Subject: Construction Materials

"METALS"

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Metals, Introduction

- In the materials world we are living in, when making a new device/component, most often we come across a very familiar problem. This is nothing but select the right material. Selection of material can play very important role preventing failures. Selection of material for a specific purpose depends on many factors. Some of the important ones are: strength, ease of forming, resistance to environmental degradation, etc. Another dimension an engineer should be aware of it is how to tailor the required properties of materials.
- Materials can be are broadly classified as metals, ceramics, plastics etc. A solid material which is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity (e.g. iron, gold, silver, and aluminium, and alloys such as steel) is called a metal.

Metals, Types

Types of metals and alloys:

Metallic materials are broadly of two kinds – *ferrous* and *non-ferrous* materials. Ferrous materials are those in which iron (***Fe***) is the principal constituent. All other materials are categorized as non-ferrous materials. Another classification is based on their formability. If materials are hard to form, components with these materials are fabricated by casting, thus they are called *cast alloys*. If material can be deformed, they are known as *wrought alloys*. Materials are usually strengthened by two methods – *cold work and heat treatment or hot rolled*. Strengthening by heat treatment involves either precipitation hardening or martensitic (a scientist) transformation, both of which constitute specific heat treating procedure. When a material can not be strengthened by heat treatment, it is referred as non-heat-treatable alloys.

Metals, *Ferrous materials*

Ferrous materials are produced in larger quantities than any other metallic material. Three factors account for it:

(a) availability of abundant raw materials combined with economical extraction, (b) ease of forming and (c) their versatile mechanical and physical properties.

One main drawback of ferrous alloys is their environmental degradation i.e. poor corrosion resistance. Other disadvantages include: relatively high density and comparatively low electrical and thermal conductivities. In ferrous materials the main alloying element is carbon (C). Depending on the amount of carbon present, these alloys will have different properties, especially when the carbon content is either less/higher than 2.14%. This amount of carbon is specific as below this amount of carbon, material undergoes eutectoid (from one phase to other) transformation, while above that limit ferrous materials undergo eutectic transformation. Thus the ferrous alloys with less than 2.14% C are termed as *steels*, and the ferrous alloys with higher than 2.14% C are termed as *cast irons*.

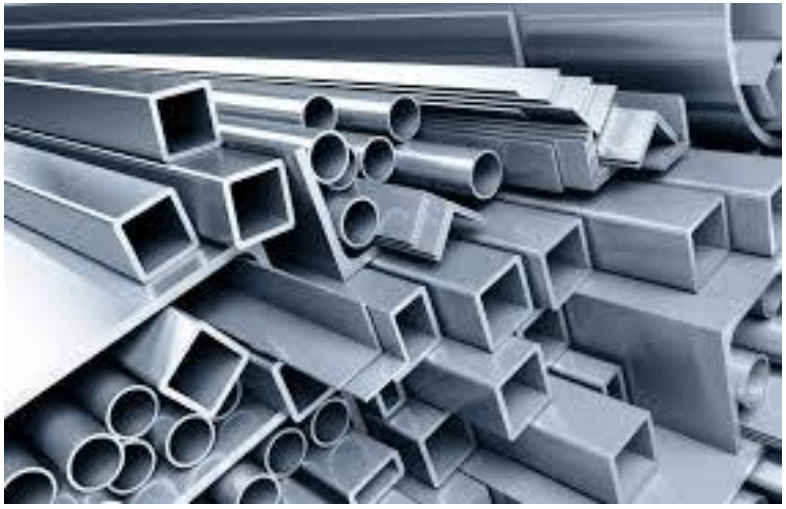
Metals, *Steel*

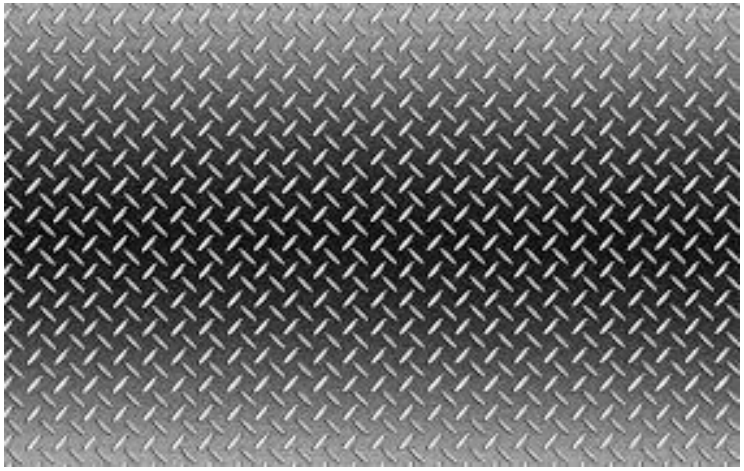
Steels are alloys of iron and carbon plus other alloying elements. In steels, carbon present in atomic form, and occupies interstitial sites of Fe microstructure. Alloying additions are necessary for many reasons including: improving properties, improving corrosion resistance, etc. Arguably steels are well known and most used materials than any other materials. Mechanical properties of steels are very sensitive to carbon content.

Hence, it is practical to classify steels based on their carbon content. Thus steels are basically three kinds: low-carbon steels (% wt of C < 0.3), medium carbon steels (0.3 <% wt of C < 0.6) and high-carbon steels (% wt of C > 0.6). The other parameter available for classification of steels is amount of alloying additions, and based on this steels are two kinds: (plain) carbon steels and alloy-steels.

Metals, *Steel*

Metals, *Steel*





Metals, *Steel types*

Low carbon steels: These are arguably produced in the greatest quantities than other alloys. Carbon present in these alloys is limited, and is not enough to strengthen these materials by heat treatment; hence these alloys are strengthened by cold work. Their microstructure consists of ferrite and pearlite, and these alloys are thus relatively soft, ductile combined with high toughness. Hence these materials are easily machinable and weldable. Typical applications of these alloys include: structural shapes, tin cans, automobile body components, buildings, etc.

Medium carbon steels: These are stronger than low carbon steels. However these are of less ductile than low carbon steels. These alloys can be heat treated to improve their strength. Usual heat treatment cycle consists of austenitizing, quenching, and tempering at suitable conditions to acquire required hardness.

Metals, *Steel types*

- They are often used in tempered condition. As hardenability of these alloys is low, only thin sections can be heat treated using very high quench rates. Ni, Cr and Mo alloying additions improve their hardenability. Typical applications include: railway tracks & wheels, gears, other machine parts which may require good combination of strength and toughness.
- High carbon steels: These are strongest and hardest of carbon steels, and of course their ductility is very limited. These are heat treatable, and mostly used in hardened and tempered conditions. They possess very high wear resistance, and capable of holding sharp edges. Thus these are used for tool application such as knives, razors, hacksaw blades, etc. With addition of alloying element like Cr, V, Mo, W which forms hard carbides by reacting with carbon present, wear resistance of high carbon steels can be improved considerably.

Metals, Stain-less steel

The name comes from their high resistance to corrosion i.e. they are rust-less (stain-less). Steels are made highly corrosion resistant by addition of special alloying elements, especially a minimum of 12% Cr along with Ni and Mo. Stainless steels are mainly three kinds: ferritic & hardenable Cr steels, austenitic and precipitation hardenable (martensitic, semi-austenitic) steels. This classification is based on prominent constituent of the microstructure. Typical applications include cutlery, razor blades, surgical knives, etc.

Cast irons:

- Though ferrous alloys with more than 2.14 wt.% C are designated as cast irons, commercially cast irons contain about 3.0-4.5% C along with some alloying additions. Alloys with this carbon content melt at lower temperatures than steels i.e. they are responsive to casting. Hence casting is the most used fabrication technique for these alloys.

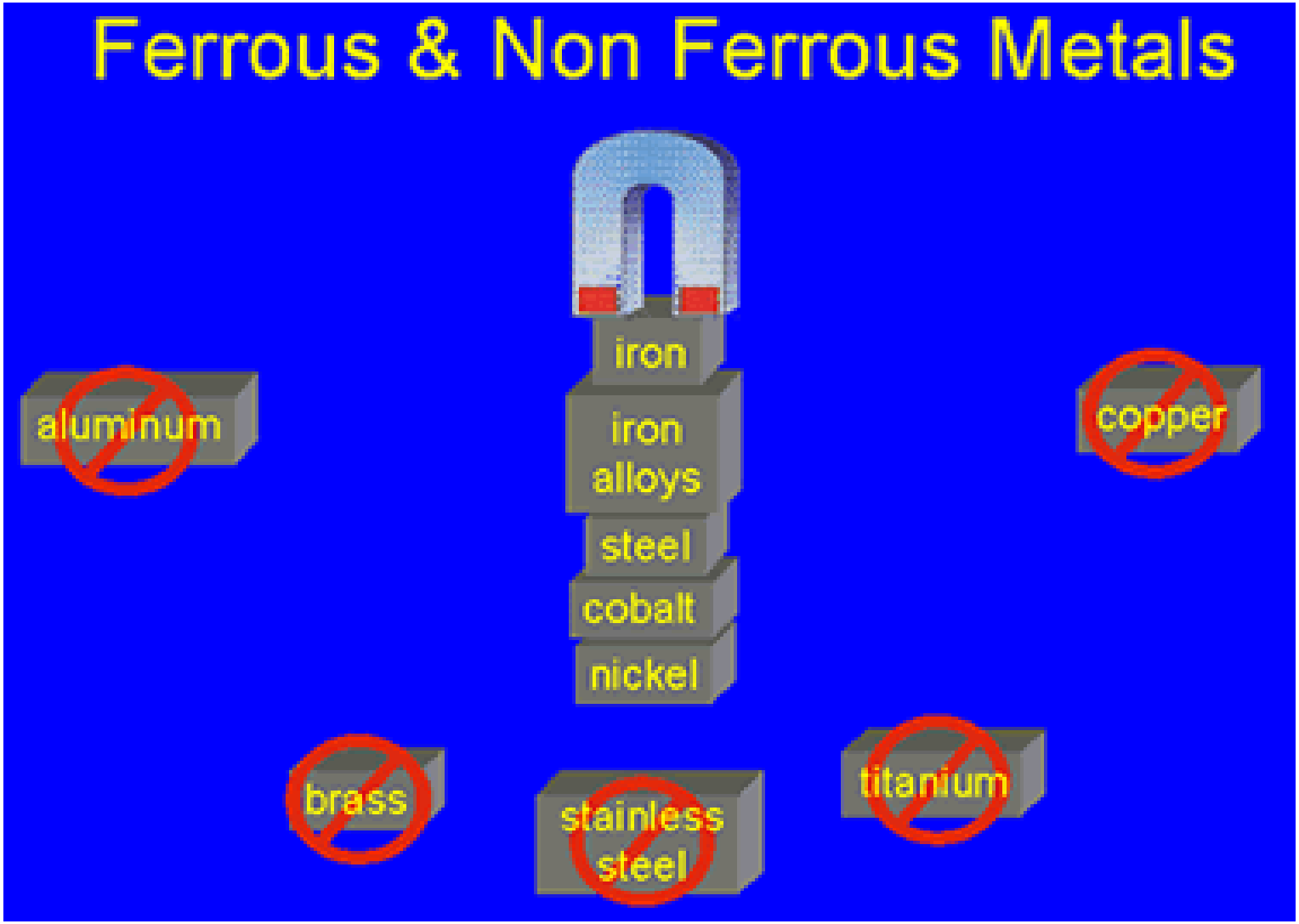
Non-ferrous Metals

Non-ferrous Metals, Introduction

- Ferrous metals (that contain iron, such as steel and tin) have less value than nonferrous metals. The nonferrous metals are nonmagnetic, and are processed differently than their ferrous-cousins. These metals include brass, copper, lead and zinc.

- Non-ferrous metals have lesser or no iron in them. Therefore they do not rust and cannot be picked up by magnets.

Ferrous and Non-ferrous Metals,



Non-ferrous Metals, Introduction

Non-ferrous Metals, properties

NON-FERROUS METALS

- Non-ferrous metals, or metals without significant iron content, are also strong. However, they are lighter than ferrous metals and cannot suspend similar loads. They are more malleable as well, and both traits can be an advantage.
- They were the first metals to be used in the art of metallurgy. Silver, copper and gold have been collected and used since ancient times as currency, jewelry, weapons and architectural components.
- The lightweight quality of nonferrous metals like copper, tin, aluminum, brass and lead has its advantages. It is far more malleable, thus greater potential to restructure and make new metals is more possible. It still has good tensile strength even though it is lighter.

Non ferrous metals

Non-ferrous materials have specific advantages over ferrous materials. They can be fabricated with ease,relatively low density, and high electrical and thermal conductivities. However different materials have distinct characteristics, and are used for specific purposes. This section introduces some typical non-ferrous metals and their alloys of commercial importance.

- Other advantages of this metal are its high conductivity of electrical current (i.e. copper), its resistance to corrosion (i.e. zinc) and its near immunity to magnetic force.
- These metals are either transformed into finished products or intermediary metals. Deformation processes like rolling, extruding and forging transmit the intermediary metal to a finished product.

Non-ferrous Metals and alloys, Types

Non-ferrous Metals, Introduction

POPULAR NON-FERROUS METALS

-Aluminum :

Second most widely used metal after steel in construction; it is lighter in weight, good conductor of electricity and heat; greyish-white; easy to cut and machine

Uses: cooking foil, drink cans, overhead power cables, casings and panels for electrical goods, road signs etc

Aluminium is malleable, ductile and a powerful heat and electricity conductor. Found in many household items. Piping, bike frames, baseballs bats and siding are examples.

Non-ferrous Metals, Aluminium alloys

<u>Aluminium alloys</u>:

- These are characterized by low density, high thermal & electrical conductivities, and good corrosion resistant characteristics. As Al has crystal structure, these alloys are ductile even at low temperatures and can be formed easily.

- However, the great limitation of these alloys is their low melting point (660°C), which restricts their use at elevated temperatures. Strength of these alloys can be increased by both cold and heat treatment – based on these alloys are designated in to two groups, cast and wrought.

Non-ferrous Metals, Aluminium alloys

- Chief alloying elements include: Cu, Si, Mn, Mg, Zn. Recently, alloys of Al and other low-density metals like Li, Mg, Ti gained much attention as there is much concern about vehicle weight reduction. Al-Li alloys enjoy much more attention especially as they are very useful in aircraft and aerospace industries.

- Common applications of Al alloys include: beverage cans, automotive parts, bus bodies, aircraft structures, etc. Some of the Al alloys are capable of strengthening by precipitation, while others have to be strengthened by cold work or solid solution methods.

Non-ferrous Metals, Aluminum

Non-ferrous Metals, Copper

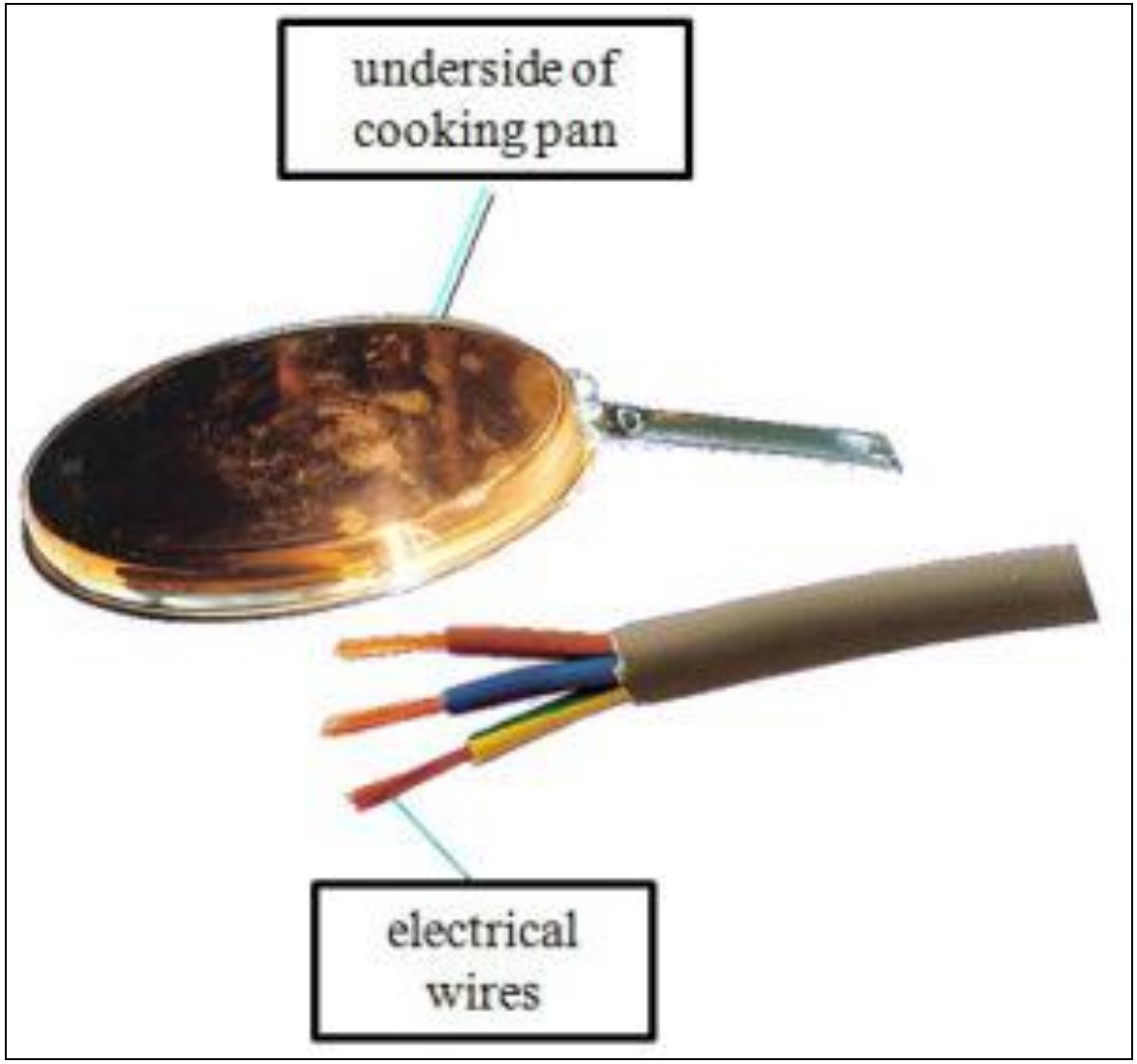
Copper

Used in various alloys. It is a great conductor. It is malleable and soft. It is used in electric motors, wiring, currency, architecture like the Statue of Liberty and sheathing for ships.

Properties: reddish-brown; ductile, malleable; can be cut sawn, filed and machined easily; excellent conductor of heat and electricity

Uses: electrical fitting and wires, printed circuit boards, tips of soldering iron, domestic water pipes, cylinders, cooking utensils, decorative ornaments

Non-ferrous Metals, Copper



Non ferrous metals

Copper alloys: Bronze is the major alloy of copper that has been used for thousands of years. It is actually an alloy of Cu and Sn. Unalloyed Cu is soft, ductile thus hard to machine, and has virtually unlimited capacity for cold work. One special feature of most of these alloys is their corrosion resistant in diverse atmospheres. Most of these alloys are strengthened by either cold work or solid solution method.

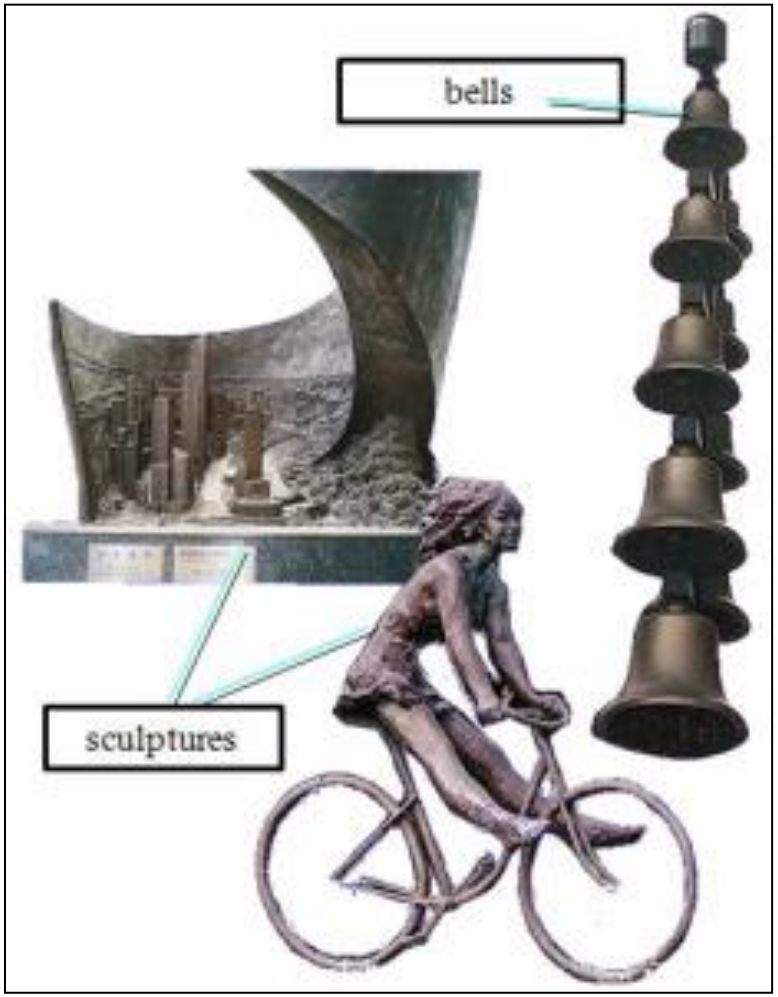
- Common most Cu alloys: Brass, alloys of Cu and Zn where Zn is substitutional addition (e.g.: yellow brass, catridge brass); Bronze, alloys of Cu and other alloying additions like Sn, Al, Si and Ni. Bronzes are stronger and more corrosion resistant than brasses. It is worth mentioning that Beryllium coppers that are possessing the combination of relatively high strength, excellent electrical, corrosion properties and wear resistance, can be cast, hot worked and cold worked. Applications of Cu alloys include: costume jewelry, coins, musical instruments, electronics, springs, bushes, surgical and dental instruments, radiators, etc.

Non-ferrous Metals, Bronze

Bronze:
This alloy is made of copper and zinc. There are corrosion resistant forms but it is susceptible to seasonal cracking. It is used in brass instruments, ancient art, doorknobs and household fixtures, locks, valves and more.

Properties: made by mixing copper and tin; reddish-yellow, hard-wearing, corrosion resistant, easily machined
Uses:

- ship propellers, bells, gears, bearings, statues



Non-ferrous Metals, Tin

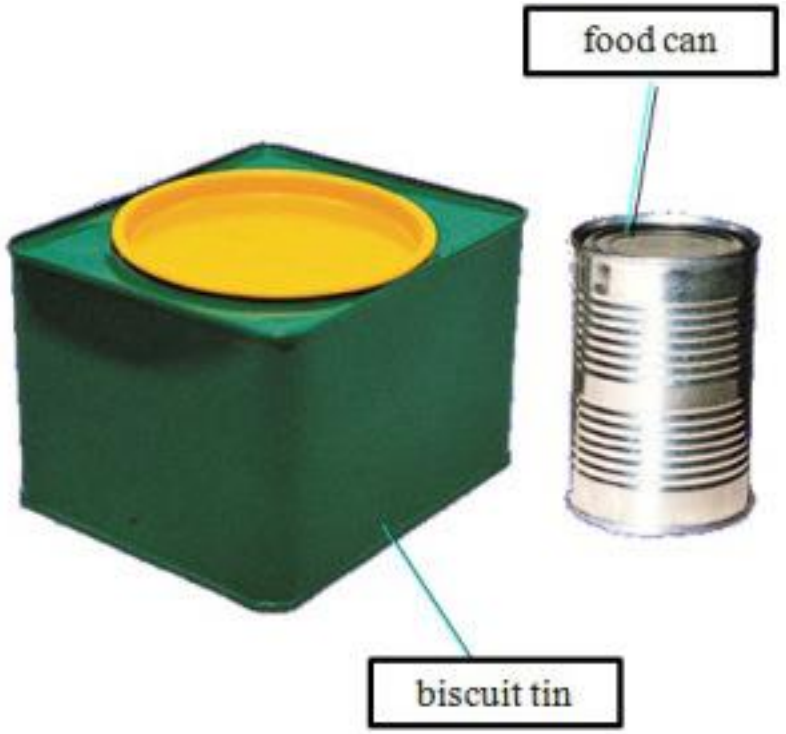
Tin

Properties:

- silvery-white, non-toxic, soft; normally used by plating it onto other metals such as mild steel (tinplate)

Uses:

- food cans, plating on copper tracks of printed circuit boards



Non-ferrous Metals, Zinc

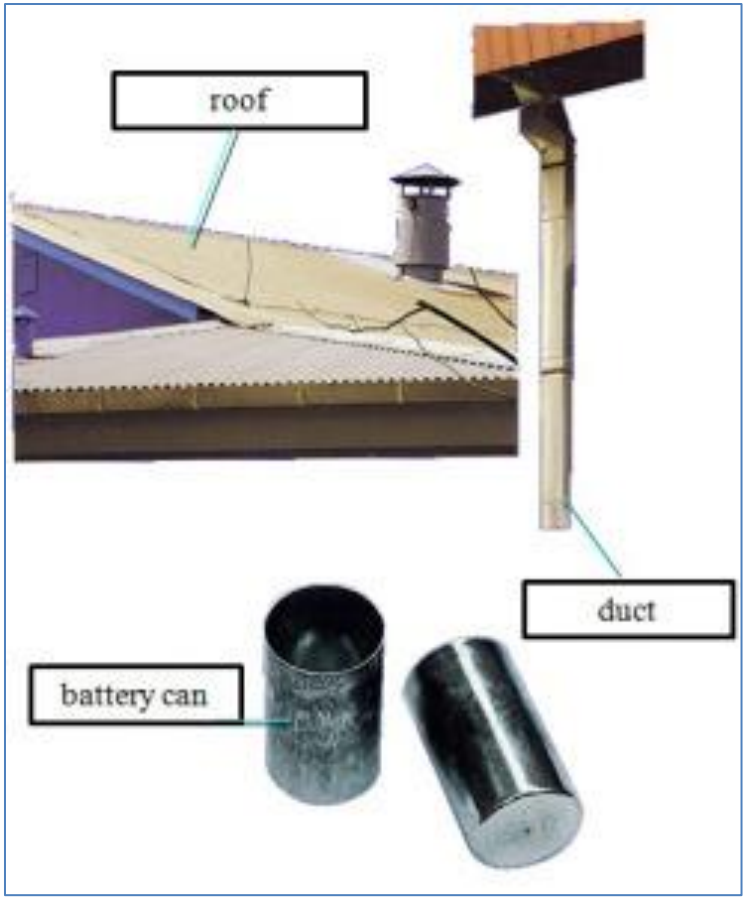
Zinc

Properties:

- silvery-blue, does not corrode easily, ductile, not very strong

Uses:

- manufacture of other metals such as brass and galvanised iron, batteries, rust-proof paints

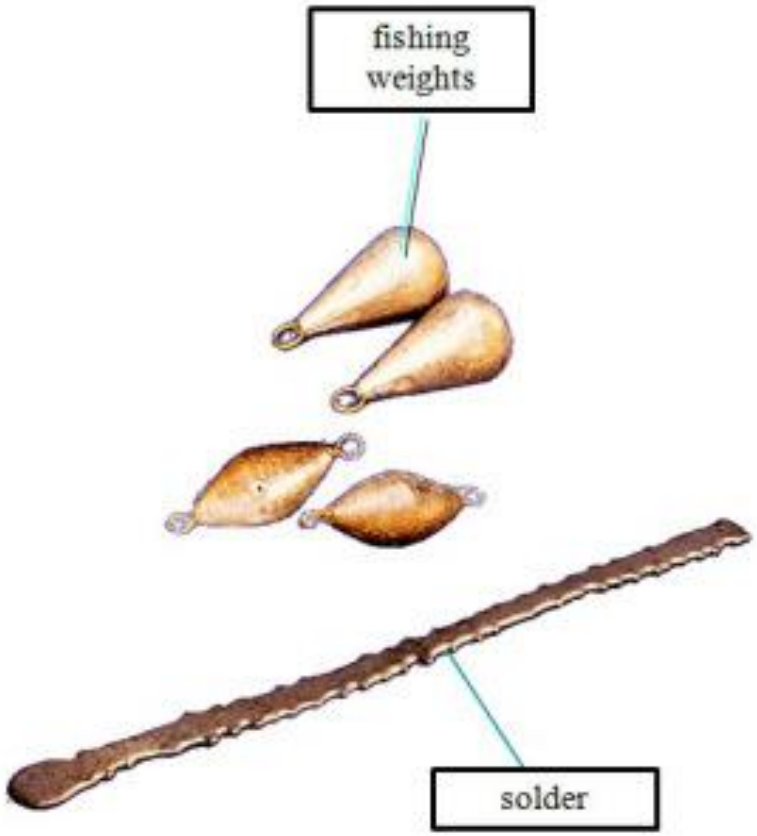


Non-ferrous Metals, Lead

Lead

Properties:

- very heavy, but soft; appears bright and shiny bluish-grey when cut but surface changes quickly to a dull grey; toxic, resistant to corrosion and many chemicals
- Uses: Can be used to produce high density concrete for radiation shielding purposes around nuclear reactors.
- can be mixed with other materials to make them easier to machine; acts as a protection against x-rays and radiation, core of some batteries



Non-ferrous Metals, Brass

Alloys of copper and zinc are termed brasses. Zinc is added to improve the strength and ductility of the alloy. There are many formulas for brasses which include other alloying elements than copper and zinc. Brass is used in decorative metal products, cartridge cases, piping and tubing, and many of the same application as copper.

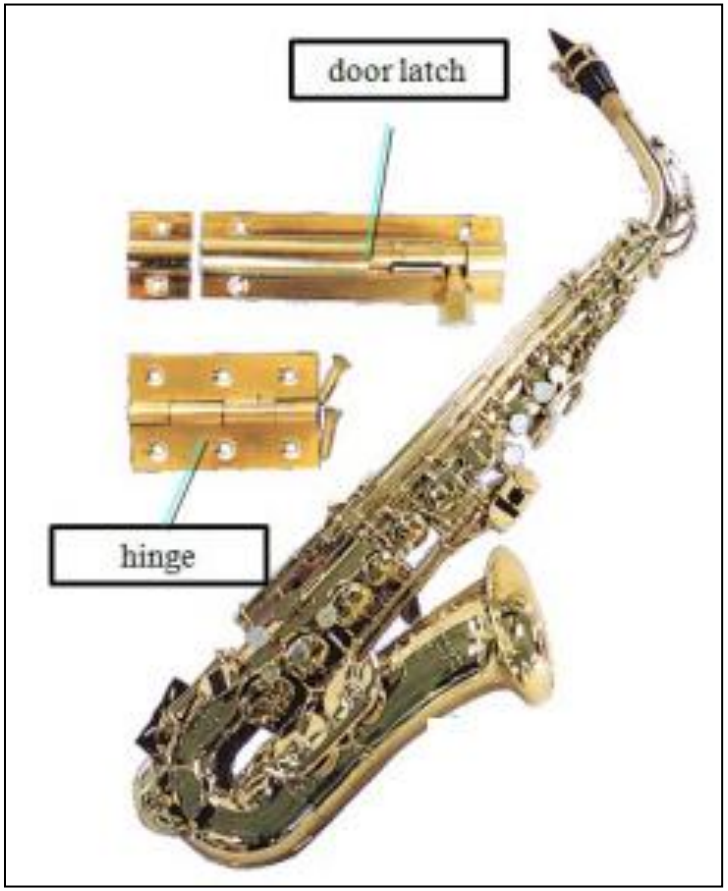
Brass

Properties:

- good conductor of heat and electricity, golden yellow alloy, easy to machine and solder, made by mixing copper and zinc

Uses:

- pins of electrical plugs, nuts, bolts, screws, hinges, some machine parts, musical instruments, decorative artifacts, locks, keys



Non-ferrous Metals, Silver

Silver

Silver also finds application in photographic films and papers. At one time, it was used to plate mirrors. It is now used in the manufacture of photochromatic lenses. Photochromatic lenses darken when exposed to ultraviolet light. Silver is also used in brazing alloys and long-life batteries. Silver fulminate (Ag2C2N2O2) is used as an explosive. Silver and silver compounds are found in many creams, ointments, and salves used for medicinal purposes. Silver iodide has been used to seed clouds to make rain.

Like gold, this precious metal is a great conductor and very resistant to corrosion, elements, chemicals and temperature. It is used in natural energy, medicine, jewelry and fine china.

Non-ferrous Metals, Platinum

Platinum

Platinum is found in a group of six metals extracted from nickel ores -- iridium, osmium, palladium, rhodium, ruthenium, and platinum. Of these, platinum has the most widespread application. It is used in corrosion-resistant coatings, as a catalyst for chemical reactions, high-resistance furnace wire, and in catalytic converters. A large percentage of platinum is used in laboratory equipment, medical instruments, and fine jewelry. Platinum is more expensive per pound than gold.

Non-ferrous Metals, Gold

--Gold

This rare, precious and highly sought after metal is extremely resistant to corrosion, heat, pressure and elements. Because it withstands heat and chemical reactions, and because it is so malleable and soft it is commonly used in electrical connectivity.