applications. The thermoformable base film described herein delivers a critical and previously unachieved combination of 1) thermoforming ease, 2) high moisture barrier and 3) recyclability.

BRIEF DESCRIPTION OF THE DRAWINGS

[020] The disclosure may be more completely understood in consideration of the following detailed description of various embodiments of the disclosure in connection with the accompanying drawings, in which:

[021] **Figure 1** is a schematic of a cross-section of an embodiment of a thermoformable base film including a first, second and third layer;

[022] **Figure 2** is a schematic of a cross-section of an embodiment of a thermoformable base film including a first, second, third and fourth layer;

[023] **Figure 3** is a schematic of a cross-section of a package including a thermoformed base component, a product and a lid component; and

[024] **Figure 4** is a schematic of a cross-section of an embodiment of a lid component for a packaged product.

[025] The drawings show some but not all embodiments. The elements depicted in the drawings are illustrative and not necessarily to scale, and the same (or similar) reference numbers denote the same (or similar) features throughout the drawings.

DETAILED DESCRIPTION

[026] Described herein is a polyethylene-based, thermoformable base film suitable for packaging products that might be sensitive to oxygen and/or moisture. A lidding film may be heat sealed to a thermoformed base packaging component made from the thermoformable base film, creating a package that may be accepted in a high-density polyethylene recycling process or a

polyethylene recycling process. The high-performance packaging may be suitable for products such as, but not limited to, pharmaceuticals, nutraceuticals, medical products, fresh foods, refrigerated foods, shelf-stable foods, consumer goods, cosmetics and chemicals.

[027] The structure and material components of the thermoformed base component are uniquely configured to provide moisture barrier, good clarity, and recyclability options. Surprisingly, the thermoformable films described herein have an acceptable operating window in a thermoforming process such that the final thermoformed base components are easily thermoformed. Also surprising is that upon thermoforming, the thermoformable base materials described herein are able to maintain the original thermoformed shape, resisting warping and shrink.

[028] The packages described herein, incorporate at least two packaging components. First is a thermoformed base component with at least one thermoformed cavity, made from a polyethylene-based film. The thermoformed cavity may be deep or shallow and is generally shaped to hold the intended product therein. The thermoformable base film should be of a thickness to provide for the desired rigidity (i.e. stiffness), durability and barrier upon thermoforming. Second is a lid packaging component. The lid is configured from a film that is capable of being hermetically heat sealed to the thermoformed base component, producing a protective package for the product.

[029] In some embodiments of the package, a high-performance lid component having a composition high in high-density polyethylene may be used in conjunction with the thermoformed base. The combination of the thermoformed base component and the lid packaging component provides for superior package characteristics while keeping a highly homogeneous polymer composition (essentially comprising polyethylene) to provide for the opportunity to recycle the entire package in a single stream, such as the high-density polyethylene bottle stream.

[030] The packaging components described herein are unique in that they are produced using high levels of high-density polyethylene, yet retain high-

performance characteristics required for demanding packaging applications. The hermetically sealed packages provide excellent product protection (i.e. moisture barrier), good appearance, good forming accuracy and consistency, good heat resistance, and good seal strength. Packages with these levels of performance have not previously been delivered using materials that can be easily recycled in the high-density recycling stream.

BASE PACKAGING COMPONENT

[031] The thermoformed base packaging component is formed from a thermoformable base film **10** that has at least a first layer **20**, a second layer **40** and a third layer **30**, with the second layer positioned between the first and third layers, as shown in Figure 1. The first and third layers may have a similar or identical composition and together make up about 10% to about 35% of the overall thickness (or volume) of the thermoformable base film. The second layer makes up about 25% to about 90% of the thermoformable base film. In some embodiments of the thermoformable base film, the second layer makes up about 50% to about 90% of the thermoformable base film. There may be additional layers in the thermoformable base film as well.

[032] The term "layer", as used herein, refers to a building block of films that is a structure of a single material type or a homogeneous blend of materials. Films contain one or more layers that are connected to each other. A layer may contain a single polymer, a blend of materials within a single polymer type (i.e. polyethylene) or a blend of various polymer types. A layer may contain metallic materials or other non-polymer materials and may have additives. Layers may be continuous with the film or may be discontinuous or patterned in comparison to the film. A film has two surfaces, opposite each other. The layer at the surface of a film is not connected to another layer of that film at that surface.

[033] The first and third layers of the thermoformable base film each contain a polyethylene and have an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3. The first and third layers may contain a high-density polyethylene, a medium-density polyethylene or a blend of one of these with a lower density

polyethylene. As used throughout this application, the term “high-density polyethylene” or “HDPE” refers to both (a) homopolymers of ethylene which have densities from about 0.960 g/cm^3 to about 0.970 g/cm^3 and (b) copolymers of ethylene and an alpha-olefin (usually 1-butene or 1-hexene) which have densities from about 0.940 g/cm^3 to about 0.958 g/cm^3. High-density polyethylene includes polymers made with Ziegler or Phillips type catalysts and polymers made with single site metallocene catalysts. The high-density polyethylene may be bimodal and may be pre-nucleated with a nucleating agent. A nucleating agent may be added to the HDPE by masterbatch. As used throughout this application the term “medium-density polyethylene” refers to homopolymers and copolymers of ethylene having a density from about 0.926 and 0.940 g/cm^3.

[034] As used throughout this application, the term “nucleating agent” refers to an additive that forms nuclei in a polymer melt to control the growth of crystals. The nucleating agent can be any of the type that is capable of nucleating high-density polyethylene and may be added at the point of polymerization of the high-density polyethylene or at a later point in time by way of the addition of and melt blending a nucleating agent containing masterbatch. Examples of nucleation additives include minerals such as chalk, talc, clay, kaolin, silicates and the like, and organic agents such as salts of aliphatic or aromatic carboxylic acids, aromatic salts, metallic salts of aromatic phosphorous compounds, quinaridones, and aromatic amides. Further examples of nucleating agents include zinc glycerolate, calcium glycerolate, calcium hexahydrophthalate, zinc hexahydrophthalate, salts and the like, and mixtures thereof. The nucleating agent may be present in the first and third layers of the thermoformable base film at a level from 0% to about 3.5% by weight of the layer.

[035] Examples of pre-nucleated high-density polyethylene materials that may be suitable for the thermoformable base film are Grade M6020SB available from Equistar and HPS167AB available from Nova Chemicals. An example of un-nucleated high-density polyethylene materials that may be suitable of the thermoformable base film is Grade M6020 available from Equistar. Examples of nucleating agent masterbatch materials that may be suitable for the

thermoformable base film are Hyperform® HPN nucleating agents available from Milliken.

[036] The first and third layer may also contain a polyethylene having a density less than 0.93 g/cm^3. For example, the first layer may contain a linear low-density polyethylene, a metallocene catalyzed linear low-density polyethylene, an ethylene-based plastomer or low-density polyethylene having a density of about 0.92 g/cm^3. The polyethylene having a density less than 0.93 g/cm^3 may be blended with a high- or medium-density polyethylene and may be present in the layer at an amount greater than 0.5%, an amount greater than 5%, an amount greater than 10%, or about 30% or more, by weight. Two or more different polyethylene materials having a density less than 0.93 g/cm^3 may be used in the first layer. The first and third layers may have the same or different composition.

[037] As used herein, a "polyethylene having a density less than 0.93 g/cm^3" is a homopolymer or copolymer of ethylene having a density lower than medium-density polyethylene, thus having significantly different physical properties. The density of the polyethylene is ideally between 0.88 g/cm^3 and 0.93 g/cm^3. The polyethylene having a density less than 0.93 g/cm^3 may be an ethylene-based plastomer or a metallocene catalyzed linear low-density polyethylene. Examples of polyethylene having a density less than 0.93 g/cm^3 that are useful for the thermoformable base film include ATTANE™ 4701 ultra-low density polyethylene (density 0.913 g/cm^3, melt index 1.0 g/10 min, Vicat softening temperature 94.0°C, available from Dow Chemical), Exceed™ 1018 metallocene catalyzed ethylene-hexene copolymer (density 0.918 g/cm^3, melt index 1.0 g/10 min, melt temperature 119°C, available from ExxonMobil), AFFINITY™ PL1850 ethylene-based plastomer (density 0.902 g/cm^3, melt index 3.0 g/10 min, seal initiation temperature 94.0°C, available from Dow Chemical), Exact™ 3139 ethylene-based plastomer (density 0.900 g/cm^3, melt index 7.5 g/10 min, Vicat softening temperature 80.0°C, melt temperature 95.0°C, available from ExxonMobil) and DOW™ LDPE 608A low-density polyethylene (density 0.023 g/cm^3, melt index 2.6 g/10 min, Vicat softening temperature 97.2°C, melt temperature 113°C, available from Dow Chemical). The polyethylene having a

density less than 0.93 g/cm^3 in the first layer should have a softening point that allows for lower temperature heat sealing when another packaging component is attached (i.e. a lid is heat sealed).

[038] The first and third layers may have the identical, similar or different composition regarding the type of polyethylene, the type and presence of nucleating agent, the overall density of the layer and the blend ratio of the materials. The first and third layers may have identical, similar or different thickness.

[039] The second layer of the thermoformable base film contains a high-density polyethylene and a hydrocarbon resin. In some embodiments, the second layer of the thermoformable base film contains a nucleating agent. The second layer may be split into multiple “second layers” which may be separated by other layers. The single or multiple second layers must be between the first and the third layers.

[040] The high-density polyethylene should be present in the second layer at an amount of about 60% to about 90%, by weight. The high-density polyethylene may be present in the second layer at an amount greater than 80% or an amount greater than 85%. Two or more different high-density polyethylene materials may be present in the second layer. A nucleating agent may be present in the second layer of the thermoformable base film at a level from about 0.2% to about 3.5% by weight of the layer.

[041] As used herein, the phrase "hydrocarbon resin" refers to a low molecular weight product (molecular weight less than about 10,000 Daltons) produced by polymerization from coal tar, petroleum, and turpentine feed stocks. A hydrocarbon resin may comprise any of those hydrocarbon resins disclosed in U.S. Pat. No. 6,432,496, issued Aug. 13, 2002, or in U.S. Patent Application 2008/0286547, published Nov. 20, 2008, both of which are incorporated in their entireties in this application by this reference. More specifically, as a non-limiting example, the hydrocarbon resin may include petroleum resins, terpene resins, styrene resins, cyclopentadiene resins, saturated alicyclic resins or mixtures of such resins. Additionally, as a non-limiting example, the hydrocarbon resin may comprise hydrocarbon resin derived from the polymerization of olefin feeds rich

in dicyclopentadiene (DCPD), from the polymerization of olefin feeds produced in the petroleum cracking process (such as crude C9 feed streams), from the polymerization of pure monomers (such as styrene, α-methylstyrene, 4-methylstyrene, vinyltoluene or any combination of these or similar pure monomer feedstocks), from the polymerization of terpene olefins (such as α-pinene, β-pinene or d-limonene) or from a combination of such. The hydrocarbon resin may be fully or partially hydrogenated. Specific examples of hydrocarbon resins include but are not limited to Plastolyn® R1140 Hydrocarbon Resin available from Eastman Chemical Company (Kingsport, Tenn.), Regalite® T1140 available from Eastman Chemical Company (Kingsport, Tenn.), Arkon® P-140 available from Arakawa Chemical Industries, Limited (Osaka, Japan) and Piccolyte® S135 Polyterpene Resins available from Hercules Incorporated (Wilmington, Del.).

[042] The hydrocarbon resin may be present in the second layer at an amount between 0% and 50%, by weight. The upper limit of hydrocarbon resin used may be dictated by processing issues (i.e. insufficient melt strength during extrusion) or film properties. For example, high levels of hydrocarbon resin may cause interlayer adhesion problems or film brittleness. The amount of hydrocarbon used in the second layer will also depend on the type of hydrocarbon resin used and the thickness of the second layer. For example, a thinner second layer may be able to be processed with a higher level of hydrocarbon resin before issues are encountered.

[043] In some embodiments of the thermoformable base film, the hydrocarbon resin may be present at a level up to 30%, by weight relative to the second layer. The hydrocarbon resin may be loaded into the second layer at a level between 2.5% and 30%. Some embodiments of the thermoformable film will have hydrocarbon resin levels in the second layer between 5% and 20%. In exemplary embodiments, the hydrocarbon resin is present at an amount of about 15% or about 7.5%, by weight. The level of hydrocarbon resin may be adjusted to control both the moisture barrier properties of the film and the thermoforming temperature window. Increasing the hydrocarbon resin level increases the

moisture barrier properties of the film. Increasing the hydrocarbon resin level increases (i.e. widens) the thermoforming temperature window of the thermoformable base film.

[044] Any additional materials present in either the first, second or third layers of the thermoformable base film, or present in other layers of the thermoformable base film should be acceptable to the polyethylene recycling process. The thermoformable base film may have an overall density less than 1.0 g/cm^3 for separation purposes. Any additional non-polyethylene materials may be present at a low level such that they do not disrupt or otherwise hamper the recycling process. The additional materials may be of a type that is acceptable to the recycling process, such as other types of polyolefin-based materials. The additional materials may be present along with a compatibilizer system.

[045] Other layers may be present in the thermoformable base film, as long as these layers are not detrimental to the properties of the film (i.e. the materials must be acceptable to the polyethylene recycling process). Other layers may be present at any location of the thermoformable base film.

[046] For example, the thermoformable base film may have a center layer. As used herein, a "center" layer is one that has an equal number of layers on either side of the center layer in a given film. For example, the center layer has two layers on either side, and thus it is in the center of the thermoformable base film. The center layer may have any composition as described herein, such as having an oxygen barrier material or a tie material.

[047] A center layer is particularly useful when the thermoformable base film is produced by way of a "collapsed bubble" process. During this process, a multilayer film is produced by an annular coextrusion process and the tube is subsequently collapsed upon itself, combining the two sides into one final film. This process results in a palindromic layer structure, and the layer that is in the center contains a material that will bond to itself under warm conditions, such as ethylene vinyl acetate copolymer. Thermoformable base films made from this process necessarily have a first layer and a third layer that have identical thickness and composition. Thermoformable base films made from this process

necessarily have a center layer. Thermoformable base films made from this process necessarily have at least two second layers.

[048] In some thermoformable base films, one or more oxygen barrier layers may be present. The oxygen barrier layer should be between the first layer and the third layer. The oxygen barrier layer contains a material that is known to limit the transmission of oxygen through the film. One choice for an oxygen barrier material is EVOH. In some cases, EVOH may be present along with a compatibilizer that allows EVOH to be incorporated into the polyethylene recycling stream.

[049] As used herein, "EVOH" refers to ethylene vinyl alcohol copolymer. EVOH is otherwise known as saponified or hydrolyzed ethylene vinyl acetate copolymer and refers to a vinyl alcohol copolymer having an ethylene comonomer. EVOH is prepared by the hydrolysis (or saponification) of an ethylene-vinyl acetate copolymer. EVOH is commercially available in resin form with various percentages of ethylene. Preferably, ethylene/vinyl alcohol copolymers comprise from about 27-48 mole % ethylene, or even 27-38 mole % ethylene.

[050] An embodiment of the thermoformable base film has a combination of options, including a first layer, a third layer, four second layers, a center layer, two oxygen barrier layers and four tie layers. This embodiment could be produced by a collapsed bubble process, in which case the film is palindromic. Alternately, the film could be produced by a different process and the film is then not necessarily palindromic. Tie layers are used in this embodiment and may be introduced into any other embodiment of the thermoformable base film. Tie layers are layers with the purpose of bonding dissimilar layers, in this case an oxygen barrier layer and a second layer. The need for tie layers is dependent upon the materials in the adjacent layers. For the embodiments of the thermoformable base film described herein, tie layers based on polyethylene copolymers are typically suitable.

[051] As shown in Figure 2, the thermoformable base film **10** may have a fourth layer **50** having high-density polyethylene with an inorganic particle, such as calcium carbonate or talc. The addition of one or more fourth layers may assist in

achieving clean cutting of the material after thermoforming. The one or more of the fourth layers **50** should be located between the first layer **20** and the third layer **30** of the thermoformable base film **10**. The inorganic particle should be present in the fourth layer in amounts of at least 5% or between 5% and 30%, by weight. Care should be taken in the addition of inorganic particles regarding significant increases in the overall density of the thermoformable base film. The overall density of the thermoformable base sheet should remain below 1.0 g/cm^3 as this is a critical feature used in separation procedures during the recycling process (i.e. sorting by floating).

[052] In some embodiments of the thermoformable base film, either the first or third layer forms the surface of the film. This surface may become the surface to which a lid component is heat sealed to a thermoformed base made of the thermoformable base film. In this arrangement, the lid is heat sealed to the first layer that contains a polyethylene and has a density between about 0.92 g/cm^3 and 0.97 g/cm^3.

[053] The thermoformable base film may be fully coextruded or may be produced by other processes such as lamination or coating.

[054] Overall, the thermoformable base film may have a thickness from about 4 mil (102 micron) to about 80 mil (2,032 micron). Some packaging applications would benefit from a thermoformable base film that has a thickness from about 8 mil (203 micron) to about 50 mil (1,270 micron). In some embodiments, the thermoformable base film has a thickness from about 8 mil (203 micron) to about 25 mil (635 micron).

[055] The thermoformable base film should have a total composition suitable for recycling. The thermoformable base film should have a total composition suitable for recycling in a process that typically accepts polyethylene-based materials. The total composition may be suitable for recycling in a process that accepts high-density polyethylene materials.

[056] The thermoformable base films described herein may be recycled after their primary use is completed. As used herein, the term “suitable for recycling” is meant to indicate that the film can be converted into a new useful item, by means

of reprocessing in a polyolefin recycle stream (i.e. recycling streams based on polyethylene). Reprocessing may entail washing, separating, melting and forming, among many other steps. Typically, when plastic packaging is recycled by reprocessing, the material is mechanically chopped into small pieces, melted, mixed and reformed into the new product. If multiple incompatible materials are present in the packaging, interactions occur during reprocessing causing gels, brittle material, poor appearance and generally un-usable or poor-quality products. Using the term "recyclable" indicates that these drawbacks are generally not present. Qualification as a recyclable material is not regulated by any specific agencies but can be obtained from specific groups such as Association of Plastic Recyclers (APR) and How2Recycle™. Recyclable films disclosed herein may be suitable for high-density polyethylene-based recycling streams. Introduction of a recyclable film into any of these recycling-by-reprocessing avenues should not require additional compatibilizer.

[057] Being suitable for recycling may be obtained by keeping the overall amount of polyethylene in the total composition of the thermoformable base film at a high level. Any additives used should be kept to a minimum. Any non-polyethylene-based polymers present should be minimized or may be accompanied by compatibilizers to achieve a composition suitable for recycling. The overall density of the thermoformable base film should be maintained below 1.0 g/cm^3.

[058] To further efforts to achieve a total composition that is suitable for recycling, some embodiments of the thermoformable base film are free from polyester materials. Polyester materials are typically used in films because of the thermoforming ease, stiffness and clarity. However, the presence of polyester may greatly hinder the recyclability of the film.

[059] To further efforts to achieve a total composition that is suitable for recycling, some embodiments of the thermoformable base film are free from EVOH materials. EVOH is typically used in films because it is a thermoformable oxygen barrier material. However, the presence of EVOH may greatly hinder the recyclability of the film.

[060] To further efforts to achieve a total composition that is suitable for recycling, some embodiments of the thermoformable base film are free from polyamide materials. Polyamide materials are typically used because of the thermoforming ease, durability and stiffness. However, the presence of polyamide may greatly hinder the recyclability of the film.

[061] The thermoformable base film may be free from polyester, EVOH and polyamide. The thermoformable base film may be free from fiber-based materials.

[062] It has been found that a thermoformable base film as described herein, having at least a first layer, a second layer and a third layer, can be used to produce a thermoformed base packaging component with excellent results. This is surprising as the thermoformable base film contains a high amount of polyethylene which has previously been shown to not have an acceptable combination of properties for high-performance thermoformed packaging applications. The thermoformable base film described herein delivers a critical and previously unachieved combination of 1) thermoforming ease, 2) high moisture barrier and 3) recyclability.

[063] Most surprising is the thermoforming characteristics of the thermoformable base films described herein. Thermoforming is a process by which a film is heated above a minimum temperature to soften the polymers to a point where they can be physically formed into a desired shape, and below a maximum temperature where the film is melting and cannot be web processed. Film or sheet structures that contain high-density polyethylene materials are notoriously known for having a very narrow temperature window (delta between the minimum and maximum processing temperatures) for thermoforming. The thermoformable base films that contain a second layer using a hydrocarbon resin as described herein may increase the thermoforming temperature window by up to 100% or even 200% over films that do not contain a hydrocarbon resin in the second layer. Even small amounts of hydrocarbon resin (i.e. 2.5%) in the second layer of the thermoformable film can have a significant impact on the ease with

which the film can be thermoformed due to the more forgiving temperature range for forming.

[064] Also surprising is that the thermoformable base films described herein, while having high levels of polyethylene, maintain the shape taken during thermoforming. In other words, the thermoformed bases produced from the thermoformable base film can be thermoformed without experiencing post-thermoforming warping or curling. Additionally, any shrinking that may happen after thermoforming is also greatly reduced or eliminated. This result is contrary to previously thermoformed films containing high-density polyethylene.

[065] The thermoformable base films advantageously have excellent moisture barrier. The moisture barrier property is dependent on the layer composition. One way to increase the moisture barrier is to increase the amount of hydrocarbon resin or nucleating agent in the second layer. Another way to increase the moisture barrier is to use a bimodal high-density polyethylene. The moisture barrier performance of the thermoformable base film is important as it allows this material to replace other standard forming films which may not be easily recyclable, such as PVC, for packaging moisture sensitive products.

PACKAGED PRODUCT

[066] The thermoformable base films may be formed into packaging components (thermoformed bases) and used in conjunction with other packaging components (such as lidding) to produce packaging. Thermoformed bases may be produced from the thermoformable base film by a thermoforming process using heat and pressure (mechanical and/or vacuum). The thermoformed base may be highly rigid and inflexible or the thermoformed base may be flexible while still maintaining the thermoformed shape. The thermoformed bases described herein have at least one cavity to hold a product and a flange surrounding each of the cavities. The flange is generally an unformed area of the film and serves as a place to connect the thermoformed base to the other packaging components, which may be a lid, another thermoformed base component or some other packaging component.

[067] An example of a packaged product **1000** is shown in Figure 3. In this embodiment the thermoformed base **100** has multiple small cavities **110** surrounded by a flange **120**. Cavities such as these may be sized specifically to hold an individual pharmaceutical tablet or capsule. Alternatively, the cavity of the thermoformed base may be large and hold multiple product pieces. Cavities of all numbers, sizes and shapes are anticipated by this application.

[068] Each cavity **110** present is surrounded by a flange **120**. The flange **120** of the thermoformed base **100** should be an area without curvature for attachment to another packaging component, such as a lid packaging component **200**. There is a product **1100** enclosed in each of the cavities. In this embodiment, the lid component is hermetically sealed to the flange in areas surrounding each of the cavities of the thermoformed base. Alternatively, the lidding may be connected to the thermoformed base at the flange in an area including the entire perimeter surrounding all the cavities, and not between each of the cavities.

[069] The thermoformed base may be attached to another packaging component by way of a seal, preferably a hermetic seal. In this manner, the product inside the package is completely enclosed in the cavity and protected by way of the thermoformed base and the other packaging component(s). The exchange of gasses, liquids, microbes or other materials is limited to those that are able to pass through the packaging components, as the hermetic seal does not permit passage in the space between the components.

[070] The product that is contained in the cavities of the thermoformed base is not limited. The package may contain a product that is sensitive to the environment, such as pharmaceuticals or foods. The product may require physical protection, such as delicate medical devices. The product may need to be contained for consumer protection, such as medicaments or cleaners that should be in child proof packaging. The product may be suitable for easy dispensing such as gum or candy.

[071] If a lid packaging component is included in the packaged product, the lid may be of any composition that is suitable for the application. The lid should have a heat sealable exterior layer that is formulated such that it can be readily

attached to the thermoformed base by way of heat sealing. The seal between the lid packaging component and the thermoformed base may be peelable (i.e. readily separated manually, peel strength less than about 2,500 g/25.4mm) or fusion.

[072] If the lid is fusion sealed to the thermoformed base, the lid may be formulated and/or designed such that the product can be pushed through the lid for dispensing. Particularly for applications of a packaged product that include pharmaceutical tablets, gum pieces or the like, the cavities of the thermoformed base may flexible enough that a consumer can depress the cavity manually, forcing the product through the lid component, for dispensing. The seal strength between the thermoformed base and the lid packaging component may be at least 2,000 g/25.4mm.

[073] The lid packaging component should have a moisture and/or oxygen barrier that is similar in performance to the thermoformed base. Materials that are commonly used in high-performance lidding include but are not limited to metal layers or paper layers. The metal and/or paper layers may be laminated or otherwise connected to polymer layers including a heat-sealing layer. The lid may be printed, scored or otherwise modified for specific properties.

[074] One example of a lid component that may be sealed to a thermoformed base to provide a packaged product is shown in Figure 4. The lid **200** may have a first exterior layer **210** containing high-density polyethylene and an inorganic particle, such as talc or calcium carbonate. This type of exterior layer provides high heat resistance during the process of sealing the lid component to the thermoformed base component to enclose the product. The lid may have a second exterior layer **220** that has a polyethylene-base material, formulated to heat seal to the thermoformed base at relatively low temperatures. The lid may have a first interior layer **230** formulated to have excellent moisture barrier. An example of a blend of materials that may work well as a moisture barrier layer is high-density polyethylene and a hydrocarbon resin. This blend is similar to the second layer of the thermoformable base component. One advantage to the lid as shown in Figure 4 is that it would have similar recyclability as compared to the

thermoformable base films described herein, such that the entire package could be recycled together without separating. In some embodiments, the entire package, including a thermoformed base and a lidding component, could be recycled together in a high-density polyethylene recycling process or another polyethylene recycling process.

EXAMPLES AND DATA

Improvement of Temperature Window for Thermoforming

[075] As compared to previously known polyethylene-based films, the structures discussed herein have the distinct advantage in ease of thermoforming. The base packaging components formed from the base packaging film disclosed herein maintain the shape to which they are formed, without warpage due to crystallization of the polymer. The thermoformed parts keep the same dimension and shape in the minutes, hours, days and weeks after thermoforming. Additionally, thermoforming of the material is easier, as there is a wider operating window (i.e. temperature) for forming.

[076] Generally, the thermoforming process is best carried out when the film is heated to a temperature between the softening temperature and the melting temperature for the polymer. In the case of high-density polyethylene, this temperature window for thermoforming is usually quite small – a few degrees. This makes the process of thermoforming standard high-density polyethylene films very difficult to control. It has been found that the base packaging films described herein have a much wider temperature operating window for thermoforming, being able to be softened at a lower temperature and without displaying sagging. As used herein, the "thermoforming temperature operating window" can be defined by the difference between the minimum heating temperature and the maximum heating temperature in the forming process described below.

[077] Additionally, high-density polyethylene-based films have been known to display secondary crystallization, causing significant part shrinkage and warping

at time spans of minutes, hours or days after thermoforming. The thermoformable base packaging films described herein do not suffer from this secondary crystallization phenomena, thus allowing for the use of the materials in thermoforming of critical parts such as packaging blisters.

[078] Thermoformable base films Example 1, Example 2 and Comparative Example 1 were manufactured using a standard blown film coextrusion process, collapsing the bubble into a single palindromic film. The details of these films are shown in Table 1. Example 1 contains a first layer having a high-density polyethylene and a nucleating agent, a second layer containing a high-density polyethylene, a hydrocarbon resin and a nucleating agent and a third layer containing a high-density polyethylene and a nucleating agent. Due to the collapsed bubble process used to manufacture the films, the second layer is split into two layers, separated by center layer containing ethylene vinyl acetate copolymer. Also, necessarily, the first layer and the third layer have identical composition. Example 2 and Comparative Example 1 were similarly processed. The second layer of Comparative Example 1 contains no hydrocarbon resin, the second layer of Example 1 contains approximately 7.5% hydrocarbon resin (18.75% loading of a 40% masterbatch) by weight and the second layer of Example 2 contains approximately 15% hydrocarbon resin (37.5% loading of a 40% masterbatch) by weight.

[079] Thermoformable base films Example 1, Example 2 and Comparative Example 1 were run as the forming web on an Uhlmann Blister machine B 1240. The Uhlmann was used to thermoform ten cavities in the thermoformable base film. The tooling used created cavities sized to fit a size zero (0) capsule. The material was cycled through the thermoforming process at a rate of 35 cycles/minute. The Uhlmann used top and bottom contact heating in three indexes prior to forming.

[080] In order to evaluate the temperature window for forming proper cavities, the contact heating temperature was slowly ramped up and the formed pockets were evaluated at each temperature. It was found that for Comparative Example 1, the minimum heating temperature required to achieve completely formed

pockets was 112°C. Testers considered the cavities to have complete forming when there was evidence of the vacuum ports on the surface of the cavity. For Comparative Example 1 the maximum heating temperature of 115°C was determined when the material began to melt, deform and have poor aesthetics. Thus, this material has a temperature window of about 3°C for thermoforming good cavities.

[081] Example 1 thermoformable base was tested in the same method as Comparative Example 1. It was found that the minimum temperature was 109°C and the maximum temperature was 115°C. This is a temperature operating window of 6°C, a 100% improvement over the Comparative Example 1 thermoformable base. Example 2 thermoformable base was tested in the same method as Comparative Example 1. It was found that the minimum temperature was 106°C and the maximum temperature was 115°C. This is a temperature operating window of 9°C, a 200% improvement over the Comparative Example 1 thermoformable base.

Table 1: Thermoformable Base Film Details

Base Film Layer	Example 1		Example 2		Comparative Example 1	
	Layer % (by mass)	Layer Components	Layer % (by mass)	Layer Components	Layer % (by mass)	Layer Components
1 (first layer)	12.45	99% HDPE1 1% Nuc MB	12.435	99% HDPE1 1% Nuc MB	12.465	99% HDPE1 1% Nuc MB
2 (second layer)	33.9	80.25% HDPE3 18.75% HC MB 1% Nuc MB	33.9	61.5% HDPE3 37.5% HC MB 1% Nuc MB	33.875	99% HDPE1 1% Nuc MB
3 (center layer)	7.3	50% EVA1 50% EVA2	7.33	50% EVA1 50% EVA2	7.32	50% EVA1 50% EVA2
4 (second layer)	33.9	80.25% HDPE3 18.75% HC MB	33.9	61.5% HDPE3 37.5% HC MB	33.875	99% HDPE1 1% Nuc MB

		1% Nuc MB		1% Nuc MB		
5 (third layer)	12.45	99% HDPE1 1% Nuc MB	12.435	99% HDPE1 1% Nuc MB	12.465	99% HDPE1 1% Nuc MB
Film Thickness	15 mil (381 micron)		15 mil (381 micron)		15 mil (381 micron)	
Flat film MVTR[2]	0.0095 g / 100 in^2 / day		0.006 g / 100 in^2 / day		Not available	

HDPE1 = high-density polyethylene, melt index = 2.0 g/10 min (190C,2160g), density = 0.96 g/cc
HDPE3 = high-density polyethylene, melt index = 1.2 g/10 min (190C,2160g), density = 0.967 g/cc
HC MB = hydrocarbon masterbatch containing 40% hydrocarbon and 60% high-density polyethylene
Nuc MB = nucleating agent masterbatch containing 4% nucleating agent in a low-density polyethylene
EVA1 = ethylene vinyl acetate copolymer, vinyl acetate content = 12%, density 0.93 g/cc
EVA2 = ethylene vinyl acetate copolymer, vinyl acetate content = 26%, density 0.95 g/cc
[2] MVTR Testing Conditions: ASTM 1249, conditions of 100°F and 90% Rh

[082] The melt index of the thermoformable base films was measured using ASTMD1238-10 and conditions of 190°C and 2,160 g. Each film was tested five times, and the average of the five tests reported. Comparative Example 1 was found to have a melt flow rate of about 1.55 g/10min. Example 1 was found to have a melt flow rate of about 1.9 g/10min. This is at least 20% greater than a thermoformable base film that is identical with the exception that the film is free from hydrocarbon resin (Comparative Example 1). A third thermoformable base film, similar to Example 1, having a thickness of 10 mil and an overall hydrocarbon resin loading of 10 weight % of the thermoformable base film, was found to have a melt flow rate of about 2.28 g/10min. Ideally, the thermoformable base film has a hydrocarbon resin loading that increases the melt flow rate of the thermoformable base film by at least 20% or between 20% and 50%.

High Oxygen Barrier Version

[083] Thermoformable base film Example 3 was manufactured using a standard blown film coextrusion process, collapsing the bubble into a single palindromic film. The details of these films are shown in Table 2. Example 3 contains a first layer having a high-density polyethylene and a nucleating agent, a second layer containing a high-density polyethylene, a hydrocarbon resin and a nucleating agent a third layer containing a high-density polyethylene and a nucleating agent, an oxygen barrier layer containing EVOH and tie layers. The second layer is split into four distinct layers, separated by other layers. The oxygen barrier layer is split into two distinct layers, separated by other layers. The first layer and the third layer have identical composition.

Table 2: Thermoformable Base Film Details

Base Film Layer	Example 3	
	Layer % (by mass)	Layer Components
1 (first layer)	8.34	99% HDPE1 1% Nuc MB
2 (second layer)	9.91	61.5% HDPE3 37.5% HC MB 1% Nuc MB
3 (tie layer)	5.17	100% MAgPE
4 (O2 barrier layer)	7.175	100% EVOH
5 (tie layer)	5.17	100% MAgPE
6 (second layer)	9.91	61.5% HDPE3 37.5% HC MB 1% Nuc MB
7 (center layer)	8.65	50% EVA1 50% EVA2
8 (second layer)	9.91	61.5% HDPE3 37.5% HC MB 1% Nuc MB
9 (tie layer)	5.17	100% MAgPE
10 (O2 barrier layer)	7.175	100% EVOH
11 (tie layer)	5.17	100% MAgPE
12 (second layer)	9.91	61.5% HDPE3 37.5% HC MB 1% Nuc MB
13 (third layer)	8.34	99% HDPE1

		1% Nuc MB
Film Thickness	15 mil (381 micron)	
Flat film OTR[1]	0.004 cm3/100in2/day	

HDPE1 = high-density polyethylene, melt index = 2.0 g/10 min (190C,2160g), density = 0.96 g/cc

HDPE3 = high-density polyethylene, melt index = 1.2 g/10 min (190C,2160g), density = 0.967 g/cc

HC MB = hydrocarbon masterbatch containing 40% hydrocarbon and 60% high-density polyethylene

Nuc MB = nucleating agent masterbatch containing 4% nucleating agent in a low-density polyethylene

EVA1 = ethylene vinyl acetate copolymer, vinyl acetate content = 12%, density 0.93 g/cc

EVA2 = ethylene vinyl acetate copolymer, vinyl acetate content = 26%, density 0.95 g/cc

MAgPE = maleic anhydride grafted polyethylene

EVOH = ethylene vinyl alcohol copolymer, 38 mol% ethylene

[1] OTR Testing Conditions: ASTM F1927, conditions of 73°F and 0% Rh

Weight Gain Study

[084] A weight gain study was carried out according to Method B of ASTM D7709-12, resulting in a comparison of weight gain per cavity for packages including thermoformed bases according to this disclosure as well as other blister packaging industry standard materials. The blister cards contained ten cavities formed to size zero blisters. Test units of five blister cards were used to calculate the weight gain. The blisters were filled with desiccant (previously stored in vacuum packed foil packaging) and sealed on the Uhlman B1240 packaging equipment described above. The storage conditions used were 40°C and 75% RH.

[085] The weight gain study included thermoformed bases from two different thermoformable base films. The first was Example 2 described in Table 1 above. The second was Example 4 which is a 10 mil white thermoformable base film, further described in Table 3.

Table 3: Thermoformable Base Film Details

Base Film Layer	Example 4	
	Layer % (by mass)	Layer Components
1 (first layer)	11.97	99% HDPE1 1% Nuc MB

2 (second layer)	19.59	61.5% HDPE3 37.5% HC MB 1% Nuc MB
3 (fourth layer)	14.92	61.5% HDPE3 15% $CaCO_3$ MB 10% White MB
4 (center layer)	7.04	50% EVA1 50% EVA2
5 (fourth layer)	14.92	61.5% HDPE3 15% $CaCO_3$ MB 10% White MB
6 (second layer)	19.59	61.5% HDPE3 37.5% HC MB 1% Nuc MB
7 (third layer)	11.97	99% HDPE1 1% Nuc MB
Film Thickness	10 mil (254 micron)	

HDPE1 = high-density polyethylene, melt index = 2.0 g/10 min (190C,2160g), density = 0.96 g/cc

HDPE3 = high-density polyethylene, melt index = 1.2 g/10 min (190C,2160g), density = 0.967 g/cc

HC MB = hydrocarbon masterbatch containing 40% hydrocarbon and 60% high-density polyethylene

Nuc MB = nucleating agent masterbatch containing 4% nucleating agent in a low-density polyethylene

$CaCO_3$ MB = calcium carbonate masterbatch containing polyethylene with greater than 30% inorganic content

White MB = white masterbatch containing polyethylene with titanium dioxide

EVA1 = ethylene vinyl acetate copolymer, vinyl acetate content = 12%, density 0.93 g/cc

EVA2 = ethylene vinyl acetate copolymer, vinyl acetate content = 26%, density 0.95 g/cc

[086] Both thermoformed bases, formed into blisters, were filled with desiccant and sealed with Lid A. Lid A had a heat-resistant exterior layer of high-density polyethylene and an inorganic particle (calcium carbonate), an interior layer having a high-density polyethylene and a nucleating agent, and a heat-sealing exterior layer containing a polyethylene-based plastomer.

[087] The combination of Example 2 base and Lid A resulted in single cavity transmission of about 0.34 mg/cavity.day. The combination of Example 4 base and Lid A resulted in single cavity transmission of about 0.45 mg/cavity.day. By comparison, a similar test run using a forming film of 10 mil PVC / 90 gsm PVDC / 1 mil PE with a 1 mil soft tempered foil lid resulted in a transmission rate of

about 0.54 mg/cavity.day and a forming film of 7.5 mil PVC / 2 mil Aclar with a 1 mil soft tempered foil lid resulted in a transmission rate of about 0.16 mg/cavity.day. The thermoformed bases described herein deliver moisture transmission rates that are suitable for pharmaceutical packaging while achieving single stream recyclability.

Improvement on Cutting

[088] While creating packages on the Uhlman B1240 packaging equipment, it is also possible to evaluate the cutting performance of the thermoformable base film. The blister cards are cut from the web after the package is sealed. It was observed that the thermoformable film of Example 4 cut much cleaner, without fraying the edges of the blister card, than other thermoformable base films that did not contain a layer with an inorganic particle (calcium carbonate).

Heat Sealing Study

[089] Heat seal strength was studied, varying the overall density of the first layer. Flat samples of thermoformable base materials having various blends in the first layer were heat sealed to lidding material (Lid A described in the Weight Gain Study above) and the seal strength was measured. Heat seals were formed using a flat seal bar with conditions of 30 PSI pressure and 0.5 seconds dwell. The temperature was varied to understand how the first layer blend could change the seal strength at a given seal temperature. Seal strength was tested by loading a one-inch (25.4 mm) strip of heat sealed film on a tensile testing unit, pulling the heat seal apart at an angle of 180 degrees and at a speed of 12 in/min. Testing was completed at 73°F and 50% humidity. Each data point in the table below is the average of three tests, recording the peak force.

[090] The heat seals peeled open at all of the sealing conditions except 130°C when the lidding remained bonded and the tensile strength of the films were beginning to be weaker than the bond strength.

[091] It was found that stronger seals (higher heat seal strengths) were obtained when a higher loading of lower density material was present in the first layer. Up to about 50 weight % of a polyethylene having a density less than 0.93 g/cm^3 could be used in the first layer without other side effects such as sticking to heating plates or thermoforming issues.

Table 4: Heat Seal Strength Data

First Layer Blend:	85% HDPE 15% mLLDPE (overall density =0.954 g/cm^3)	70% HDPE 30% mLLDPE (overall density =0.947 g/cm^3)	50% HDPE 50% mLLDPE (overall density =0.940 g/cm^3)	50% HDPE 50% ethylene-based plastomer (d=0.930 g/cm^3)
T = 80°C	N/A	82 g/25.4mm	158 g/25.4mm	451 g/25.4mm
T = 90°C	956 g/25.4mm	357 g/25.4mm	704 g/25.4mm	1070 g/25.4mm
T = 100°C	1304 g/25.4mm	892 g/25.4mm	903 g/25.4mm	1394 g/25.4mm
T = 110°C	1929 g/25.4mm	1150 g/25.4mm	1193 g/25.4mm	1420 g/25.4mm
T = 120°C	2588 g/25.4mm	1488 g/25.4mm	1534 g/25.4mm	1907 g/25.4mm
T = 130°C	2838 g/25.4mm	1840 g/25.4mm	2067 g/25.4mm	2413 g/25.4mm

[092] Further study of the heat seal strength provides the data in Table 5. The testing was done as described above, except that the heat seals were formed using a flat seal bar with conditions of 40 PSI pressure and 1.0 seconds of dwell.

Table 5: Heat Seal Strength Data

First Layer Blend:	50% HDPE 50% mLLDPE (overall density =0.942 g/cm^3)	50% HDPE 50% LDPE (overall density =0.941 g/cm^3)
T = 87.8°C	419 g/25.4mm	847 g/25.4mm
T = 93.3°C	970 g/25.4mm	1825 g/25.4mm
T = 98.9°C	1695 g/25.4mm	2373 g/25.4mm