

# Characteristics of Glass and Metal

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# Glass

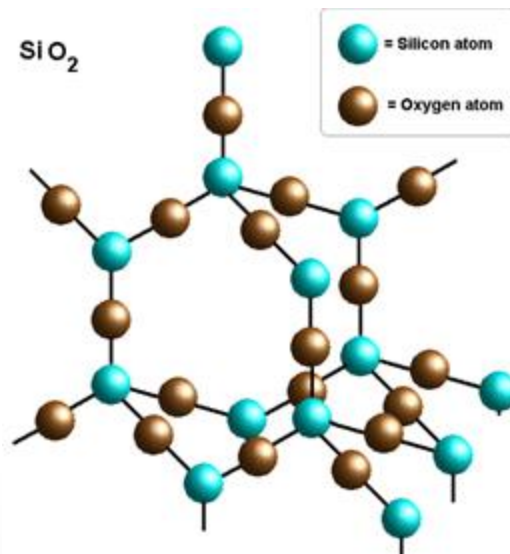
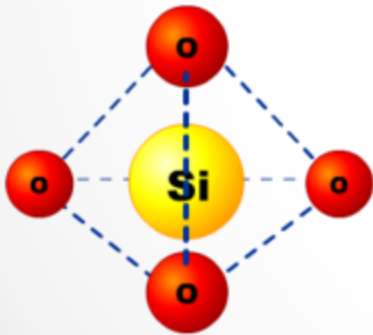
# Introduction

- Glass generally refers to hard, brittle, transparent material
- It has high barrier and see-through properties.
- Glass is an inorganic substance formed from a mixture of sand (73%), sodium oxide (13%), and calcium oxide (12%), with a proportion of broken glass or cullet (15 to 30% of total weight). Many glasses contain silica as their main component and glass former.



# Chemical nature of glass

Glass is a mixture in which all the constituent atoms have been persuaded by heating to line up in to a random but rigid net wall in which each silica atom is linked to '4' oxygen atoms and then to other silica atoms, both atoms of sodium and calcium distributed in holes in the network.



# Approximate composition of glass

## Natural White Glass:

- Silica ( $\text{SiO}_2$ ) – 73%
- Lime ( $\text{CaO}$ ) – 11%
- Soda ( $\text{Na}_2\text{O}$ ) – 13-14%
- Alumina ( $\text{Al}_2\text{O}_3$ ) – 1.7%
- Magnesia ( $\text{MgO}$ ) – 0.3%
- Potash ( $\text{K}_2\text{O}$ ) – 0.3-0.4%
- Iron oxide ( $\text{Fe}_2\text{O}_3$ ) 0.05%
- Sulphur Trioxide ( $\text{SO}_3$ ) – 0.19%

The content of soda decides the cost of the glass.

For coloured glass:

- Green colour – Chromium and Iron,
- Amber – Iron, Sulphur and carbon
- Opal – Fluorine

The principal raw materials required for manufacture of glass are sand lime stone and soda ash. Screen printing, ceramic spray and plastic coating are used for decoration or printing on the glass.



# Characteristics of Glass Containers

Glass containers have several characteristics that make them ideal for food and beverage packaging:

- They are impervious to moisture, gases, odors, and microorganisms.
- They are inert and do not react with or migrate into food products.
- They have filling speeds comparable to those of cans.
- They are suitable for heat processing when hermetically sealed.
- They are transparent to microwaves.
- They are reusable and recyclable.
- They are resealable.
- They are transparent and display the contents.
- They can be molded into a variety of shapes and colors.
- They are perceived by the customer to add value to the product.
- They are rigid and allow stacking without container damage.

## **The main disadvantages of glass as a packaging container are:**

1. Higher weight and hence higher transportation costs than other types of packaging containers.
2. Lower resistance than other materials to fractures, scratches, and thermal shock.
3. More variable dimensions than other containers.
4. Potentially serious hazards arise from glass splinters or fragments in foods.
5. Permeability to UV light.

To overcome the UV problem incorporation of various oxides, sulphides, or selenides to color glass is done and block out the incident UV radiation.

# Types of Glass Containers

Commonly used glass containers are bottles, jars, tumblers and jugs, carboys, vials, and ampoules.

**Bottles** account for the bulk of glass containers. They are made in various shapes and sizes (from 100 ml to 4 lit) and are characterized by a round neck that is much narrower than the body. The glass bottles used in Dairy industry are heat resistant bottles. But, they can withstand 50°C temperature difference during heating and only 30°C temperature difference during cooling, which is important during in-bottle sterilization of milk.

**Jars** are wide mouthed bottles with no neck, and this affords easy access to the product.



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- **Tumblers** are similar to jars but without a neck and a “finish” for the end closure. They are shaped like a drinking glass and are used for such products as jams and jellies.



- **Jugs** are large sized bottles with carrying handles. They are used to package wine and institutional, industrial, and household products.



- **Carboys** are large globular wicker-covered glass bottles for holding acids or other corrosive liquids.



- **Vials and ampoules** are small, thin-walled glass containers. They are mainly used in the pharmaceutical industry for drugs and in the food industry for small quantities of very expensive ingredients, such as flavors.



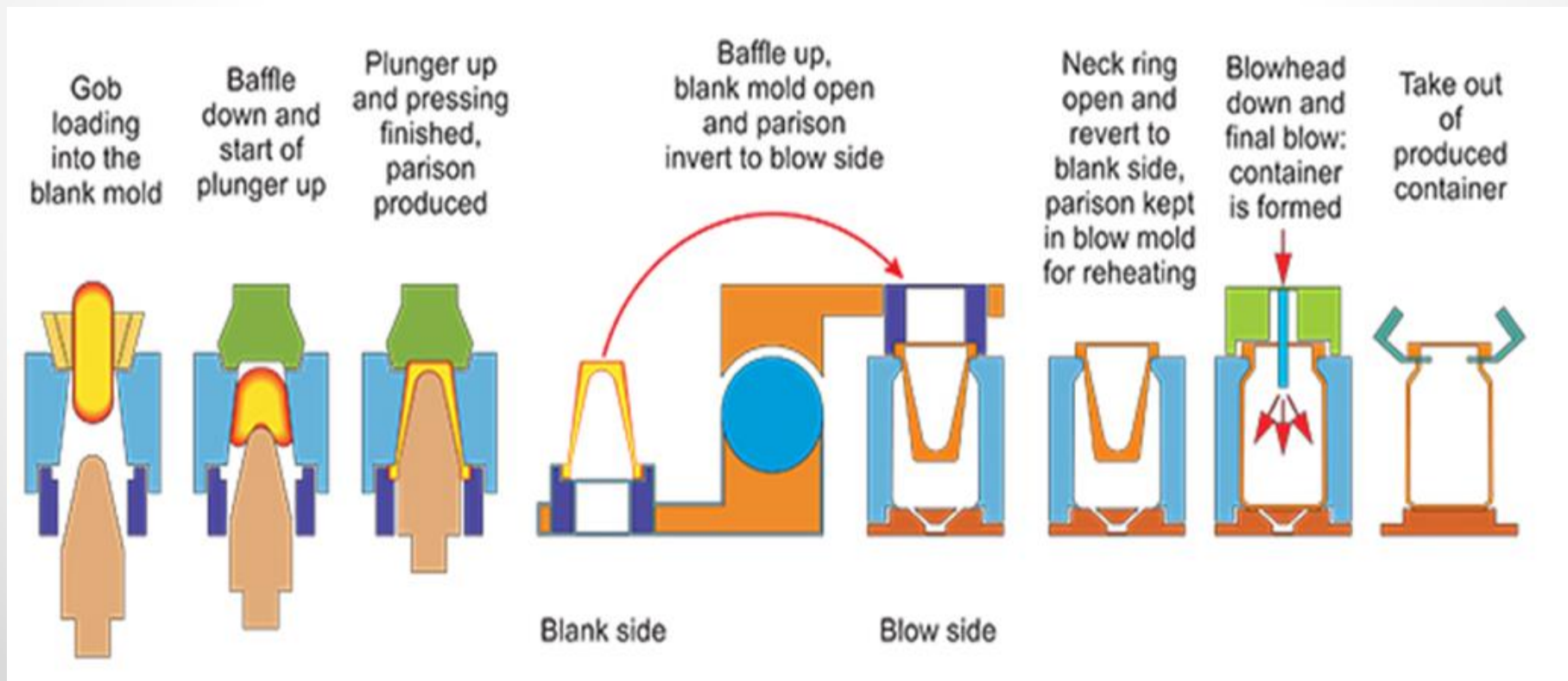
- Food products packed in glass: Baby foods, malted milk foods, sterilized flavoured milk, beer, soft drinks, meat/fish products, fruits and vegetable products.

# Glass container forming process

There are, currently, two primary methods of making a glass container —

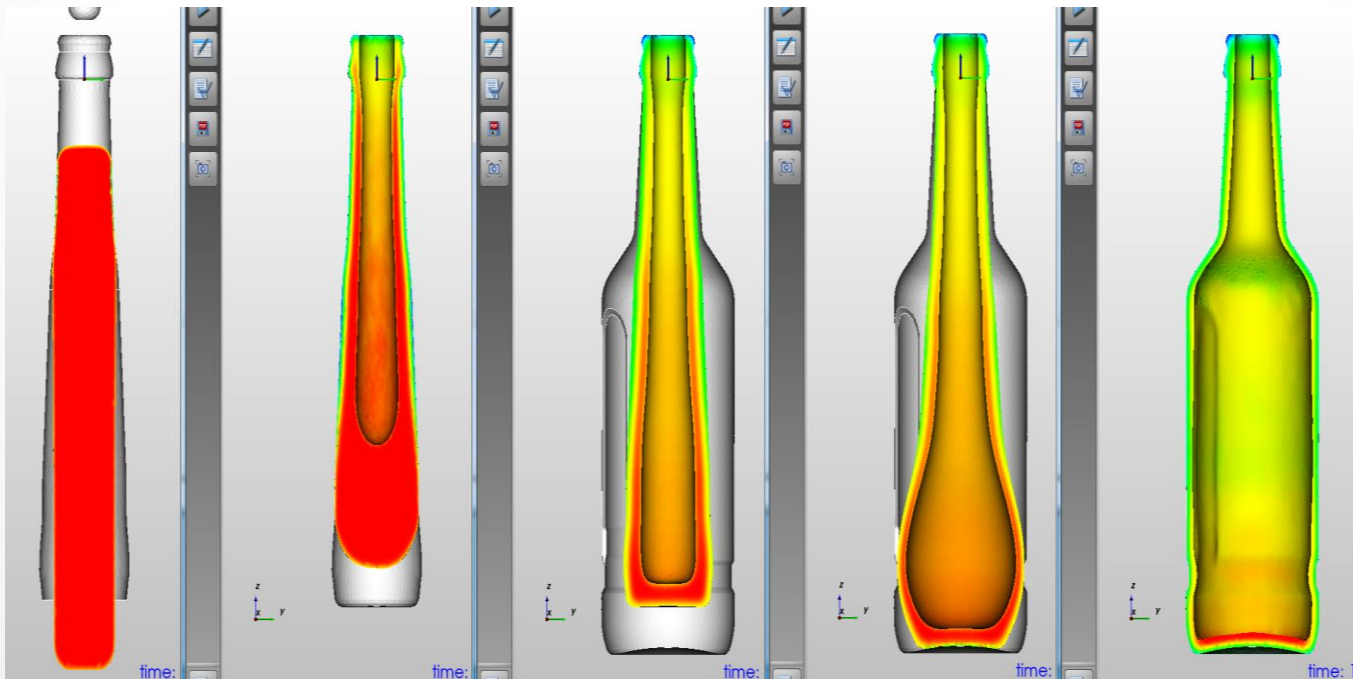
## 1. The blow and blow method:

The glass first is blown from below, into the blank moulds, to create a parison, or pre-container. The parison is then flipped over into a final mould, where a final blow blows the glass out, in to the mould, to make the final container shape.



## 2. The press and blow method:

The parison is formed with a metal plunger, which pushes the glass out, into the blank mould. The process then continues as before, with the parison being transferred to the mould, and the glass being blown out into the mould.



- When heated to a high temperature (1500°C), the raw materials liquefy.
- Specific amounts of molten glass or gobs are shaped in a parison mold by the blow-and-blow process or the press-and-blow process.
- The glass is then annealed at ~ 540°C to remove stresses and cooled under carefully controlled conditions to prevent distortion or fracturing.
- In all cases a stream of molten glass, at its plastic temperature (1050°C-1500°C), is cut with a shearing blade to form a cylinder of glass, called a gob.
- Both processes start with the gob falling, by gravity, and guided, through troughs and chutes, into the blank moulds.

# Considerations for Selection of Glass Containers

- When selecting a glass container for a food it is, important to be careful in choosing dimensions and finish so that the correct volume will be available, the product can be easily filled and dispensed, and a proper closure can be selected.
- Other important factors are its colour which can influence the type of light reaching the food and its ability to resist thermal shock.
- Though total quantity of glass used is steadily increasing, its market share in packaging has been diminishing due to the entry of newer and cheaper materials like plastics.
- Of late, the rediscovered virtue of recyclability of low weight and scratch resistant glass is likely to bring back its lost glory in food packaging.

- Recent developments in West have given rise to light weight scratch resistant glass bottles and researches are on for making unbreakable bottles.
- Novel features like vacuum ring; press-on and twist-off lug caps are being increasingly used.
- In India, though glass is used in a wide variety of single use packaging applications, the technology needs updating and the light weight bottle is yet a dream.
- The economic advantage of the returnable glass bottle as in case of soft drinks is still unbeatable.

# CHARACTERISTICS OF METALS AND METALLIC CONTAINERS

# Introduction

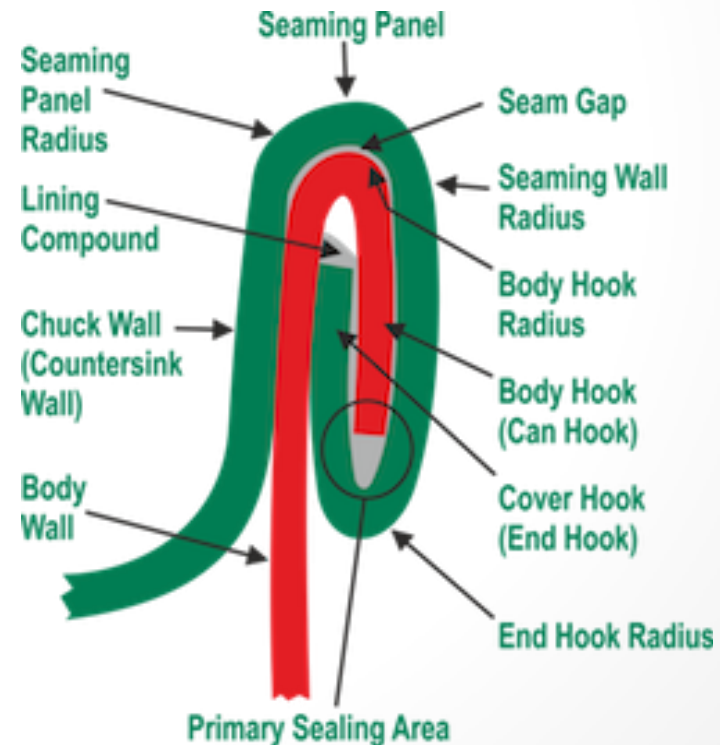
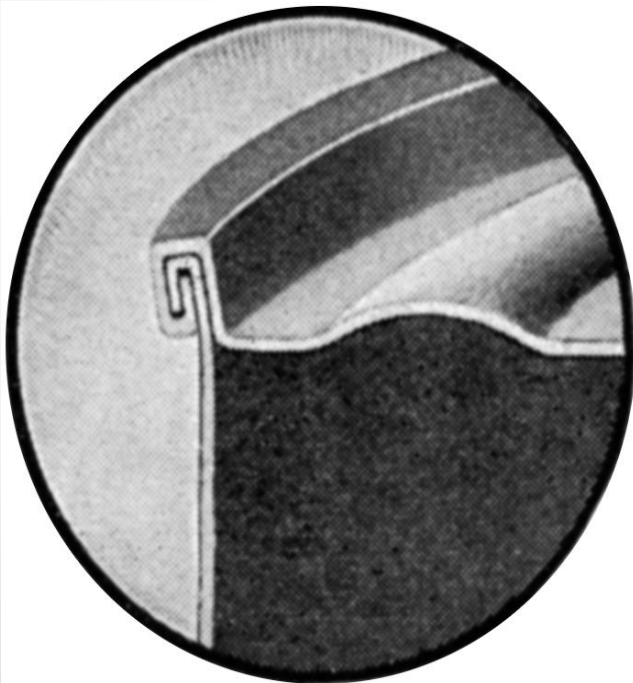
- Metal packaging materials are appropriate for packaging of light, moisture and oxygen sensitive products and carbonated beverages such as soft drinks, flavoured milk etc.
- Mainly aluminum is used as packaging material in the form of cans.
- Also tin plates are now a day used as metal packaging material.
- Tin plate is solid, heavy steel covered with tin to protect it against rust. It is used to package canned foods. It can be recycled and again can be used as an outer packing material.
- The earliest metals used by man were those found in native state, which were soft and easily workable. These include copper, silver and gold.
- The commercial packaging of food stuffs in metal containers began in the early 19th century.
- Metal cans, made from steel or aluminum, are widely used by the food industry to pack a wide range of foods.



## There are two basic types of metal cans:

1. Those that are sealed using a 'double seam' and are used to make canned foods:

Double-seamed cans are made from tinplated steel or aluminum and are lined with specific lacquers for different types of food.



2. Those that have **push-on lids** or **screw-caps** that are used to pack dried foods (e.g. milk or coffee powder, dried yeast) or cooking oils respectively.



# Tin plate

- “The term tin plate refers to low-carbon mild steel sheet varying in thickness from 0.15 mm to 0.5 mm with a coating of tin between 2.8 g/m<sup>2</sup> and 7 g/m<sup>2</sup> (0.4mm to 2.5mm thick) on each surface of material”
- The chemical composition of the base steel determines the corrosion resistance and mechanical properties of tin plate. For the packaging of acidic aggressive foods high purity type-2 steel is used



# Chemical composition of type-I steel

## Constituent (% Maximum)

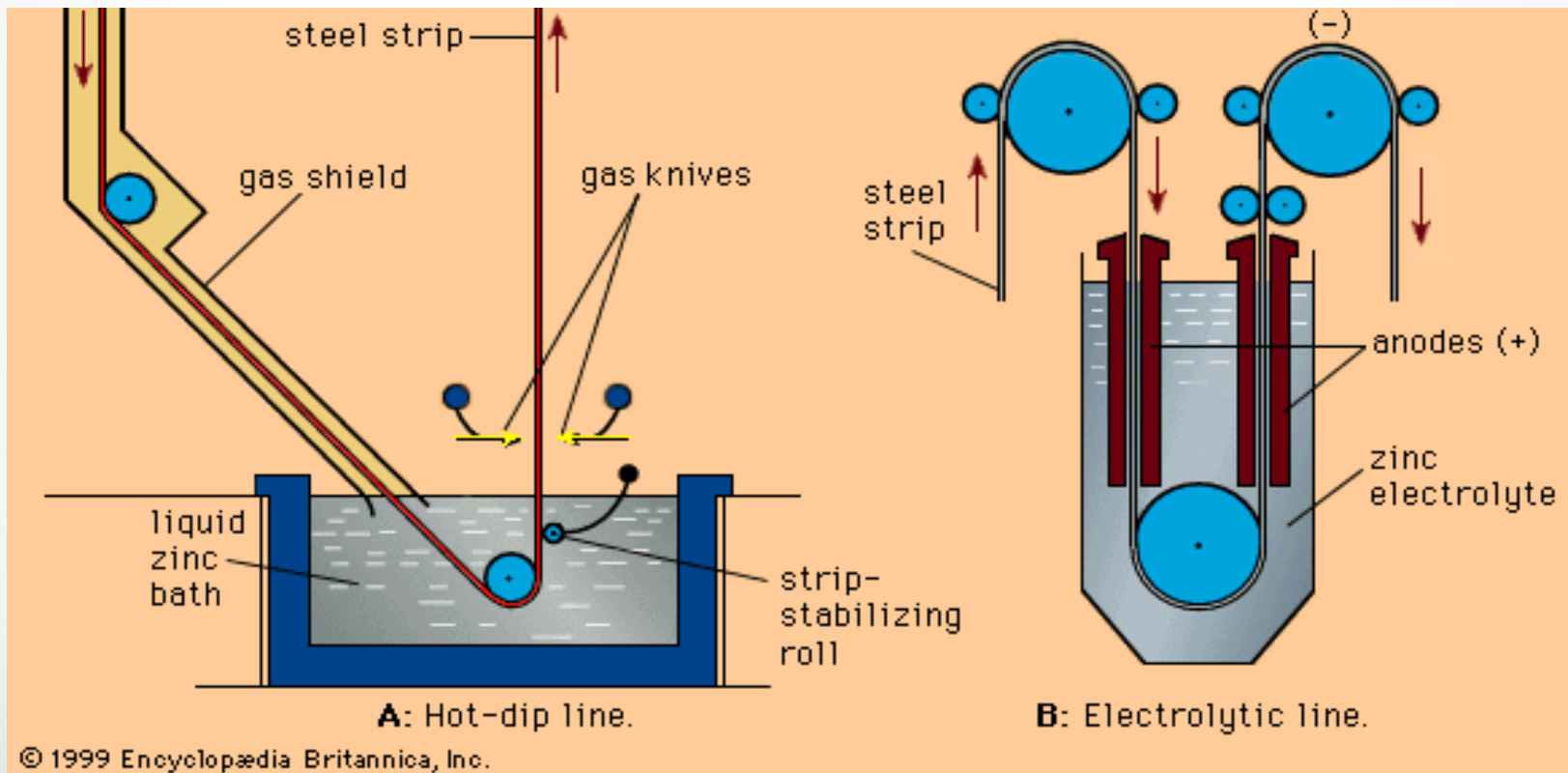
- Carbon - 0.13
- Manganese - 0.60
- Phosphorus - 0.15
- Sulphur - 0.05
- Silica - 0.01
- Copper - 0.06

For the fabrication of containers where high strength and rigidity is essential e.g. carbonated beverage ends, tin plate based on type 'N' steel or nitrogenized steel is used.

The chemical composition of nitrogenized steel is similar to type-2 steel except with the addition of 0.02% Nitrogen to increase the rigidity.

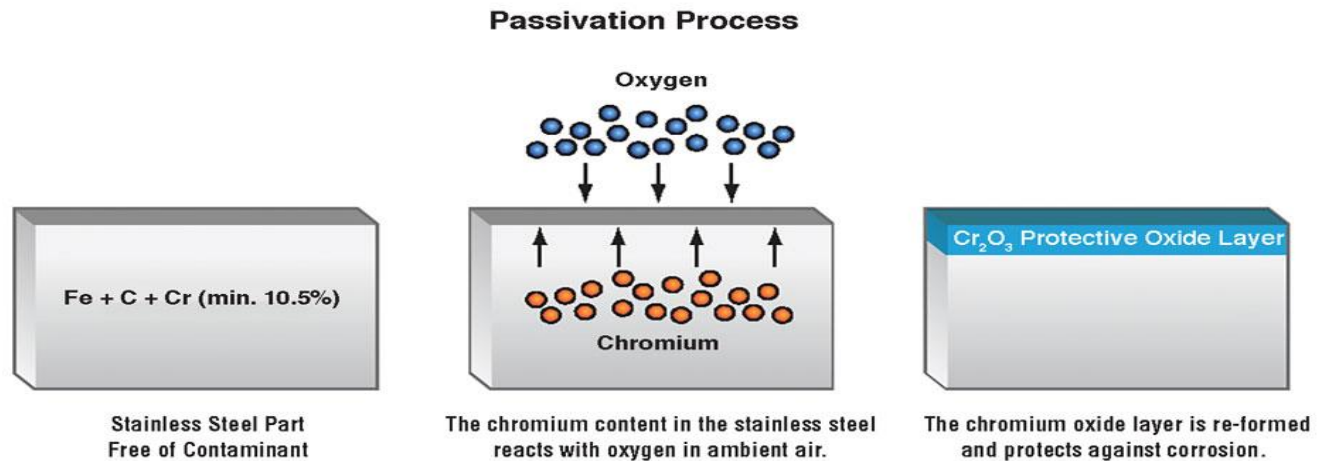
To make the tin plate corrosion resistant, the base steel plate is coated with tin. Tin is applied either by

- Hot dipping process
- Electrolytic deposition



Tin plate in addition to the corrosion resistance gained by tin layers, is further protected by two surface treatments i.e

- **Passivation:** The passivation treatment is a cathodic electrochemical process using sodium dichromate solution. The passivation stabilizes the surface by controlling the growth of natural oxide film.



- **Oiling:** Surface oiling is to lubricate the plate to reduce the surface scratching and adhesion. The most common lubrication system used is dioctyl sebacate (DOS) is applied by electrostatic precipitation or by direct immersion

Thinner gauge double reduced tin plate (DR) can also be used.

Tin plates with bright finish or stone finish are also available.

# Tin free steel

- The high cost of Tin created necessity for the alternative to tin. Japanese developed a printable/lacquerable duplex chromium/chromium oxide treated low carbon steel material known as tin free steel or TFS.
- TFS has a surface more acceptable for lacquer coatings, printings than tin plate.
- However, TFS is less resistant to corrosion than tin plate. Further, TFS containers cannot be soldered with Lead or tin. They are welded or organic adhesives are used.

## **Advantages of using metal cans**

- They have a high strength-to-weight ratio.
- They can be heat processed.
- They have excellent barrier and protective properties.
- They produce shelf-stable products that are safe and nutritious to eat and can be stored at ambient temperature.
- They are tamperproof.
- When sealed with a double-seam they provide total protection of the contents
- They can be made in a wide range of shapes and sizes.
- Ease of fabrication.

## **Limitations of metal cans**

- High cost of metal
- They are heavier than other materials, except glass, resulting in increased transportation costs for the finished product.



# Steel Cans

## Three-piece cans

- One of the most commonly used primary packaging containers for a wide variety of processed fruits and vegetables are the three-piece can or sanitary can.
- It is made from steel that is electrolytically coated on both sides with either a thin layer of tin (tin-plated steel) or a layer of chromium–chromium dioxide (tin-free steel).

Two main types of base steel are commonly used in can manufacturing:

**Type L:** It is very corrosion-resistant and is used in canning of very corrosive products, e.g., apple juice, berries, prunes, and pickles.

**Type MR:** It is more suitable for canning moderately to mildly corrosive products, e.g., grapefruit, peaches, peas, and corn.

- Plain, uncoated tin plate or tin-free plate can be used to make cans when the interactions between the food and the container are not significant or when the quality of the food is better in an uncoated can.
- However, to further improve the tin plate or tin-free plate for use with certain classes of food products, it is coated with a lacquer or enamel.
- There are certain desirable qualities that enamels (lacquers) should possess before being applied to food cans. They should:
  1. Be nontoxic
  2. Not affect the flavor or color of the food
  3. Provide a good barrier between the food and the container
  4. Be easy to apply to the tin plate
  5. Not peel off during sterilization or storage of canned product
  6. Have mechanical resistance to can manufacturing
  7. Be economical

## Common types of enamels used by the food industry are

No.	Coating	Typical Uses	Type
1	R-Fruit enamel	Dark colored berries and other fruits requiring protection from metallic salts	Oleo-resinous
2	C-Corn enamel	Corn, peas, and other sulphur-bearing products	Oleo-resinous suspended zinc oxide pigment
3	Citrus enamel	Citrus fruits and concentrates	Polybutadienes
4	Beverage can enamel	Vegetable juices; red fruit juices; highly corrosive fruits; noncarbonated beverages	Two-coat systems with various base coats and vinyl or acrylic top coats

Oleoresinous linings are the most common enamels used in the food industry. These are formulated to give a good barrier between the can and acid products. They include

- **R fruit enamel:** It is used to protect the natural pigment of highly colored food products such as berries, cherries, and beets.
- **C corn enamel:** It is used to prevent black discoloration in foods such as corn and peas. The C oleoresin enamel contains about 15% zinc oxide, which reacts with sulphides evolved during heat processing to form white or essentially colorless products.
- Epoxy linings are characterized by their heat stability. They do not impart flavor to the food and can be modified with phenolics for use with fruit products.
- Vinyl linings are used as double coatings in combination with oleo-resinous and phenolic enamels for highly corrosive products, e.g., fruit juices. They do not impart flavor to the food but have poor resistance to high temperatures. They are well suited for acidic products that do not need to be heat-sterilized and can be processed at temperatures below 100°C.
- Outer coatings can also be applied to the outer can surfaces to prevent corrosion. Outside coatings of acrylics, phenolics, oleoresins, and vinyls are usually pigmented. They must be able to survive the heat-processing treatment and be receptive to decorative coatings and inks.

# Aluminum Cans

- Aluminum is attractive, light, and strong, but requires lot of energy and raw materials to produce the packaging cans. The majority of cans of soft drinks, lids, foils etc are made from aluminum. Two-piece cans made of aluminum are commonly used for packaging fruit drinks and beverages. Aluminum cans were first used for food products in Europe.

Aluminum can be used

- For making rigid containers/cans
- For making Aluminum foil
- For making collapsible metal tubes

Aluminum is obtained from **Aluminum ore – Bauxite**

## **Properties of aluminum**

- It is lightest of the commonly used metals. Density is 2700 kg/m<sup>3</sup>
- Melting point is 660°C.
- High electrical and thermal conductivity.
- Soft, ductile and low tensile strength – i.e 93 MPa

## **Advantages of aluminum:**

- In comparison to tin plate & TFS, Aluminum is lighter and more ductile.
- Lower transportation costs, thus economical.
- It has a good weight-strength ratio
- It has a high quality surface for decorating or printing.
- Easier to recover or recycle.
- More resistant to corrosion as compared to tin plate.
- Easier to open (pull tab)
- 8. It is pleasant to handle.
- 9. Aluminum is non-toxic, odorless and does not have metallic taste.
- 10. Even thin aluminum foils are impervious to moisture & gases.

## **Disadvantages of aluminum**

- It cannot be soldered
  - Its chemical resistance is limited
  - Aluminum is softer than tin plate
  - Aluminum bleaches the pigments in food.
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# Uses

- For increasing strength, aluminum alloys contain Magnesium and Manganese.
- Pure or commercially pure aluminum (Type 1100 and 1050) is used for the manufacture of foil and extruded containers.
- Hardest grade (5182) alloy containing 4-5 % Magnesium and 0.35% Manganese is used for manufacture of carbonated beverage can ends.
- Two-piece aluminum cans are made by the draw-and-wall-iron (DWI) or the drawand- redrawn (DRD) process. The DWI process results in cans with thinner walls than the DRD process and is used to produce cans for carbonated drinks where the gas pressure supports the container. Thicker-walled DRD cans are able to withstand the head-space vacuum required in heat sterilization.
- Lacquers are applied internally to prevent interactions between the metal and the product. The type of lacquer used depends on the type of product packed. Epoxyphenolic or vinyl-based lacquers are commonly used.

# Aluminum foil

- Aluminum foil is usually defined as pure aluminum (not less than 99.4% purity) which has been rolled to a thickness not more than 0.152 mm.
- Commercial foils generally range in thickness of 30-70 gauge. In thinner gauges pinholes are problems in aluminum foils.

## Properties

- Aluminum foil is impermeable to light, gas, moisture, odors, solvents and has the stiffness. However, Aluminum foil is subject to abrasion, scratching and rupture.

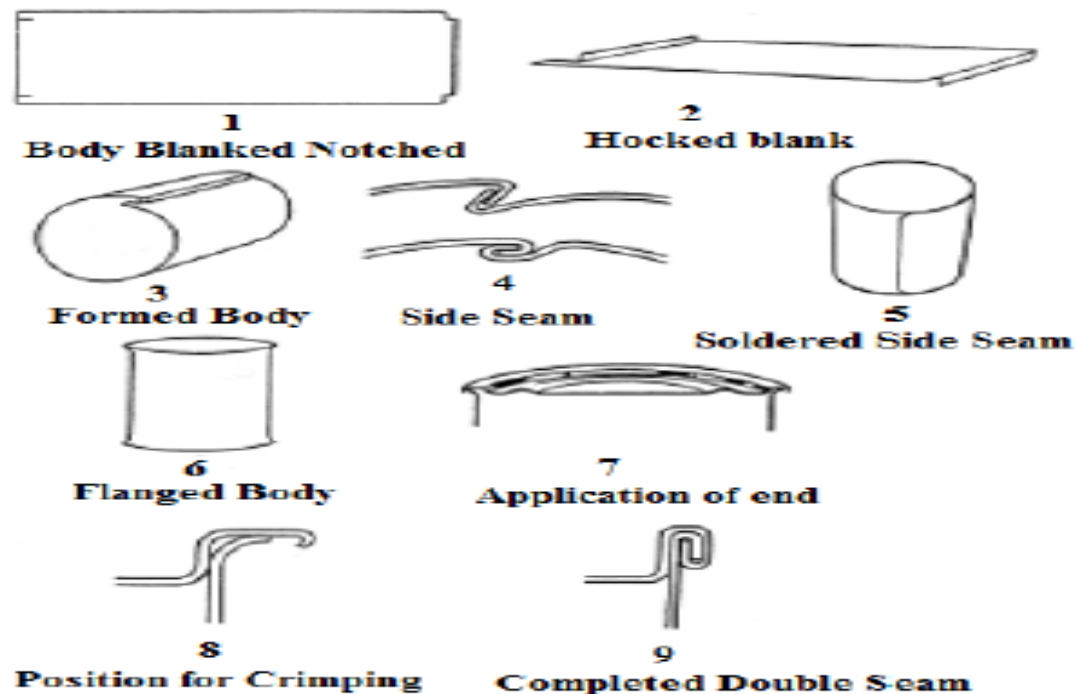
## Uses

- 0.009 mm thickness foils are used for wrapping confectionary, processed cheese
- 0.05 mm foils are used for milk bottle caps.
- 0.05 to 0.1 mm thickness is used for making rigid and semi rigid foil containers.
- Thin foils are used for laminates (eg. Tetrapak film etc.).



Thank you

- Three-piece cans are fabricated as shown in Figure 6.1. Sheets of tin plate or tin-free plate, with or without enamel coating, are cut into pieces to form the body of the can. Each body blank is hooked at the corners, flattened, and then seamed by soldering, cementing, or welding (Figure 6.1). The body blank is flanged, and the can bottom (manufacturer's) is double seamed onto the body. The can top is seamed on at the production line after the can is filled with product.



**Fig. 6.1 Construction of three-piece (sanitary) tin can**

Three-piece cans come in a variety of shapes and sizes. Examples of common can sizes used by the food industry are summarized in Table 6.2.

Two-piece drawn and ironed and two-piece drawn and redrawn cans are also made. The advantage of two-piece steel cans is that it is possible to eliminate the side seam and bottom sealing steps, resulting in improved structure and elimination of leakage problems; however, their production rate is slower than for three-piece cans.