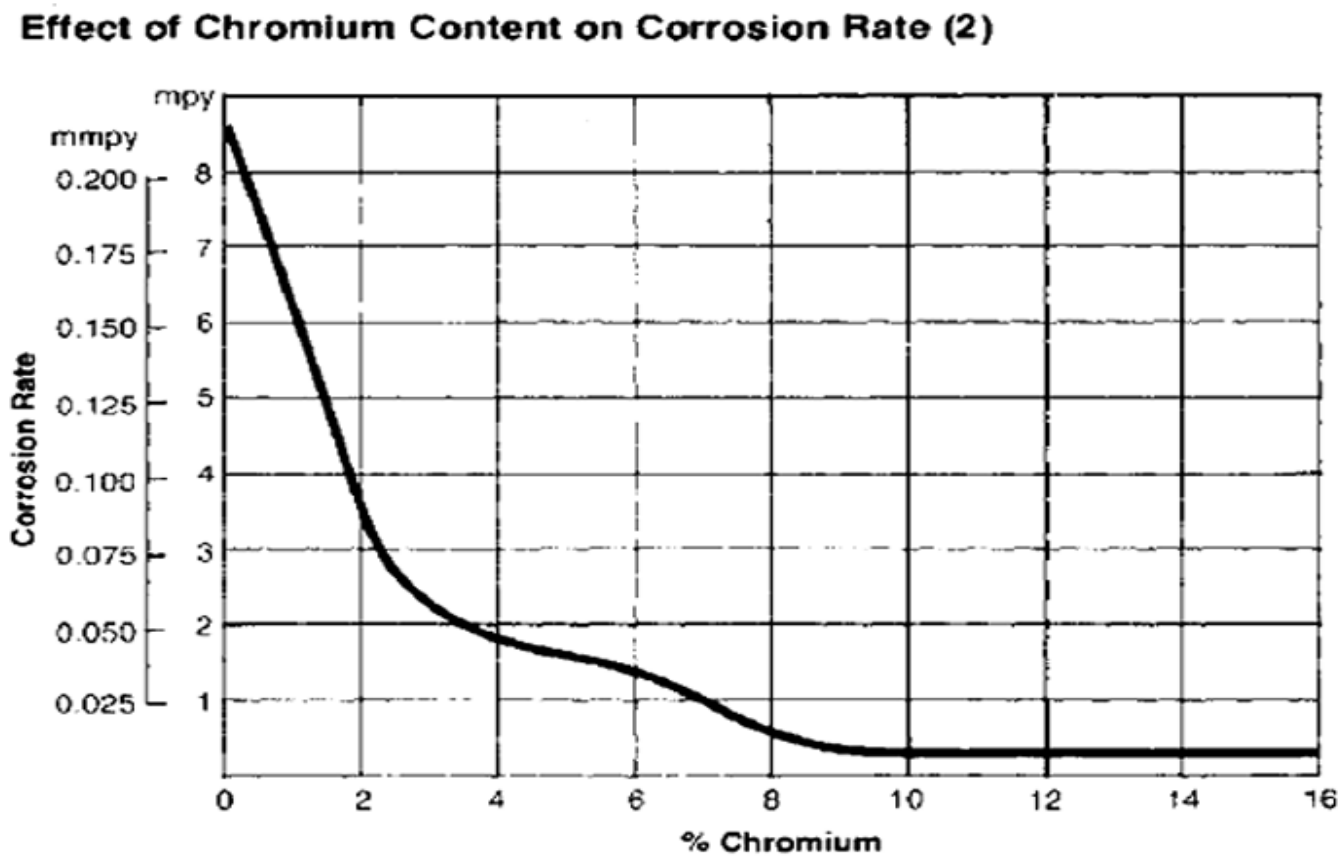

Types of Stainless steels

- It is classified basis of the predominant phase constituent of the microstructure.

1) Austenitic stainless steels
2) Ferritic stainless steels
3) Martensitic stainless steels

Austenitic Stainless steels

- Composition
  - C- 0.03 to 0.15%
  - Mn- 2 to 10%
  - Si- 1 to 2%
  - Cr- 16 to 26%
  - Ni- 3.5 to 22%
- Properties
  - Highest corrosion resistance
  - Good strength
  - Non magnetic
  - Very tough and can be welded , forged or rolled

Austenitic Stainless steels

- Applications

  - Engine Parts (Aircraft industry)
  - Chemical processing (Heat Exchanger)
  - Food processing (Tanks)
  - Household (Cooking tools)
  - Transport industry (Trailers and railway cars) Etc.

Ferritic Stainless steels

- Composition
  - C- 0.08 to 0.10%
  - Mn- 1 to 1.5%
  - Si- 1 %
  - Cr- 12 to 25%
- Properties
  - Good ductility
  - Magnetic
  - It can be welded , forged , rolled and , machined

Ferritic Stainless steels

- Applications

  - Lining for petroleum industry
  - Heating elements for furnaces
  - Interior decorative work
  - Screws and fittings, Etc.

Martensitic Stainless steels

- Composition
  - C- 0.1 to 1.5%
  - Mn- 1 %
  - Si- 1 %
  - Cr- 12 to 25%
- Properties
  - Good ductility , hardness and thermal conductivity
  - Good toughness and corrosion resistance

Martensitic Stainless steels

- Applications
  - Pumps and Valve parts
  - Turbine buckets
  - Surgical instruments

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Cast Irons

- Carbon – Greater than 2% carbon
- Its also Contain small amounts of silicon, sulphur, manganese and phosphorous

- **<u>Features of cast iron</u>**

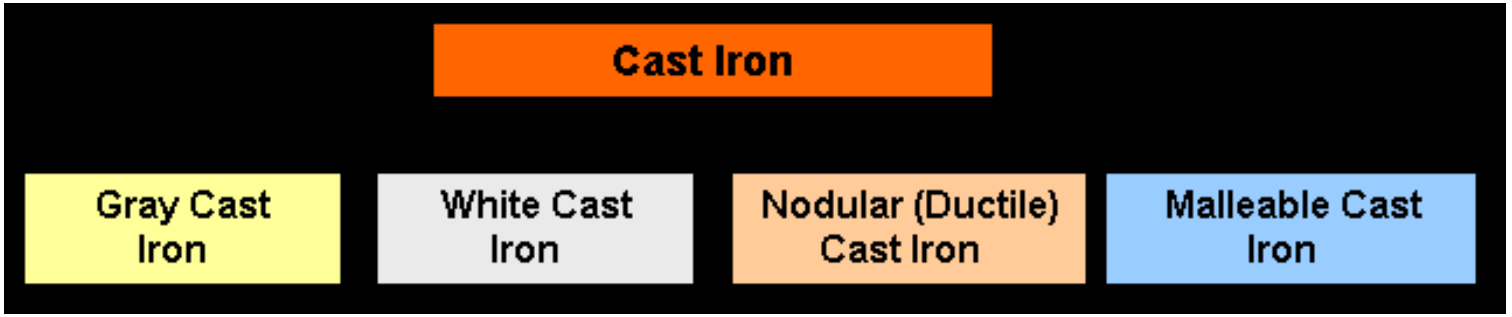
✓ Least expensive . Plentiful resources available.

✓ Good mechanical rigidity and good strength under compression

✓ Good machinability can be achieved

Composition of Cast Irons

- Carbon -3.0 to 4.0%
- Silicon- 1.0 to 3.0%
- Manganese – 0.5 to 1.0%
- Sulphur- upto 0.1%
- Phosphorus – upto 1.0%



Non-Ferrous Materials

- All the metallic elements other than iron are referred as non ferrous materials
- Non – ferrous materials are not produced in as great tonnages and are more costly than ferrous metals
- Non- ferrous materials are employed in current engineering due to the following characteristics

  - Lighter in weight
  - Higher electrical and thermal conductivity
  - Better resistance to corrosion
  - Ease of fabrication

Various Non-Ferrous Materials

- Copper
- Aluminium
- Lead
- Magnesium
- Nickel
- Tin
- Titanium
- Zinc.

Copper and its alloys

- Copper is one of the oldest and most widely used metals in industry

Melting point	1083°C
Young's Modulus	122.5Gpa
Tensile Strength	220Mpa
Corrosion resistance	Very good

Principal Properties of pure copper

- **Properties of copper**
  - Copper possess very high electrical conductivity .
  - Very high thermal conductivity
  - Very soft , ductile
  - It can be worked in hot or cold condition , but it can not be welded

Applications

- Manufacturing power cables, telephone cables , cables for computer networks
- Printed circuit boards
- Mainly used in the manufacturing of important alloys such as brass and bronze

Copper alloys

- Brasses (Copper –Zinc alloys)
- Bronzes (Copper- tin alloys)
- Gun-metals (Copper-tin-zinc alloys)
- Cupro nickels (copper- nickel alloys)

Brasses (Copper-Zinc alloys)

- Its an alloy of copper and Zinc
- Sometimes, small amounts of other metals such as tin, lead, aluminium and manganese may be added
- Upto 36% Zinc
- Soft ductile and easily cold worked

- **Characteristics**
  - Brasses is stronger than copper
  - Lower thermal and electrical conductivity than copper
  - Very often 1 to 3% of lead is added to brass for improving its machining properties

Bronzes (Copper- tin alloys)

- Alloy of copper and tin
- High strength alloys with a good corrosion resistance than brasses
- It can be shaped or rolled in to wires , rods and sheets

Applications

- Pump valves
- Bearings
- Marine castings
- Hydraulic values
- Gears

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Aluminium and its alloys

- **Characteristics:**
  - Light in Weight (one-third the weight of steel)
  - Soft ductile
  - High strength to weight ratio
  - High thermal and electrical conductivity

Melting Point	600°C
Young's modulus	70.5 Gpa
Tensile strength	45 Mpa
Corrosion resistance	Very good

Principal properties of pure Aluminium

Aluminium and its alloys

- **Applications:**
  - Making parts of aero plane, window frames, surgical instruments Etc.
  - It is used as a reducing agent in the manufacturing of steels

- **Aluminium VS Copper**
  - The price of the aluminium is much lower than that of copper
  - If equal weights of aluminium and copper conductors of a given length are compared, it is found that aluminium conducts 201% as much current as does copper

Types of Aluminium alloys

- Heat-treatable aluminium alloys
  - Al-Cu alloys
  - Al-Cu- Ni alloys
  - Al-Mg-Si alloys
  - Al-Zn-Cu alloys
  - Al-Li alloys
- Non-heat treatable aluminium alloys
  - Al-Mn alloys
  - Al-Mg alloys
  - Al-Si alloys

Precipitation Strengthening Treatment (Age Hardening)

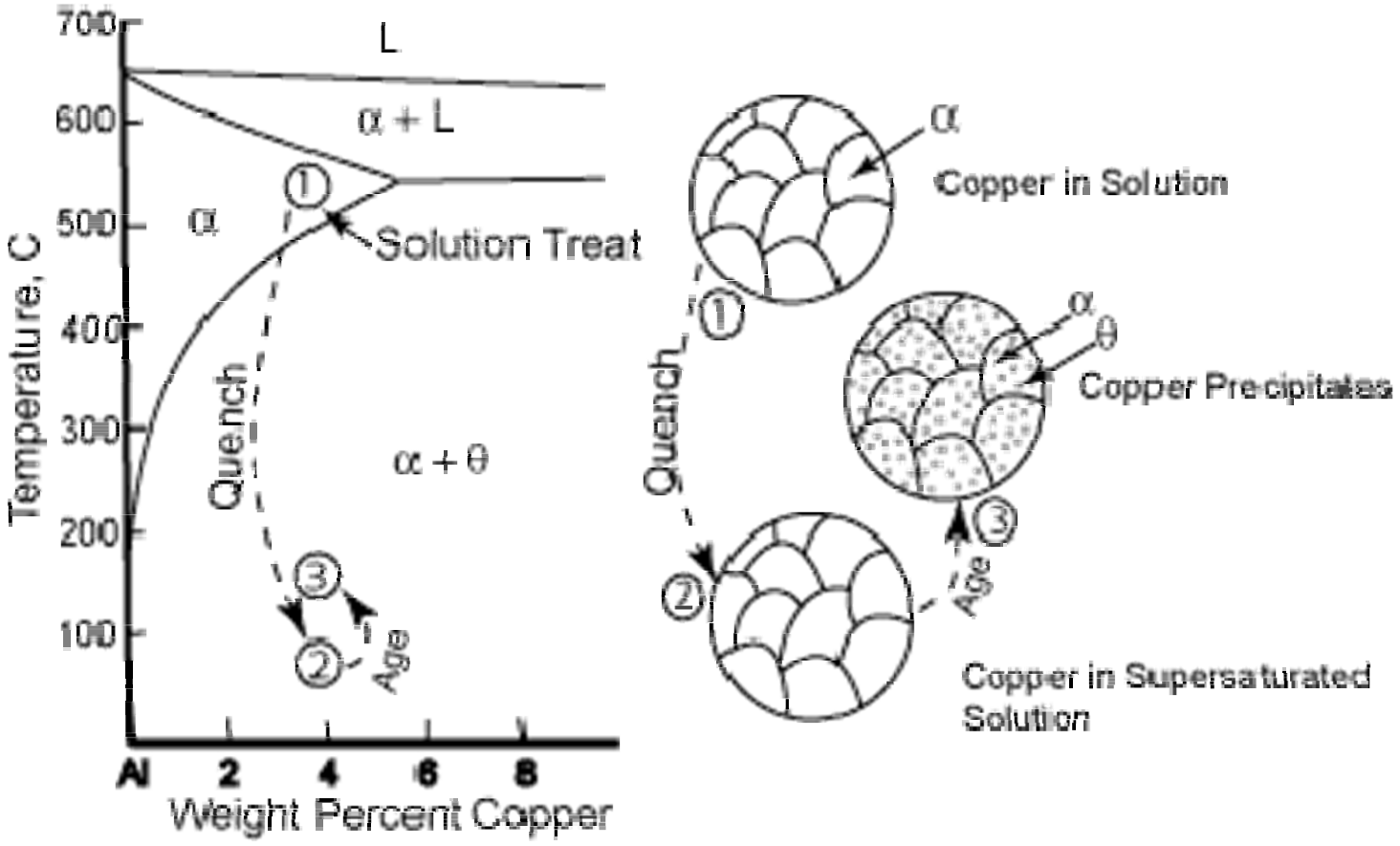
- It is the important method of improving the physical properties of some of the non-ferrous alloys by solid state reaction
- Its is mostly applicable to the alloys of aluminium, magnesium and nickel.

Alloys that are hardened by precipitation treatment:

- Aluminium – copper
- Copper –tin
- Magnesium – aluminium

- This processed is called precipitation hardening because the fine precipitate particles of the new phase are formed in this hardening process

Precipitation Strengthening Treatment (Age Hardening)



Precipitation Strengthening Treatment (Age Hardening)

- **Solution treatment:**
  - Alloy is heated above the solvus temperature to obtain its solid solution
  - The alloy is held at this temperature until a solid solution α is formed
  - Temp: 500°C to 548°C
- **Quenching Process**
- **Ageing Process**
  - Solid solution is heated below the solvus temperature
  - At this ageing temperature, the diffusion of unstable α may take place and precipitate particles can form
  - Then, if we hold the alloy for a sufficient time at the ageing temperature, the stable α + $CuAl_2$ structure is produced
  - The fine precipitate particles of $CuAl_2$ increase the hardness and strength of the alloy

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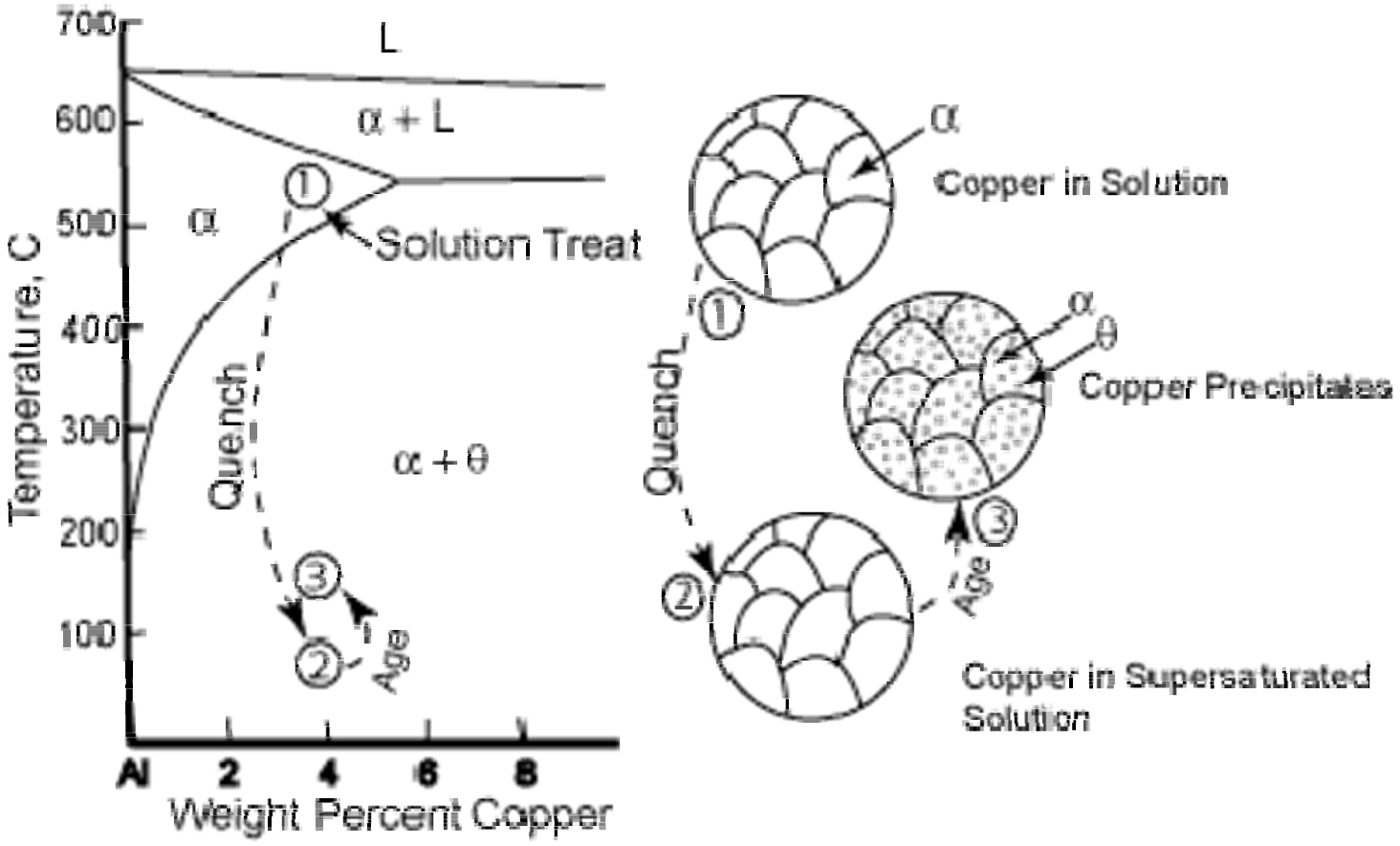

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