Types of plastic used in packaging

1. *Polyethylene:*PE is structurally the simplest plastic and is made by addition polymerisation of ethylene gas in a high temperature and pressure reactor. A range of low, medium and high density resins are produced, depending on the conditions (temperature, pressure and catalyst) of polymerisation. Polyethylenes are readily heat sealable. They can be made into strong, tough films, with a good barrier to moisture and water vapour. They are not a particularly high barrier to oils and fats or gases such as carbon dioxide and oxygen compared with other plastics, although barrier properties increase with density. The heat resistance is lower than that of other plastics used in packaging, with a melting point of around 120°C, which increases as the density increases.

LDPE or low density PE is easily extruded as a tube and blown to stretch it by a factor of three times the original area. It is commonly manufactured around 30μm, with newer polymers allowing down gauging to 20 or 25 μm within a density range 0.910–0.925 g/cm^3.

LLDPE or linear low-density PE film has a density range similar to that of LDPE. It has short side chain branching and is superior to LDPE in most properties such as tensile and impact strength and also in puncture resistance. A major use has been the pillow pack for liquid milk and other liquid foods.

MDPE or medium-density PE film is mechanically stronger than LDPE and therefore used in more demanding situations. LDPE is coextruded with MDPE to combine the good sealability of LDPE with the toughness and puncture resistance of MDPE, e.g. for the inner extrusion coating of sachets for dehydrated soup mixes.

HDPE or high-density PE is the toughest grade and is extruded in the thinnest gauges. This film is used for boil-in-the-bag applications. To improve heat sealability, HDPE can be coextruded with LDPE to achieve peelable seals where the polymer layers can be made to separate easily at the interface of the coextrusion.

2. Polypropylene (PP): The high melting point of PP (160°C) makes it suitable for applications where thermal resistance is needed, for example in hot filling and microwave packaging. PP may be extrusion laminated to PET or other high-temperature resistant films to produce heat-sealable webs which can withstand temperatures of up to 115–130°C, for sterilising and use in retort pouches. The surfaces of PP films are smooth and have good melting characteristics. PP films are relatively stiff. The film is glass clear and heat sealable when casted.

It is used for presentation applications to enhance the appearance of the packed product. Unlike PE, the cast film becomes brittle just below 0°C and exhibits stress cracking below -5°C and hence has to be used in a laminate if the application requires deep freeze storage. OPP film, on the other hand, is suitable for use in frozen storage. PP is chemically inert and resistant to most commonly found chemicals, both organic and inorganic. It is a barrier to water vapour and has oil and fat resistance. Oriented PP film (OPP or BOPP) was the first plastic film to successfully replace regenerated cellulose film (RCF) in major packaging applications such as biscuit packing.

3. *Polyethylene terephthalate (PET or PETE):* PET can be made into film, extrusion coated on paperboard and extruded as sheet for thermoforming. Film thicknesses range from thinner than 12µm for most polyester films to around 200 µm for laminated composites. No processing additives are used in the manufacture of PET film. PET melts at a much higher temperature than PP, typically 260°C, and due to the manufacturing conditions does not shrink below 180°C. This means that PET is ideal for high-temperature applications using steam sterilisation, boilin-the-bag and for cooking or reheating in microwave or conventional radiant heat ovens. The film is also flexible in extremes of cold, down to -100°C. Heatsealable versions are available, and it can also be laminated to PE to give good heat-sealing properties.
PET is a medium oxygen barrier on its own but becomes a high barrier to oxygen and water vapour when metallised with aluminium. This is used for vacuumised coffee and bag-in-box liquids, where it is laminated with EVA on both sides to produce highly effective seals. It is also used in snack food flexible packaging for products with a high fat content requiring barriers to oxygen and ultra violet (UV) light. Metallised PET, either as a strip or as a flexible laminate, is used as a susceptor in microwaveable packaging.

4. *Polycarbonate (PC):* PC is a polyester containing carbonate groups in its structure. It is formed by the polymerisation of the sodium salt of bisphenolic acid with phosgene. It is glass clear, heat resistant and very tough and durable. PC is mainly used as a glass replacement in processing equipment and for glazing applications. Its use in packaging is mainly for large, returnable/refillable 3–6 litre water bottles. It is used for sterilisable baby feeding bottles and as a replacement in food service. (This polycarbonate is not to be confused with the thermosetting polycarbonate used in contact lens manufacture.) It has been used for returnable milk bottles, ovenable trays for frozen food and if coextruded with nylon could be used for carbonated drinks.

5. *Ethylene vinyl acetate (EVA):* EVA is a copolymer of ethylene with vinyl acetate. It is similar to PE in many respects, and it is used, blended with PE, in several ways. EVA with PVdC is a tough high-barrier film which is used in vacuum packing large meat cuts and with metallised PET for bag-in-box liners for wine.

6. *Polyamide (PA):* Polyamides (PA) are commonly known as nylon. However, nylon is not a generic name; it is the brand name for a range of nylon products made by Dupont. They were initially used in textiles, but subsequently other important applications were developed including uses in packaging and engineering. Polyamide plastics are formed by a condensation reaction between a diamine and a diacid or a compound containing each functional group (amine). The different types of polyamide plastics are characterised by a number which relates to the number of carbon atoms in the originating monomer. Nylon 6 and a related polymer nylon 6.6 have packaging applications. It has mechanical and thermal properties similar to that of PET and therefore similar applications.

It has good clarity and is easily thermoformed, giving a relatively deep draw. It provides a good flavour and odour barrier and is resistant to oil and fat. It has a high permeability to moisture vapour and is difficult to heat seal.

7. *Polystyrene (PS):* PS is an addition polymer of styrene, a vinyl compound where a hydrogen atom is replaced with a benzene ring. PS has many packaging uses and can be extruded as a monolayer plastic film, coextruded as a thermoformable plastic sheet, injection moulded and foamed to give a range of pack types. It is also copolymerised to extend its properties.
PS is easily processed by foaming to produce a rigid lightweight material which has good impact protection and thermal insulation properties. It is used in two ways. The blown foam can be extruded as a sheet which can be thermoformed to make trays for meat and fish, egg cartons, a variety of fast food packs such as the clam shell-shaped container, as well as cups and tubs. Thin sheets can be used as a label stock. The foam can also be produced in pellet or bead form which can then be moulded with heat and pressure. This is known as expanded polystyrene or EPS. It can be used as a transit case for fresh fish, with thick walls for insulation.

8. *Acrylonitrile butadiene styrene (ABS):* ABS is a copolymer of acrylonitrile, butadiene and styrene, with a wide range of useful properties which can be varied by altering the proportions of the three monomer components. It is a tough material with good impact and tensile strength and good flexing properties. ABS is either translucent or opaque. It is thermoformable and can be moulded. A major use is in large shipping and storage containers (tote boxes), and it has been used for thin-walled margarine tubs and lids.

9. *Polyvinyl acetate (PVA):* PVA is a polymer of vinyl acetate which forms a highly amorphous material with good adhesive properties in terms of open time, tack and dry bond strength. The main use of PVA in food packaging is as an adhesive dispersion in water. PVA adhesives are used to seal the side seams of folding cartons and corrugated fibreboard cases and to laminate paper to aluminium foil.

10. *Ethylene vinyl alcohol (EVOH):* EVOH is a copolymer of ethylene and vinyl alcohol. It is related to polyvinyl alcohol (PVOH), which is a water-soluble synthetic polymer with excellent film-forming, emulsifying and adhesive properties. It is a high-barrier material with respect to oil, grease, organic solvents and oxygen. It is moisture sensitive and, in film form, is water soluble.

Can making metals

Steel and aluminium are used for metal container and closure construction for food and drink products. Both are relatively low-cost materials that are nontoxic, having adequate strength and are capable of being work hardened.

1. Steel

Steel is used in the form of a low-carbon steel which is initially produced as blackplate. This is then converted into tinplate or tin-free steel (TFS) for container and closure manufacture.
Tinplate is created by electrolytically coating blackplate with a thin layer of tin. The tin is coated on both sides of the plate in thickness to suit the internally packed product and the external environment. Different thicknesses of tin may be applied to each side of the plate. Tin, plated in sufficient thickness, provides
good corrosion-resisting properties to steel, and is suitable for direct contact with many products including specific foodstuffs such as *white* fruits (e.g. peaches, apricots, pineapple and pears) and certain tomato-based products (e.g. tomatoes in brine and beans in tomato sauce). However, for most foods and drinks it is necessary to apply an organic coating to the inside surfaces of the tinplate container to provide an inert barrier between the metal and the product packed. This barrier acts to prevent chemical action between the product and container and to prevent taint or staining of the product by direct contact with the metal (see later). The tin surface assists in providing good electrical current flow during welding processes. Being a very soft metal, it also acts as a solid lubricant during the wall ironing process of forming twopiece thin wall cans.

TFS, also referred to as electrolytic chromium/chrome oxide coated steel (ECCS), is created by electrolytically coating blackplate with a thin layer of chrome/chrome oxide. This must then be coated with an organic material to provide a complete corrosion-resistant surface. The metallic layer of ECCS provides an excellent key for adhesion of liquid coatings or laminates to the surface. ECCS is usually marginally less expensive than tinplate. However, being a matt surface, after coating with clear lacquer it does not provide a reflective surface like tinplate. ECCS in its standard form is not suitable for welding without prior removal of the chrome/chrome oxide layer. The Japanese steel makers have developed modified tin-free metallic coatings for steel that do permit satisfactory welding of this material.

2. *Aluminium*

Aluminium for light metal packaging is used in a relatively pure form, with manganese and magnesium added to improve the strength properties. This material cannot be welded by can-making systems and can only be used for seamless (two-piece) containers. The internal surfaces of aluminium containers are always coated with an organic lacquer because of the products normally packed.

Types of glass in packaging:

1. White flint (clear glass) Colourless glass, known as white flint, is derived from soda, lime and silica.

This composition also forms the basis for all other glass colours. A typical composition would be: silica (SiO_2) 72%, from high purity sand; lime (CaO) 12%, from limestone (calcium carbonate); soda (Na_2O) 12%, from soda ash; alumina (Al_2O_3), present in some of the other raw materials or in feldspar-type aluminous material; magnesia (MgO) and potash (K_2O), ingredients not normally added but present in the other materials. Cullet, recycled broken glass, when added to the batch reduces the use of these materials.

2. Pale green (half white): Where slightly less pure materials are used, the iron content (Fe_2O_3) rises and a pale green glass is produced. Chromium oxide (Cr_2O_3) can be added to produce a slightly denser blue green colour.

3. Dark green: This colour is also obtained by the addition of chromium oxide and iron oxide.

4. Amber (brown in various colour densities): Amber is usually obtained by melting a composition containing iron oxide under strongly reduced conditions. Carbon is also added. Amber glass has UV protection properties and could well be suited for use with light-sensitive products.

5. *Blue:* Blue glass is usually obtained by the addition of cobalt to a low-iron glass. Almost any coloured glass can be produced either by furnace operation or by glass colouring in the conditioning forehearth. The latter operation is an expensive way of producing glass and commands a premium product price. Forehearth colours would generally be outside the target price of most carbonated soft drinks.

Corrugated fiberboard boxes

Corrugated fiberboard boxes are well known for their good stacking strength (when dry), easy availability and inexpensive cost. Corrugated fiberboard is the most common material used for shipping containers, and the regular slotted container (RSC). In a well-designed box, the load bearing panels have their flutes parallel to the direction of the anticipated load: for stacking strength the flutes should run vertically. When side-to-side strength is more important (in clamp handling, for example), it may be better for the flutes to run horizontally.

Corrugated fiberboard is easy to recycle, both from a technical and a logistical point of view. Used boxes are generally discarded in large, homogenous piles by factories, warehouses and retail stores – businesses which have an incentive to reduce their disposal cost by recycling. As a result, corrugated board has a very high recycling rate. Corrugated fiberboard has been used to make shipping containers for almost 100 years. A series of standard grades have been adopted by most countries. It is categorized in three ways: by the thickness and spacing of the fluted *medium*, by the weight of the *facings*, and by the quality of paper used.

The most widely used flute configurations are known simply as A, B, C, and E. The first corrugated materials were either coarsely fluted A-flute or fine B-flute. The intermediate grade, C-flute has now become the most commonly used type, being a compromise of the best qualitites of the other two. E-flute has very small flutes, and there are even finer grades called microflute, which are used as alternatives to solid fiberboard.

Dimension of commonly used flutes

Flute	**Flutes/meter**	**Flutes/ft**	**Flute height**
A	105 – 125	36 (± 3)	4.8mm or 3/16”
B	150 – 185	50 (± 3)	2.4mm or 3/32”
C	120 – 145	42 (± 3)	3.6mm or 9/64”
E	290 – 320	94 (± 4)	1.2mm or 3/64”

Single wall board (with 2 facings) is the most common form used for cases and trays. Double and triple wall boards are used for palletload-sized intermediate bulk containers, used for some dry ingredients in the food industry. At one extreme, single face board is soft and used for wrapping items like light bulbs and glass bottles. The other extreme is multi-wall laminated structures made into lightweight pallets.

Corrugated board has an important drawback: it can lose much of its strength (indeed, all of its compression strength) when it is wet. Further, the commonly used starch-based adhesives are also moisture sensitive. It makes good design sense, where possible, to design the box with minimal head space, allowing the inside products to help support the load. This will prevent the uneven collapsing of containers which can topple a palletload. Wax dipping or coating has been used for particularly wet contents, like broccoli which is shipped with ice, but this practice is diminishing because the wax causes problems during recycling.

Corrugated fiberboard boxes are increasingly being used as advertising media in point-of-purchase displays, and so higher quality printing is demanded. There are three options: direct printing, preprinted liners and litho lamination. The uneven surface of the board limits direct printing to relatively simple one or two color flexography. Ink jets can also print directly on a box, and ink jet printing is particularly well suited for variable short-run information like lot codes. Preprinted liners – high quality flexo printed facing materials –can be built in to the corrugated board at the point of manufacture. Litho lamination can produce the highest quality printing, including full color halftones. It is made by laminating lithograph printed paper to the already converted board.