# 4 Types, Forms, and Uses of Flexible Plastic Packaging

## 4.1 Types of Flexible Plastic Packaging

Flexible plastic packaging refers to a package or container made of flexible or easily yielding plastic materials that when wrapped up or filled and closed with a product can be readily changed in shape. The term is used to describe monolayer and multilayer packaging films having a thickness less than 250 μm and applies generally to bags, pouches, or wraps [1].

Flexible packaging has played an increasing role in containing a wide variety of products ranging from liquid and dry chemicals to food products. Because of this wide variety of products, the flexible packaging industry is constantly changing the characteristics of the packaging structures to meet the needs of the packers and consumers. Desired flexible packaging characteristics include optical clarity, rigidity, toughness, heat resistance, and recyclability.

Some of the key market converters in the flexible packaging industry are Amcor Ltd., Sealed Air Corporation, Sigma Plastics Group, American Packaging Corporation, Amerplast, ProAmpac, Bischof + Klein SE and Co. KG, Bryce Corporation, Clondalkin, Constantia Flexibles International GmbH, Coveris, Dai Nippon Printing, Flextrus AB (Part of AR Packaging Group), Huhtamaki Group, Innovia Films, Mondi Group, Printpack, Schur Flexibles Group, and Sonoco Products [2].

The main types of flexible plastic packaging are single film or monolayer and multilayer packaging. All types of flexible plastic packaging create a large amount of waste that must be disposed of or recycled.

### *4.1.1 Monolayers*

A monolayer film is produced with a single film layer typically comprising low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), or polypropylene. The monolayer film is made from either a single polymer or a blend of several polymers. A monolayer film is an economical choice when single

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layer film properties are sufficient to protect the product from oxygen transfer, water vapor transfer, or other gaseous or greasy substances.

Monolayer, single material flexible packaging is commonly found in plastic bags, produce bags, and self-sealed food storage bags. Monolayer, single material flexible packaging constitutes about half of flexible packaging waste. It is currently collected and mechanically recycled using store drop-off programs or in limited municipal curbside collection programs.

### 4.1.2 Multilayers

Most packaging, especially that involved in the flexible packaging, is made up of a plurality of layers (ranging from 3 up to 20 layers) of a variety of plastic films, adhesives, inks, and metals. These layers are firmly adhered together by either the inherent bonding action of the polymers themselves or adhesives. A multilayer packaging film can be coextruded or laminated.

There is, currently, no practical method of disposing of or recycling this heterogeneous, multi-ply packaging material after use. There has, thus, been a difficulty in recycling multilayer flexible plastic packaging due to the combination of different materials in the laminate. Flexible plastic packaging cannot be readily separated back into the individual components. In the combined form, certain layers melt at different process temperatures than other polymer layers, and some layers such as an aluminum coating do not melt at all at polymer processing temperatures. Most discarded multilayer packaging films are not accepted in Material Recycling Facilities (MRFs) and are disposed of by incineration or burial in landfills.

#### 4.1.2.1 Coextruded Films

In coextrusion, separate extruders are used to produce layers of different polymers. The layers join together in the molten state in the extrusion die. The combined layers then pass through the die to be cast or blown into one multilayer film. The combination of several layers of different materials improves the mechanical and physical properties of the film including puncture, tear, and heat resistance, as well as moisture and oxygen barrier properties.

Multilayer films find many applications in the high-volume food packaging industry. The combination of several polymer layers significantly increases shelf-life by controlling the transmission rate of oxygen, carbon dioxide, and moisture, which is a key factor in preserving the freshness of fresh produce for longer period of time.

Multilayer films constitute about 17% of all produced packaging films [3]. The majority of today's packaging films include more than one polyethylene layer. LLDPE layer, which is widely used in food packaging, is sometimes combined with HDPE, which is stiffer, harder, and has higher tensile and bursting strength but lower impact and tear strength than LLDPE. The combination of LLDPE and HDPE provides superior mechanical properties and allows for thinner films. Because the polyethylene films have poor gas barrier properties, they are often combined with polar polymers such as polyamide, ethylene vinyl alcohol (EVOH), or poly(vinylidene chloride) (PVDC). For example, a barrier cereal liner film (bag-in-box) consists of several layers of HDPE (as moisture barrier), EVOH (as aroma barrier) and ethylene vinyl acetate (EVA) (as sealant), e.g., HDPE-tie layer-EVOH-tie-EVA [4]; whereas films that require higher mechanical strength and/or improved heat resistance (microwavable and hot-filled food packaging) often include a layer of polypropylene. Besides superior heat resistance, polypropylene provides the basic strength of the packaging and contributes to the moisture barrier.

Many multilayer barrier films for food packaging consist of a combination of polyethylene and polyamide 6 (nylon 6 or PA6), where polyethylene acts as a barrier for moisture and polyamide 6 as a barrier for oxygen, thus significantly extending the shelf life of the packaged food. Such packaging cannot be produced with a monomaterial polyethylene film, as the layer thickness to achieve sufficient barrier properties would become too high. The addition of polyamide 6 in the multimaterial solution reduces the total layer thickness and improves the mechanical integrity of the film resulting in less rupture during transportation and logistics. This leads to a lower food waste percentage and, thus, to a significantly better carbon footprint in a life-cycle analysis [5]. However, the recycling of the multilayer packaging films has several problems. The hydrophilic polyamide and hydrophobic polyethylene are not compatible with each other and there is a 40−50°C difference between their processing temperatures. Thus, the conventional compounding methods are not suitable for their homogenization, and their separation is not feasible. DSM and APK developed a solvent-based process, the so-called Newcycling® technology (see Chapter 7, Section 7.3), for the recycling of multilayer polyethylene/polyamide 6 packaging waste [5].

Further, the coextrusion of dissimilar polymers requires tie resins because the different layers do not adhere well to each other. A typical packaging film for fresh produce consists of 4 to 7 layers. Two examples are LLDPE-tie-EVOH-tie-LLDPE and LLDPE-HDPE-tie-EVOH-tie-HDPE-LLDPE among many others. Most of these multilayer films consist of at least 50% olefins (see Table 4.1).

#### 4.1.2.1.1 Tie Layers

To improve adhesion between poorly adhering layers, special adhesive polymers or tie resins have been developed. Tie layers are functional polymers coextruded between two chemically different polymers to improve the adhesive strength of a multilayer structure. These resins are commonly ethylene copolymers of polar and nonpolar monomers and with or without functional reactive groups [7] (see Table 4.2).

Typical nonreactive tie resins include EVA and ethylene methyl acrylate. Other important tie resins include acid-modified olefin copolymers

**Table 4.1** Common Coextruded (Multilayer) Flexible Packaging Films

| Multilayer | Structure | Application |
|---|---|---|
| LLDPE/HDPE/LLDPE | 15/70/15 | Grocery bags |
| HDPE/LLDPE/HDPE/EVA | 30/30/30/10 | Cereal liners |
| Paper-LDPE-Al-LDPE | Laminated packaging | Liquid/paste packaging (juice, milk cartons) |
| PET/Tie/LDPE/Al/LDPE | Laminated packaging | Liquid/paste packaging (juice, milk cartons) |
| LLDPE-Tie-EVOH-Tie-LLDPE | | Fresh meat |
| LLDPE-Tie-PA-Tie-LLDPE | 40/5/10/5/40 | Fresh meat |
| LLDPE-Tie-PA-EVOH-PA-Tie-LLDPE | 30/5/10/10/10/5/30 | Fresh meat |
| LLDPE-HDPE-Tie-EVOH-Tie-HDPE-LLDPE | 20/20/5/10/5/20/20 | Processed meat |

*Al, aluminum; EVA, Ethylene vinyl acetate; EVOH, Ethylene vinyl alcohol; HDPE, High-density polyethylene; LDPE, Low-density polyethylene; LLDPE, Linear low-density polyethylene; PA, Polyamide; PET, Poly(ethylene terephthalate).*

**Table 4.2** Typical Tie Layer Resins

| Tie Layer Resin | Adherent Layer |
|---|---|
| Ethylene vinyl acetate (EVA) | HDPE, LDPE, PP, PS, PVDC |
| Ethylene methyl acrylate (EMA) | HDPE, LDPE, PP, PS, PVDC |
| Ethylene acrylic acid (EAA) | PA, PET, ionomers, LDPE, EVA, EMA, Al |
| Ethylene-grafted maleic anhydride (AMP) | PA, Al, EVOH, cellulose |

such as ethylene acrylic acid (EAA) and ethylene methacrylic acid (EMAA). They are considered nonreactive as no or only a small portion of the acid groups undergo chemical reactions such as esterification. These resins still provide excellent adhesion to many polar polymers because they form strong hydrogen and polar bonds with many polar polymers such as nylon and polyesters.

The most important reactive tie layer resin is anhydride-modified polyethylene (AMP).[1] This adhesive resin is frequently employed when polyolefins have to be bonded to polyamides (nylons) or to EVOH copolymers. The anhydride reacts with amine end groups to form imides and with alcohols to form ester crosslinks. A very important parameter is the amount of functionality in the tie resin. The anhydride level is usually less than 1% because a higher percentage is often cost prohibitive and/or does not yield enough improvements in performance and adhesion (peel strength) to justify the higher cost. AMPs can also be employed when no chemical reaction between the two resin layers takes place, as it is the case with PET and PVDC.

In the case of metalized films or aluminum foils, tie resins with acid functionalities are used. Typically, copolymers of ethylene and acrylic acid and/or methacrylic acid (EAA, EMAA) are employed for these applications that also bond well to nylon, whereas acrylate-modified olefin resins are a good choice when the film has to adhere to inks and polyesters.

[1] Anhydrides are usually grafted onto a polyethylene backbone. These resins are much more reactive than ordinary anhydride–ethylene copolymers with same percentage of anhydride because there is less steric hindrance involved, that is, the grafted anhydride groups are more accessible.

### 4.1.2.2 Laminates

Lamination adheres multiple film layers together with a bonding agent. Adhesive is applied to the less absorbent layer. A second layer is then pressed against the first to produce a multilayer film. The process is repeated for additional layers.

### 4.1.2.3 Adhesives

The different types of adhesives currently used to laminate flexible packing layers include: (1) one component solvent-based; (2) two component solvent-based; (3) one component water-based; (4) two component water-based; and (5) two component solvent-free type adhesives (2005, **US2005163960** A1, NORTHWEST COATINGS, LLC).

Solvent-based adhesives have inherent limitations that include: (1) emission of volatile organic compounds (VOCs); (2) high cost of solvent recovery equipment; (3) flammability; and (4) analysis and control of residual solvents in the package.

Water-based adhesives have inherent limitations that include: (1) need for extended drying equipment; (2) effect of heat used in drying on thermally sensitive packaging films; (3) variable drying rates dependent on ambient humidity level; and (4) difficulty in starting and stopping due to adhesive drying on the application equipment (2005, **US2005163960** A1, NORTHWEST COATINGS, LLC).

Any two component system (solvent-based, water-based, or solvent-free) has inherent disadvantages that include: (1) the need for accurate mixing of the two components; (2) limited pot life of the mixed components; and (3) the time delay (typically 2–5 days) required for the two components to react to achieve the final adhesive properties. Other limitations associated with two component solvent-free adhesives include: (1) the need for heated application equipment and (2) residual toxic aromatic amines, which are by-products of isocyanate-based curing systems (2005, **US2005163960** A1, NORTHWEST COATINGS, LLC).

Radiation-curable adhesives can potentially be used as flexible packaging laminating adhesives. They may offer: (1) stable one-part compositions; (2) little or no VOCs; and (3) full adhesive performance immediately on cure. UV-curable laminating adhesives require at least one layer of packing material that is sufficiently transparent to allow penetration of UV light to cure the adhesive. Electron beam curing has the added advantage of being able to penetrate opaque or printed packaging materials to cure the adhesive (2005, **US2005163960** A1, NORTHWEST COATINGS, LLC).

### 4.1.3 Metalized and Metal Foil Containing Films

For more demanding packaging applications, plastic films are metalized with a very thin metal coating layer (about 400−500 Å), usually aluminum, deposited on the film as a vapor. The most commonly used polymers for metalized films are polypropylene and PET. The aluminum layer greatly reduces the moisture and oxygen transmission rate and also provides a metallic and glossy appearance.

Flexible packaging films are often laminated to a metal foil, typically of a thickness of about 6−10 μm, so that a desired combination of properties of both materials can be obtained. Aluminum foil laminated with plastic films is also used as labels in flexible plastic packaging. These labels should not be confused with metalized film. Metal foil labels are extremely problematic in two areas. First, they alarm metal detectors that are employed at the beginning of the recycling process to protect machinery. When this occurs, the entire package containing the offending part is discarded and landfilled. Secondly, if they happen to pass through the process into the extruder, they can quickly blind a melt filter causing a pressure upset, which automatically shuts down the process for safety [7a].

The applications of these films in flexible packaging include packaging of food products, medical items, and industrial products, such as household electrical appliances and electronic items.

Aluminum cannot be microwaved and is not recyclable [6]. In recent years, the amount of aluminum foil used in packaging has decreased to reduce recycling problems.

#### 4.1.3.1 Metalized Polypropylene

The surface of polypropylene film is nonpolar with a low surface energy or tension of about 30 mN/m (dyne/cm) and, hence, lacks strong adhesion to metals. To improve adhesive properties, the polypropylene film is, thus, often treated with corona discharge plasma to increase the surface energy to a minimum surface energy of 38 mN/m [8].

The applications of metalized polypropylene film are numerous. Metalized biaxially oriented polypropylene (BOPP) is used in food packaging for meat, potato chips, biscuits, and other food products. Metalized BOPP is also used for decorative packaging or gift wrapping as metalized BOPP lends a sparkle to packages that paper and others do not. Personal care industries use metalized BOPP films to create containers lined with water-resistant and gas-resistant packages for preservation and protection [9]. Characteristically, a multilayer potato chip bag is composed of a metalized BOPP (inside layer), LDPE (middle layer), BOPP (middle layer), and Surlyn® (outermost layer and sealant).

Major companies operating in the global metalized BOPP market include Jindal Poly Films, VacMet, Uflex, Formosa Plastics Group, DK Enterprises, Mondi Group, Viam Films, Vitophel, and General Binding [9].

Metallized cast polypropylene film (CPP film) with good bonding between a metallized layer and CPP provides excellent barrier properties to oxygen and moisture. Retort CPP film has strong heat sealing properties, good heat resistance, and low temperature impact performance. Indicative applications include bread or noodle packaging, retort pouch, dry fruit packaging, and meat product packaging.

Metalized polypropylene packaging films, such as crinkly bags and wraps, are not currently recycled and put in the trash bin.

#### 4.1.3.2 Metalized Poly(ethylene terephthalate)

Metalized PET films cover an ever-growing range of applications, making it one of the fastest growing segments in the flexible packaging market. Metalized PET films provide an optimal solution for high oxygen and general gas barrier levels, aroma and flavor retention, and significant improvement in water vapor barrier. Metalized PET film is also proven to achieve special optical properties or a metal look for decorative applications. Although the metalized PET film market continues to grow, there are no established sustainable solutions to recover and recycle post-consumer and postindustrial metalized PET films waste. Unlike PET bottle recycling, which is a viable and profitable business, metalized PET films are discarded as waste and end up in the landfill. Similarly, trim scrap generated during the process of making metalized PET films has traditionally been discarded. The absence of collection schemes for metalized PET films makes a poor business case for the technology to be designed for this material. Currently, there are no recycling facilities for metalized PET films (2014, **WO2014162238** A2, JAIN PRANAY).

There are numerous issues that make recycling of PET films difficult. The intrinsic viscosity of metalized PET film is typically less than 0.6 dL/g, making it unsuitable for many applications such as sheet extrusion/thermoforming after recycling (2014, **WO2014162238** A, JAIN PRANAY).

## 4.2 Forms of Flexible Plastic Packaging

The most common forms of flexible plastic packaging are:

- bags,
  - T-shirt bags,
  - wave top bags,
  - soft loop handle bags,
  - die cut handle bags,
- wraps,
  - shrink wraps,
  - stretch wraps,
  - bubble wraps,
  - twist wraps,
- pouches/sachets,
  - stand-up pouches (SUPs),
  - lay flat/pillow pouches,
- labels and sleeves.

### 4.2.1 Bags

Plastic bags (of thin film) are usually made of LDPE or HDPE and also of polypropylene. Common uses include bags for shopping, household garbage, dry cleaning, newspapers, frozen foods, fresh produce, agricultural products, medical and biohazard waste, antistatic bags, etc.

Plastic bags are inexpensive to mass produce, relatively easy to transport due to their lightweight, and have the ability to fold up to a small size. They are water resistant and add virtually no weight to the goods they carry. Plastic bags are used once and discarded as trash, typically ending up in landfills or incinerated, adding to air pollution. Many plastic bags escaping the disposal process end up in gutters, sewers, waterways, or in the sea creating a modern menace for the environment [10].

### 4.2.2 Wraps

Plastic wrap is a generic term commonly used to describe a variety of flexible packaging products. Plastic wrap is most often referring to industrial plastic wrap for securing pallets or food grade plastic wrap.

Food plastic wrap, also known as cling film, or food wrap, is a thin plastic film commonly used for sealing and securing food items in containers to keep fresh. Food plastic wrap is sold in rolls or more typically sold with a roll in a box that has a cutting edge on it. Most monolayer film wraps range in thickness from 0.5 to 2 mil, and at such low thickness, they are highly flexible and generally not able to support their own weight.

#### 4.2.2.1 Shrink Wraps

A shrink wrap film is a heat-activated LDPE film that wraps around an object or a cluster of objects such as cans or bottles (see Fig. 4.1). Shrinkage occurs when the film absorbs energy, typically through the form of heat energy (e.g., a heat gun), causing the molecule chains to return to a more natural arrangement. The manufacturing process of LDPE film allows the shrink potential around a product to be between 50 and 70% in the machine direction (MD), or length of the film, and 5 to 25% in the transverse direction (TD), or width of film. The film casts to the product, creating a tight unitized pack. This provides additional shipping, palletizing, and handling benefits compared with unitizing and packaging products within a corrugated box.

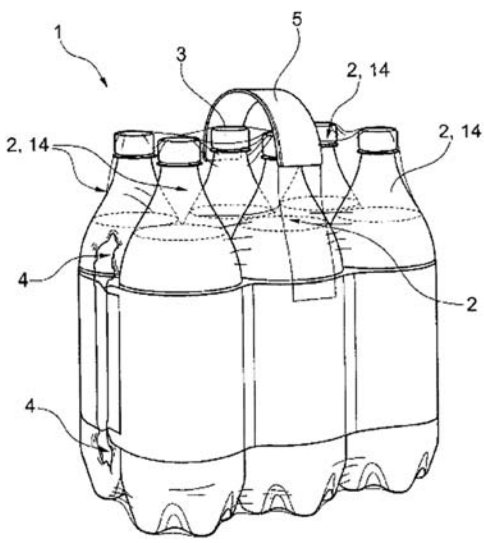


**Figure 4.1** Cluster pack having six bottles encased by a shrink film (2014, **DE102012016340** A, KHS GMBH). 1, Cluster pack; 2, Six PET bottles; 3, Shrink film (LDPE); 4, Shrink holes; 5, Carrying plastic strip; and 14, Corner container.

The following types of shrink wraps are used [11]:

Centerfold shrink wrap: This is one of the most common types of shrink wrap for retail packaging. Centerfold shrink wrap is folded in half length ways and placed on a roll. This allows users to slide the product being wrapped between the film, seal the open ends, and then apply heat. Centerfold shrink wrap is most commonly made from polyolefin and PVC.

Shrink sleeves: This is another very common type of shrink wrap for retail packaging. Shrink sleeves are often printed on and placed over bottles to brand products. Shrink sleeves often have a lower maximum shrink rate to keep from distorting printing.

Shrink tubing: The main difference between shrink tubing and shrink sleeves is that shrink tubing is often on a continuous roll. Shrink sleeves are precut to fit the product being packaged. Shrink tubing is often made from polyethylene or PVC. Tubing made from PVC is often used for retail packaging longer objects, while polyethylene tubing is often used for packaging cases of liquids and canned products.

Shrink banding: This is another form of tubing or sleeve except much smaller. Most people are familiar with shrink banding as a safety seal wrapped around over-the-counter medicines and toiletries. Shrink banding is often made from a PVC shrink wrap and requires a low shrink temperature. Shrink banding often comes with easy-to-open perforations. Most shrink banding is custom made to fit the specific bottle being packaged, but some companies do stock a lot of different banding sizes.

Shrink Bags: These have three enclosed sides and one open side. Users insert a product inside the bag, seal the open end, and apply heat. Shrink bags are most commonly available in polyethylene or PVC.

Pallet shrink wrap bags: Before the popularity of stretch film, pallet shrink bags used to be the preferred method of stabilizing and protecting pallet loads of products. Pallet bags are normally made from 3−6 mil clear LDPE shrink wrap. Pallet bags are often shrunk with a propane heat gun. They are used to stabilize and protect products during transport.

#### 4.2.2.2 Stretch Wraps

Stretch wrap or stretch film is a highly stretchable plastic film that is used in packaging and shipping to wrap around items to keep them in place. The elastic recovery of stretch wrap keeps the items tightly bound. In contrast, shrink wrap is applied loosely around an item and shrinks tightly with heat. Stretch film is frequently used to unitize pallet loads, and it may also be used for bundling smaller items such as food (e.g., fruits).

Stretch film also finds applications as diverse as wrapping of furniture and airport luggage. Stretch wrap is usually made from LLDPE.

Some of the most important types of stretch wraps, as described by IPS Packaging [11a] are:

Cast stretch film, like blown stretch film, is created using an extensive manufacturing process known as cast extrusion. This process requires the continuous propelling of thermoplastic material through a flat die onto a chilled roll. The film thickness is then determined by how fast the casting roll pulls the plastic away from the die. This process causes cast films to have excellent clarity, which allows users the ability to see the wrapped products.

This film, unlike blown film, is extremely quiet when coming off the roll and is easier to stretch. Cast stretch film also offers two-sided cling that allows products to stay securely wrapped during shipping processes. While cast film has excellent qualities, including a lower price tag from blown film, it does not stand up to blown film in holding power and tear resistance. Cast stretch film is initially easier to stretch, but because it is less dense, the film does not have as strong of a stretch memory.

Blown stretch film is manufactured by a process known as blown extrusion. This process consists of plastic melt being pumped through a circular slit die, to create a thin walled tube. Air is then introduced to the tube, allowing the volume of air contained to stretch the tube to the desired width. On top of the tube, an air ring blows onto the film to cool it. This process of cooling the film allows the blown film to be tougher and more resilient to other types of film.

Because blown film is tougher than most other films, it also has a higher tear resistance. This becomes an advantage when securing loads that may have sharper edges susceptible to breaking through less dense films. Blown films also have a higher degree of memory once stretched, which allows for packages to stay better secured. While blown film has the advantage of higher tear resistance and strength due to its manufacturing process, this also results in higher costs to consumers and poorer film clarity. Blown film is also a bit noisier than most films, including cast film.

Hand stretch film is designed specifically to be applied manually. It is also referred to as hand film, hand stretch wrap, hand wrap, or manual pallet wrap. It is typically utilized in lower capacity packaging operations. However, the efficiency of manual stretch wrap packaging should be regularly reevaluated against potential benefits of upgrading to a machine wrapper. Choosing the right stretch applicator will result in more efficient and cost-effective packaging operations.

Machine stretch film is designed to be applied with a stretch wrap machine. It provides many advantages over hand film including faster and more efficient packaging, reduced packaging material costs, safer application, more secure loads, and more. Common machine stretch film types are cast machine stretch film, blown machine film, and prestretched films.

Prestretched film is stretched close to its ultimate breaking point before being wound onto rolls. As a result, the film does not require as much stretching energy as the standard stretch film to accomplish the same wrapping force. Prestretched film consumption can be one half of that of traditional stretch films, allowing for vast cost savings.

Stretch wrap films can only be recycled in a special process and therefore cannot be put in the curbside recycling bin.

#### 4.2.2.3 Bubble Wrap

Bubble wrap is a flexible plastic film made from LDPE containing numerous small air pockets, and is used in cushioning items during shipment. Standard average bubble diameter is 6.0−25.4 mm and height is about 4 mm. Bubble wrap is commonly used for packing fragile items.

Bubble wrap must be flattened before it can be recycled. The bubble wrap needs to be a flat sheet to be processed with other types of similar stretch plastics. Once flattened, the bubble wraps and similar plastics are taken to a facility to be ground up and turned into plastic pellets. Those pellets can then be reused to create other plastic products.

#### 4.2.2.4 Twist Wraps

Twist wrapping is a particular method of closing complete wrappings for packaging of goods. A prerequisite for the use of twist wrapping is that the film must exhibit neither tear starting nor tearing-off at the twist points, but on the other hand, it must be sufficiently stiff so that no shrinkage or crumpling occurs during twisting. While early twist wrappers were made mostly from cellophane, modern twist wrappers are made of nonoriented (cast) polypropylene film. This packaging method is used for the complete wrapping of relatively small goods items, including round articles such as candies, bottles, candles, rolls of circular candies, chocolate bars, marzipan bars, or the like (1987, **EP0217388** A2, HOECHST AG). This type of packaging is very large in piece count, but it represents a small weight percentage of the total flexible plastic packaging.

### *4.2.3 Pouches, Sachets*

Pouches and sachets are small bags comprising two side flat sheets that are flexible and sealed along the edges to form a compartment, whose volume is dependent on the relative position of the walls. There is no clear distinction between a pouch and a sachet other than the common understanding that a sachet is smaller.

There are mainly two types of pouches: stand-up pouches (SUPs) or free-standing pouches and lay flat or pillow pouches. Conventional SUPs are generally constructed by forming a gusset in the bottom to provide a flat bottom surface or base for the upper portion of the pouch. SUPs are fabricated from two or more layers of laminated materials such as PET, BOPP, nylon, polyethylene, and other polymers, aluminum foil, and specialty materials. The PET, nylon, or BOPP offers good clarity, rigidity, and heat resistance, while the polyethylene offers a sealant layer to seal the bag closed using heat and pressure. The heat resistance on the outer layer is used to resist sticking to the high temperature sealing jaws of the packer machine. A printed layer is applied inside on the contact surface either on the outer film or the inner film in such a laminate before adhesion of the inner film to the outer film and is then visible through the transparent outer film. The pouch's walls have a thickness in the range from 2 to 5 mil (0.002−0.005 in or 0.051−0.127 mm), and while flexible, they have a degree of stiffness. SUPs dominate the types segment in terms of both revenue and growth rate.

On the basis of product type, the SUPs can be distinguished into aseptic, standard, retort, and hot-filled pouches. Aseptic segment is anticipated to dominate the global market in terms of revenue over the period 2018 to 2025. In terms of form, the SUPs can be distinguished into round bottom, rollstock, K-style, plow/folded bottom, flat bottom, and others. Round bottom SUPs are popularly used across several application industries as they are ideal for packaging products weighing less than one pound. K-style is the second most popular segment after round bottom pouches. SUPs are available in three closure types, namely, top notch, zipper, and spout. Top notch pouches dominate the global market due to the ease of usage and reclosability [12].

Flexible pouches are currently used in the packaging of a broad variety of products, from food and beverage products to cleaning supplies and other household items. Single-use plastic sachets allow low-income consumers in developing countries to buy small amounts of quality products that would otherwise be unaffordable to them. These products tend to provide hygiene or nutrition benefits. Despite the numerous benefits, pouches and sachets also pose a serious waste challenge. These multilayer flexible packaging materials are not currently recycled and have little or no economic value, so they leak into the environment. Huge amounts of pouches and sachets are used once and just thrown away, all over the world, ending up in landfill or in waterways and oceans [13].

In the last few years, there are intense efforts to develop recyclable pouches. The trend is to make a pouch from a monocomponent material, namely polyethylene that will allow recycling [14]. Nowadays, many recycling facilities are able to recycle a coextruded or laminated film that contains at least 95% polyethylene. However, polyethylene suffers from some disadvantages that make it difficult to design an SUP using polyethylene as the only material of construction. For example, HDPE provides the stiffness that is required for a SUP, but the physical and optical properties of HDPE (such as haze and gloss) are comparatively poor. In contrast, LLDPE provides very good physical and optical properties but poor stiffness. The physical and optical properties of medium-density polyethylene (MLDPE) generally fall in between those of HDPE and LLDPE. Accordingly, a simple "all-polyethylene" SUP design will not have the combination of optical and stiffness properties that are provided by the prior art design that contains a layer of PET and a layer of polyethylene (2016, **WO2016128865** A1, NOVA CHEMICALS (INTERNATIONAL) S A).

Mondi and Werner & Mertz developed a 100% recyclable pouch made of polyethylene monomaterial, with detachable decorative panels. The pouch is free of glue or adhesive. Spout and cap are also made of polyethylene. The pouch replaces conventional flexible packaging for Frosch products. The monomaterial pouch is disclosed in **EP3168169** A1 (2017, MONDI CONSUMER PACKAGING TECH GMBH; WERNER & MERTZ GMBH) which describes a pouch (see Fig. 4.2) having front (2) and back face panels formed of a body film and each having two generally parallel and normally vertical side edges bridging ends of respective upper and lower edges, respective longitudinal side welds (3) fixing the side edges of the front panel to the side edges of the back panel; a separate piece of label film (6) different from the body film, covering a mid-portion of one of the face panels between the respective longitudinal edges (3), and spaced downward from the upper edge of the one face panel (2) and upward from the lower edge of the one face panel (2), and structure at the longitudinal edges holding the piece of label film (6) on the one face pane (2)l without surface bonding of the piece of label film (6) to the one face panel (2) between the respective longitudinal edges (3).

According to the invention, the additional piece of label film and the body film are not fully attached to one another. Preferably, large

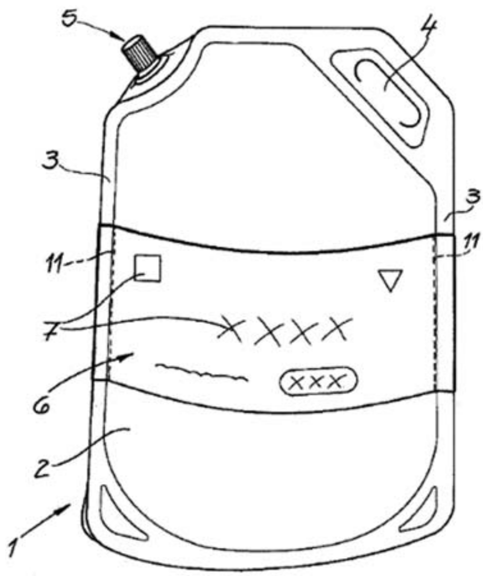


**Figure 4.2** Front view of a pouch having a body made from a monocomponent film and a separate piece of label film (2017, **EP3168169** A1, MONDI CONSUMER PACKAGING TECH GMBH; WERNER & MERTZ GMBH). 1, Pouch body; 2, Face panel; 3, Longitudinal welds; 4, Stamped-out handle; 5, Reclosable spout; 6, Label film; 7, Printing; and 11, Tear lines.

unattached areas remain so that the particles resulting from shredding can then be fully separated from one another.

To allow for good recycling of the pouch body (1), this is made from a monocomponent material. Polyolefins such as polyethylene or polypropylene are preferred. The body film is then labeled as single-origin, in particular, if it can be classified according to the German Ordinance of the Avoidance and Recovery of Packaging Waste (Packaging Ordinance—Verpack V) according to appendix IV, in which recycling number 02 HDPE, recycling number 04 LDPE, and recycling number 05 polypropylene are allocated, for example. Depending on the intended use, however, polyethylenes or polypropylenes with differing densities can be used as a blend or in a multilayer body film.

The label film is preferably a multilayer laminate. Furthermore, the body film and the label film have different densities with a difference of at least 0.02 g/cm$^3$. The materials can therefore be separated from one another using a suitable density separation in a liquid technique. In the simplest case, separation can occur in a liquid bath, thanks to the different densities. If, for example, the body film has a density greater than 1 g/cm$^3$, which is the density of water, and the piece of label film has a density greater than 1 g/cm$^3$according to a preferred design of the invention, separation can occur in a simple water bath using a float-sink process.

Another approach is to use flexible pouches, whose constituent parts can be easily deconstructed and placed into appropriate recycling streams. **US2018009587** A1 (2018, NESTEC SA) discloses such a recyclable flexible pouch (10), as shown in Fig. 4.3, comprising a flexible pouch body defining a chamber into which a product may be disposed, the pouch body having a front wall (14) and a rear wall (16) each formed of a plurality of flexible layers of different materials so as to form at least an inner layer (60, 66), an intermediate layer (66, 68), and an outer layer (64, 70) connected with one another; the connection of the intermediate layer and the outer layer having a connection strength less than the strength of the connection between the intermediate layer and the inner layer such that the intermediate layer and the outer layer can be selectively peeled from the inner layer; and means for assisting in the removal of one or more

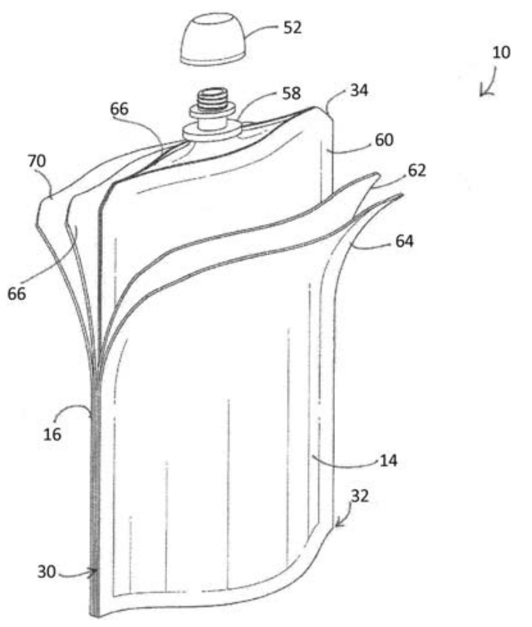


**Figure 4.3** A perspective view of a flexible pouch in a partially deconstructed configuration (2018, **US2018009587** A1, NESTEC SA).10, Flexible pouch; 14, Front wall; 16, Rear wall; 30, First side edge; 32, Second side edge; 34, Upper edge; 52, Cap; 58, Dispensing device; 60, 66, Inner layers; 62, 68, Intermediate layers; and 64, 70, Outer layers.

of the inner layer, the intermediate layer, and the outer layer from one another. The means for assisting in the removal of one or more of the inner layer, the intermediate layer, and the outer layer from one another comprises an unconnected portion or a cut associated with at least one of the inner layer, the intermediate layer, and the outer layer.

**EP3059061** A1 (2016, MONDI CONSUMER PACKAGING TECHNOLOGIES GMBH) discloses a recyclable flexible pouch, wherein the first surface of the pouch wall is formed of a transparent outer film, preferably PET, and the second surface of the pouch wall is formed of an inner film, preferably polyethylene or polypropylene. The inner film and the outer film are connected to each other with a water-soluble pressure adhesive applied only at the side edges of the pouch body. When the pouch is cut or shredded into particles after being used for recycling, the particles formed by the outer film separate easily from the particles of the inner film (see also Chapter 8, Section 8.2.1).

Avantium's business unit Synvina produced pouches from biaxially oriented poly(ethylene furanoate) (BOPEF), which is a biobased polyester. The pouches consist of a two-layer laminate of a BOPEF layer and commercial 55% biobased polyethylene (bio-PE) sealing layer. BOPEF/bio-PE's inherent oxygen permeability of about 10 $cm^3/m^2 \cdot day \cdot atm$ fits well with oxygen-sensitive products such as cheese and dairy, dry snacks, sauces, and cosmetics, which, today, employ more complex multilayer structures such as PVDC-coated BOPET or EVOH-containing sealant layer. Besides the reduced complexity, BOPEF/bio-PE pouches offer excellent toughness and clarity and are suitable for dry and liquid products [15].

### 4.2.4 Air Pillows and Envelopes

Packaging air pillows or air cushions are inflatable plastic bags that are made out of two layers of polyethylene (LDPE and HDPE). They are used extensively in e-commerce, thanks to their ease-of-use, low cost, product protection, and convenience. They are more environmentally friendly when compared with alternative forms of void fill such as foam peanuts made of expanded polystyrene. In fact, many disposal companies will not even accept packaging peanuts for disposal anymore due to the complexity of disposal and their harmful effects on the environment (see also Section 4.3.5).

Plastic shipping envelopes that have bubble wrap inside of them cannot be placed in the curbside recycling bin. They must be put instead in the curbside trash bin. Plastic shipping envelopes having the labels removed, air pillows, and bubble wraps can go into the curbside recycling bin.

### 4.2.5 Labels and Sleeves

Labels (or stickers) and sleeves are essential components of plastic packaging, especially plastic containers. They are used for informational and promotional purposes, giving details relating to the brand, product composition, use-by date, usage precautions where applicable, and the procedure to follow for recycling the packaging after use.

The labels can be mono- or multilayers comprising one or more polymers, typically produced by coextrusion, while some labels are aluminized. A label is known as "dry" if adhesive has to be applied before it is stuck to the product or "self-adhesive" if it is supplied precoated with an adhesive [16].

There are two types of sleeve: stretch and shrink (wrap) sleeves. The sleeves do not require an adhesive to attach them to a plastic bottle.

The polymers used for labels and sleeves are polypropylene, oriented polypropylene (OPP), glycol-modified PET (PET-G), LDPE, PVC, and polystyrene. PET-G is the preferred material for shrink wrap labels and sleeves for PET containers because of its optimum shrink properties or printability.

Label and sleeve made of the same or compatible polymer as the film or the plastic container do not become contaminates and are recycled with the film [17]; for example, OPP-based labels can be recycled with HDPE and polypropylene bottles.

If the label and the shrink wrap sleeve are made of a polymer that is incompatible to the film and the plastic container, it is necessary to remove the label from the flexible plastic packaging and the shrink wrap sleeve from the plastic container to allow recycling. OPP-based labels and sleeves are easily separated from their commercially used PET food and beverage containers before recycling the containers to recover the PET for subsequent use in other plastic products. In connection with this recycling process, the OPP-based labels that are separated from the PET plastic containers generally are disposed of by incineration, by being transported to landfills or by being used in low-quality molding applications.

Shrink sleeve separation from PET containers is typically achieved in float-sink tanks as part of the overall PET recycling. However, shrink sleeve flakes of PET-G have a high density (about 1.3), which hinders their separation from PET flakes in float-sink tanks.

The effect the plastic labels and sleeves can have on the recycling of PET, HDPE, and polypropylene bottles are summarized in Table 4.3.

When the labels and sleeves are not easily separable from the containers, many containers are not recycled that otherwise would be, and

**Table 4.3** Effect of Plastic Labels and Sleeves on the Various Processing Steps of the Recycling of Plastic Bottles

| **Polymer** | **Recycling Step** | **Effect** | **Evaluation** |
|---|---|---|---|
| PET stream | | | |
| PVC | Sorting on bottles | PVC L/S detected = up to 3 bottles without PVC L/S ejected | Increase in losses and waste to be processed |
| | Float-sink | Undetected PVC flakes cannot be separated from PET flakes by flotation (density of the two materials >1) | Recycling stream pollution |
| | Sorting on pellets | PVC flake detected = up to 100 flakes ejected | Recycling stream pollution and increase in losses |
| | Granulation/ recycling | Decomposition of PVC into carbon residues at PET conversion temperature: Clogging of extruder filters and/or quality problems with the granules | Increase in machine stoppages, increase in losses, quality problems, and increase in waste to be processed |
| PS | Float-sink | Depending on their density, PS flakes are sent into the | Pollution of the recycling stream and the |

**Table 4.3** Effect of Plastic Labels and Sleeves on the Various Processing Steps of the Recycling of Plastic Bottles (*Continued*)

| Polymer | Recycling Step | Effect | Evaluation |
|---|---|---|---|
| | | PET stream ($d > 1$ g/cm$^3$) or polyolefin stream ($d < 1$ g/cm$^3$) | polyolefin stream |
| | Granulation/ recycling | With a fusion temperature well below that of PET, deterioration of the PS during shaping | Creation of impurities and yellowing of pale-colored materials (not visible in dark materials), and quality problems |
| Stretch LDPE | | None | Favorable |
| PET-G | Float-sink | PEGT flakes not separated from PET flakes (density of the two materials $>1$ g/cm$^3$) | PET stream pollution |
| | Washing | Tendency of PEGT to stick to the walls of the machines during drying and transfer | Blocking of pipes |
| | Granulation/ recycling | Yellowing of pale-colored PET streams over a certain concentration | Quality problems |
| PP/OPP | | None | Favorable |

(*Continued*)

**Table 4.3** Effect of Plastic Labels and Sleeves on the Various Processing Steps of the Recycling of Plastic Bottles (*Continued*)

| Polymer | Recycling Step | Effect | Evaluation |
|---|---|---|---|
| HDPE/PP stream | | | |
| PVC | Granulation/ recycling | Traces of PVC create black stains during recycling | Quality problems |
| PS | Float-sink | Depending on their density, flakes are sent into the HDPE/ PP stream ($d < 1$ g/cm$^3$) or into postsorted waste ($d > 1$ g/ cm$^3$) | Recycling stream pollution and increase in losses |
| | Granulation/ recycling | Given their conversion temperatures close to those of PS, PP, and HDPE, the shaping process is identical. PS incompatible with HDPE and PP | Tendency to agglomerate and impair the final properties of the material (creation of areas of weakness, incipient breaks) |
| Stretch LDPE | | None | Favorable |
| PP | | None | Favorable |

*HDPE, High-density polyethylene, LDPE, Low-density polyethylene, L/S, Labels or sleeves, OPP, Oriented polypropylene, PET, Poly(ethylene terephthalate), PET-G, Glycol-modified PET, PP, Polypropylene, PS, Polystyrene, PVC, Poly(vinyl chloride).*
*Adapted from Cotrep (Comité Technique pour le Recyclage des Emballages Plastiques). General notice 12 – the behaviour of labels and sleeves during the recycling of PET, HDPE and PP bottles; February 3, 2012. https://www.mondigroup.com/en/newsroom/mondi-flexible-packaging-leapfrogs-ahead-in-the-recycling-game/.*

recycling yields are reduced. This is the case with the full wrap sleeve of PET bottles, which tend to obscure the automated detection systems during the sorting process [18]. To alleviate the problems with sorting, recyclers and brand owners tend to recommend paper labels, or partial sleeves made with low-density thermoplastic materials, such as polyolefins. However, such materials do not have the desirable shrink properties or printability of higher density substrates such as PET-G.

If the density of the sleeve before printing is not low enough, it is possible for the printed sleeve to become too dense and therefore unable to be separated from the standard PET to be recycled (2017, **US2017213484** A1; 2018, **WO2018187203** A1, SUN CHEMICAL CORP).

Several film/resin suppliers (including Exxon, Topas, and Cryovac or converters such as Fuji Seal) have introduced low-density films or coextruded film structures with low density (below 1.0 or at least below 1.05 g/cm$^3$) based on mono- or multilayer structures including polymers built around a low-density core, such as polyolefins, or microvoided polymer, optionally wrapped by a PET-G skin, and, if needed, a tie layer between the core and the PET-G. The overall density of the film is designed to make it floatable in a float-sink tank (2015, **WO2015026479** A1; 2017, **US2017213484** A1; 2018, **WO2018187203** A1, SUN CHEMICAL).

The National Association for PET Container Resources is looking at a combination of solutions including the addition of perforations to the labels or sleeves to help them come off during the normal bailing processes, providing recycle facilities with delabeling equipment and making labels from materials that float. This last idea is promoted by the Association of Postconsumer Plastic Recyclers because PET flakes sink in a float-sink separation process, as do other common shrink sleeve materials such as poly(lactic acid) (PLA) or PVC. Using a floatable label makes the separation process much more successful.

**WO2015026479** A1 (2015), **US2017213484** A1 (2017), and **WO2018187203** A1 (2018) of SUN CHEMICAL disclose a coating composition for use with labels, including wrap around and sleeve labels, particularly shrink wrap labels, for containers that will allow for an easy separation of the label from the container during recycling. The coating composition comprises at least a first resin with a $T_g$ or a softening point from 25 to 115°C, a second resin having a $T_g$ or a softening point lower than the $T_g$ or softening point of the first resin, and in some instances, a third resin having a $T_g$ or a softening point lower than the first resin but higher than the second resin. At least one of the first and second resins is a polyester resin, while the third resin is preferably a hydrogenated rosin.

The coating composition provides good bond strength in the seam area of the label, and the coating composition and/or each of the resins thereof may be at least partially hydrolyzable but not solutionable in a hot caustic bath, enabling separation of the label from the article during recycling.

Aluminized labels are problematic to recycling and have a negative effect on the purity of the recovered polymer.

### 4.2.6 Straps/Tapes/Six-Pack Rings

Packaging straps and tapes are strapping thin, flat pieces of plastic bands used to preserve the integrity of a package or bundle numerous packages during transportation and storage. They are usually made of polypropylene or PET.

Polypropylene strapping is the most common form of strapping for unitizing and protecting smaller containers and boxes. Polypropylene strapping is often used to complement stretch film during load stabilization. Polypropylene strapping is also used to secure crates, bales of netting, frozen bait, and bundle products together for retail sales.

Six-pack rings are composed of a semiflexible LDPE. They are used in the packaging of beer cans, sodas, etc. Although six-pack rings account for only a tiny fraction of the marine plastic debris, they are responsible for the deaths of hundreds thousands of seabirds and marine mammals [19] (see also Chapter 2, Section 2.4.1).

Both, packaging straps and six-pack rings, are not mechanically recycled and are not accepted in return collection centers or drop-off sites.

### 4.2.7 Net Bags and Woven Bags/Sacks

Net bags (or mesh bags or poly bags) are used for transport and retail packaging of agricultural products (e.g., onions, oranges lemons, limes, nuts, and the like), chocolate coins, or as reusable shopping bags. Transport packaging includes knitted (raschel) and woven (leno) net bags. Retail packaging includes extruded and knitted tubular net bags.

Because the net bags are usually used for packaging vegetables, fruits, or chocolates, it is likely to be discarded after use. However, net bags are made of HDPE, polypropylene, PET, or nylon, which do not decompose naturally and tend to cause environmental problems.

Woven bags or sacks are flexible containers with a single opening of strong, coarse material for storing and handling various products. Plastic woven bags are mainly made of HDPE or polypropylene. Polypropylene woven bags are the highly preferred choice for packaging purposes. One of the latest trends in the packaging industry is the manufacture of BOPP laminated woven polypropylene bags.

Polypropylene woven bags are used in the construction and building industry (e.g., for packing cement) and agrochemical industry (e.g., for packing chemicals, fertilizers, vegetables, and fruits) because of their high strength, inertness toward moisture, chemical resistance, and low cost. Polypropylene woven bags are also increasingly used in food packaging. Common food woven bags include rice woven bags, flour woven bags, maize woven bags, etc. Key companies operating in the global market for polypropylene woven bags and sacks include Mondi Group plc, United Bags, Inc., Berry Global, Inc., Muscat Polymers Pvt. Ltd., Al-Tawfiq Company, Emmbi Industries Limited, Uflex Ltd., Palmetto Industries, and Printpak Inc., among others [20].

Industrial woven polypropylene slit film products are currently recycled (e.g., industrial bulk sacks) [21].

### 4.2.8 Coated/Printed Films

Coatings and inks add functional benefits and aesthetics to flexible packaging. The most common type of coating is PVDC, which is used to improve the gas barrier properties of transparent films as well as the gloss of printed films.

The printing of flexible plastic packaging requires a printing ink spectrum that is suitable for a large variety of flexible plastic substrates, ranging from construction industry films and peat bags all the way through to food packaging. The printing inks used must be as flexible as the packaging types themselves and have to offer good printability for very low up to extremely high printing speeds (see also Chapter 3, Section 3.12). Multilayer packaging structures, especially in food packaging, incorporate reverse printing on the outer layer of packaging and laminating to an internal layer. The selection of inks to be used in such packaging applications requires careful consideration [22].

The main printing technologies used in flexible plastic packaging are

- flexography,
- rotogravure,
- digital printing, and
- others.

Flexography is the preferred printing technology for flexible plastic packaging. It is used for printing on a wide range of flexible plastic packaging forms such as SUPs, flat pouches, roll stocks, gusseted bags, wicketed bags, and wraps. Flexography printing technology has several benefits such as the flexographic ink requires extremely less drying time and allows for printing both the nonporous and porous surfaces. Also, its simple plate-manufacturing process allows for printing huge quantities of images with just one template; and the technology allows for printing continuous image patterns [23].

The process of printing on a flexible packaging involves the application of a liquid ink on a plastic film. The solvent used (normally organic compounds or water), which volatilizes, is then removed by means of a drying process. The desired drawing is printed on the film after evaporation, and it is ready for use as packaging for various products. It is common practice to adjust the parameters of the printing machine and to adjust the different colors used during printing to obtain quality printing that has no imperfections. The plastic film circulates through the printer at speeds that can reach up to 500 m/min during machine adjustment. Large amounts of defect plastic film (5−10% of the total packaging film production) are generated due to this speed (2013, **WO2013144400** A1, UNIV ALICANTE) (see also Chapter 7, Section 7.2).

Coating and printing on flexible plastic packaging are significant sources of contamination that reduce the value of plastic materials at the end of packaging life cycle [24]. The coatings are not easily removed in the film recycling process and are either melted or blended together with the film material. Heavily printed film of dark colors is detrimental to recycling as the dark colors affect a large amount of polymer, limiting its potential for reuse. Further, high levels of ink volatize in the extruder and may cause gels in the final product, even if most recyclers use vented extruders [17]. Currently, the scrap film is recovered for recycling by means of processes in which the printed ink is not removed. A low-quality brownish or black film is thus obtained, so its price is significantly lower than the price of films free of starting ink. Therefore, the recycled film is usually used for the preparation of trash bags or applications of low visual quality.

## 4.3 Applications of Flexible Plastic Packaging

The flexible packaging market is segmented on the basis of application in industries of:

- food and beverage;
- cleaning products;

- pharmaceutical;
- medical and personal care;
- construction and building; and
- others.

### 4.3.1 Food and Beverage

Food and beverage are the largest application market segments of flexible plastic packaging [23]. Flexible food packaging for perishable foodstuffs is prepared from multilayers comprising aluminum foil and polyolefins, such as polyethylene, polypropylene, or condensation polymers, such as PET or polyamide (nylon) films. These films are often coated with barrier coatings such as PVDC to improve oxygen barrier properties and may be provided with a heat sealing material such as wax or hot melt adhesive. The multilayer flexible plastic packaging is one of the fastest growing packaging types on the food market. Table 4.4 gives a representative list of flexible plastic packaging forms for food.

### 4.3.2 Cleaning Products

Soaps and detergents are available in a variety of forms. Common examples of detergent and soap packaging include:

soap wrappers;
laundry detergent pods;
liquid detergent pouches;
liquid hand soap tubes;
powder soap pouches;
dishwater pouches;
dishwater pods;
natural bar soaps;
septic system cleaning soap packets; and
pouch packing for cleaning chemicals, etc.

Flexible containers allow a more controlled dispensing of soap, and the packaging can be rolled up to squeeze out nearly every last drop. SUPs manufactured from multilayers are primarily used to package liquid detergents and cleaning materials. Resealable spouts or pouring devices

**Table 4.4** Forms of Flexible Plastic Packaging for Food [25]

| Packaging Form | Exemplary Food Products |
|---|---|
| Stand-up pouches | Frozen prawns, scallops, fish fillets; frozen fruits; and vegetables;<br>Frozen prepared food such as chicken wings, shrimps;<br>Baby food;<br>Pet food |
| Zipper lock pouches | Sugar, oatmeal, grated cheese, rice, grain, coffee, dried fruits and nuts, candies |
| Zipper lock bags | Grape bags, deli meat, and cheese bags |
| Crinkly bags | Chips, candies, dried pasta, cereal, and cookie bags |
| Crinkly wrappers (nonstretchable); | Cheese wrappers, vacuum seal packaging, plastic safety seal on bottles and jars, plastic inner seal on yogurt |
| Crinkly wrappers | Cheese slice wrappers, snack and chocolate wrappers, candy wrappers, individual cookie wrappers |
| Cellophane | Flower and gift wrapping |
| Flexible packaging with plastic seal | Fresh pasta, prepackage deli meat, prepackage cheese packaging |
| Net plastic bags | Oranges, lemons, limes, avocado, nuts, onions |
| Woven plastic bags | Rice |
| Shrink wrap | Meat, poultry, cheese, vegetables |

are ideal for both refill packaging and for primary packaging. Today, nearly all the big names in laundry detergent packaging are using SUPs as their preferred method to ship their products. Water-soluble films are used by packaging manufacturers to package laundry detergents, dish wash, other products, such as shaving creams, cosmetics for spa services, etc. These products are packaged in poly(vinyl alcohol) (PVOH) films in the form of small packs termed as water-soluble pods.

Henkel sells its Megaperls powder laundry pods in a flexible package, called a Quadro Seal Bag that consists of an OPP/polyethylene laminate. At present, 30% of the package's polyethylene layer consists of industrial waste reclaimed from Mondi. That means the overall package structure contains approximately 10% reground material (see also Chapter 8, Section 8.7).

### 4.3.3 Medical/Personal Care/Cosmetics

The major end users in the flexible packaging market are pharmaceutical manufacturing, contract packaging, implant manufacturing, and medical device manufacturing. The packaging of these medical products is of great importance because it increases their shelf life.

The global medical flexible packaging market size was estimated at $20.14 billion in 2016 and is expected to witness rapid growth owing to the rising demand from the pharmaceutical and medical device−manufacturing industries. Flexible packaging provides various advantages such as low waste, reduction of the overall weight by around 70%, and product protection [9].

Flexible plastic packaging is used to protect various pharmaceuticals such as tablets, pills, capsules, and powders. According to Gupta [27], almost 75% of oral tablets and powders in the United States are packaged in flexible materials. The most common forms of flexible packaging for pharmaceutical use include blisters, sachets, pouches, and strips.

A blister package is generally composed of two layers: a forming film and a lid. The lid is usually a multilayer material including a barrier layer (e.g., aluminum foil) with a print primer on one side and a sealing material on the other side (see Fig. 4.4). The forming film may be a single film, a coated film, or a multilayer. LDPE, LLDPE, BOPP, OPP, PET, polyamide, PVC, and PVDC used in single- or multilayer form are the main components in forming the film and coating layers of a pharmaceutical package.

Blister packets are classed as hazardous waste and are usually either landfilled, which has environmental consequence if the aluminum leaks into the environment, or incinerated, which can produce gas and ash exhausts that also have a negative environmental impact [28].

The major products that come under medical flexible packaging are seals, high barrier films, wraps, pouches and bags, lids, labels, and others.

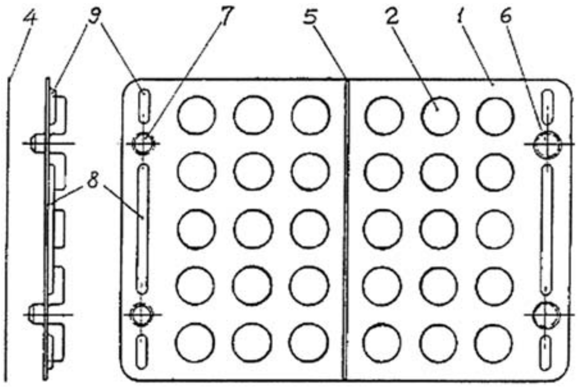


**Figure 4.4** Example of a blister type flexible plastic packaging card (1996, **US5549204**, TOREN CONSULTING PTY LTD). 1, Flexible plastic sheet; 2, Thermoformed blisters or pockets; 3, Round tablets and pills; 4, Aluminum foil; 5, Perforated hinge line; 6, 7, Resealable fastening means; and 88, 9, Ribs.

Pouches and bags are the major products in the market and expected to remain the largest segment over the forecast period, recording a CAGR[2] of 5.9% from 2017 to 2025. Pouches and bags cater to wide variety of applications in the healthcare sector [9].

The use of flexible pouches is much more developed in the medical field where flexibility is particularly important as it makes it possible to obtain zero-volume chambers (i.e., empty of gas and particularly of ambient air) in the absence of internal liquid. As such, flexible pouches make it possible to retain the asepsis of the products contained (blood, solutions, medicinal products) throughout the use thereof. All flexible pouches of the medical pouch type are produced with high frequency or heat sealing, using thermoplastic films. More specifically, a medical pouch is produced by sealing from three sides, and one side is left open for filling and sealing thereafter. In general, the films are made of PVC or polypropylene, and the pouches may have different sizes to exhibit a content volume between 50 and 1000 mL. Flexible pouches and squeeze tubes allow for improved product evacuation, which can reduce waste, while maintaining visibility.

There is also a growing trend toward flexible packaging for cosmetics and personal care. According to Smithers-Pira [29], pharmaceuticals,

[2] Compound annual growth rate.

medical, cosmetics, and toiletries are the largest nonfood markets for flexible packaging. Flexible plastic packaging keeps cosmetic and personal care products fresh and safe from contamination and extends their shelf life. Some examples of personal care packaging are lay flat pouches for shampoos and conditioners; packets and sachets for baby wipes; sample sachets; SUPs (or doypacks) for liquid soap refill and shower gel; shrink sleeves for cleansers, creams, and lotions; and roll-fed labels films. Commonly used polymers include polyethylene (LDPE or LLDPE), polypropylene, and PET. Often, multilayer packaging is used for cosmetic products.

TerraCycle® and Garnier® have partnered to create a free recycling program for personal care and cosmetic product packaging, as well as a fundraising opportunity for participants [30]. The program accepts waste from (semi)rigid and flexible packaging for hair care, skin care, and cosmetics as follows:

Hair care packaging such as shampoo caps, conditioner caps, hair gel tubes and caps, hair spray triggers, and hair paste caps.

Skin care packaging such as lip balm tubes and caps, soap dispensers and tubes, body wash caps, lotion dispensers, and caps.

Cosmetics packaging such as lipstick cases, lip gloss tubes, mascara tubes, eye shadow cases, bronzer cases, foundation packaging, powder cases, eyeliner cases, eyeliner pencils, eye shadow tubes, concealer tubes, concealer sticks, and lip liner pencils.

### 4.3.4 Construction and Building

Products for construction (such as bricks, brickwork, tiling, paving, roofing, beams, truss structures) and building materials (such as mortar and plaster mixtures, lime, cement, and other construction materials) they need industrial packaging, which reliably ensures the products and the materials during transport and storage.

Stretch films are commonly employed, for example, to wrap goods and products of various types positioned on a pallet, the film wholly or partially covering the goods or products and also typically applied to the pallet itself to secure the pallet to the items positioned.

Stretch films, typically made from LLDPE, are used to protect and unitize construction products on a pallet. For heavier construction loads (such as bricks, cement blocks, bags, drums, steel tubes, pipes, etc.), high-strength stretch films are being continuously wrapped around the pallets to achieve load retention. Currently, the safety concerns are strong enough that the stretch film has to be wrapped with heavier gage material, such as

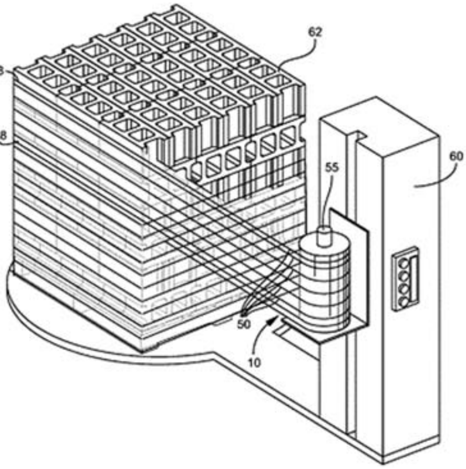


**Figure 4.5** Perspective view of a reinforced stretch film being wrapped around bricks on a pallet through use of a stretch wrapping machine (2017, **US2017313020** A1, GRUBBS JR RONALD; LOPEZ LUIS ARURO). 10, Reinforced stretch film; 28, Folded edges; 50, Reinforcement strips; 55, Roll of reinforced stretch film; 60, Stretch film wrapping machine; 62, Pallet.

straps, bags, or stretch hoods, or a large amount of film with low prestretch is used to keep the heavy product secure. However, both of these options clearly increase packaging and/or shipping costs. Fig. 4.5 shows a reinforced stretch film being wrapped around bricks positioned on a pallet through use of a stretch wrapping machine.

Woven polypropylene bags and sacks are used for carrying sand, bricks, rubble, and cement bags (see also Section 4.2.7). Polypropylene aggregate rubble sacks are used for carrying debris, bricks, rubble, sharp items, metal, etc.

Polypropylene or PET straps are used for strapping of packed construction material, e.g., ceramic tiles of layers of pavers and building blocks with or without pallet.

In construction, demolition, and renovation, plastic packaging films are voluminous waste. Plastic films are readily compactable and permit easy transport. Most commonly used means of collection are containers, preferably containers with a press for the packaging films, big bags, and special bags. Some systems make it possible to deposit these bags free of charge at the building materials dealer. The packaging is, then, sent to a recycling center. Some packaging is supported by a "take-back obligation" (obligation for any party responsible for packaging to attain a certain percentage of recycling for the packaging he puts on the market). Other types of flexible plastic packaging such as woven bags can be reused [31].

Total (BE) and several partners (Valipac, Oerlemans Packaging, Morssinkhof Rymoplast Group, Wienerberger, and Fema) along the construction value chain have formed the Clean Site Circular Project that aims at recycling films used for protection and stabilization of goods during storage and transport on pallet (shrink hoods) wastes from the construction sector in closed system without film performances degradation. Total has developed a film recipe showing that a closed loop "shrink hood to shrink hood" is industrially feasible and can technically match virgin solutions. It uses Lumicene Supertough® 22ST05 of Total as a "booster" for the recyclate. Lumicene Supertough® 22ST05 is a metallocene-polymerized polyethylene multilayer film for flexible packaging [32].

### 4.3.5 E-Commerce

E-commerce represents 8.5% of the overall retail market, but it is growing at a rate of 18−20% annually, and it is likely to accelerate [33]. The growing e-commerce sales are subsequently creating a demand for safe packaging for the entire supply chain duration. Flexible plastic packaging plays a significant role in e-commerce in that respect. Because shippers charge based on dimensional weight (volume + weight), flexible packaging can reduce shipping costs and allow more items to fit on delivery trucks compared with corrugated cardboard boxes. The last years, Amazon has reduced the portion of shipments it packs in its cardboard boxes in favor of lightweight plastic mailers, which enable the retailing company to squeeze more packages in delivery trucks and planes. Amazon is by far the biggest shipper and producer of flexible packaging and a trendsetter, meaning that their switch to plastic mailers could signal a shift across the industry.

Some of the common types of packaging bags used for the shipment of items to customers by online shopping websites, and for the transportation of documents and valuable papers are plastic courier bags and envelopes, bubble courier bags, festive courier packing bags, tamper evident security bags and envelopes, poly bags with POD (proof of delivery) jackets, and premium courier bags.

The courier bags and envelopes are made from multilayer film manufactured by a coextrusion process. The multiple linings make the courier bag durable and printable. Multiple linings in courier bags are made of layers of LDPE and HDPE (see also Section 4.2.4). They are milky white in the outside layer and black inside to ensure confidentiality of the content. Hot melt adhesive seal on top ensures that once it is sealed, it cannot be opened without tearing. Some plastic bags have a bubble lining on the inner surface of the bag, which protects the valuables inside from the outside pressure or load and even provides light protection when in transition. The bubble wrap is most often made from LDPE.

E-commerce flexible plastic packaging and its disposal has unaccountable environmental costs. Shipping envelopes, such as those having a bubble wrap inside of them, cannot be put in a curbside recycling bin. They need to be recycled separately, and if they end up in the usual stream, they gum up recycling systems and prevent larger bundles of materials from being recycled. Another problem with the new padded plastic mailers is that retailers affix a paper address label that renders them unfit to be recycled, even at a store drop-off location. The label needs to be removed, separating the paper from the plastic, for the material to be recyclable [34].

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