



Aluminium in the Packaging Industry

»Production · Use · Recycling«



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Markets for aluminum packaging

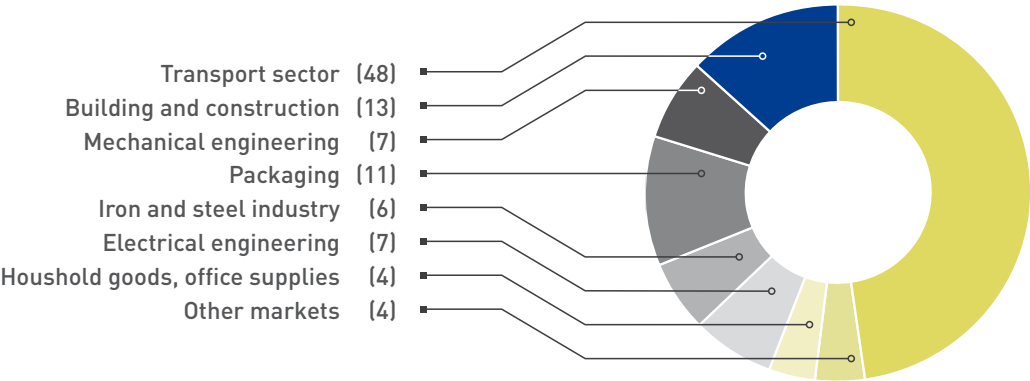
Of some 74,000 people employed in the German aluminium industry, about 15,000 work in the packaging sector. In 2016 the sector had a turnover of 2.3 billion euros, representing around 16 per cent of the total turnover of the industry. This is equivalent to some 414,000 tonnes. Thus about eleven per cent of the total production of the aluminium industry is used in the packaging sector, making it the third largest market for aluminium products in Germany.

Some 60 per cent of the aluminium used for packaging is processed to foil or thin strip. Food and beverage cans account for 24 per cent. Eleven per cent goes into flexible tubes and aerosol cans and five per cent is used for capsules and screw closures.

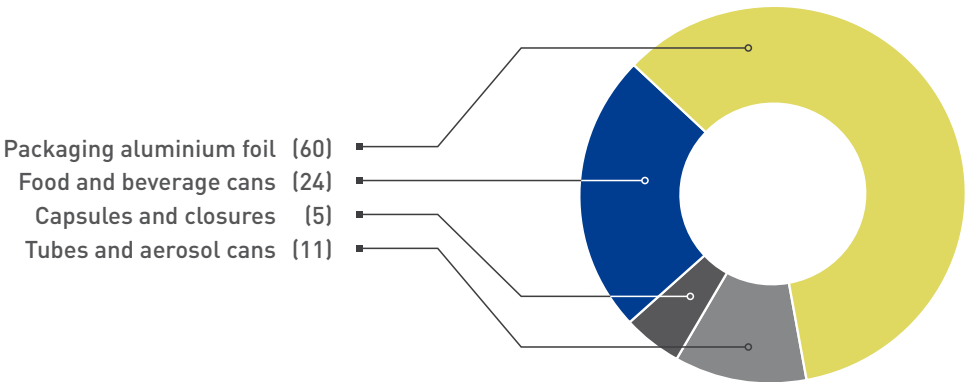
The production of primary aluminium is not covered by this brochure. However, a brief description will first be given of the production of recycled aluminium and rolling ingots (continuous casting) and the rolling process.

The manufacture of different types of aluminium packaging and their fields of application will then be described. ■

Aluminium products in Germany in %



Aluminium packaging in Germany in %





The pyrolysis process recycles aluminum.

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Recycling

Aluminium has a high intrinsic material value. This has meant that recycling aluminium has always been worthwhile economically, especially since it can be remelted time and again without any loss in quality. That is why one refers to aluminium as a permanent material which, unlike other materials, can be recycled an unlimited number of times thanks to its inherent physical properties. The recycled material comes from every field of application and is fed into the aluminium pool together with primary aluminium, to then be used for high-grade products. In Germany, it has been possible in recent years to recover ever-greater amounts of aluminium, also from packaging, thanks to the combination of the deposit system (beverage cans), the household collection of packaging via the so-called dual system and appropriate investment in modern collection, sorting and recycling technologies.

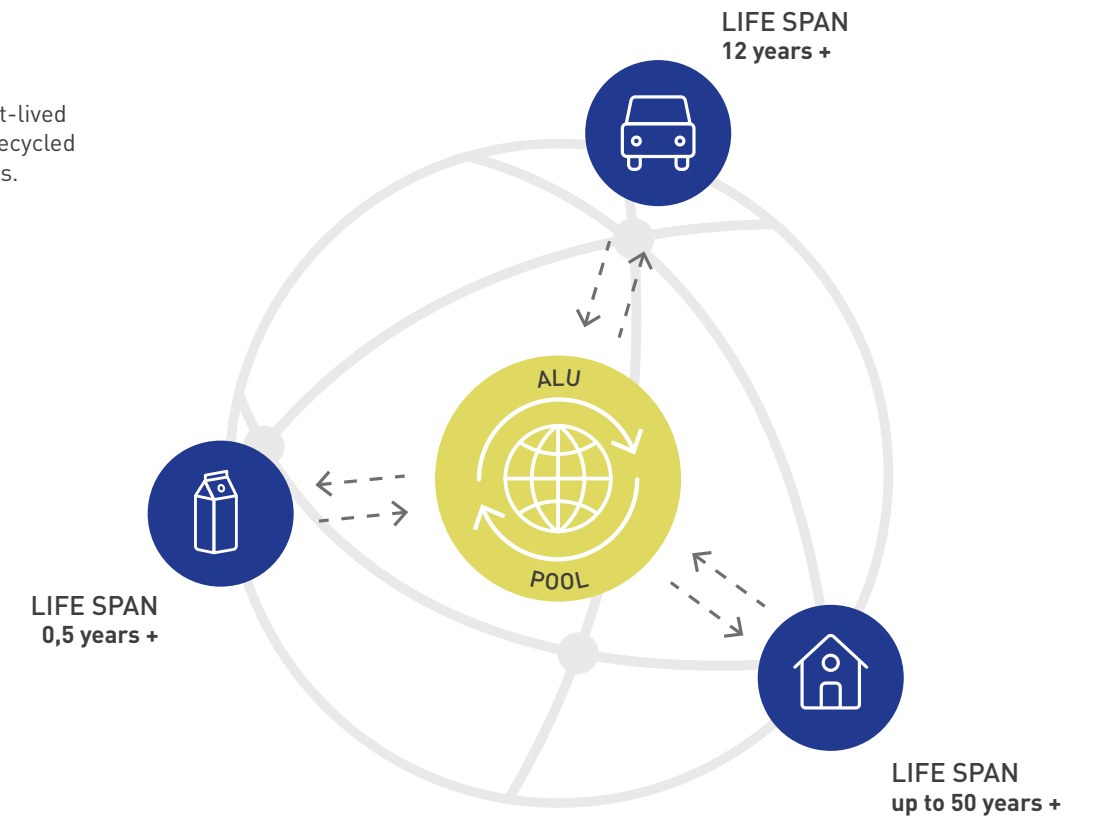
Since the introduction of the deposit on beverage cans in 2003, the recycling of aluminium beverage cans has been optimised continually. Today, about 96 per cent of the cans used are collected and recycled thanks to this system. Redemption is via reverse vending machines located in supermarkets or beverage stores or manually at kiosks or filling stations. The beverage cans are usually compacted in the machines and supplied by the trade to the smelter. This material stream is defined by the alloy used to produce the beverage can because the deposit scheme does not apply to other forms of aluminium packaging; therefore reverse

vending machines do not accept such packaging. This means there is no mixing with other aluminium scrap. Beverage cans made of tinplate that are collected via the same scheme are separated from the aluminium beverage cans using magnets. This avoids the need for elaborate sorting and processing. Producing a beverage can weighing approximately 15 grams results in 120 g of CO₂ less being emitted than would be the case with production of the aluminium via electrolysis. The smelters recover high-grade aluminium from the can scrap and this is used to produce new products, including new beverage cans.

The recycling of aluminium packaging or packaging containing aluminium that is not subjected to a deposit and is obtained via a collection system is a process that begins with the user. The consumer collects the packaging at home or at work in the yellow bins or sacks of the dual system. Such packaging includes, for example, pet-food cans, chocolate foil, trays, tubes, aerosol cans and single-portion packs for coffee. The yellow bins and sacks are then collected by a local waste-disposal company on behalf of the dual system, loaded onto trucks and compacted. The recyclable material is subsequently transported to a transshipment point from where the compacted material is distributed to one of about 40 sorting plants throughout Germany. At the sorting plant, all of the material is separated into the groups of recyclables. Non-magnetic aluminium is separated out from the

Recycling Loop

Aluminum from short-lived applications can be recycled into long-life products.



conglomeration of materials using so-called eddy-current separators. The fraction comprising aluminium or aluminium-laminate packaging is then baled and transported to the recycling plant for processing. The bales supplied weigh up to a tonne and are decompacted using special equipment. A shredder reduces the size to 10–15 centimetres. The next stage is a large storage bunker, from where it is transported via conveyor belts or metering screw conveyors to the so-called pyrolysis oven.

Pyrolysis is a process in which organic substances, such as paint, labels, films or residual contents, that are adhering to the aluminium packaging are separated from the aluminium in a so-called pyrolysis drum in the absence of oxygen. Energy is released in the form of heat during the low-temperature carbonisation and this heats the drum in a continuous process. The temperature in the drum reaches 450–500 °C. The residence time is 30–60 minutes. Aluminium packaging maintains its shape after pyrolysis, and can be melted down to aluminium or processed.

The collection and recycling of aluminium packaging has undergone a remarkable development in Germany. The recycling rate was 57 per cent in 1995 but only ten years later 76 per cent of aluminium packaging was already being recycled. The recycling rate has continually increased since then and is now about 90 per cent. ■



In modern sorting plants the collected material is split up into different material groups.

The casting process (continuous casting)

Various shapes of rolling ingot can be cast in computer controlled continuous casting plants, in which the casting process is performed completely automatically.

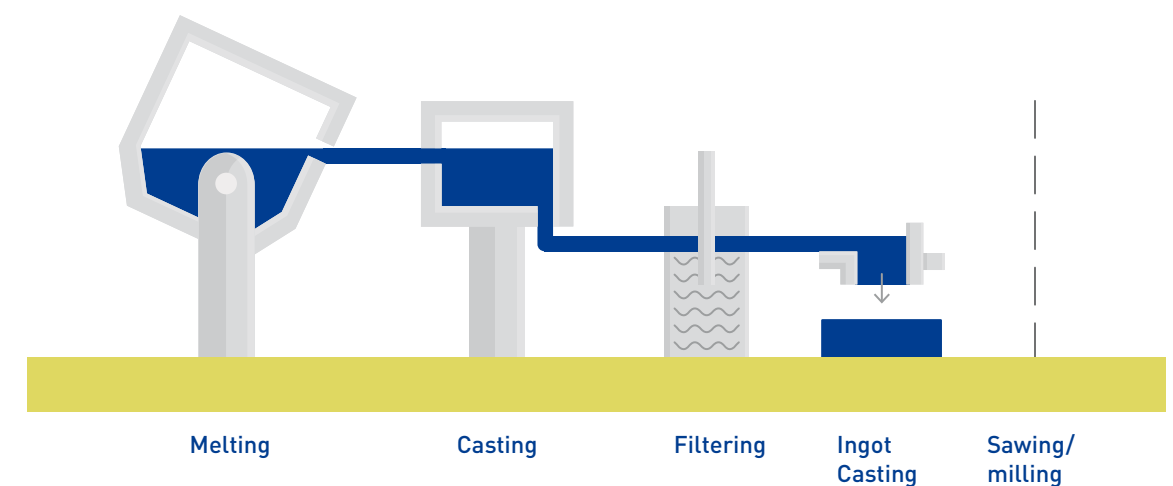
The casting device comprises a water-cooled mould with a base that can be lowered. The molten aluminium is poured slowly into the mould and solidifies on the walls and base; it thus forms a beaker whose contents are still molten. While molten metal is continuously poured into the mould at the top, the base is lowered uniformly at such a rate that the level of the molten metal in the mould remains constant. This leads to the formation of a strand or ingot, which is sprayed with water from all sides to cool it completely.

Solidification proceeds from the bottom to the top into the innermost parts of the ingot. In this way, an ingot is produced that is fine-grained, compact and free from pores over its whole cross-section. Only the surface solidified by water cooling is irregular and thus has to be post-worked: both ends of the ingot are sawn off to remove irregularities arising from the casting process and the cast skin is removed on all sides by milling.

The vertical continuous casting process described here is the preferred method of producing ingots worldwide. In addition, there are horizontal continuous casting plants in which the strands are allowed to grow in a horizontal direction. In the various types of strip casting process, molten aluminium is cast between two water-cooled steel strips, rotating steel moulds or rolls and, depending on the process used, strip 6–30 mm thick solidifies at a low flow rate. The strip is subsequently rolled directly.

Casting wheels (so-called rotary Rigamonti casting wheels) are used to cast strip for slug production, for example for aerosol cans and tubes. The wheels have a recess that is covered by a steel strip, whose width and depth corresponds to the dimensions of the strip. Molten metal at 750 °C is guided to the inlet pouring gate of the casting wheel. The casting wheel and the steel strip are water-cooled. Thus, when the aluminium leaves the casting wheel its surface is already solidified and can be removed without any support at a temperature of 500 °C. The cast strip is hot rolled further, cooled to about 50 °C in a water bath, cold rolled to make it smooth and to achieve the desired thickness, and then coiled. ■

Continuous/strip casting



The rolling process

The rolling process includes hot and cold rolling. The products are plate (thickness \rightarrow 6 mm), strip (0.021–6 mm) and foil (\leftarrow 0.021 mm). The term 'thin strip' is used for thicknesses from 0.2 mm down to 0.021 mm.

Continuously cast aluminium ingots, which can be up to 9 m long, 2.2 m wide and 600 mm thick, and weigh up to 30 tonnes, are the starting material for hot rolling. The ingots are either commercially pure aluminium (max. 1 % impurities) or aluminium alloys depending on the demands made on the metal by subsequent downstream processing. They are heated to a temperature of 500–600 °C and then rolled in a reversible blooming mill stand (four-high hot-rolling stand) in a dozen or two passes until they are over 100 m long and several centimetres thick. Reductions per pass of over 50 per cent are possible. Cropping shears cut off the ends of the strip; this process scrap is then melted down again. The billets are subsequently rolled on multiple-stand finishing trains to produce hot strip that is typically 2.5–8 mm thick. This strip is subsequently wound to produce a coil with a maximum diameter of 2.7 m weighing 24 tonnes.

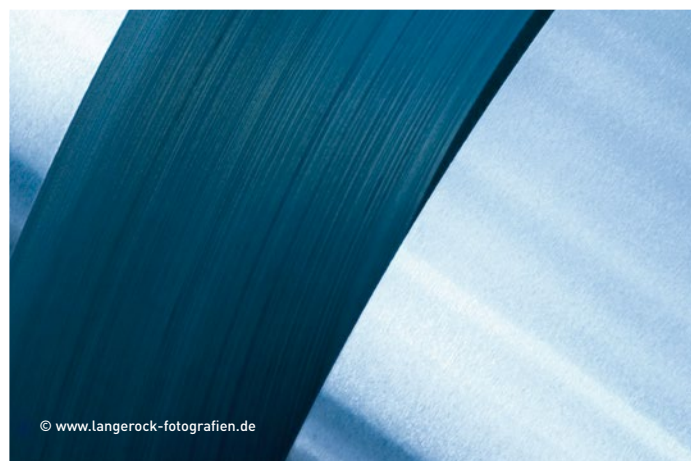
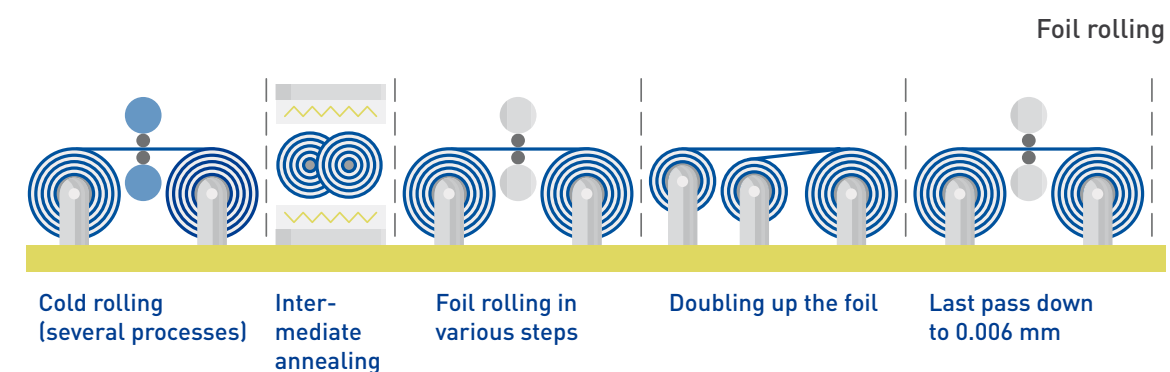
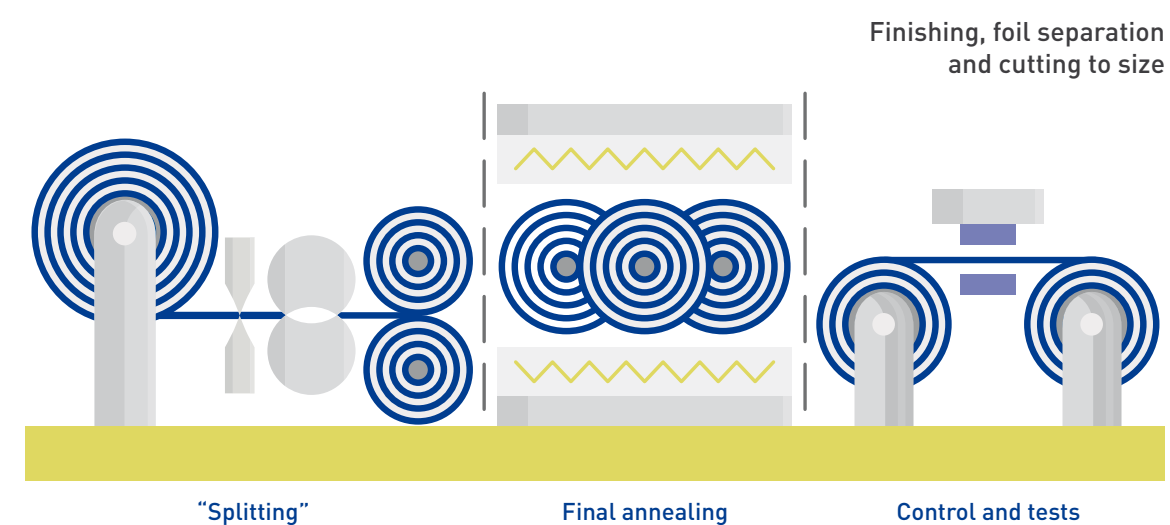
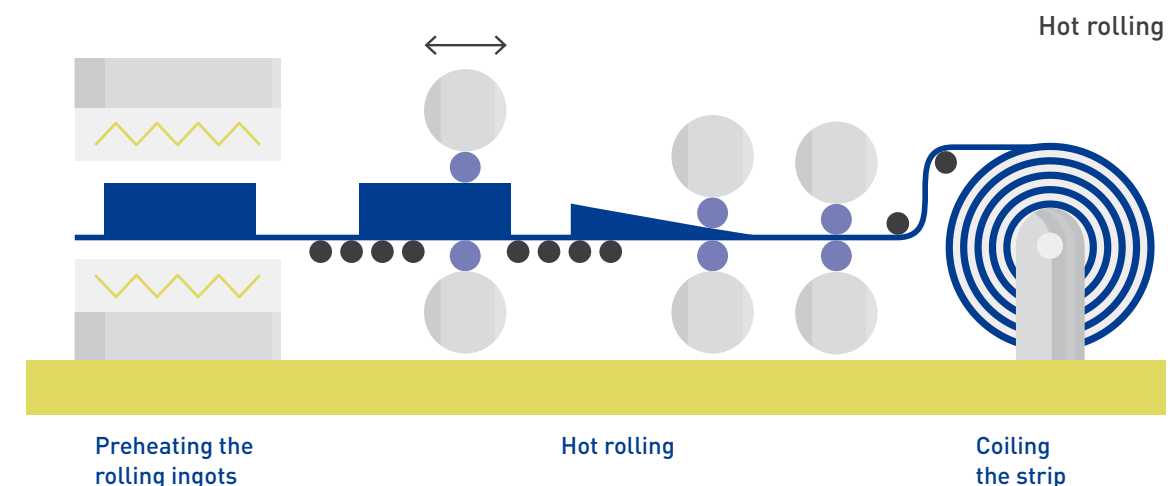
Once the coil has been cooled to room temperature, it is subjected to cold rolling on a four-high stand. Steel back-

up rolls ensure that the high pressure does not cause the smaller diameter working rolls to bow out. During rolling, the deformation energy causes the metal to heat up to over 100 °C, which is why coolants are used. After several passes one finally obtains thin strip (EN 485-1), can stock (EN 541) or foilstock (EN 12482), which is trimmed and coiled. If the strip is not intended for further processing internally, it is coated or lacquered if necessary prior to being shipped to the client.

Forming causes hardening, which results in the strip becoming hard and brittle. In foil rolling mills the thin strip is subjected to intermediate annealing, which causes recrystallisation, in order to make it soft and ductile again. Aluminium foil (EN 546) is produced in a series of rolling stages on single or tandem roll stands at speeds of up to 2,500 m/min: the most technically demanding foil is less than 0.006 mm thick and thus only about a tenth of the thickness of a human hair. Rolling oils provide cooling and lubrication and are circulated in a closed loop.

The final pass is carried out using a 'sandwich process'. As the material is very thin, two coils are fed simultaneously through the foil rolls. This produces the different finishes that one is familiar with from household foil: the sides that come into contact with each other are matt, whereas the sides that come into contact with the rolls are shiny.

Following the final pass, the individual foils are separated again during slitting and then cut to the width and length required by the client. After passing through the finishing rolls, the foil is usually annealed to facilitate further processing. This treatment also leads to vaporisation of residual rolling oil and renders the foil completely sterile. ■



Surface treatment and foil conversion

Depending on the specific requirements, the foil and strip can be mechanically or chemically treated, lacquered, laminated, coated, processed with other materials to produce foil laminates, or embossed and printed. Besides decorative purposes, these measures serve to improve the mechanical loading capability and chemical resistance or to produce specific properties such as heat sealability. Some aspects of surface treatment and conversion are outlined briefly below.

Degreasing

The degreasing of oily or greasy surfaces is carried out using aqueous cleaners. The aim is primarily to remove organic compounds such as rolling oil residues.

Pickling

The aim of pickling is to remove oxide layers. As the protective oxide layer is only stable over the pH range 5–8, the surface treatment can be carried out using either alkaline or acidic solutions. After pickling, the surface is rinsed with water and neutralised with nitric acid solution.

Protective lacquering

In the case of protective lacquering, colourless, thin layers of lacquer are applied to the aluminium foil. These layers are not completely free from pores and offer only limited resistance to chemical attack but provide a good adhesive base for printing. If greater chemical resistance is required, thicker film thicknesses are applied. Thermoplastic (plastic) lacquers ensure good heat sealability. When it comes to colouring, additional pigments are incorporated in the lacquer binder. Opaque colouring is carried out using pigmented lacquers; the metallic character of the surface is maintained in the case of transparent colouring.

It is always necessary to carry out a thorough surface treatment including degreasing and pickling prior to lacquering. In order to apply lacquer systems to aluminium foil, they are

mixed with organic solvents. These are released again later during drying and returned to the production loop via extraction and recovery systems. Low-solvent and solvent-free lacquers are increasingly being used.

Lamination

With lamination, aluminium foil and strip are bonded with other materials such as plastic films and paper. The various forms of lamination include adhesive, lacquer, wax and hot-melt lamination.

Coating

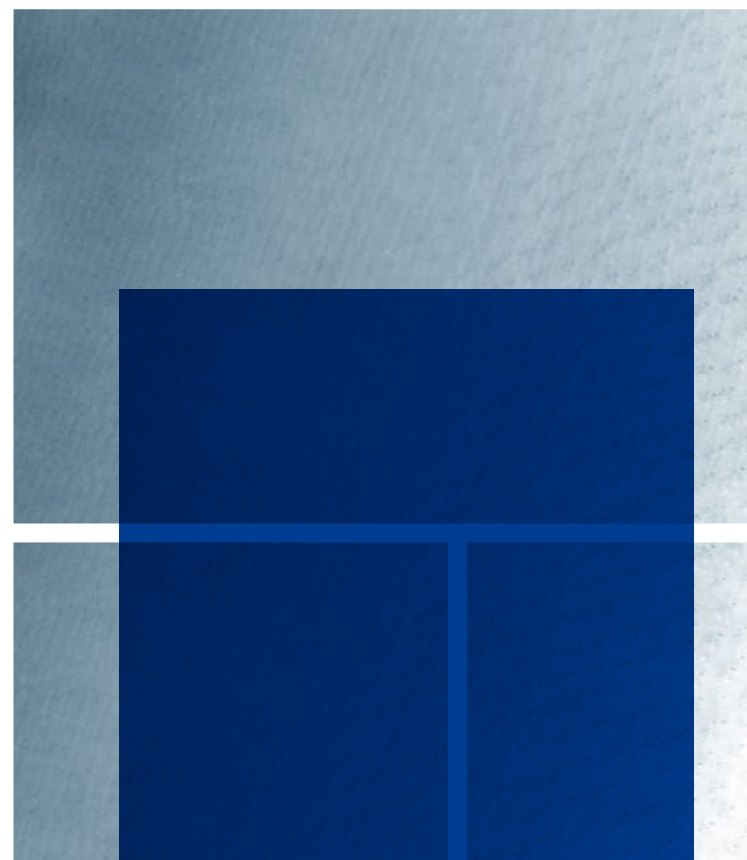
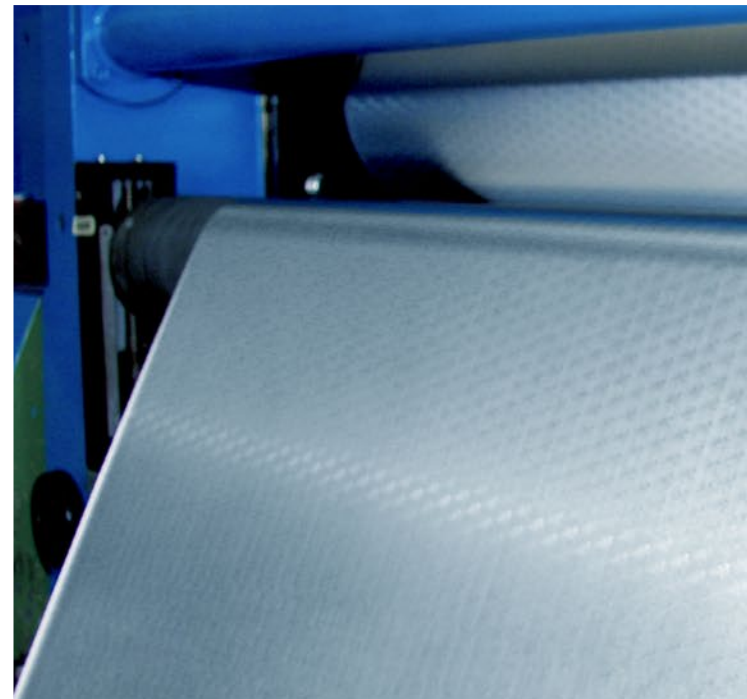
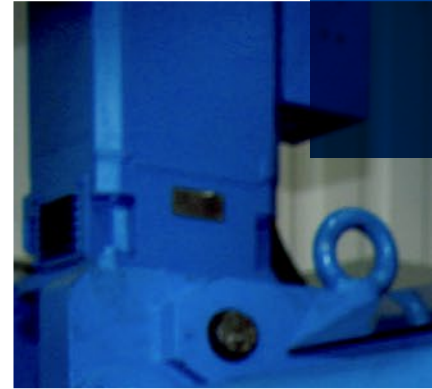
In the case of coating, a plastic is applied to the aluminium foil either in molten form, as a dispersion or as a solution. Several layers of different plastics are used depending on the specific demands made on the packaging material.

Printing

The two most important printing processes used in foil conversion are flexo and gravure printing. Flexo printing allows three-dimensional shapes to be printed and is also economical for small production runs. Gravure printing is particularly well suited for large production runs and is striking because of the high quality of its colour reproduction. Digital printing is also gaining in importance in the course of the increasing customisation and personalisation of packaging.

Embossing

The embossing of foil and thin strip is carried out using engraved or etched steel embossing rolls and a counter roll made of resin-bonded paper. It causes items such as company logos, trademarks and slogans to stand out three dimensionally over the surface. The process is being increasingly used to 'upgrade' packaging in order to set the contents of a pack apart from those of a competitor. ■



Material properties

The quality of packaging is determined to a large extent by the properties of the material used. With aluminium packaging, it is the good barrier property that is the material's main characteristic. Even foil 0.006 mm (6 µm) thick will protect the pack contents completely against the detrimental effects of environmental influences such as temperature, air, light, moisture, microorganisms or foreign odours. Conversely, the neutral-tasting aluminium barrier layer protects the contents from any loss of aroma or other volatile components.

Further outstanding characteristics of aluminium as a packaging material are:

- its light weight, which reduces transport costs
- its high thermal conductivity, which reduces the energy requirement for hot sealing and sterilisation as well as for freezing, cooling and heating in the pack
- its high reflectivity of light and UV rays
- its corrosion resistance due to the natural oxide layer that forms spontaneously on aluminium on exposure to air; the level of protection can be increased further by foil conversion
- its chemical resistance to the pack contents
- its neutral taste
- its good formability whilst at the same time maintaining shape stability, which proves useful for example when deep drawing containers or wrapping hollow shapes
- the resistance of containers to breakage and pressure
- the good printing and embossing properties
- its excellent recyclability

The European standard EN 546-2 covers alloys used for foil and their mechanical properties. The technical terms of delivery and other requirements for slugs of aluminium and aluminium wrought alloys for use in impact extrusion are standardised in EN 570. ■

Applications in the packaging industry

Aluminium is used as a packaging material for completely different types of goods: foodstuffs, drinks, pharmaceuticals, cosmetics, pet food and tobacco products as well as for chemicals and industrial products. With foodstuffs, where foil in particular is used, aluminium's complete barrier performance also protects perishable goods such as dairy products. Exactly the same applies for medication that requires reliable protection against light, moisture and gases even under extreme conditions, such as those experienced in the tropics.

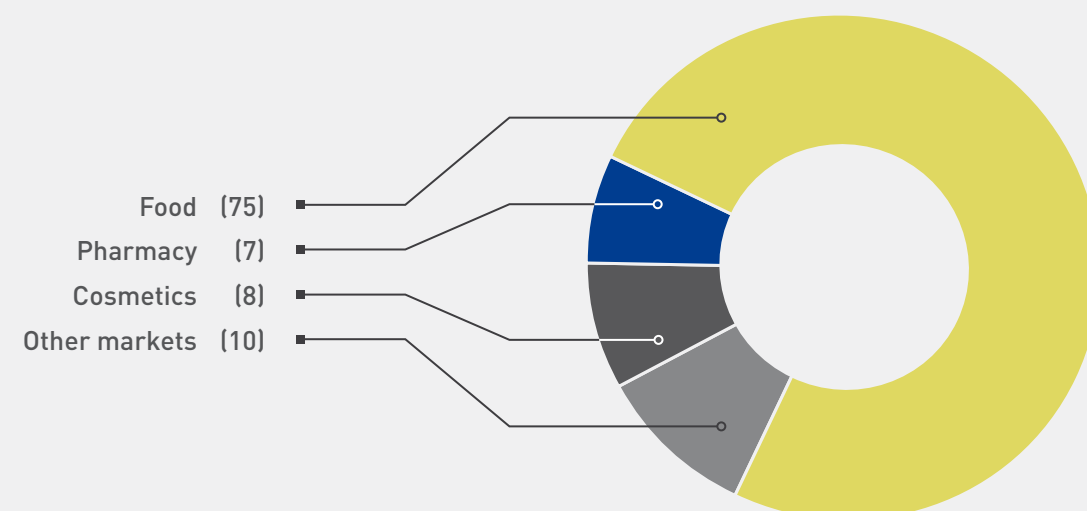
Aluminium bottles, cans and cartridges are mainly used for chemical products, such as laboratory chemicals, agrochemicals, sealants and adhesives. Here, the material's resistance to breaking, diffusion and pressure play a decisive role.

Aerosol cans and tubes made from aluminium are the preferred packaging for pharmaceuticals, hygiene and/or body-care products and cosmetics.

Aluminium foil is used either as a single material or as a composite material in combination with other packaging materials such as paper and/or plastics. Such 'tailored' composites combine the positive properties of differing materials, usually with the use of less material. In this way they offer maximum packaging benefits with minimum use of material.

EN 573-3 specifies limits for the composition of aluminium and wrought aluminium alloys and contains an overview of alloys that are available as feedstock for packaging. Rolled products for packaging in general are covered by the EN 14287 standard, foil by EN 546, Parts 1-4 and slugs for impact extrusion by EN 570. In addition, the EN 601 and EN 602 standards lay down limiting values for the individual alloying elements that have to be observed if an alloy is to be allowed to come into contact with foodstuffs. ■

Markets for aluminium packaging in %



Rigid aluminium packaging

Rigid aluminium packaging includes beverage, food and aerosol cans, bottles and closures. They are produced by deep drawing and impact extrusion.

Beverage cans

Beverage cans are used above all for beer, carbonated soft drinks and energy drinks. This form of packaging has increasingly taken over other product segments such as sparkling wines, iced teas and coffee-based refreshments. Some 64 billion aluminium or steel beverage cans were produced in Europe in 2015. Production worldwide is some 320 billion units. The aluminium beverage can's market share is continually increasing and worldwide is now about 75 per cent.

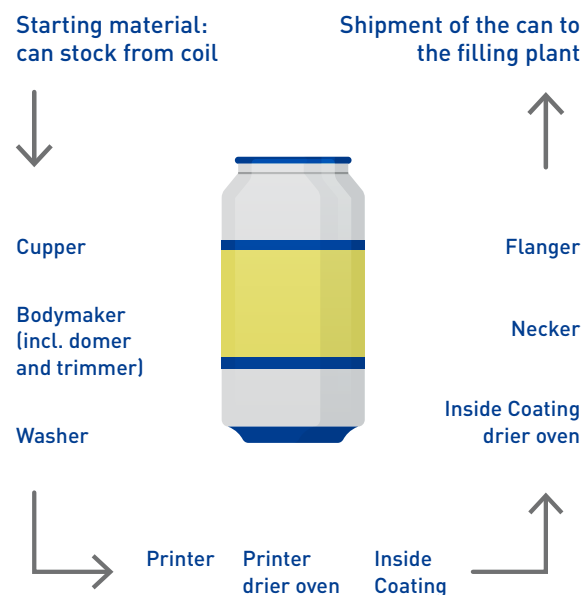
The aluminium beverage can is characterised by numerous innovative developments: one only has to think of the various can formats (standard, slim, sleek, king can) or in the case of the easy-open lid, which is made of aluminium for both types of can body material, of the development from the ring-pull can to the stay-on-tab system or the LOE lid with its enlarged drinking aperture. Materials savings resulting from thinner-walled aluminium can bodies and a necked-in top have led to lower production costs and reduced transport weight. Embossed aluminium beverage cans are also to be found on supermarket shelves. Innovative coating processes produce surfaces with a wet-look appearance or, for example, feel like an orange. There are aluminium beverage cans with thermo-sensitive lacquers that indicate whether the temperature is suitable for drinking and cans with luminescent paints that light up in the dark when illuminated with UV light. The pack itself becomes an effective marketing instrument that can positively influence a brand's image.

Manufacture: Aluminium beverage cans are produced by deep drawing as a two-part can with a crimped-on tear-off lid. The starting material is mill-finished strip containing manganese and magnesium as alloying elements for high strength and ductility. Degreasing, lacquering the interior and exterior of the can, and printing the can body are first carried out on the finished can body because of the large amount of material deformation that takes place during the forming process.

First of all, so-called cups are stamped out of the pre-greased aluminium strip. Canmaking is carried out by means of a deep drawing process in which the cups are drawn through dies using a punch to produce a hollow body in the shape of the punch. The process takes place in several steps, with the cups being drawn to can bodies with ever-smaller diameters, ever-thinner walls and ever-greater lengths. The can body is then trimmed to the exact height required. On modern production lines, about 2,500 units a minute can be manufactured in this way.

Subsequent washing and drying remove the lubricant. The can is then subjected to external base coating, drying in hot air ovens, printing with up to eight colours, another lacquering treatment and final drying. The interior of the can body is also subjected to a protective lacquer to avoid any direct contact between the beverage

Manufacturing process for aluminium beverage cans



and the metal. The can rim is then necked-in and flanged outwards in order to enable the lid to be attached after filling. Finally, a detailed quality control is carried out to examine the can body for pores or cracks.

The next step is to ship the cans to the filling plant, which fills and seals the cans. In contrast to the can body, the can lids are produced from pre-lacquered aluminium strip. In coil coating plants, the strip is coated on both sides with client-specific lacquers. The basic lid shapes with a smooth surface (shells) are stamped out of strip or sheet. The basic shape is produced in a so-called shell press: the edges are curled so that they can be seamed onto the can rim later. A sealant is then sprayed onto the inside rim of the lid blank. The inside of the shell is scored where the drinking aperture is to be so that the tab can be pushed through easily and without any risk of injury.

The tab itself is produced separately in numerous working stages using an automatic machine. It is attached to the lid by feeding a strip of tabs together with the shells into a second automatic machine, where the tab is attached to the end. Finally, the finished lids are sealed onto the filled cans.

Aerosol cans



Food cans

Like beverage cans, food cans made from aluminium alloys (AlMnMg) are made in two pieces. For decades they were produced mainly as relatively flat containers for tinned fish and pasty foodstuffs. Nowadays, however, the range of products has multiplied both in terms of the foodstuffs packaged and the size and shape of the cans.

The cans are deep drawn from sheet 0.2–0.3 mm thick. In principle, the process is the same as that for producing beverage cans. The sheet is pre-treated before being deep drawn and is subsequently lacquered and/or plastic coated and printed. As far as the closures are concerned, the cans have full-aperture tear-off lids with differing types of tear-open tabs, e.g. with a grooved surface for better grip or with a finger ring. Two-component systems comprising a membrane made of thin aluminium strip and an aluminium ring are an alternative to conventional can lids. The membrane strip is either colourless on the outside or coloured with a protective lacquer, and sometimes printed as well; there is a plastic peel coating on the inside. The lids can thus be removed just as easily as yoghurt-pot lids. Food cans are also suitable for sterilising the foodstuffs in autoclaves.

Aerosol cans

In 2015, about 7.7 billion aluminium aerosol cans were produced worldwide. This is equivalent to a 50 per cent share of the whole aerosol can market. The cosmetics industry is the largest user with some 80 per cent. Aerosol cans are also used as packaging for chemical, household and pharmaceutical products as well as for foodstuffs.

Aerosol cans are produced as a monobloc without any seam or joints by means of so-called impact extrusion. This enables them to withstand internal pressures of 18 bar, for example, which are standard in the cosmetics industry. However, cans can also be produced to withstand a pressure of 23 bar for special applications. Cans are mainly manufactured from commercially pure aluminium (99.5 % purity) and sometimes they are made from aluminium alloys. As in tube making, the diameter of the slug processed depends on the desired can size. In addition to their size, aerosol cans differ from other cans above all in the shape of their shoulders (round, spherical, sloping, stepped and ogival) with neck apertures for 1-inch or 20-mm valves. The cans can now be manufactured in completely new shapes and complex designs thanks to new conification and embossing technologies. Some active ingredients cannot simply be mixed with a propellant inside the can – this is particularly the case with products that are not sprayable, like pastes, gels or emulsions. With these types of aerosol can, the propellant and the active ingredient are kept apart inside the can with the help



Pet food trays

of a twin-chamber system (e.g. a bag-on-valve system). Aerosol cans with a twin-chamber system also operate upside down.

The process steps in detail: A circular disc, called a slug or a circle, is stamped out of aluminium strip and placed in a steel die. A punch whose diameter is smaller than the monobloc can by an amount twice the can's wall thickness then forces the slug into the die at high pressure (2500–4000 kN depending on the size of the slug). The aluminium is plastically deformed with generation of heat (180–200 °C), flows past the punch in the opposite direction to the action of punch and takes on the shape dictated by the tool. The extrusion process only lasts a fraction of a second. The thickness of the bottom is determined by the immersion depth of the punch, which is subsequently withdrawn with the can body from the die. The punch passes through a stripper which separates the can from the punch. As a result of cold working, can bodies have high strength, a smooth surface and high dimensional accuracy.

The rim of the can, which is slightly wavy because of the extrusion process, is trimmed and the surface brushed to remove any traces of the impact extrusion. The can body is cleaned inside and out to remove any abraded particles and the lubricants used to grease the slugs. Annealing of the can with resultant cleaning (as in the case of tubes) is not possible because the cans have to be hard and maintain their shape. The metal surface is thus degreased using an alkaline cleaning solution, lightly pickled, and then rinsed and dried.

The can is subsequently lacquered on the inside to prevent the contents coming into direct contact with the aluminium. Besides lacquers based on epoxy phenolic resin or polyamide imide, polyester, aqueous or powder-based lacquer systems are used. They are applied with a spray nozzle and



then baked in using a stove furnace. Further process steps are lacquering of the outside, printing and overvarnishing with a transparent protective film.

The desired shaping or embossing of the can body is carried out in a conification machine, where the final manufacturing step, the necking-in of the shoulder, is also carried out. This takes place in several steps, the number of which depends on the diameter of the can and the shape of the can body and shoulder chosen. Finally, the rim is crimped over and, if necessary, a screw thread is formed. The aperture is milled flat so that it can serve as a sealing surface and a snap-on groove for the cap is formed below the shoulder.

The design of the can opening depends on whether a spray nozzle, a valve or a hand pump is to be fitted or a thread is needed. The necessary preparatory work has to be carried out when forming the aperture. In addition, the bottom of the aerosol can, which is under pressure, has to be domed inwards. This is also carried out during necking-in if the process step has not been carried out at the pre-production stage. It is achieved by forcing the can into a suitably shaped die.

As an alternative to impact extrusion, aerosol cans can also be made using a combined deep drawing and ironing process, like that used to produce beverage cans. This process

can result in material savings and is especially suitable economically for producing larger-diameter cylindrical cans in large lot sizes with only limited changeover effort required.

Bottles

Aluminium bottles are used for chemical products, as drinks containers for leisure and outdoor activities or as stylish packaging for beverages.

Aluminium bottles are produced either by means of an impact extrusion process (as for aerosol cans) or using a deep drawing and ironing process (as for beverage cans).

Above all, it is the tapered shoulder/neck section that makes it more reminiscent of a bottle than a can. The second characteristic of the aluminium bottle is that it has a screw closure or crown cork like a traditional bottle.

In Europe, as far as beverage packaging is concerned the aluminium bottle is still a niche market that is used as a form of premium packaging at special events. By contrast, bottles are more common in the USA and Japan, for example for soft drinks, beer and isotonic drinks.

Small tubes and small tins

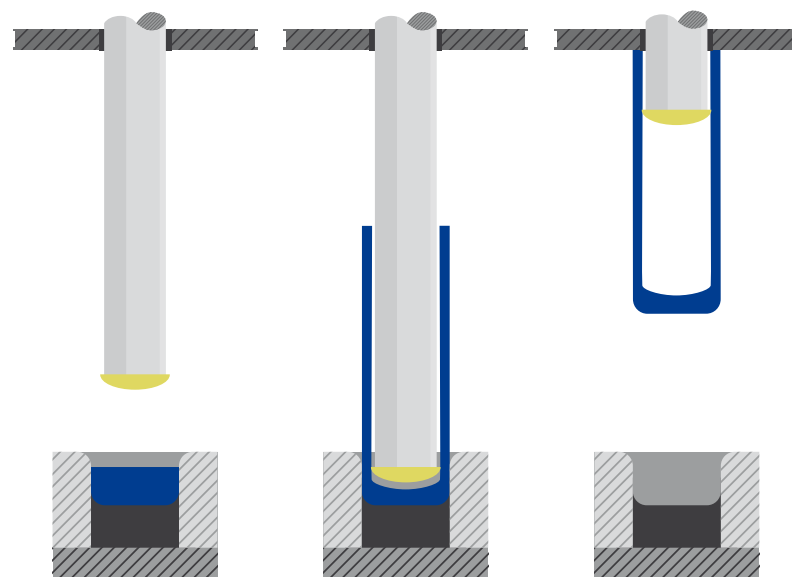
Small tubes and small cans, for example for tablets, cigars, spices or granule-shaped pharmaceuticals, are also produced by impact extrusion. They usually have aluminium screw-on lids.

Closures

The screw tops for wide-mouth glass jars are usually made from aluminium whereas there is competition with other materials when it comes to glass bottles. In the case of the well-known 'pilfer-proof' closures on bottles of mineral water, which are increasingly being used for wine bottles, the aluminium top is rolled into the threads of the glass bottle during the closing operation. The ring round the bottle neck at the bottom edge of the closure (made of aluminium or plastic), which acts as a guarantee for the integrity of the contents, becomes separated or forced apart when the bottle is first opened. For fruit juices, which might ferment, there are even aluminium screw closures available that have been developed with an overpressure safety device. ■

Impact extrusion

The impact of the tool on the slug in the die liquefies the aluminum. It flows along the tool and adopts the form of the container.



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Semi-rigid aluminium packaging

Semi-rigid packaging includes tubes, capsules as well as trays and containers made from thin aluminium strip.

Collapsible tubes

Aluminium tubes are produced by impact extrusion without a seam as a single piece in a similar manner to aerosol cans. The tube material is commercially pure aluminium (99.7 % purity) and tube diameters range from 11–60 mm. The approximately 0.1 mm thick aluminium tube body can be readily deformed plastically with little elastic spring-back. The contents of the tube can thus be dosed exactly without any contents or air being sucked back. This makes the tube particularly well suited for everything that has a pasty consistency, ranging from foodstuffs, cosmetics and pharmaceutical products to paints, adhesives and lubricating grease.

Manufacture: The slug is placed in a steel die and then depending on the size of the slug a steel punch applies a force of 800–1600 kN on it. The aluminium is deformed and adopts the shape dictated by the tooling. In addition to the usual cylindrical tubes, there are conical designs in which one opens out the cylindrical tube by one or two degrees in a conification machine in an additional processing step. This allows the empty tubes to be shipped inside each other, which simplifies transport packaging and leads to a significantly reduced shipped volume.

After impact extrusion, the raw tubes are cut to length in automated machining centres, threads are rolled into the necks of the tubes and the mouths of the tubes are deburred. The

tubes are then fed into a continuous furnace and annealed so that the cylinders become soft and thus plastically deformable. In addition, the annealing treatment achieves the necessary level of cleanliness for subsequent internal lacquering and printing, with drying being carried out in appropriate ovens in each case. Finally, the aluminium or plastic tube closure is added in a capping machine. Screw closures with metric or fine threads as well as twist, snap-on or flip-top closures are used.

The closure of the tubes after filling is carried out by folding: the tube cylinder is pressed together at the open end with folding tongs and folded over several times to produce a double, triple or saddle fold. Imperviousness is achieved by subsequent pressing. In the case of particularly runny substances, a sealing strip of lacquer is applied to the inside of the tube end during production of the tube. One can achieve an even better seal using a heat-seal lacquer and heat-sealing by pressing the fold with heated pressure clamps.

In addition to all-aluminium tubes, plastic and laminated tubes are available. The latter are composites of a polyethylene film on the inside and outside with aluminium foil or other substrates as the barrier layer.

Capsules

Aluminium coffee or tea capsules are becoming ever more popular with consumers worldwide. Since they were first launched by Nespresso in 1986, various coffee producers have committed themselves to aluminium as the capsule material. The capsules excel as being premium packaging and an aroma safe, and they offer ever-smaller households single-serve portions and easy preparation. Thanks to aluminium's outstanding barrier properties they ensure optimal protection, for example against oxygen, sunlight and moisture, which can adversely affect the taste and quality of the coffee.

Strictly speaking, coffee capsules are not packaging and consumers in Germany are not allowed to dispose of them by means of the yellow bins or sacks of the dual system. Like teabags, for example, they must be disposed of with the household waste (black bin). However, within the dual system manufacturers can obtain a licence by making a voluntary financial contribution to the disposal of the empty capsules. This has happened in Germany and means that after use consumers can throw the used capsules into either the

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yellow bins or sacks of the dual system. Alternatively, they can be returned to Nespresso outlets or other businesses that cooperate with Nespresso, the locations of which can be found via a mobile app or the coffee producer's website. There are already about 14,000 collection points worldwide. In Switzerland, it is even possible to hand over the aluminium capsules to the postman as part of the so-called Recycling@ Home service when he delivers new capsules. Capsules that are not collected as part of the dual system are transported to special processing centres, where the aluminium and the coffee grounds are separated. Shredded aluminium free from foreign material is then processed at a secondary smelter using the latest technology.

Like trays, for example, aluminium capsules are produced by deep drawing, which gives them their typical conical shape.

Trays and containers

Trays and containers can be produced simply by deep drawing using standard deep drawing presses. They are heat resistant, retortable and available in the most varied range of colours. They are mainly used for frozen meals and ready meals by catering companies and in aircraft catering and for portion packs for jam, honey, milk, sausage products and the like.

Container strip is available to suit all types of contents to be packaged: various alloys in thicknesses ranging from

0.04–0.3 mm are used (the standard range for foil dishes is between 0.07 and 0.1 mm). Depending on the application, it is uncoated on the side that comes into contact with the contents or coated with lacquer or plastic. Container strip for ready meals, for example, comprises polypropylene, a layer of synthetic resin, thin aluminium strip, baking-in lacquer and printing ink. The containers can be sealed either with plastic film or aluminium foil. Whereas it was common at one time to use 'permanent' seals that had to be cut open along the edge of the container, peelable lids are now widely used.

The good forming properties of aluminium enable the lightweight containers to be produced in the most varied range of shapes. To ensure stability, correspondingly thicker gauge aluminium strip is used for large-diameter containers.

The process steps involved in the deep drawing of containers are briefly as follows: the strip is fed into the tool and a blank corresponding to the size of the finished container is cut out. The tool is lowered into the material and forms the container. The shoulder ring (a part of the tooling that determines the height of the container) is moved into place and the tool is then lowered a little further in order to form the edge of the container. In the process, the rolled edge is folded over some 1½–2½ times. The tool then moves upwards again and ejects the container. The whole process takes place in a single stroke; several blanks are shaped simultaneously. Depending on the press type, tooling and container shape, a modern deep-drawing press operates at between 70 and 120 strokes/min. ■





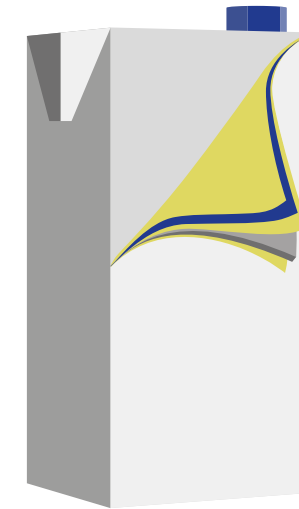
Flexible packaging with aluminium foil

Foil wrappers are one of the oldest applications of aluminium foil, having been in common use for chocolate (since 1911), butter, cheese and tobacco products right up to the present day. Many of these products are laminated or coated with paper or plastic respectively and are available as sealed or adhesive wrappers that are impervious or very nearly so and guarantee the authenticity of the contents. Depending on the application, the thickness of chocolate foil is 0.010–0.015 mm.

A further field of application of thin aluminium strip are the lids for dairy products such as yoghurt. The lids are made

from material that is 0.03–0.05 mm thick with a heat-sealing lacquer on the underside. The lid foils are attached to the plastic container by heat sealing.

Capsules made from thin aluminium strip fulfil a decorative purpose on wine and sparkling wine bottles as well as protecting the cork and serving to confirm the integrity of the contents. This applies in a similar manner to the tamper-evident seal and hygiene protection for beer, which cover the crown cork and guarantee as far as possible the integrity of the contents. In the case of large-area neck foils, the aluminium foil also emphasises the premium character of



Layer composition of beverage carton

- Polyethylene 21 %
- Aluminium 4 %
- Carton 75 %

the product. The security foils are made from thin foil some 0.010–0.015 mm thick.

Impervious membranes made from aluminium foil with or without paper lamination act as proof of originality and diffusion protection for instant drinks such as instant coffee or cocoa.

Strip packs made from laminated aluminium foil and push-through packs made from shaped plastic film with a sealing aluminium layer are indispensable commercially as blister packs for tablets and caplets. The all-aluminium blister, in which both lid and bottom are made from aluminium foil, has gained in importance recently.

Retortable pouches, for example for ketchup and ready-meal components containing small pieces of solids, are made from aluminium foil (0.006–0.02 mm) laminated with plastic on bag forming, filling and sealing machines. Outside the food sector one can mention pressurised pouches for tennis balls made from an aluminium-plastic laminate. A pressure of about 1 bar is applied to the pouch and this then ensures that there is no loss of pressure inside the balls during storage.

Colour-printed and embossed aluminium foil is available to enhance the premium character of beverage cans and offer increased hygiene protection. It is mechanically crimped on the rim of the can, and spot-bonded if necessary, and prevents dust or impurities, which have gathered for example after standing for a longer period on the supermarket shelf, from entering the can when it is opened. At the same time, spot-bonded foil is suitable as a temporary closure, such as for keeping out insects.

The foil can be printed in up to ten colours using flexo or gravure and can be used additionally as an effective advertising space.

Aluminium foil with security features to combat counterfeiting is used for highly sensitive pharmaceutical products. These make use of the reflective surface of the metal foil, such as the so-called 'pattern shifting' process, which is based on Moiré surface effects. Other processes are based on specially coloured layers, which cause colour shifts when the incident light on the surface of the aluminium foil is reflected. Yet other processes are based on the partial metallisation of plastic film with aluminium.

Strictly speaking, aseptic packaging for UHT milk is not aluminium packaging but a drinks carton; a laminate of paper, aluminium foil and polyethylene to be precise. The pack material is immersed in a warm bath of hydrogen peroxide to sterilise it. It is subsequently shaped into a so-called Brik-Pack, filled and sealed. Of the around 28 grams of packaging used for a litre carton of UHT milk, the one and a half grams of aluminium foil provide the barrier layer against external influences and help ensure that the milk can be kept for several months without refrigeration.

For the sake of completeness, one should also mention aluminium household foil here. This is not packaging by definition but still involves the packaging of foodstuffs – whether it be for cooking or storage. It is typically 0.01–0.02 mm thick without any coating or printing, wound onto a cardboard reel and available in various widths and lengths.

When it comes to uncoated aluminium materials and articles, there is appropriate labelling along the whole supply chain, e.g. on outer packaging or on pack inserts in order to avoid them being used incorrectly by the consumer (e.g. to avoid using household foil to store or prepare salty or acidic products or to cover such products on serving platters made of stainless steel). Failure to observe such information can result in the release of an undesirably high level of aluminium compounds into foodstuffs. ■

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