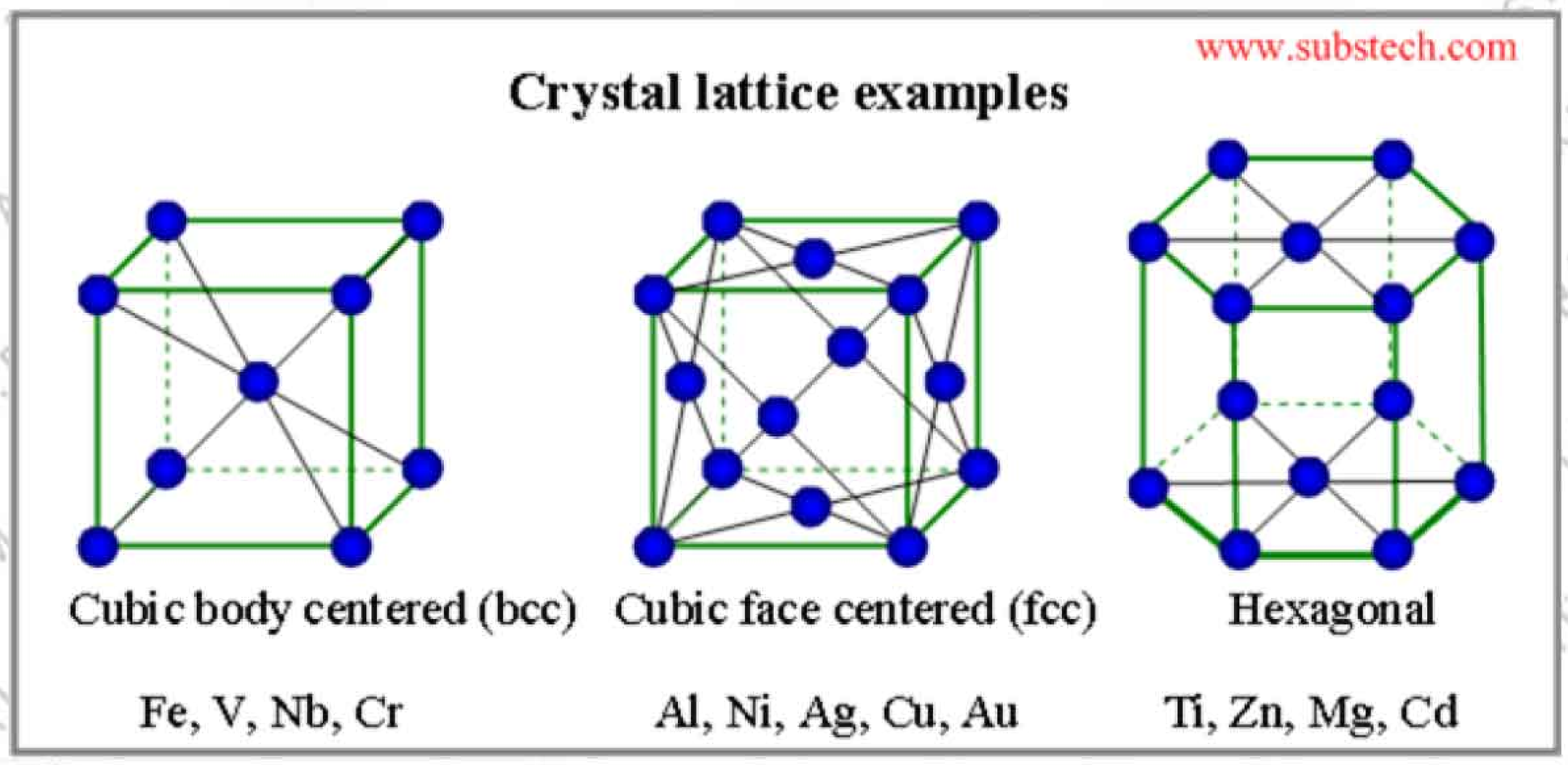
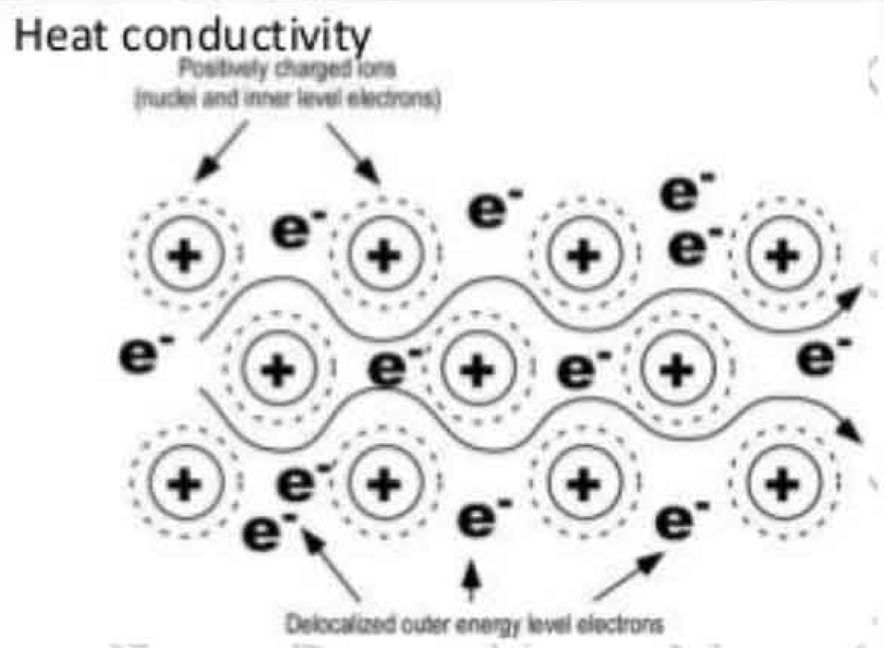
METALS

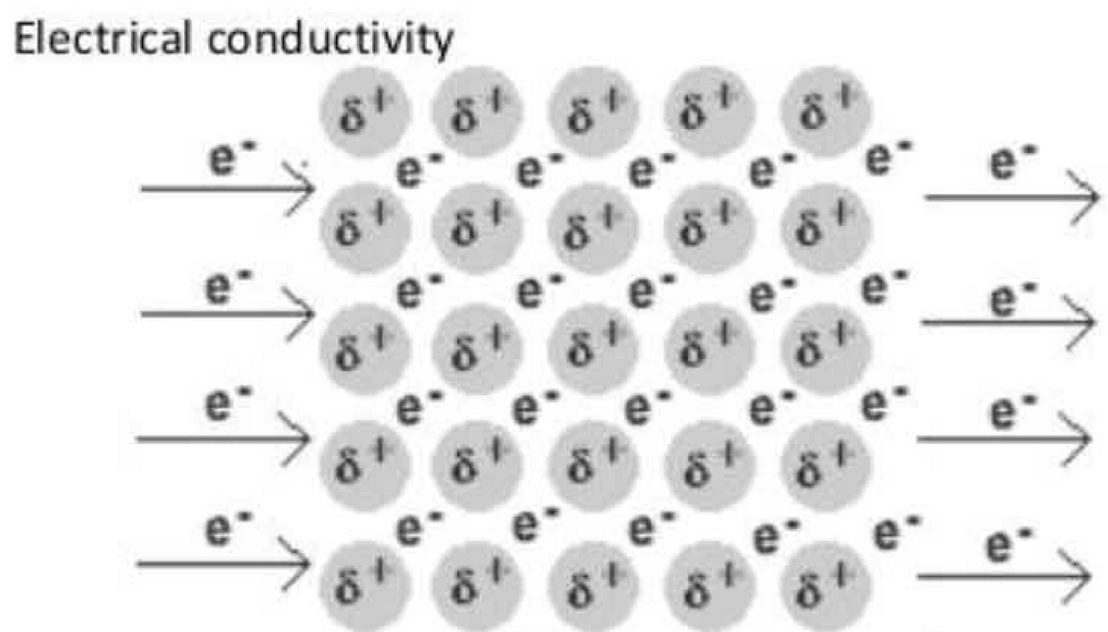
A metal is a material (can be an element, a compound or an alloy[1]) that is usually opaque, shiny, stiff, homogenous solid in different colors.

Their internal structures are mostly crystalline and non-porous (with high densities, compactness ratio and low porosity or void ratio) that presents isotropic properties.



Due to this microstructure and free electrons, metals have mostly high thermal transmittance, sound transmission and electrical conductivity.

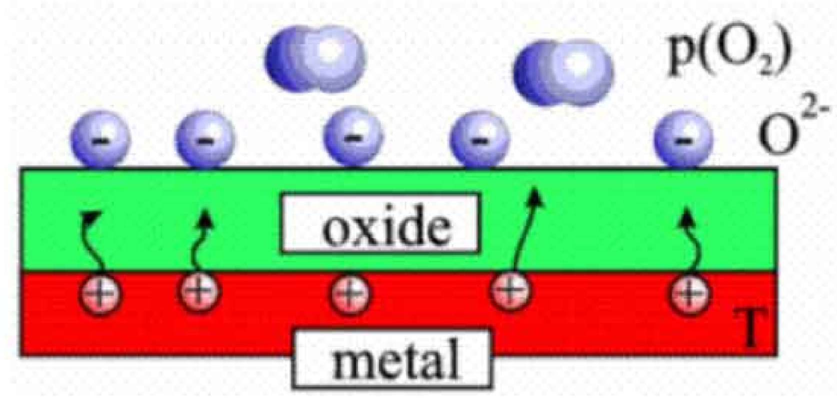




Although, due to the spacing between crystalline structures, pure metals have lower strengths, hammering and alloying can increase the compactness of crystals and earn them higher strength. Mostly, they show elasto-plastic behavior and have ductile properties under stress, because of this, metals are generally malleable[2] as well as fusible[3]. Forces larger than the elastic limit or heat may cause permanent (irreversible) deformation of the object. Irreversible change in atomic crystalline arrangement may occur as a result of an applied force or a change in temperature. Viscous flow can raise to creep and fatigue in metals.

[1] Alloy: An alloy is a mixture of metal or a mixture of a metal and another element: such as steel, brass, bronze, etc.
[2] They can be hammered or pressed permanently out of shape without breaking or cracking.
[3] To be able to fused or melted.

Metals are usually inclined to form compounds through electron loss, reacting with oxygen in the air to form oxides over various timescales (iron rusts over years, while potassium burns in seconds / some metals are slower to oxide, others like palladium, platinum and gold, do not react with the atmosphere at all / some metals form a barrier layer of oxide on their surface which cannot be penetrated by further oxygen molecules and thus retain their shiny appearance and good conductivity).



Because metals are non-porous, they do not absorb water and their diffusion resistance is very high.

Metals are often extracted from the earth by means of mining ores[4]. Ore is located by prospecting[5] techniques, followed by the exploration and examination of deposits. Once the ore is mined, the metals must be extracted, usually by chemical or electrolytic reduction. Metals are inherently recyclable, so in principle, can be used over and over again, minimizing the negative environmental impacts and saving energy.


an open iron ore mining


iron ore

An alloy is a mixture of two or more elements in which the main component is a metal. Most pure metals are either too soft, brittle or chemically reactive for practical use. Combining different ratios of metals as alloy modifies the properties of pure metals to produce desirable characteristics. The aim of making alloys are generally to make them less brittle, harder, resistant to oxidation, to have a more desirable color and luster.


raw iron ore

stainless steel

Metals used for engineering purposes are classified as ferrous metals, with iron as the main constituent and others like aluminum, copper, zinc, lead, bronze, chrome and titanium as non-ferrous metals.

Iron

Iron, which is by mass the most common element on earth, is by far the most important of the metals used in construction. It is available in abundance, but does not occur freely in nature. Metallic or native iron is rarely found on the surface of earth, because it tends to oxidize, but its oxides are pervasive and represent the primary ores. Most of the iron in the crust is found combined with oxygen as iron oxide minerals such as:

[4] Metals exist in nature as compounds like oxides, carbonates, sulphides and phosphates and are known as ores. Metals are derived from ores by removing the impurities.

[5] Prospectiong is the first stage of the geological analysis, it is the physical search for minerals, fossils, precious metals or mineral specimens.

magnetite (Fe_3O_4)


hematite (Fe_2O_3)


limonite ($2Fe_3O_3.3H_2O$)


iron pyrite (FeS_3)


siderite ($FeCO_3$)

The fundamental chemical principles in the extraction of iron form the ores is very simple. Heating the ores in the presence of a reducing agent will result in the formation of CO or CO_2, liberated as a gas and metallic iron. Iron owes its greatest utility to the fact that it alloys freely with other elements and its inherent properties are markedly altered and improved for varying conditions of service.

Pig Iron:

Industrial iron production starts with iron ores, principally hematite and magnetite. The iron ore is dressed by crushing it to about 50 mm cubes. These ores are reduced to the metal in a carbothermic reaction. The conversion is typically conducted in a blast furnace. Carbon is provided in the form of coke. The process also contains a flux such as limestone, which is used to remove silicaceous minerals in the ore, which would otherwise clog the furnace. The coke and limestone are fed into the top of the furnace, while a massive blast of heated air is forced into the furnace at the bottom. In the furnace, the coke reacts with oxygen in the air blast to produce carbon monoxide ($2C + O_2 \rightarrow 2\ CO$). The carbon monoxide reduces the iron ore (hematite) to molten iron, becoming carbon dioxide ($Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$). The flux present to melt impurities in the ore is principally limestone and dolomite. In the heat of furnace the limestone flux decomposes to quicklime ($CaCO_3 \rightarrow CaO + CO_2$). Then calcium oxide combines with silicon dioxide to form a liquid slag ($CaO + SiO_2 \rightarrow CaSiO_3$). The slag melts in the heat of furnace. In the bottom of the furnace, the molten slag floats on top of the denser molten iron and apertures in the side of the furnace are opened to run the iron and slag separately. The iron, once cooled, is called pig iron.

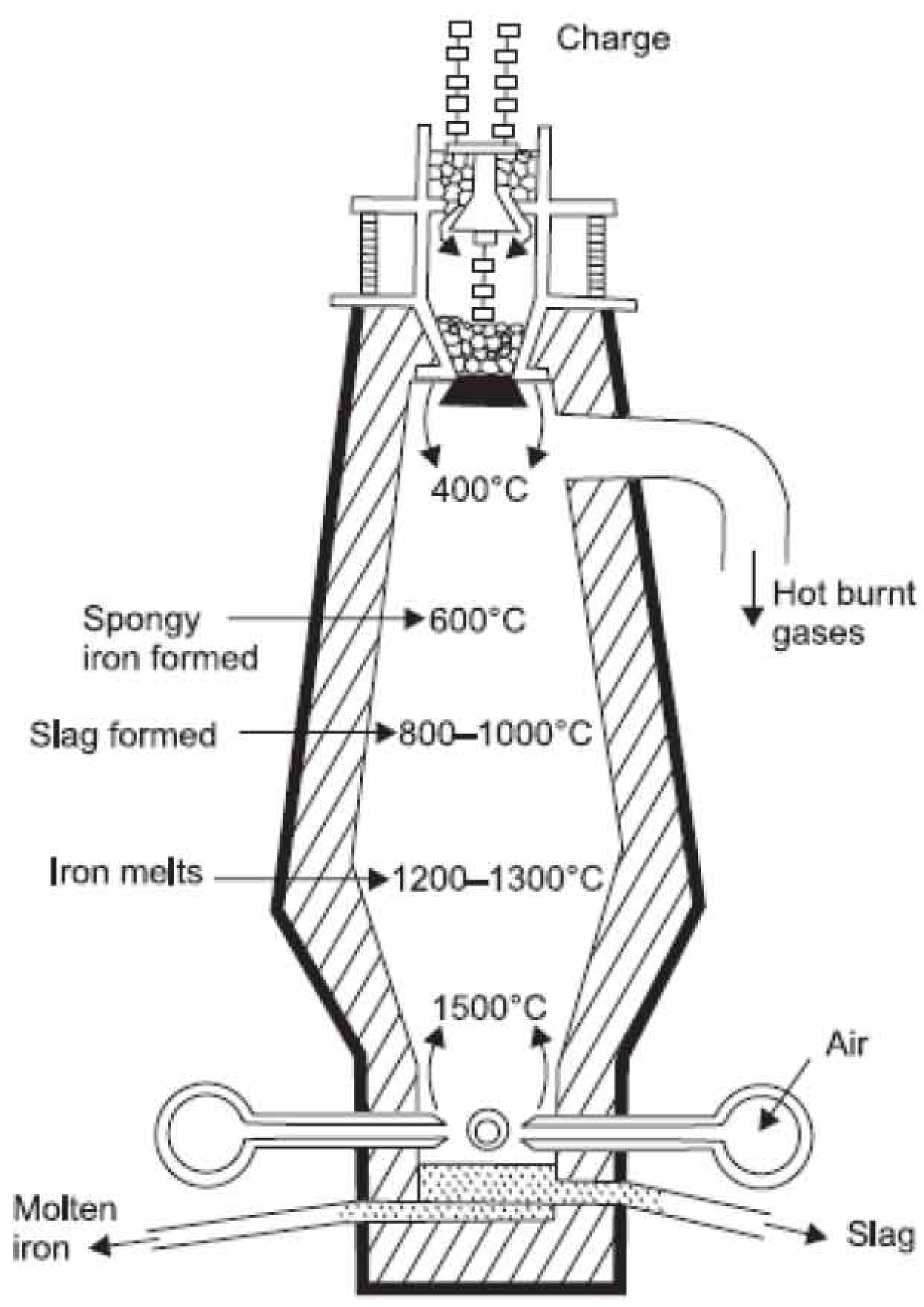
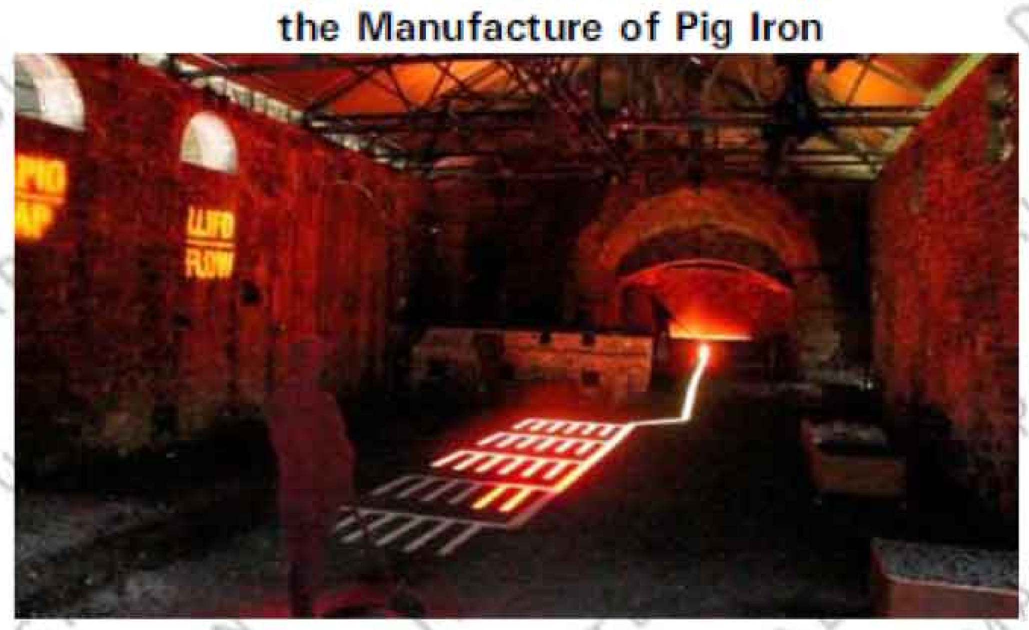


Fig. 13.1 Blast Furnace for the Manufacture of Pig Iron



The traditional shape of the molds used for pig iron ingots was a branching structure formed in the sand, with many individual ingots at right angles to a central channel or runner, resembling a litter of piglets being suckled by a sow.

Pig iron is not pure iron, but has 4 – 5 % carbon dissolved in it with small amounts of other impurities like 0,5 – 3,5 % silicon, 0,02 – 0,1 % sulfur, 0,03 – 1 % phosphorus and 0,5 – 2 % manganese. As the carbon is the major impurity, the pig iron becomes brittle and hard with fusion temperature of 1200°C and melts easily. It can be hardened but cannot be tempered. Its compressive strength is high, but it is weak in tension and shear. Pig iron does not rust and cannot be riveted or welded.

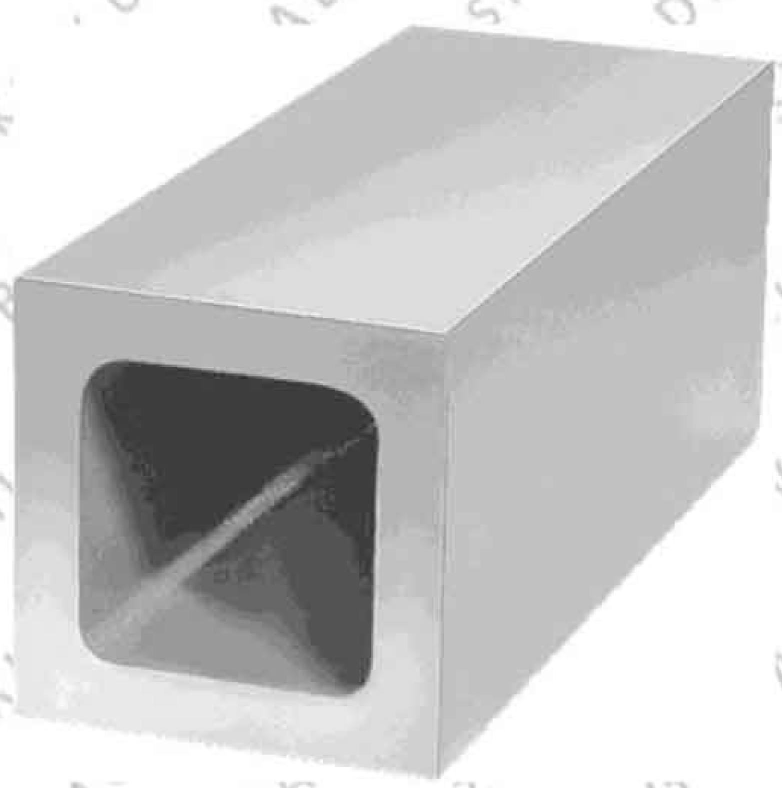
Pig iron is classified as Bessemer pig, foundry pig, forge pig and mottled pig.

Bessemer pig derives its name because of its use in the manufacture of steel by Bessemer process using hematite ore. Impurities such as sulfur, phosphorus and copper are not desirable in the Bessemer pig. Foundry pig, also known as grey pig, contains sufficient quantity of free carbon and is produced when the furnace is provided with sufficient fuel. With grey pig, water pipes, grits, radiators can be molded. When fuel provided is insufficient and if sufficient sulfur is present in the ore, forge pig is produced. This is also known as white pig. Because white pig is more fragile and hard then the grey pig, only pieces resistant to abrasion can be made. Mottled pig is in between the grey and white varieties. They exhibit mottled fracture.

Cast Iron:

Removing other impurities from pig iron results in cast iron. Pig iron is remelted with limestone and coke in Cupola furnace. It is then poured into molds of desired size and shape. It contains about 2 – 4 % carbon. Methods of casting include sand, hollow, vertical sand, centrifugal and die casting. The most common casting procedure is the sand casting which involves pouring molten metal into a cavity in a mass of packed sand. In hollow casting, a solid core is placed where the hollow is to be maintained, mostly for making columns and piles. After casting the core and moulds are taken out, cast material becomes hollow due to the core.

sand casting

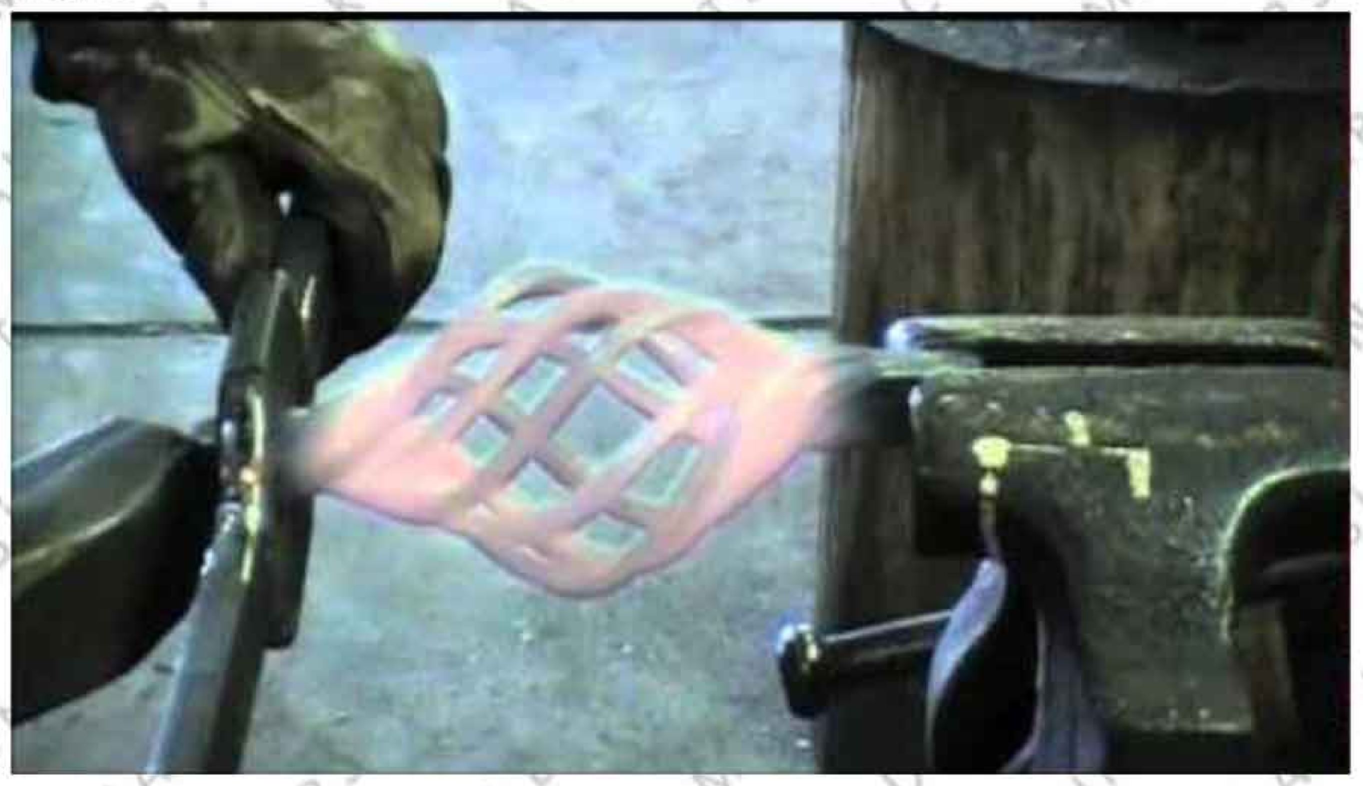


hollow casting

Cast iron is hard and brittle, it can neither be riveted nor welded. It is stron in compression but weak in tension and shear. It has low melting point (1200 °C)and is affected by sea water. Iron containing large amounts of manganese and chromium are likely to be white, while those having a high silicon content are grey.

Wrought Iron:

Wrought iron is considered to be pure iron, produced by removing the impurities of cast iron. Wrought iron is ductile, malleable, tough and moderately elastic. The melting point of wrought iron is 1500°C. It can be forged and welded. It effectively resists corrosion. At about 900°C, wrought iron becomes so soft that its two pieces can be joined by hammering. Roof coverings, rivets, chains, ornamental iron works can be made of wrought iron.

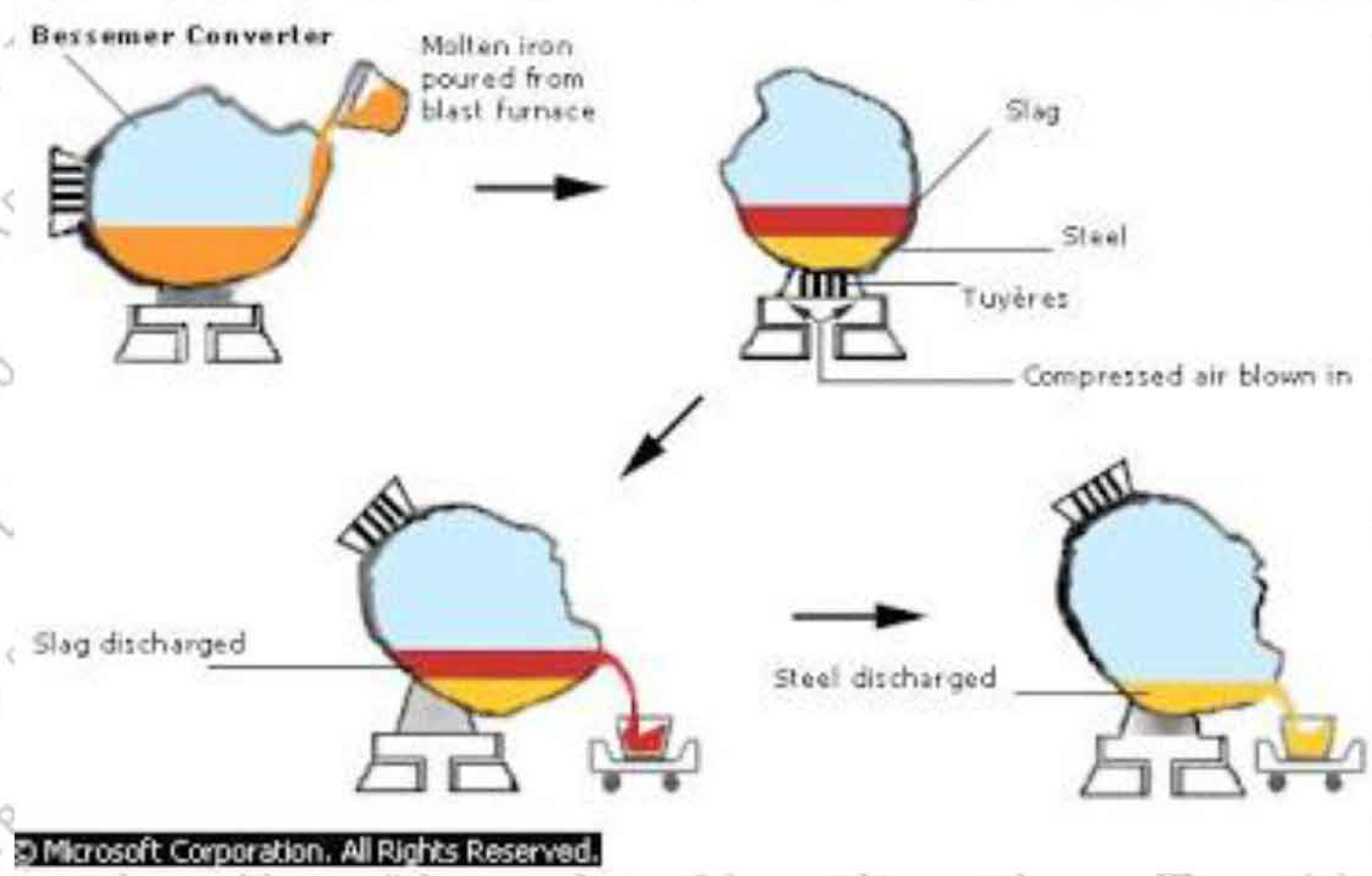


Steel

Steel is an alloy of iron and other elements, primarily carbon and it is widely used in construction and other applications because of its high tensile strength and low cost. By suitably controlling the carbon content, alloying elements and heat treatment, a desired combination of hardness, ductility and strength can be obtained in steel. On the basis of carbon content, steel may be classified as:

dead mild steel	**mild steel**	**medium carbon steel**	**high carbon steel**	**hard steel**
<0,15% carbon	**0,15-0,3% carbon**	**0,3-0,8% carbon**	**0,8-1,5% carbon**	**>1% carbon**
				

The most prominent present-day steel-making process is the Bessemer process. The pig iron is first melted in Cupola furnace and sent to Bessemer converter. Blast of hot air is given to oxidize carbon. Depending upon the requirement, some carbon and manganese is added to the converter and hot air is blasted once again. Then the molten material is poured into moulds to form ingots.



mild steel Also known as low carbon or soft steel. It is ductile, malleable, tougher and more elastic than wrought iron. Mild steel can be forged and welded, difficult to temper and harden. It rusts quickly. Its ultimate compressive strength is 800 – 1200 N/mm² and tensile strength is 600 – 800 N/mm². It is used in the form of reinforcing bars, roof coverings and sheet piles.

high carbon steel It is also known as hard steel. It is tougher and more elastic than mild steel. It can be forged and welded with difficulty. Its ultimate compressive strength is 1350 N/mm² and tensile strength is 1400 – 2000 N/mm². High carbon steel is used for reinforcing concrete and prestressed concrete. It can take shocks and vibrations.

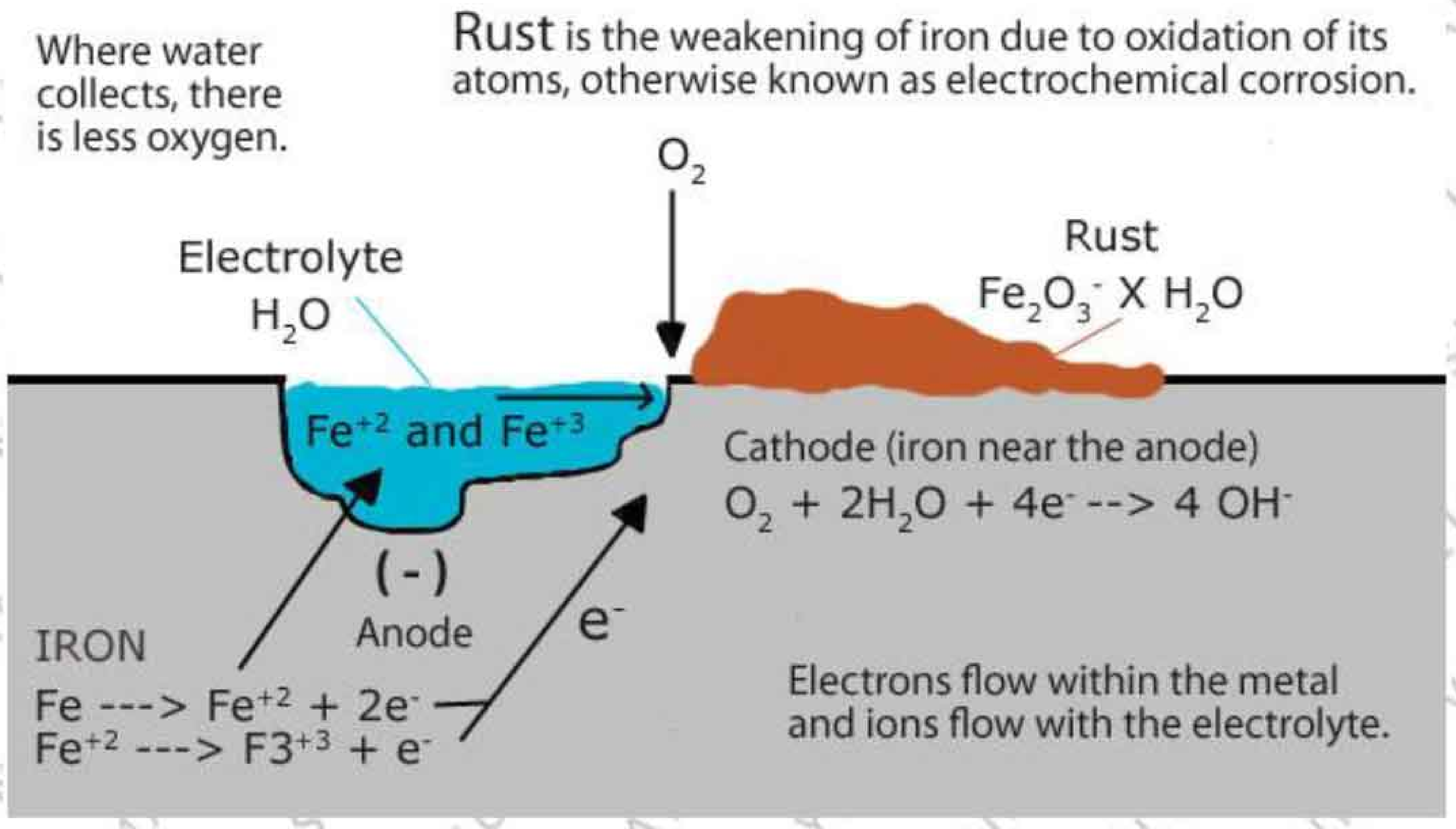
Heat Treatment: The object of heat treatment is to develop desired properties in steel. The properties of steel can be controlled and changed as well by various heat treatments. A steel of given composition may be made soft, ductile and tough by one heat treatment and the same steel may be made relatively hard and strong by another. The most common are annealing, quenching and tempering.

Annealing is the process of heating the steel to a sufficiently high temperature to relieve local internal stress. It does not create a general softening of the product but only locally relieves strains and stresses locked up within the material.

Quenching involves heating the steel to create the austenite phase then quenching it in water or oil. This rapid cooling results in a hard but brittle structure. The steel is then **tempered** which is just a specialized type of annealing, to reduce brittleness. In this application the annealing process reduces the internal stresses and defects. The result is a more ductile and fracture resistant steel.

Rusting and Corrosion

When steel is exposed to atmosphere, the humid air and water causes the formation of oxides on the surface of steel. Once rusting is initiated, it gradually increases and corrodes iron. Consequently the physical and mechanical properties of steel products are affected.

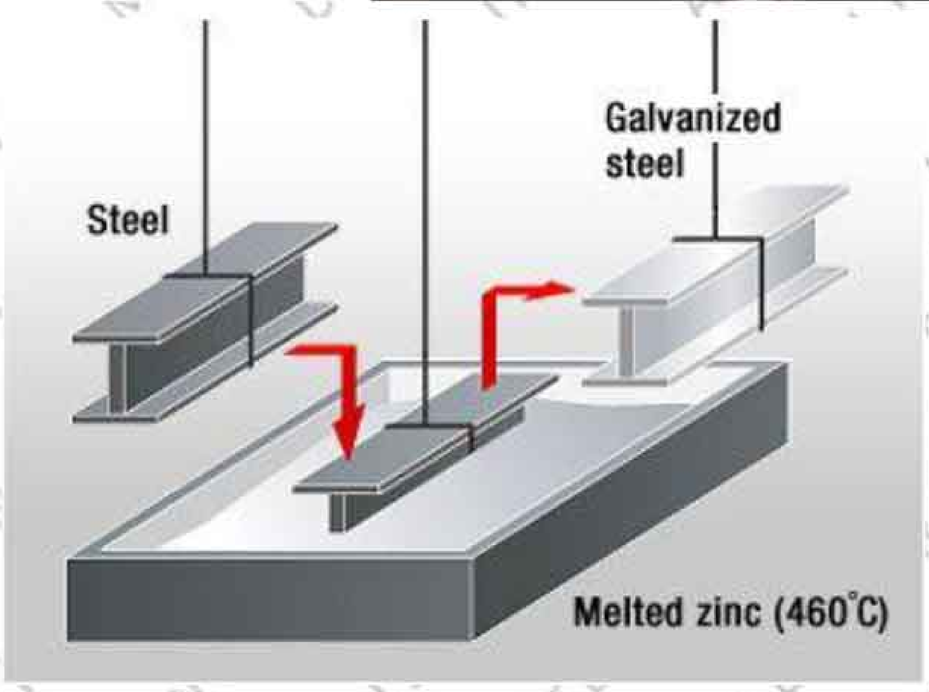


To safeguard iron and steel from rusting and corrosion, some of the prevalent methods can be used:

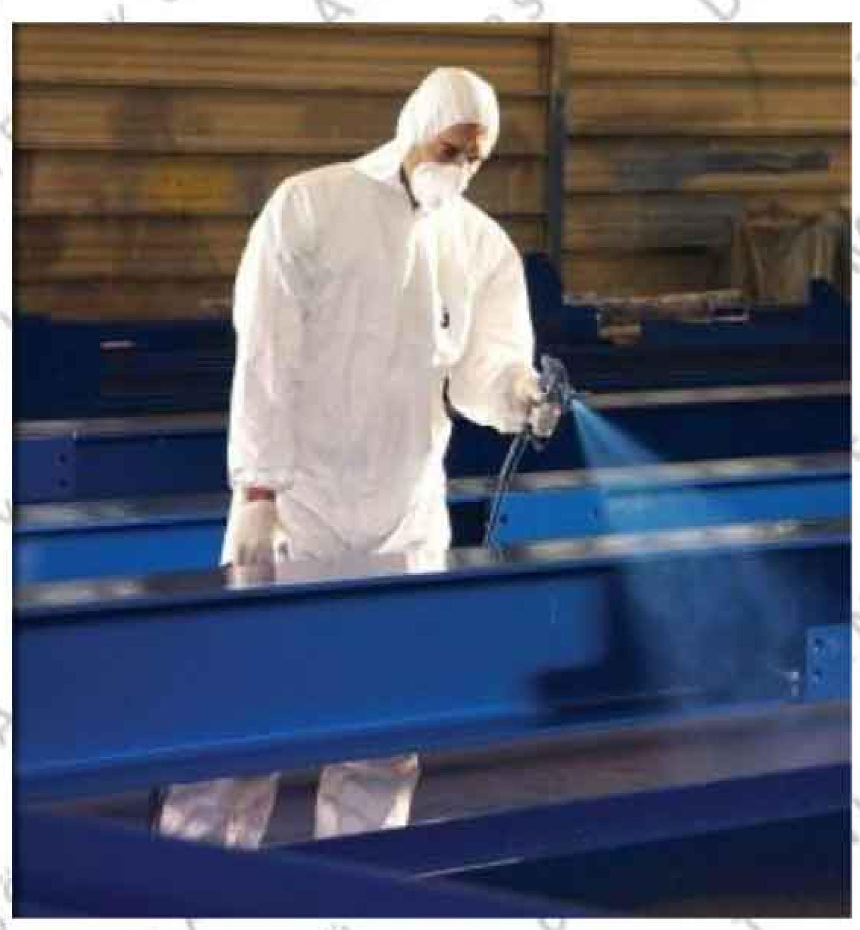
- Applying metal coatings: galvanizing, tin plating, electroplating
- Applying coatings: painting and coal tarring.

Enameling consists in melting a flux on the surface of iron in muffle furnace and then coating it with a second layer of more fusible glaze. Enamel is a material made by fusing powdered glass to a substrate by firing. The powder melts, flows and then hardens to a smooth, durable vitreous coating on metal.

Galvanizing is the process of coating iron with a thin film of zinc, whereas in tin plating, a film of tin is coated.

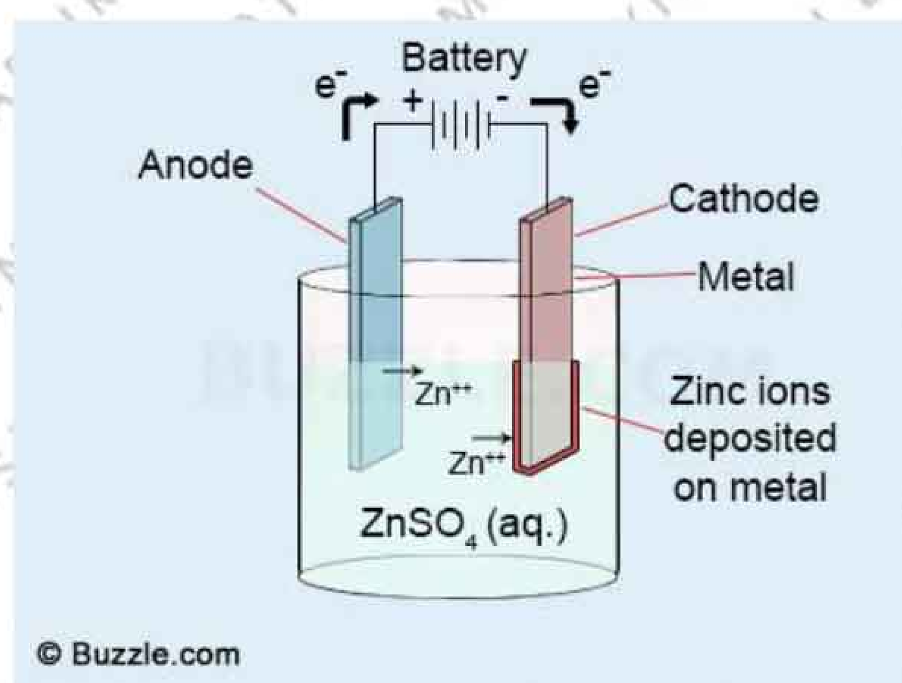


Painting consists in applying a coat of read lead and then applying a coat of enamel or aluminum paint.



For the use of iron or steel in substructures instead of enamel paint, coal tar is applied on its surface.

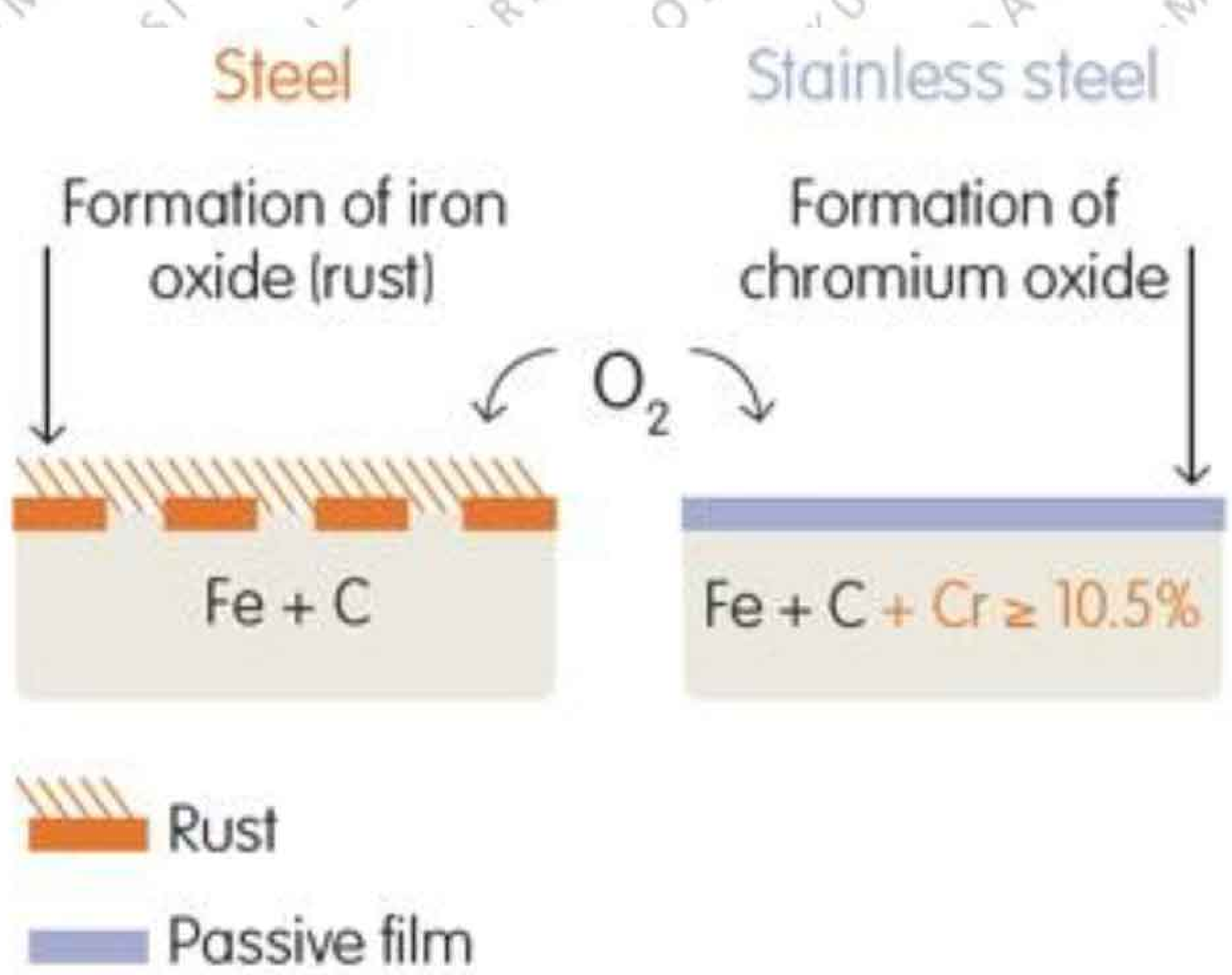
In electroplating, some metal coating, such as chromium, nickel or zinc is applied on the surface of iron.

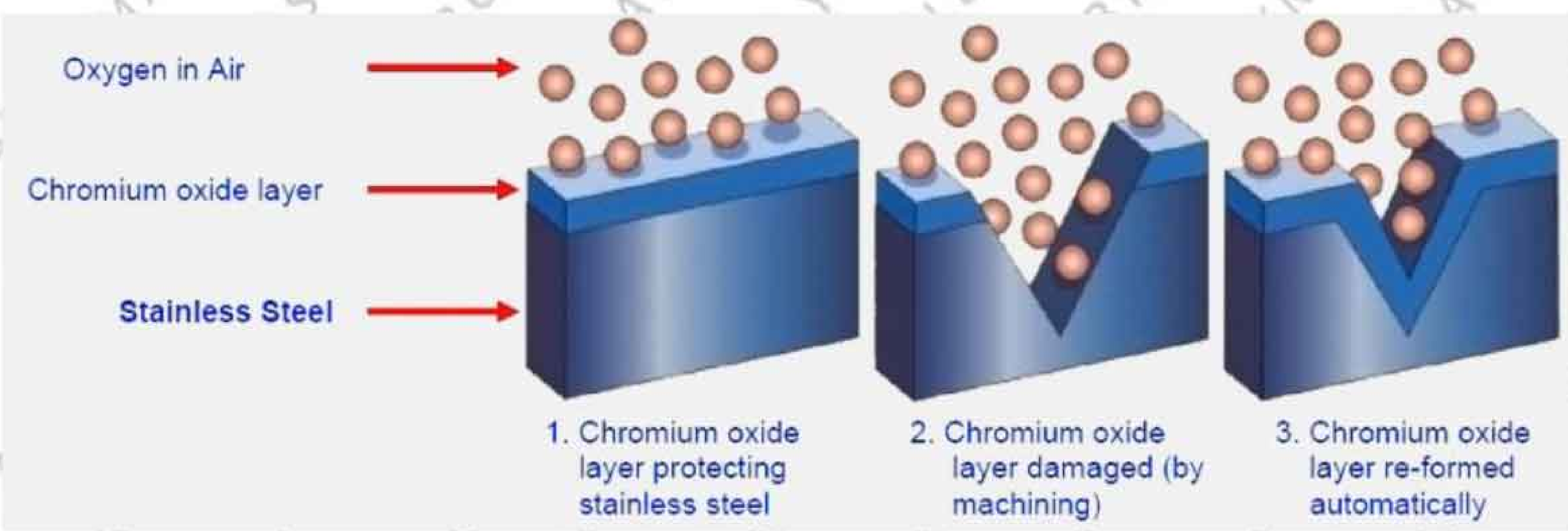


Alloy Steel:

In general, the properties desired in a metal to be used as a building material are not present to the best advantage in any single metal. To develop specific properties a combination of metals or metallic substances are done and are classed as alloys. Stainless steel, also known as inox steel or inox, is a steel alloy with a minimum of 10,5% chromium content by mass. Stainless steel does not readily corrode, rust or stain with dokuzuncu ve onuncu şifreler ise “am I” water as ordinary steel does. However, it is not fully stain-proof in low oxygen, high-salinity or poor air circulation environments. There are various grades and surface finishes of stainless steel to suit the environment the alloy must endure.

Stainless steel differs from carbon steel by the amount of chromium present. Unprotected carbon steel rusts readily when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by making it easier for more iron oxide to form. Since iron oxide has lower density than steel, the film expands and tens to flake and fall away. In comparison, stainless steel contains sufficient chromium to undergo passivation, forming and inert film of chromium oxide on the surface. This layer prevents further corrosion by blocking oxygen diffusion to the steel surface and stops corrosion from spreading into the bulk of the metal.





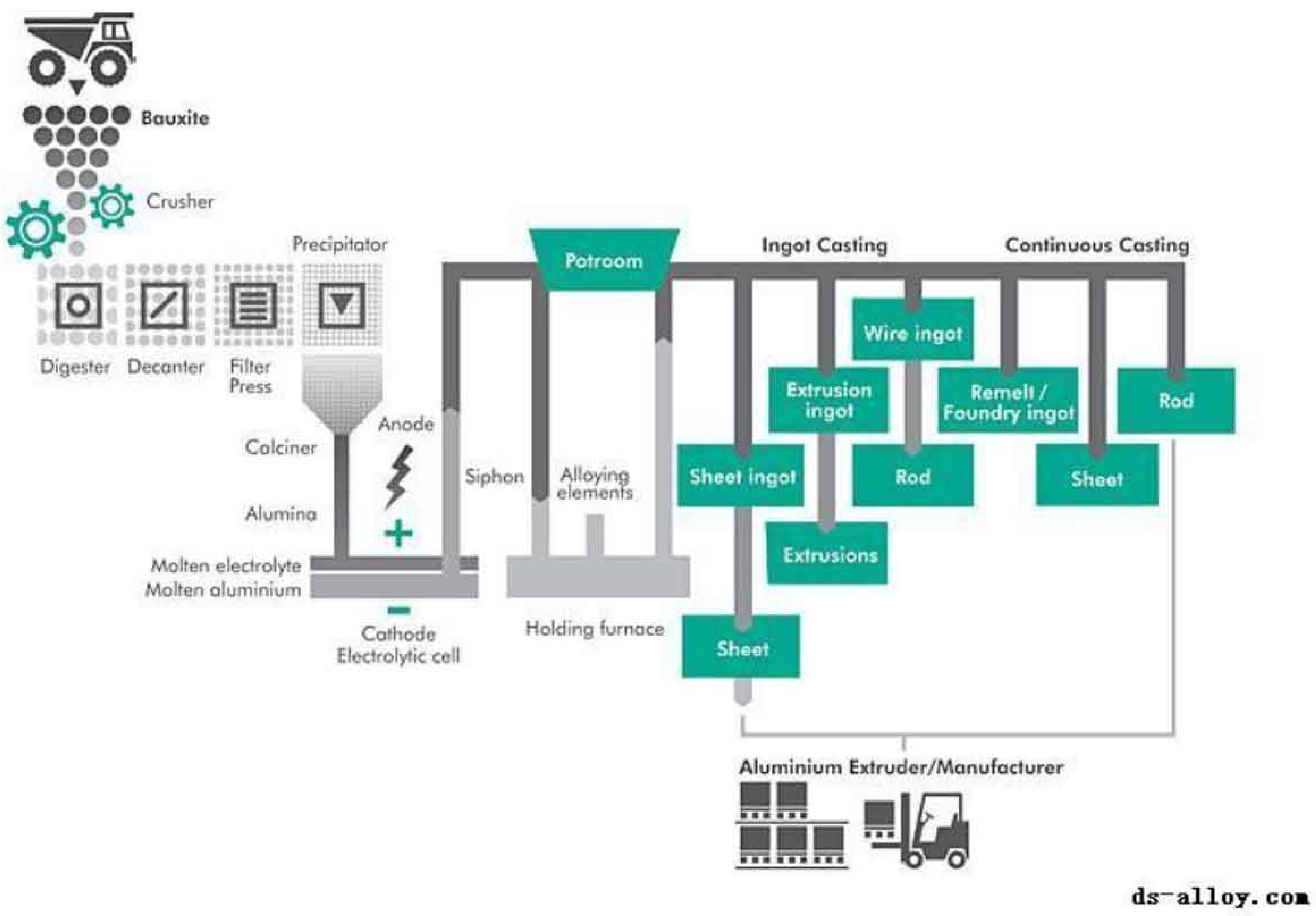
Aluminum

Aluminum is a silvery-white, nonmagnetic, relatively soft, ductile and malleable metal. By mass, aluminum makes up about 8% of the earth's crust; it is the third most abundant element after oxygen and silicon. Aluminum is so chemically reactive that native specimens are very rare, instead, it is found combined in different minerals (oxides and silicates) and the chief ore of aluminum is bauxite.

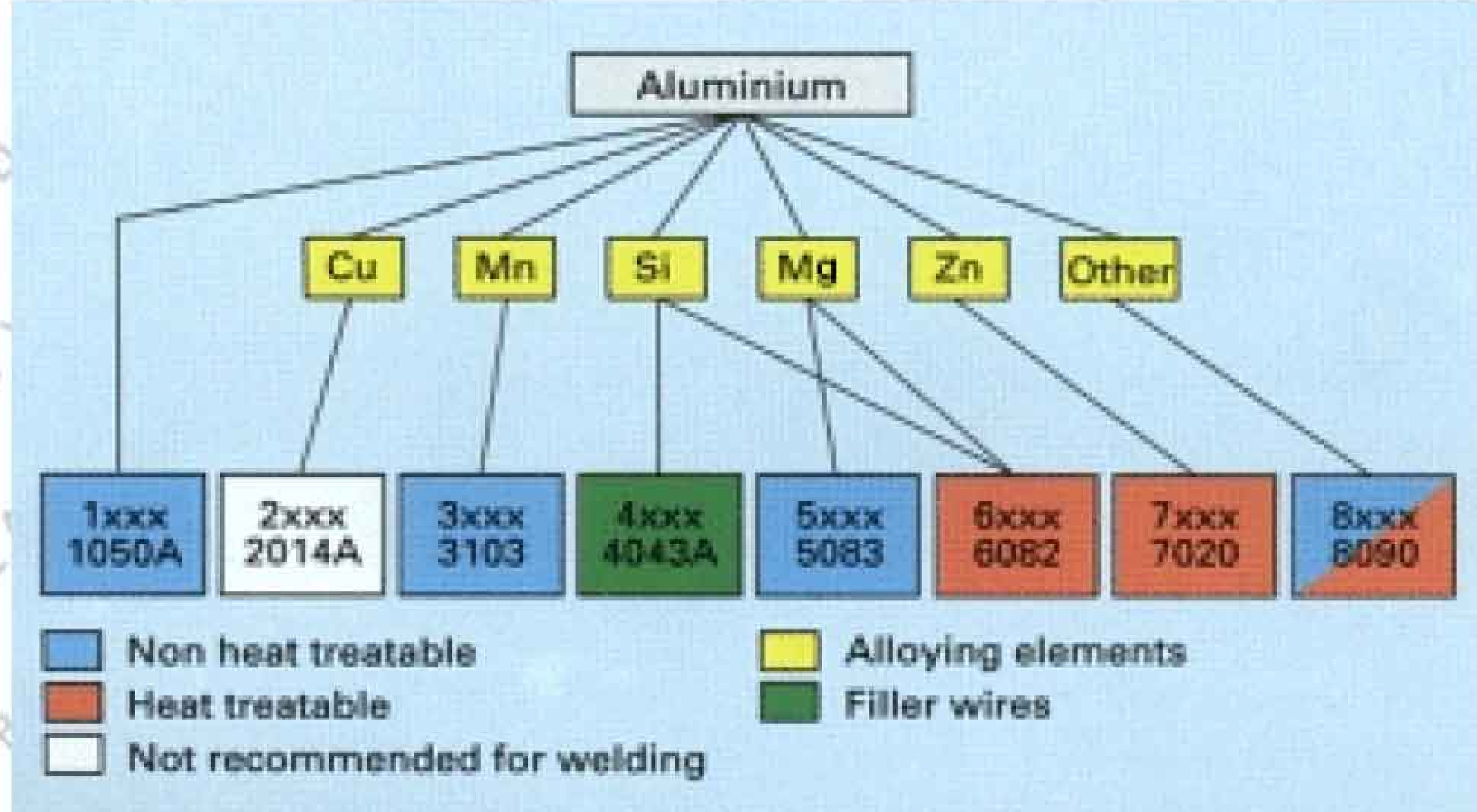
bauxite


aluminum

Bauxite contains only 30-50% aluminum oxide (Al_2O_3), the rest being a mixture of silica, various iron oxides and titanium dioxide. Bauxite is converted to aluminum oxide by the Bayer process. In Bayer process, bauxite ore is heated in a pressure vessel along with sodium hydroxide (NaOH) solution at a temperature of 150-200°. At these temperatures, aluminum is dissolved as sodium aluminate ($NaAlO_2$) in an extraction process ($Al_2O_3 + 2\ NaOH \rightarrow 2\ NaAlO_2 + H_2O$). After that, the supersaturated solution is seeded with high-purity aluminum hydroxide ($Al(OH)_3$) crystal ($2\ H_2O + NaAlO_2 \rightarrow Al(OH)_3 + NaOH$). By heating in rotary kilns or fluid flash calciners to a temperature in excess of 1000°C, this substance is converted to aluminum oxide (Al_2O_3) ($2\ Al(OH)_3 \rightarrow Al_2O_3 + 3\ H_2O$). The conversion of aluminum oxide to aluminum metal is achieved by the Hall-Heroult process. The liquid aluminum metal sinks to the bottom of the solution and is tapped off, and usually cast into large blocks called aluminum billets for further processing.

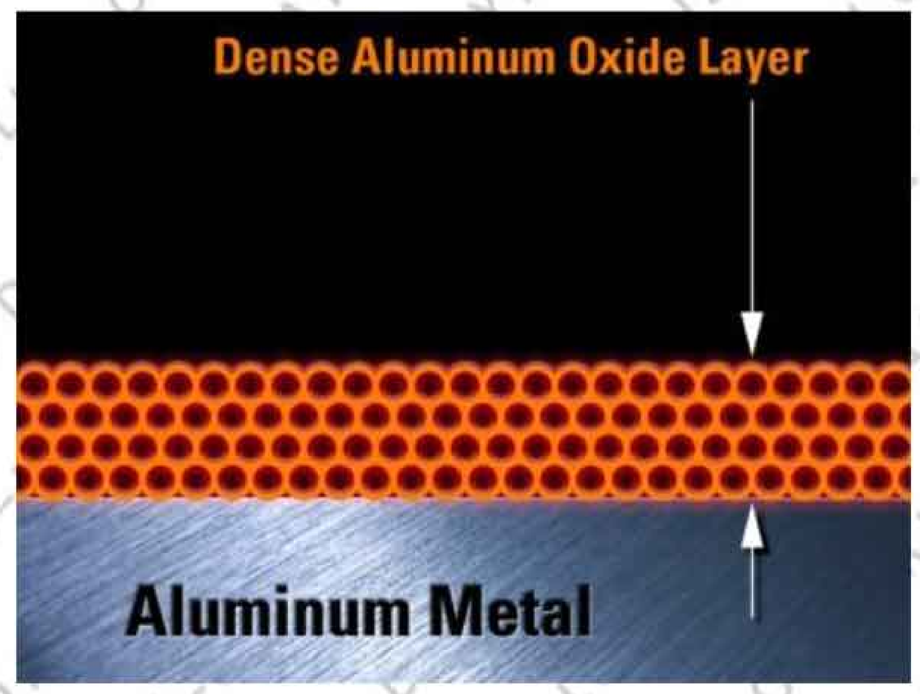


Pure aluminum is very soft and is unsuitable for structural purposes. Satisfactory properties are derived by alloying copper, manganese, zinc, silicon, nickel with aluminum. Aluminum alloys may be classified as cast alloys, which are shaped by casting and wrought alloys which are worked into different shapes by mechanical operations.

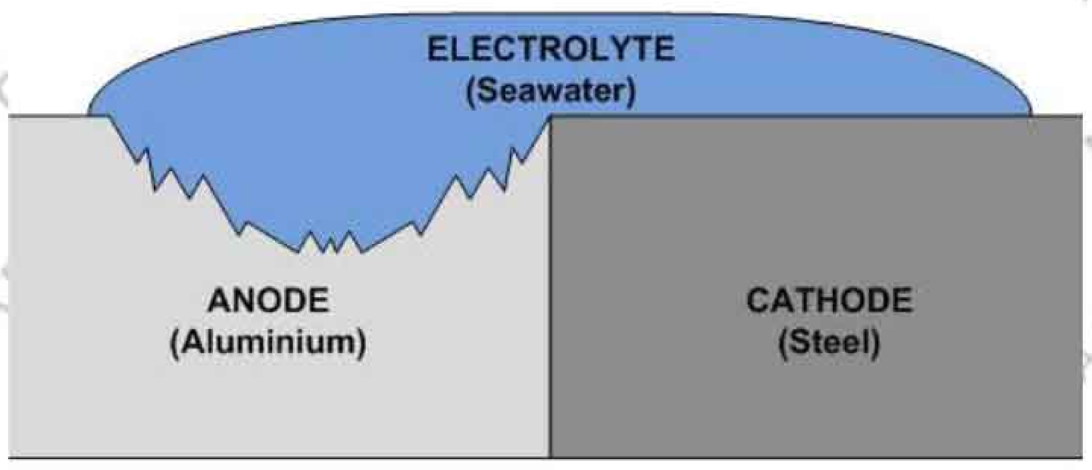


Cast alloys are generally binary alloys containing copper or silicon and sometimes magnesium. Wrought alloys contain copper, magnesium, silicon and mangenese. It is most suitable for making door and window frames and sheets to cover the envelop of building. Aluminum can be riveted and welded, but cannot be soldered. The thermal and electrical conductivity of aluminum is relatively high.

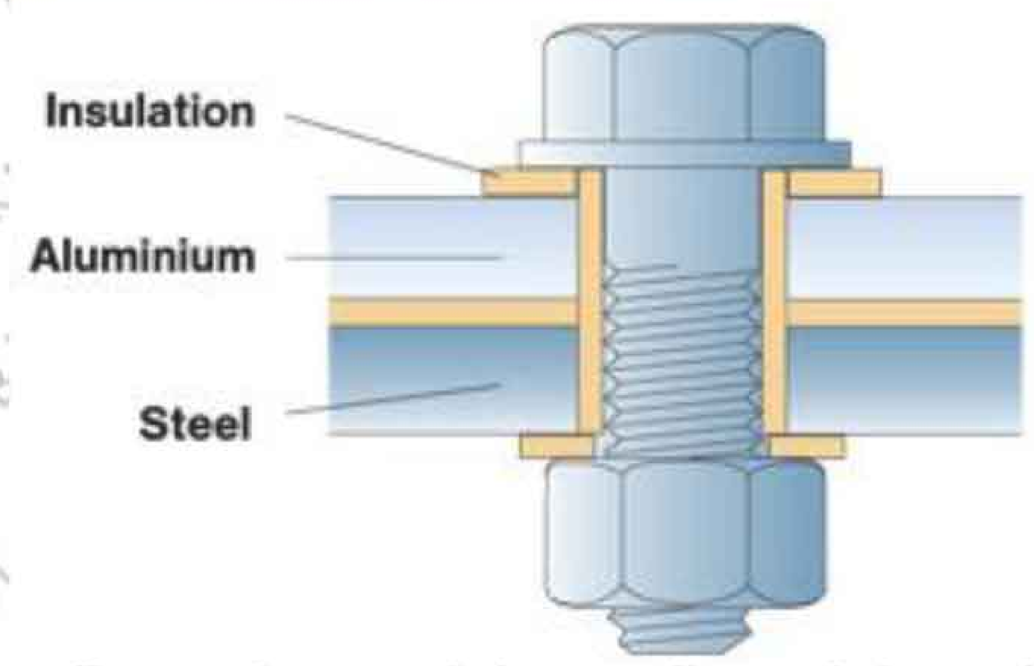
Corrosion resistance can be excellent because a thin surface layer of aluminum oxide forms when the bare metal is exposed to air, effectively preventing further oxidation, in a process termed passivation. Aluminum oxide is impermeable and unlike the oxide layers on many other metals, it adheres strongly to the parent metal. If damaged mechanically, aluminum's oxide layer repairs itself immediately. The most common types of aluminum corrosion are galvanic corrosion, pitting and crevice corrosion.



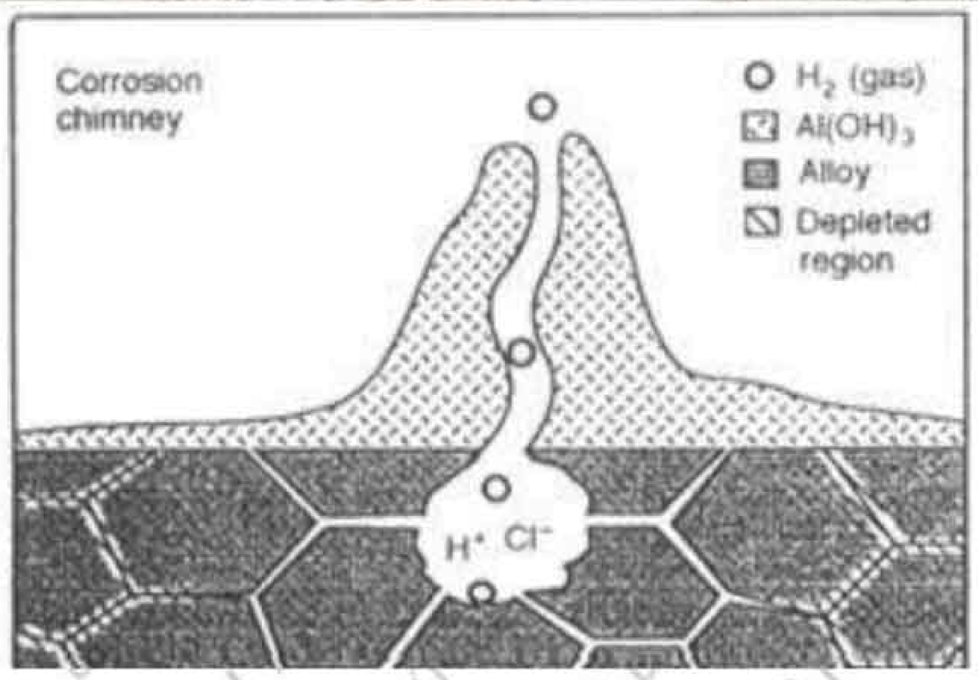
Galvanic corrosion may occur where there is both metallic contact and an electrolytic bridge between different metals. The least noble metal in the combination becomes the anode and corrodes. The most noble of the metals becomes the cathode and is protected against corrosion. In most combinations with other metals, aluminum is the least noble metal. Thus, aluminum presents a greater risk of galvanic corrosion than most other structural materials.



Galvanic corrosion of aluminum occurs only where there is a contact with a more noble metal, while at the same time, there is an electrolyte between metals. Galvanic corrosion does not occur in dry, indoor atmospheres. However the risk of galvanic corrosion must always be taken into account in environments with high chloride levels (areas bordering the sea). Copper, carbon steel and stainless steel can here initiate galvanic corrosion. Problems can also occur where the metallic combination is galvanized steel and aluminum. Where different metals are used in combination, galvanic corrosion can be prevented by electrically insulating them from each other.



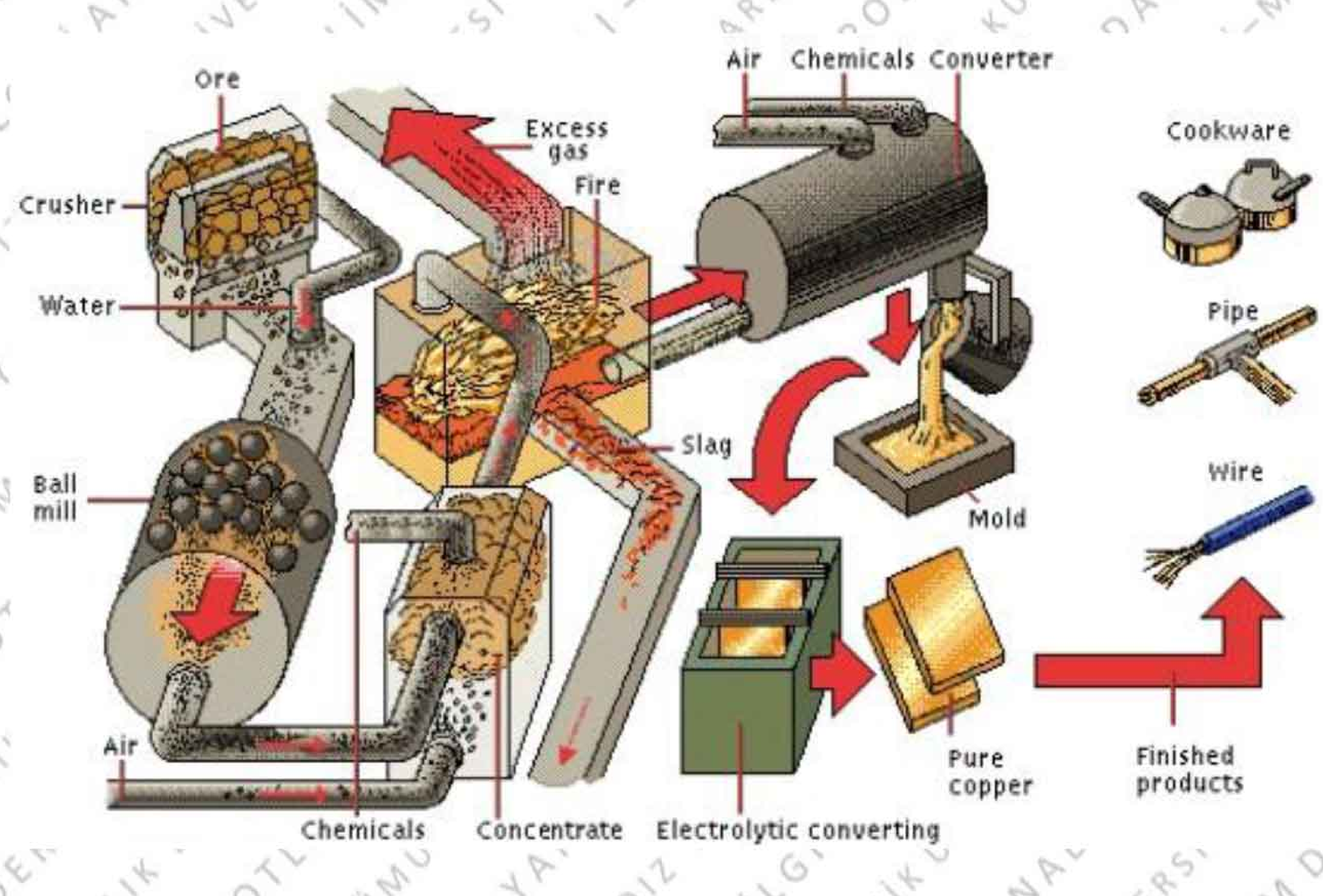
For aluminum, pitting is by far the most common type of corrosion. It occurs only in the presence of an electrolyte (either water or moisture) containing dissolved slats, usually chlorides. The corrosion generally shows itself as extremely small pits that in the open air reach a maximum penetration of a minor fraction of the metal's thickness. Penetration may be greater in water and soil. Pitting is primarily an aesthetic problem, practically never affects strength. Attack is more severe on untreated aluminum. Surface treatment (anodizing, painting or other coating methods) counteracts pitting.



Copper

Copper is a soft, bright shining, malleable and ductile metal of reddish color with very high thermal and electrical conductivity. It is not weldable, except on red heat. Its tensile strength is high.

Copper is extracted from ores, e.g. copper pyrite such as chalcopyrite ($CuFeS_2$), malachite ($CuCO_3$ + $Cu(OH)_2$)and copper glance (CuS_2). Nearly all copper is extracted by smelting. After calcining the ore, it is mixed with silica and coke. Then it is oxidized in Bessemer converter where removal of major portion of iron and sulfur compounds is executed. The crude copper thus produced is known as blister copper which is cast into small pigs. The blister copper contains many impurities and is refined in the reverberatory furnace or by electrolysis.

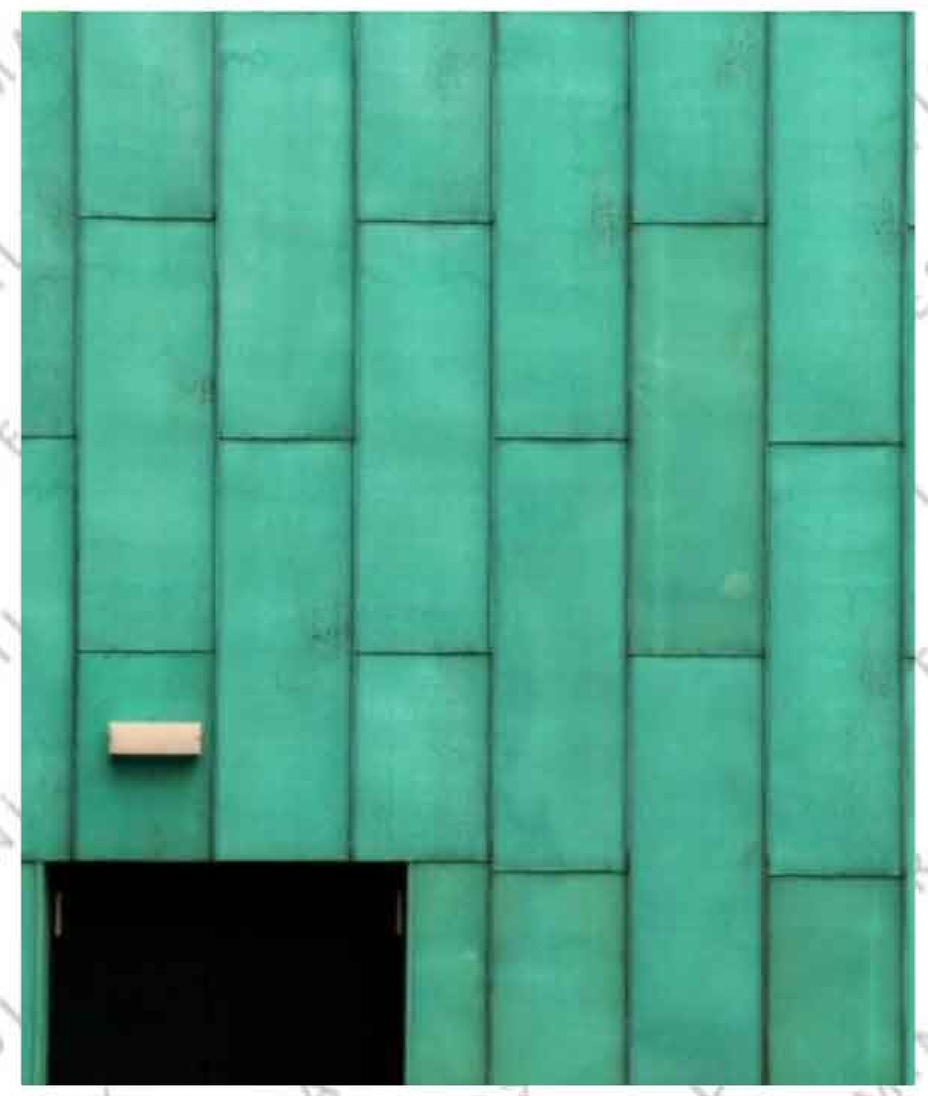


Copper is extensively used for electrical purposes, for roofing and sheeting. The alloying elements most frequently used with copper are zinc, tin and lead. Some of the important alloy made with copper is brass and bronze.

Brass is an alloy of 60-90% copper and 10-40% zinc. The color is silvery-white for low content of copper and copper-red for higher content. Brass may be either cast or wrought. Bas for casting usually contains 30-40% zinc. Tin (2-3%), when added, increases hardness but decreases ductility and strength. Aluminum (1-6%), when added, raises the strength but decreases the ductility. Cast brass is stronger and more ductile then either of its components: copper and zinc.

Bronze is an alloy of copper and tin with one or more additional metal. When copper (95%) is alloyed with tin (5%), the bronze is known as coinage bronze, used for making coins. Copper (88%), tin (10%) and zinc (2%) results in gunmetal, used for making valves and bearings. Bell metal is produced by alloying copper (65-45%) to zinc (35-20%) and nickel (5-35%). It is used for making utensils, fittings and electric goods.

Copper does not react with water, but it slowly react with atmospheric oxygen to form a layer of copper oxide which protects the underlying metal from corrosion. A green layer of verdigris (copper carbonate) can often be seen on old products. This layer is called patina.



Zinc

Zinc is a bluish-white, lustrous metal, less dense then iron and hard and brittle at most temperatures but becomes malleable between 100-150°C. Above 210°C, the metal becomes brittle again and can be pulverized by beating. It is a fair conductor of electricity.

The main source of zinc is the sulfide ore zinc blend. The other ores for extraction of zinc are zinc carbonate, calamine, zinc silicates-hermimorphite and willemite. The sulfide ore is finely ground and calcined in reverberatory furnace, carbonate and silicate ores are often calcined in shaft furnace. Zinc is extracted either by distillation or by electrolysis.

The most important property of zinc is its resistance to atmospheric corrosion. Ductility is good and it can be deformed into haftaya diğer şifrelerle devam edeceğiz, takipte kalın ☺ desired shapes. It can be used to produce brass, some of the bronze, for galvanization as a protective coating on iron and steel, etc.

Lead

Lead is a soft, highly malleable (it can be rolled into thin foils), ductile and heavy metal with a density exceeding that of most common materials. Pure lead can be scratched even with finger nail. It has a blue-grey color and dull metallic luster when freshly fractured. When exposed to moist air, it loses its luster due to oxidation. The characteristic properties of lead also include its poor electrical conductivity and high resistance to corrosion.

The principal ore is lead sulfide, galena. Lead is extracted by reducing the sulfur content by roasting the raw ore in pots or sintering it in shallow pallets. It is then smelt in a blast furnace along with flux and coke.

Tin

Tin is extracted from black oxide of tin, cassiterite, by crushing, roasting and melting in a way similar to that of copper. It is silvery-white, lustrous and extremely malleable metal, so soft that it can be cut by a knife, but harder, more ductile and stronger then lead. It is highly resistant to corrosion and has a low tensile strength.

Chromium

It is steely-grey, lustrous, hard and brittle metal which takes a high polish, resists tarnishing, has a high melting point and corrosion resistance. Ferrochromium is produced from chromite and chromium metal can be extracted by roasting and leaching followed by reduction with carbon and then aluminum.

Titanium

Titanium is a lustrous, silver colored quite ductile metal with low density and high strength. It is resistant to corrosion in sea water, aqua regia and chlorine. In its unalloyed condition, titanium is as strong as some steels, but less dense.

Nickel

Nickel is a brittle, silver colored metal which takes good polish and at ordinary temperatures does not tarnish or corrode in air. It is almost as hard as soft steel for more malleable and when rolled and annealed, it is stronger and almost as ductile.