THERMOFORMABLE BASE FILM, THERMOFORMED BASE, AND PACKAGED PRODUCT

TECHNICAL FIELD

The present application relates generally to a thermoformable base film, and in particular to a high-performance recyclable film that is suitable for thermoforming into a thermoformed base for packaging applications.

BACKGROUND

High-performance packaging films are used to package many products, such as food, pharmaceuticals, consumer goods, and industrial items. Such packages may be made from an all-polyethylene (PE) packaging film to provide desirable recyclability, thermoformability, and other critical properties, such as barrier properties, to the package. Another critical property for packaging applications is a sealing performance of the all-PE packaging films in order to achieve desirable speeds on packaging lines.

The all-PE packaging films may be multilayered and include a sealing layer for sealing to a lidding packaging component. However, sealing layers of conventional all-PE packaging films may not provide a desirable sealing performance. For example, the sealing layers of conventional all-PE packaging films may have a high seal initiation temperature (SIT) and/or take a longer than desired time to seal properly with the lidding packaging component.

SUMMARY

A thermoformable base film has been developed. The thermoformable base film includes a first layer including at least one polyethylene and an overall density between about 0.85 g/cm^3 and 0.92 g/cm^3, a second layer including a high-density polyethylene and a hydrocarbon resin, and a third layer including at least one polyethylene. The second layer is located between the first layer and the third layer.

The overall density between about 0.85 g/cm^3 and 0.92 g/cm^3 of the first layer may be achieved by including a high level (e.g., greater than 50%, greater than 75%, or greater than 95%, by weight of the first layer) of a polyethylene having a density less than 0.92

g/cm^3 in the first layer. Examples of the polyethylene having a density less than 0.92 g/cm^3 include, but are not limited to, linear low-density polyethylene (LLDPE), very low density polyethylene (VLDPE), ultra-low density polyethylene (ULDPE), and polyethylene plastomer.

The first layer may be a sealing layer of the thermoformable base film. It has been found that the first layer including the at least one polyethylene and the overall density between about 0.85 g/cm^3 and 0.92 g/cm^3 may improve a sealing performance of the thermoformable base film. Specifically, the first layer may have a low seal initiation temperature (SIT) while providing a high seal strength at the low SIT. For example, the first layer may have an SIT of about 80 degrees centigrade and a seal strength of about 10 N/15mm at 80 °C.

Moreover, the first layer may be made thin (e.g., less than 20 microns) without compromising the sealing performance of the thermoformable base film. The first layer being thin may allow reducing an overall thickness of the thermoformable base film. The first layer being thin may also allow increasing thicknesses of other layers (e.g., thicknesses of the second layer and the third layer) of the thermoformable base film, for example, to impart specific properties (e.g., water vapor barrier properties) to the thermoformable base film.

The thermoformable base film may be suitable for thermoforming. Specifically, the thermoformable base film may maintain the shape taken during thermoforming and may resist post-thermoforming defects such as curling, warping, and shrinking. Furthermore, the thermoformable base film may be recyclable due to a high polyethylene content, and therefore, environmentally friendly.

A first embodiment of the present disclosure is a thermoformable base film. The thermoformable base film includes a first layer including at least one polyethylene and having an overall density between about 0.85 g/cm^3 and 0.92 g/cm^3. The thermoformable base film further includes a second layer including a high-density polyethylene and a hydrocarbon resin. The thermoformable base film further includes a third layer including at least one polyethylene and having an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3. The second layer is located between the first layer and the third layer. After

thermoforming, the thermoformable base film maintains the shape taken during thermoforming.

The overall density between about 0.85 g/cm^3 and 0.92 g/cm^3 of the first layer may be achieved by including a high level (e.g., greater than 50%, greater than 75%, or greater than 95%, by weight of the first layer) of a polyethylene having a density less than 0.92 g/cm^3 in the first layer. Examples of the polyethylene having a density less than 0.92 g/cm^3 include, but are not limited to, linear low-density polyethylene (LLDPE), very low density polyethylene (VLDPE), ultra-low density polyethylene (ULDPE), and polyethylene plastomer.

The first layer may be a sealing layer of the thermoformable base film. The first layer may improve a sealing performance of the thermoformable base film. Specifically, the first layer may have a low seal initiation temperature (SIT) (e.g., 80 °C) while providing a high seal strength at the low SIT. Moreover, the first layer may be made thin (e.g., less than 20 microns) without compromising the sealing performance of the thermoformable base film. The first layer being thin may allow reducing an overall thickness of the thermoformable base film. The first layer being thin may also allow increasing thicknesses of other layers (e.g., a thickness of the second layer and a thickness of the third layer) of the thermoformable base film, for example, to impart specific properties (e.g., water vapor barrier properties) to the thermoformable base film.

The thermoformable base film may be suitable for thermoforming. Specifically, the thermoformable base film may maintain the shape taken during thermoforming and may resist post-thermoforming defects such as curling, warping, and shrinking. Furthermore, the thermoformable base film may be recyclable due to a high polyethylene content, and therefore, environmentally friendly.

In some embodiments, the first layer and the third layer each form a surface of the thermoformable base film. For example, the first layer may form a first surface of the thermoformable base film, and the third layer may form a second surface of the thermoformable base film. The first and second surfaces may be exterior surfaces of the thermoformable base film. The first surface (formed by the first layer) may correspond to a surface to which a lid packaging component is sealed (e.g., heat sealed).

In some embodiments, the first layer includes an overall density between 0.86 g/cm^3 and 0.92 g/cm^3.

In some embodiments, the first layer includes a polyethylene plastomer in a range of from 50% to 100% and a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight. In some examples, the polyethylene plastomer may be in a range of from 75% to 100%, and the medium-density polyethylene or the high-density polyethylene may be in a range of from 0% to 25%, by weight. The high polyethylene plastomer content (e.g., greater than 50%, by weight of the first layer) in the first layer may improve the sealing performance of the thermoformable base film. The high polyethylene plastomer content in the first layer may also allow making the first layer thin (e.g., less than 20 microns) without compromising the sealing performance of the thermoformable base film.

In some embodiments, the first layer has a thickness including less than 25% of a thickness of the thermoformable base film. As discussed above, the first layer may be made thin without compromising the sealing performance of the thermoformable base film. In some examples, the thickness of the first layer may be less than 20%, less than 15%, or less than 10% of the thickness of the thermoformable base film. This may allow increasing thicknesses of other layers of the thermoformable base film to improve specific properties (e.g., water vapor barrier properties) of the thermoformable base film.

In some embodiments, the hydrocarbon resin is present from 2.5% to 30% by weight with respect to the second layer. Presence of the hydrocarbon resin in the second layer in a range of from 2.5% to 30%, by weight of the second layer may significantly improve the ease with which the thermoformable base film can be thermoformed due to a wider thermoforming temperature window for thermoforming. The hydrocarbon resin may also improve moisture barrier properties of the thermoformable base film.

In some embodiments, the third layer includes a medium-density polyethylene or a high-density polyethylene. The medium-density polyethylene or the high-density polyethylene may be the materials of choice for the third layer, which may be an exterior layer of the thermoformable base film.

A second embodiment of the present disclosure is a thermoformable base film. The thermoformable base film includes a first layer including a high-density polyethylene

and a polyethylene having a density less than 0.92 g/cm^3. The thermoformable base film further includes a second layer including from 60% to 90%, by weight, of a high-density polyethylene and from 2.5% to 30%, by weight of a hydrocarbon resin. The thermoformable base film further includes a third layer including at least one polyethylene and having an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3. The second layer is located between the first layer and the third layer. The second layer has a thickness that is from 15% to 95% or from 25% to 95% of a thickness of the thermoformable base film.

Examples of the polyethylene having a density less than 0.92 g/cm^3 include, but are not limited to, linear low-density polyethylene (LLDPE), very low density polyethylene (VLDPE), ultra-low density polyethylene (ULDPE), and polyethylene plastomer. In some examples, the first layer may include the high-density polyethylene in a range of from 0% to 50% and the polyethylene having a density less than 0.92 g/cm^3 in a range of from 50% to 100%.

The first layer may be a sealing layer of the thermoformable base film. The first layer may improve a sealing performance of the thermoformable base film. Specifically, the first layer may have a low seal initiation temperature (SIT) (e.g., 80 °C) while providing a high seal strength at the low SIT. Moreover, the first layer may be made thin (e.g., less than 20 microns) without compromising the sealing performance of the thermoformable base film. The first layer being thin may allow reducing an overall thickness of the thermoformable base film. The first layer being thin may also allow increasing thicknesses of other layers (e.g., a thickness of the second layer and a thickness of the third layer) of the thermoformable base film, for example, to impart specific properties (e.g., water vapor barrier properties) to the thermoformable base film.

The thermoformable base film may be suitable for thermoforming. Specifically, the thermoformable base film may maintain the shape taken during thermoforming and may resist post-thermoforming defects such as curling, warping, and shrinking. Furthermore, the thermoformable base film may be recyclable due to a high polyethylene content, and therefore, environmentally friendly.

Furthermore, presence of the hydrocarbon resin in the second layer in a range of from 2.5% to 30%, by weight of the second layer may significantly improve the ease with

which the thermoformable base film can be thermoformed due to a wider thermoforming temperature window for thermoforming. The hydrocarbon resin may also improve moisture barrier properties of the thermoformable base film.

In some embodiments, the first layer and the third layer each form a surface of the thermoformable base film.

In some embodiments, the first layer includes an overall density between 0.86 g/cm^3 and 0.92 g/cm^3. The overall density between about 0.86 g/cm^3 and 0.92 g/cm^3 of the first layer may be achieved by including a high level (e.g., greater than 50%, greater than 75%, or greater than 95%, by weight of the first layer) of the polyethylene having a density less than 0.92 g/cm^3 in the first layer.

In some embodiments, the first layer includes a polyethylene plastomer in a range of from 50% to 100% and a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight. The high polyethylene plastomer content (e.g., greater than 50%, by weight of the first layer) in the first layer may improve the sealing performance of the thermoformable base film. The high polyethylene plastomer content in the first layer may also allow making the first layer thin (e.g., less than 20 microns) without compromising the sealing performance of the thermoformable base film.

In some embodiments, the first layer has a thickness of less than 20 microns. The thickness of the first layer may be made less than 20 microns without compromising the sealing performance of the thermoformable base film due to a high content (e.g., greater than 50%, by weight of the first film) of the polyethylene having a density less than 0.92 g/cm^3.

In some embodiments, the hydrocarbon resin is present from 5% to 10% by weight with respect to the thermoformable base film.

Presence of the hydrocarbon resin in the second layer in a range of from 5% to 10%, by weight of the thermoformable base film may significantly improve the ease with which the thermoformable base film can be thermoformed due to a wider thermoforming temperature window for thermoforming. The hydrocarbon resin may also improve moisture barrier properties of the thermoformable base film.

An amount of the hydrocarbon resin in the second layer may be adjusted to control both moisture barrier properties and the thermoforming temperature window of

thermoformable base film. Specifically, increasing the hydrocarbon resin level may increase moisture barrier properties of thermoformable base film. Further, increasing the hydrocarbon resin level may increase the thermoforming temperature window of the thermoformable base film. The moisture barrier performance of the thermoformable base film due to the second layer may allow omitting non-polyethylene barrier materials, such as polyvinyl chloride (PVC) from the thermoformable base film.

In some embodiments, the third layer includes a medium-density polyethylene or a high-density polyethylene.

In some embodiments, the thermoformable base film further includes a fourth layer including a high-density polyethylene and an inorganic particle. The inorganic particle is present in the fourth layer at a level of at least 3% by weight. The fourth layer is located between the first layer and the third layer. The fourth layer may assist in achieving clean cutting of the thermoformable base film after thermoforming.

In some embodiments, the overall density of the thermoformable base film is less than 1.0 g/cm^3. The overall density of the thermoformable base film being less than 1.0 g/cm^3 may be a critical feature used in separation procedures during the recycling process (i.e., sorting by floating).

In some embodiments, the thermoformable base film is essentially free from polyester, polypropylene, cyclic olefin copolymer, and polyamide. The thermoformable base film being essentially free from these materials may improve the recyclability of the thermoformable base film, as presence of these materials may hinder the recyclability of thermoformable base film.

In some embodiments, the thermoformable base film further includes an oxygen barrier layer. The oxygen barrier layer includes an ethylene vinyl alcohol copolymer. The oxygen barrier layer is located between the first layer and the third layer. The oxygen barrier layer may limit transmission of oxygen through the thermoformable base film.

A third embodiment of the present disclosure is a thermoformed base. The thermoformed base includes the thermoformable base film of the first embodiment or the second embodiment. The thermoformed base further includes at least one cavity. The thermoformed base further includes a flange surrounding each of the cavities.

The thermoformed base may be produced from the thermoformable base film by thermoforming the thermoformable base film. The thermoformed base may be free from post-thermoforming defects such as warping, curling, and shrinking.

The at least one thermoformed cavity may be shaped to hold a product therein. The flange may be generally an unformed area of the thermoformable base film and may connect the thermoformed base to other packaging components (e.g., a lid packaging component), another thermoformed base component, or some other packaging component.

In some embodiments, the thermoformed base maintains the shape taken during thermoforming. The thermoformed base may be highly rigid and inflexible, or the thermoformed base may be flexible while still maintaining the shape taken during thermoforming.

A fourth embodiment of the present disclosure is a packaged product. The packaged product includes the thermoformed base of the third embodiment. The packaged product further includes a lid packaging component. The packaged product further includes a product. The lid packaging component is hermetically sealed to the flange of the thermoformed base. The product is enclosed in the at least one cavity of the thermoformed base.

The hermetic seal may limit ingress of gasses, liquids, microbes, or other materials in the cavities. The packaged product may therefore protect products that are sensitive to the environment, such as pharmaceuticals or foods. The packaged product may provide excellent moisture barrier, good appearance, good forming accuracy and consistency, good heat resistance, and good seal strength.

In some embodiments, the lid packaging component includes a heat-sealing layer and a layer including at least one of metal and paper. The heat-sealing layer may form a surface of the lid packaging component that is heat sealed to the thermoformed base.

In some embodiments, the lid packaging component is peelably sealed to the flange of the thermoformed base. In other words, the lid packaging component may be sealed to the flange in such a manner that the lid packaging component can be manually removed from the flange without use of any tools.

In some embodiments, the thermoformed base and the lid packaging component are recyclable in the same recycle process. This may facilitate recycling of the packaged product.

In some embodiments, the at least one cavity of the thermoformed base may be depressed manually, and the product may be pushed through the lid packaging component for product dispensing.

In some embodiments, the seal strength between the thermoformed base and the lid packaging component is at least 2,000 g/25.4mm.

There are several aspects of the present subject matter which may be embodied separately or together. These aspects may be employed alone or in combination with other aspects of the subject matter described herein, and the description of these aspects together is not intended to preclude the use of these aspects separately or the claiming of such aspects separately or in different combinations.

BRIEF DESCRIPTION OF THE DRAWINGS

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:

FIG. 1 is a schematic cross-sectional view of a thermoformable base film in accordance with an embodiment of the present disclosure;

FIG. 2 is a schematic cross-sectional view of a thermoformable base film in accordance with another embodiment of the present disclosure;

FIG. 3A is a schematic bottom perspective view of a thermoformed base in accordance with an embodiment of the present disclosure;

FIG. 3B is a schematic top view of the thermoformed base of FIG. 3A in accordance with an embodiment of the present disclosure; and

FIG. 4 is a schematic cross-sectional view of a packaged product in accordance with an embodiment of the present disclosure.

The figures are not necessarily to scale. Like numbers used in the figures refer to like components. It will be understood, however, that the use of a number to refer to a

component in a given figure is not intended to limit the component in another figure labeled with the same number.

DETAILED DESCRIPTION

The present application describes a thermoformable base film. The thermoformable base film includes a first layer including at least one polyethylene and an overall density between about 0.85 g/cm^3 and 0.92 g/cm^3, a second layer including a high-density polyethylene and a hydrocarbon resin, and a third layer including at least one polyethylene. The second layer is located between the first layer and the third layer.

The overall density between about 0.85 g/cm^3 and 0.92 g/cm^3 of the first layer may be achieved by including a high level (e.g., greater than 50%, greater than 75%, or greater than 95%, by weight of the first layer) of a polyethylene having a density less than 0.92 g/cm^3 in the first layer. Examples of the polyethylene having a density less than 0.92 g/cm^3 include, but are not limited to, linear low-density polyethylene (LLDPE), very low density polyethylene (VLDPE), ultra-low density polyethylene (ULDPE), and polyethylene plastomer.

The first layer may be a sealing layer of the thermoformable base film. It has been found that the first layer including the at least one polyethylene and the overall density between about 0.85 g/cm^3 and 0.92 g/cm^3 may improve a sealing performance of the thermoformable base film. Specifically, the first layer may have a low seal initiation temperature (SIT) while providing a high seal strength at the low SIT. For example, the first layer may have an SIT of about 80 degrees centigrade and a seal strength of about 10 N/15mm at 80 °C. The first layer may have an SIT of about 100 degrees centigrade.

Moreover, the first layer may be made thin (e.g., less than 20 microns) without compromising the sealing performance of the thermoformable base film. The first layer being thin may allow reducing an overall thickness of the thermoformable base film. The first layer being thin may also allow increasing thicknesses of other layers (e.g., thicknesses of the second layer and the third layer) of the thermoformable base film, for example, to impart specific properties (e.g., water vapor barrier properties) to the thermoformable base film.

The thermoformable base film may be suitable for thermoforming. Specifically, the thermoformable base film may maintain the shape taken during thermoforming and may resist post-thermoforming defects such as curling, warping, and shrinking. Furthermore, the thermoformable base film may be recyclable due to a high polyethylene content, and therefore, environmentally friendly.

As used herein, the term "film" refers to a material with a very high ratio of a length or a width to a thickness. A film has two major surfaces defined by a length and a width. Films typically have good flexibility and can be used for a wide variety of applications, including flexible packaging. Films may also have thickness and/or material composition such that they are flexible, semi-rigid, or rigid. Films may be described as monolayer or multilayer.

As used herein, the term "layer" refers to a thickness of material that may be homogeneous or heterogenous. Layers may be of any type of material including polymeric, cellulosic, and metallic, or a blend thereof. A layer may include a single polymer-type or a blend of polymers and may be accompanied by additives. A given layer may be combined or connected to other layers to form films. A layer may be either partially or fully continuous as compared to adjacent layers or the film. A given layer may be partially or fully coextensive with adjacent layers. A layer may contain sub-layers.

The term "exterior surface" refers to a surface of a film that does not have contact with another film or layer surface.

The term "about," unless otherwise specifically defined, means to a high degree of approximation (e.g., within +/- 5% for quantifiable properties) but without requiring absolute precision or a perfect match.

As used herein, the term "thermoforming temperature window" can be defined by a difference between a minimum heating temperature and a maximum heating temperature in a thermoforming process. Thermoforming of the material may be easier when a wider operating window (i.e., temperature) for forming is provided. 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. In order to evaluate the temperature window for forming proper cavities, the forming heating temperature may be ramped up and the formed pockets evaluated at each temperature. Cavities have complete forming when there was evidence of the vacuum ports on the surface of the cavity, and this defines a minimum forming temperature. Maximum forming temperature can be determined by raising the forming temperature and noting when the material begins to melt, deform and have poor aesthetics.

As used herein, the terms “polyethylene” and “polyethylene polymer” refers to polymers that include an ethylene linkage. Polyethylenes may be homopolymers, copolymers, or interpolymers. Polyethylene copolymers or interpolymers may include other types of polymers (i.e., non-polyethylene polymers). Polyethylenes may have functional groups incorporated by grafting or other means. Polyethylenes include, but are not limited to, low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), medium-density polyethylene (MDPE), ultra-low density polyethylene (ULDPE), and high-density polyethylene (HDPE).

As used herein, the term “high-density polyethylene” or “HDPE” refers to homopolymers of ethylene which have densities from about 0.960 gram per cubic centimeter (g/cm^3) to about 0.970 g/cm^3, as well as 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. HDPE includes high molecular weight “polyethylenes.”

As used herein, the term "medium density polyethylene" or “MDPE” refers to homopolymers or copolymers of ethylene which have densities from about 0.928 to 0.940 grams per cubic centimeter. Medium density polyethylene includes linear medium density polyethylene (LMDPE).

As used herein, the term “low-density polyethylene” or “LDPE” refers to branched homopolymers of ethylene having densities from about 0.915 g/cm^3 to about 0.930 g/cm^3, as well as copolymers of ethylene containing polar groups resulting from copolymerization (such as with vinyl acetate or ethyl acrylate).

As used herein, the term "Linear Low Density Polyethylene" or "LLDPE" refers to copolymers of ethylene with alpha-olefins having densities from 0.915 g/cm^3 to 0.940 g/cm^3. The α-olefin utilized is usually 1-butene, 1-hexene, or 1-octene and Ziegler-type catalysts are usually employed (although Phillips catalysts are also used to produce LLDPE having densities at the higher end of the range, and metallocene and other types of catalysts are also employed to produce other well-known variations of LLDPEs).

As used herein, the term "Very Low Density Polyethylene" or "VLDPE" refers to copolymers of ethylene with α-olefins, usually 1-butene, 1-hexene or 1-octene and are recognized by those skilled in the art as having a high degree of linearity of structure with short branching rather than the long side branches characteristic of LDPE. However, VLDPEs have lower densities than LLDPEs. The densities of VLDPEs may range between 0.860 g/cm^3 and 0.915 g/cm^3. Sometimes VLDPEs having a density less than 0.900 g/cm^3 are referred to as "plastomers." VLDPE and the terms "Ultra-low Density Polyethylene" or "ULDPE" may be interchangeably used herein.

As used herein, the term "polyethylene plastomer" refers to ethylene alpha olefin copolymers that have properties of both elastomers and plastics. Examples of polyethylene plastomers include those available in the Affinity™ Polyolefin Plastomers grade slate available from The Dow Chemical Company.

Ethylene α-olefin copolymers are copolymers having an ethylene as a major component copolymerized with one or more alpha olefins such as octene-1, hexene-1, or butene-1 as a minor component. EAOs include polymers known as LLDPE, VLDPE, ULDPE, and plastomers and may be made using a variety of processes and catalysts including metallocene, single-site and constrained geometry catalysts as well as Ziegler-Natta and Phillips catalysts.

As used herein, the terms "polypropylene" and "polypropylene polymer" refer to polymers that are derived from monomers of propylene. Polypropylenes may be homopolymers, copolymers, or interpolymers. Polypropylene copolymers or interpolymers may include other types of polymers (i.e., non-polypropylene polymers). Propylene linkage can be represented by the general formula: $[CH_2—CH(CH_3)]_n$. Polypropylenes may have functional groups incorporated by grafting or other means.

Polypropylenes include, but are not limited to, propylene-ethylene copolymers, ethylene-propylene copolymers, and maleic anhydride grafted polypropylenes (MAHgPP).

As used herein, the term "polyester" refers to a homopolymer or copolymer having an ester linkage between monomer units which may be formed, for example, by condensation polymerization reactions between a dicarboxylic acid and a diol. The ester linkage can be represented by the general formula: [O—R—OC(O)—R—C(O)], where R and R′ are the same or different alkyl (or aryl) group and may be generally formed from the polymerization of dicarboxylic acid and diol monomers containing both carboxylic acid and hydroxyl moieties.

As used herein, the term "cyclic olefin copolymer" refers to copolymers having at least one norbornene structural moiety within the repeating backbone of the polymer.

As used herein, the term "polyamide" refers to a high molecular weight polymer having amide linkages (—CONH—)n which occur along the molecular chain, and includes "nylon" resins which are well known polymers.

As used herein, the term "ethylene/vinyl alcohol copolymer" or "EVOH" refers to polymerized ethylene vinyl alcohol. Ethylene/vinyl alcohol copolymers include saponified (or hydrolyzed) ethylene/vinyl acrylate copolymers and refer to a vinyl alcohol copolymer having an ethylene comonomer prepared by, for example, hydrolysis of vinyl acrylate copolymers or by chemical reactions with vinyl alcohol. 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.

As used herein, the term "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 Synthomer, Regalite® T1140 available from Synthomer, Arkon® P-140 available from Arakawa Chemical Industries, Limited (Osaka, Japan) and Piccolyte® S135 Polyterpene Resins available from Hercules Incorporated (Wilmington, Del.).

As used herein, 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.

As used herein, the term "sealing layer" refers to a layer, or layers, involved in the sealing of a film: to itself; to another layer of the same film or another film; and/or to another article which is not a film. In general, the sealing layer is a surface layer, i.e., an exterior or an interior layer of any suitable thickness, that provides for the sealing of the film to itself or another layer.

As used herein, the term "barrier" refers to a material that controls permeability of one or more elements through a film structure including moisture, chemicals, heat, odor and oxygen or other gases. A barrier material can be provided by a single film layer or multiple film layers acting individually or in concert with each other, respectively.

FIG. 1 shows a schematic cross-sectional view of a thermoformable base film 100 in accordance with an embodiment of the present disclosure.

Thermoformable base film 100 includes a first layer 102, a second layer 104, and a third layer 106. Second layer 104 is located between first layer 102 and third layer 106.

First layer 102 includes at least one polyethylene and has an overall density between about 0.85 g/cm^3 and 0.92 g/cm^3. In some embodiments, first layer 102 may include an overall density between 0.86 g/cm^3 and 0.92 g/cm^3.

The overall density between about 0.85 g/cm^3 and 0.92 g/cm^3 may be achieved by including a high level (e.g., greater than 50%, greater than 75%, or greater than 95%, by weight of first layer 102) of a polyethylene having a density less than 0.92 g/cm^3 in first layer 102. First layer 102 may also include other types of polyethylene having higher densities (e.g., a medium-density polyethylene or a high-density polyethylene) along with the polyethylene having a density less than 0.92 g/cm^3, such that the overall density of first layer 102 remains between about 0.85 g/cm^3 and 0.92 g/cm^3. Examples of the polyethylene having a density less than 0.92 g/cm^3 include, but are not limited to, linear low-density polyethylene (LLDPE), very low density polyethylene (VLDPE), ultra-low density polyethylene (ULDPE), and polyethylene plastomer.

Specifically, in some embodiments, first layer 102 may include a polyethylene plastomer in a range of from 50% to 100% and a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight. In other words, first layer 102 may include at least 50% of the polyethylene plastomer, and less than or equal to 50% of the medium-density polyethylene or the high-density polyethylene, by weight.

In some embodiments, first layer 102 may include a polyethylene plastomer in a range of from 50% to 100% and a low-density polyethylene, a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight. In other words, first layer 102 may include at least 50% of the polyethylene plastomer, and less than or equal to 50% of the low-density polyethylene, medium-density polyethylene or the high-density polyethylene, by weight.

In some embodiments, first layer 102 may include the polyethylene plastomer in a range of from 75% to 100% and the medium-density polyethylene or the high-density polyethylene in a range of from 0% to 25%, by weight. In some embodiments, first layer

102 may include the polyethylene plastomer in a range of from 95% to 100% and the medium-density polyethylene or the high-density polyethylene in a range of from 0% to 5%, by weight.

In some embodiments, first layer 102 may include the polyethylene plastomer in a range of from 75% to 100% and the low-density polyethylene, medium-density polyethylene or the high-density polyethylene in a range of from 0% to 25%, by weight. In some embodiments, first layer 102 may include the polyethylene plastomer in a range of from 95% to 100% and the low-density polyethylene, medium-density polyethylene or the high-density polyethylene in a range of from 0% to 5%, by weight.

In some embodiments, first layer 102 includes a high-density polyethylene and the polyethylene having a density less than 0.92 g/cm^3. In some embodiments, first layer 102 may include the polyethylene having a density less than 0.92 g/cm^3 in a range of from 50% to 100% and the high-density polyethylene in a range of from 0% to 50%, by weight.

In some embodiments, first layer 102 may include the polyethylene having a density less than 0.92 g/cm^3 in a range of from 75% to 100% and the high-density polyethylene in a range of from 0% to 25%, by weight. In some embodiments, first layer 102 may include the polyethylene having a density less than 0.92 g/cm^3 in a range of from 95% to 100% and the high-density polyethylene in a range of from 0% to 5%, by weight.

First layer 102 further includes a first major surface 102A and a second major surface 102B opposite to first major surface 102A. First major surface 102A and second major surface 102B may define a thickness 102T of first layer 102.

Second layer 104 includes a high-density polyethylene and a hydrocarbon resin. Compositions of the high-density polyethylene and the hydrocarbon in second layer 104 may vary depending upon desired application attributes. In some embodiments, the hydrocarbon resin may be present from 2.5% to 30% by weight with respect to second layer 104. In other words, second layer 104 may include the hydrocarbon resin in a range of from 2.5% to 30%, by weight. In some embodiments, second layer 104 may include from 60% to 90%, by weight, of the high-density polyethylene and from 2.5% to 30%, by weight of the hydrocarbon resin. In some embodiments, the hydrocarbon resin may be present from 5% to 10% by weight with respect to thermoformable base film 100.

The hydrocarbon resin may facilitate thermoforming of thermoformable base film 100 due to a wider thermoforming temperature window for forming. Specifically, presence of the hydrocarbon resin in second layer 104 may widen the thermoforming temperature window for thermoforming by up to 100% or even 200% compared to a conventional all-PE film having a layer without the hydrocarbon resin. Moreover, an amount of the hydrocarbon resin may be adjusted to control moisture barrier properties of thermoformable base film 100. Increasing the amount of hydrocarbon resin in second layer 104 may improve the moisture barrier properties of thermoformable base film 100.

Second layer 104 further includes a first major surface 104A and a second major surface 104B opposite to first major surface 104A. First major surface 104A and second major surface 104B may define a thickness 104T of second layer 104.

Third layer 106 includes at least one polyethylene. Third layer 106 has an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3. In some embodiments, third layer 106 may include a medium-density polyethylene or a high-density polyethylene.

Third layer 106 further includes a first major surface 106A and a second major surface 106B opposite to first major surface 106A. First major surface 106A and second major surface 106B may define a thickness 106T of third layer 106.

As discussed above, second layer 104 is located between first layer 102 and third layer 106. In some embodiments, the second layer 104 may be split into multiple "second layers" which may be separated by other layers. Single or multiple second layers 104 must be between first layer 102 and third layer 106. Furthermore, thermoformable base film 100 may include other layers between the first layer 102 and third layer 106. The other layers may be selected to impart desirable properties (e.g., barrier properties, cutting properties, etc.) to thermoformable base film 100. The other layers may be included in thermoformable base film 100, as long as these layers are not detrimental to the recycling properties of thermoformable base film 100 (i.e., the materials must be acceptable to a polyethylene recycling process). The other layers may be present at any location of thermoformable base film 100 between first layer 102 and third layer 106.

First layer 102 and third layer 106 each may form a surface of thermoformable base film 100. Specifically, in the illustrated embodiment of FIG. 1, first major surface 102A of first layer 102 forms a first surface 100A of thermoformable base film 100, and

second major surface 106B of third layer 106 forms a second surface 100B of thermoformable base film 100 opposite to first surface 100A. First surface 100A and second surface 100B may be exterior surfaces of thermoformable base film 100.

First surface 100A and second surface 100B may define a thickness 100T of thermoformable base film 100. In some embodiments, thickness 100T of thermoformable base film 100 may be from about 102 micron (4 mil) to about 2032 micron (80 mil). In some embodiments, thickness 100T may be from about 203 micron (8 mil) to about 1270 micron (50 mil). In some embodiments, thickness 100T may be from about 203 micron (8 mil) to about 635 micron (25 mil). Thickness 100T of thermoformable base film 100 may be selected to provide desired rigidity (i.e., stiffness) and durability to thermoformable base film 100 upon thermoforming.

First layer 102 may be a sealing layer of thermoformable base film 100. Consequently, first surface 100A (which is formed by first layer 102) of thermoformable base film 100 may correspond to a surface to which a lid packaging component is sealed (e.g., heat sealed).

First layer 102 may improve a sealing performance of thermoformable base film 100. Specifically, first layer 102 may have a low seal initiation temperature (SIT) (e.g., about 80 degrees centigrade or less) while providing a high seal strength (e.g., greater than 10 N/15mm) at the low SIT. The low SIT may enable a lid packaging component to be quickly sealed with thermoformable base film 100, or more specifically, to a thermoformed base made from thermoformable base film 100 at low temperatures and facilitate in achieving desirable speeds on packaging lines.

Moreover, first layer 102 may be made thin (e.g., less than 20 microns) without compromising the sealing performance of thermoformable base film 100. Specifically, in some embodiments, thickness 102T of first layer 102 may be less than 20 microns. First layer 102 having thickness 102T less than 20 microns may provide desirable sealing performance at low temperatures. In some embodiments, thickness 102T of first layer 102 may be less than 25% of thickness 100T of thermoformable base film 100. In some embodiments, thickness 102T of first layer 102 may be less than 20% of thickness 100T of thermoformable base film 100. In some embodiments, thickness 102T of first layer 102 may be less than 15% of thickness 100T of thermoformable base film 100. In some

embodiments, thickness 102T of first layer 102 may be less than less than 10% of thickness 100T of thermoformable base film 100.

First layer 102 being thin may allow reducing thickness 100T of thermoformable base film 100. First layer 102 being thin may also allow increasing thicknesses of other layers (e.g., thickness 104T of second layer 104 and thickness 106T of third layer 106) of thermoformable base film 100, for example, to impart specific properties (e.g., water vapor barrier properties) to thermoformable base film 100.

In some embodiments, thickness 104T of second layer 104 may be from 15% to 95% or from 25% to 95% of thickness 100T of thermoformable base film 100. Thickness 104T of second layer 104 being from 15% to 95% or from 25% to 95% of thickness 100T of thermoformable base film 100 may improve thermoforming capabilities of thermoformable base film 100. For example, it may allow thermoformable base film 100 to be thermoformed under a wider thermoforming temperature window and impart desirable moisture barrier properties to thermoformable base film 100.

After thermoforming, thermoformable base film 100 maintains the shape taken during thermoforming. Thermoformable base film 100 may also resist defects such as warping, curling, or shrinking after thermoforming. Specifically, a thermoformed base manufactured by thermoforming thermoformable base film 100 may resist post-thermoforming defects such as warping, curling, or shrinking.

Thermoformable base film 100 may be substantially free from materials that negatively impact the recyclability thereof. In some embodiments, thermoformable base film 100 may be essentially free from polyester, polypropylene, cyclic olefin copolymer, and polyamide. These materials may hinder the recyclability of thermoformable base film 100. Any non-polyethylene materials in thermoformable base film 100 (and layers thereof) may be present at a low level such that they do not disrupt or otherwise hamper the recycling process. The non-polyethylene materials may be of a type that is acceptable to the recycling process, such as other types of polyolefin-based materials. The non-polyethylene materials may be present along with a compatibilizer system. In some embodiments, thermoformable base film 100 may be free from fiber-based materials.

In some embodiments, the overall density of thermoformable base film 100 may be less than 1.0 g/cm^3. The overall density of thermoformable base film 100 being less

than below 1.0 g/cm^3 may be a critical feature used in separation procedures during the recycling process (i.e., sorting by floating).

A melt index of thermoformable base film 100 may be between 1.7 g/10min and 2.3 g/10min when tested at 190°C and 2160 g. The melt index of the thermoformable base film 100 may be between 1.7 g/10min and 8.0 g/10min when tested at 190°C and 2160 g. The melt index of thermoformable base film 100 may be measured according to ASTMD1238-10 and conditions of 190°C and 2160 g.

Thermoformable base film 100 may be produced by any suitable manufacturing technique. For example, thermoformable base film 100 may be fully coextruded or may be produced by other processes such as lamination or coating. In some embodiments, thermoformable base film 100 may be manufactured using a cast extrusion process.

FIG. 2 shows a schematic cross-sectional view of a thermoformable base film 200 in accordance with another embodiment of the present disclosure. Thermoformable base film 200 is similar to thermoformable base film 100 of FIG. 1, with like elements designated by like reference characters. However, thermoformable base film 200 includes additional layers as compared to thermoformable base film 100.

In the illustrated embodiment of FIG. 2, thermoformable base film 200 includes a fourth layer 108 located between first layer 102 and third layer 106. Fourth layer 108 may include a high-density polyethylene and an inorganic particle. The inorganic particle may be present in fourth layer 108 at a level of at least 3% by weight. The inorganic particle may include, for example, calcium carbonate ($CaCO_3$), titanium dioxide (TiO_2), and talc. In some embodiments, fourth layer 108 may include $CaCO_3$ in a range of from 7% to 12%, by weight. In some embodiments, fourth layer 108 may include TiO_2 in a range of from 1% to 4%, by weight.

In some embodiments, thermoformable base film 200 may include a plurality of fourth layers 108 located between first layer 102 and third layer 106. One or more fourth layers 108 may assist in achieving clean cutting of thermoformable base film 200 after thermoforming. However, it should be noted that presence of the inorganic particle in fourth layer 108 should not significantly increase the overall density of thermoformable base film 200. For example, presence of the inorganic particle in fourth layer 108 should not increase the overall density of thermoformable base film 200 to greater than 1.0 g/cm^3.

In the illustrated embodiment of FIG. 2, thermoformable base film 200 further includes an oxygen barrier layer 110 located between first layer 102 and third layer 106. Oxygen barrier layer 110 may include a material that limits the transmission of oxygen through thermoformable base film 200. In some embodiments, oxygen barrier layer 110 may include an ethylene vinyl alcohol copolymer (EVOH). In some examples, EVOH may be present along with a compatibilizer that allows EVOH to be incorporated into a polyethylene recycling stream. That is, oxygen barrier layer 110 may not hinder the recyclability of thermoformable base film 200.

In some embodiments, first layer 102 and third layer 106 each may form a surface of thermoformable base film 200. Specifically, in the illustrated embodiment of FIG. 2, first major surface 102A of first layer 102 forms a first surface 200A of thermoformable base film 200, and second major surface 106B of third layer 106 forms a second surface 200B of thermoformable base film 200 opposite to first surface 100A. First surface 200A and second surface 200B may be exterior surfaces of thermoformable base film 200. First surface 200A and second surface 200B may define a thickness 200T of thermoformable base film 200. Thicknesses of first, second, and third layers 102, 104, 106 relative to thickness 100T of thermoformable base film 100 discussed above are equally applicable to thicknesses of first, second, and third layers 102, 104, 106 relative to thickness 200T of thermoformable base film 200.

Second layer 104, fourth layer 108, oxygen barrier layer 110, and other layers of thermoformable base film 200 may have various suitable relative locations between first layer 102 and third layer 106. For example, in the illustrated embodiment of FIG. 2, oxygen barrier layer 110 is located between first layer 102 and fourth layer 108. Further, fourth layer 108 is located between oxygen barrier layer 110 and second layer 104. However, the relative locations of second layer 104, fourth layer 108, oxygen barrier layer 110, and other layers may be different than shown in FIG. 2 in other embodiments.

After thermoforming, thermoformable base film 200 maintains the shape taken during thermoforming. Thermoformable base film 200 may substantially resist defects such as warping, curling, or shrinking after thermoforming. Specifically, a thermoformed base manufactured by thermoforming thermoformable base film 200 may resist post-thermoforming defects such as warping, curling, or shrinking.

Thermoformable base film 200 may be substantially free from materials that negatively impact the recyclability thereof. In some embodiments, thermoformable base film 200 may be essentially free from polyester, polypropylene, cyclic olefin copolymer, and polyamide. These materials may hinder the recyclability of thermoformable base film 200. Any non-polyethylene materials in thermoformable base film 200 (and layers thereof) may be present at a low level such that they do not disrupt or otherwise hamper the recycling process. The non-polyethylene materials may be of a type that is acceptable to the recycling process, such as other types of polyolefin-based materials. The non-polyethylene materials may be present along with a compatibilizer system. In some embodiments, thermoformable base film 200 may be free from fiber-based materials.

In some embodiments, the overall density of thermoformable base film 200 may be less than 1.0 g/cm^3. The overall density of thermoformable base film 200 being less than below 1.0 g/cm^3 may be a critical feature used in separation procedures during the recycling process (i.e., sorting by floating).

FIGS. 3A and 3B show a thermoformed base 300 in accordance with an embodiment of the present disclosure. Specifically, FIG. 3A illustrates a schematic bottom perspective view of thermoformed base 300, and FIG. 3B illustrates a schematic top view of thermoformed base 300.

Referring to FIGS. 3A and 3B, in some embodiments, thermoformed base 300 includes thermoformable base film 100. In other words, thermoformed base 300 may be produced from thermoformable base film 100 using a thermoforming process. In some other embodiments, thermoformed base 300 may include thermoformable base film 200 (shown in FIG. 2).

Thermoformed base 300 further includes at least one cavity 302. At least one cavity 302 may be deep or shallow and may be shaped to hold an intended product therein. In the illustrated embodiment of FIGS. 3A and 3B, thermoformed base 300 has ten numbers of cavities 302 surrounded by a flange 304. In other words, flange 304 surrounds each of cavities 302. At least one cavity 302 and flange 304 may be formed by thermoforming thermoformable base film 100 (or thermoformable base film 200 of FIG. 2). Flange 304 may be generally an unformed area of thermoformable base film 100 and may be used to connect thermoformed base 300 to other packaging components (e.g., a

lid packaging component), another thermoformed base component, or some other packaging component.

In some examples, at least one cavity 302 may be sized specifically to hold an individual pharmaceutical tablet or capsule. In other examples, at least one cavity 302 may be large and hold multiple pieces of product. Cavities 302 of all numbers, sizes, and shapes may be configured in thermoformed base 300 as per requirement.

Thermoformed base 300 may maintain the shape taken during thermoforming. Thermoformed base 300 may not exhibit post-thermoforming defects such as warping, shrinking, and curling. Additionally, thermoformed base 300 may be highly rigid and inflexible, or thermoformed base 300 may be flexible while still maintaining the shape taken during thermoforming.

FIG. 4 illustrates a schematic cross-sectional view of a packaged product 400 in accordance with an embodiment of the present disclosure.

Packaged product 400 includes thermoformed base 300 and a lid packaging component 410. In some embodiments, lid packaging component 410 may have a moisture and/or oxygen barrier that is similar in performance to thermoformed base 300.

Packaged product 400 further includes a product 420. Product 420 that may be contained in cavities 302 of thermoformed base 300 is not limited. In some examples, product 420 may be sensitive to the environment, such as pharmaceuticals or foods. In some examples, product 420 may require physical protection, such as delicate medical devices. In other examples, product 420 may need to be contained for consumer protection, such as medicaments or cleaners that should be in child proof packaging. In some examples, product 420 may be suitable for easy dispensing, such as a gum or a candy.

Lid packaging component 410 may be hermetically sealed to flange 304 of thermoformed base 300. Product 420 may be enclosed in at least one cavity 302 of the thermoformed base 300. Specifically, lid packaging component 410 may enclose product 420 in cavities 302. The hermetic seal between flange 304 and lid packaging component 410 may limit passage of gasses, liquids, microbes, or other materials from the environment to cavity 302 containing product 420. Packaged product 400 may provide excellent product protection (e.g., moisture barrier), good appearance, good forming

accuracy and consistency, good heat resistance, and good seal strength. In some embodiments, lid packaging component 410 may be connected to thermoformed base 300 at flange 304 in an area including entire perimeter surrounding all cavities 302, and not between each of cavities 302.

In some embodiments, lid packaging component 410 may include a heat-sealing layer 412 and a layer 414 including at least one of metal and paper. At least one of metal and paper may be laminated or otherwise connected to polymer layers including heat-sealing layer 412. Heat-sealing layer 412 of lid packaging component 410 may form a surface of lid packaging component 410 that is heat sealed to flange 304 of thermoformed base 300.

In some embodiments, lid packaging component 410 that is heat sealed to thermoformed base 300 may contain a polyethylene and may have a density between about 0.92 g/cm^3 and 0.97 g/cm^3. In some embodiments, lid packaging component 410 may be of any composition that is suitable for required application. In some embodiments, lid packaging component 410 may be printed, scored, or otherwise modified for specific properties.

In some embodiments, lid packaging component 410 may be peelably sealed to flange 304 of thermoformed base 300. That is, lid packaging component 410 can be manually removed from flange 304 without use of any tools. In some embodiments, the seal strength between thermoformed base 300 and lid packaging component 410 may be at least 2,000 g/25.4mm.

In some embodiments, at least one cavity 302 of thermoformed base 300 may be depressed manually, and product 420 may be pushed through lid packaging component 410 for product dispensing. Lid packaging component 410 may be formulated and/or designed such that product 420 may be pushed through lid packaging component 410 for product dispensing. In some examples, particularly for applications of product 420 that may include pharmaceutical tablets, gum pieces or the like, cavities 302 of thermoformed base 300 may flexible enough that a consumer can depress cavity 302 manually, forcing product 420 through lid packaging component 410, for product dispensing. In some embodiments, lid packaging component 410 may be a “push through” lid.

In some embodiments, thermoformed base 300 and lid packaging component 410 may be recyclable in the same recycle process. In such embodiments, lid packaging component 410 may have a composition high in polyethylene (e.g., high-density polyethylene). In some embodiments, lid packaging component 410 may be multi-layered, with each layer include a polyethylene. This may facilitate recycling of packaged product 400.

In some embodiments, lid packaging component 410 may include a heat-resistant exterior layer including high-density polyethylene and an inorganic particle (e.g., calcium carbonate), an interior layer including a high-density polyethylene and a nucleating agent, and a heat-sealing exterior layer containing a polyethylene-based plastomer.

Examples

The following illustrative examples are merely meant to exemplify the present disclosure and are not intended to limit or otherwise define the scope of the present disclosure.

A Comparative Example was selected from one of previously known polyethylene-based films. Example 1 was produced by modifying the structure of Comparative Example in accordance with the present disclosure. Examples 2-4 were produced in accordance with the present disclosure.

Table 1 summarizes the details of Comparative Example and Tables 2-5 summarize the details of Examples 1-4, respectively.

In Tables 1-5, the term "PE $CaCO_3$ MB" refers to a calcium carbonate masterbatch containing polyethylene with greater than 30% inorganic content. The term "HC" is a hydrocarbon resin additive. The term "PE white MB" refers to a white masterbatch containing polyethylene with titanium dioxide. The term "PEP" refers to polymer plastomer. The term "MI" refers to a melt index of the component when tested at 190 °C and 2160 g according to ASTM D1238. The term "WVTR" refers to water vapor transmission rate tested at conditions 38 °C and 90% Rh according to ASTM F1249. The films of Examples also contained standard processing aids such as slip and antiblock for cast films in minor amounts, which are not listed in Tables 1-5.

Table 1: Comparative Example Details

Film Layer	Comparative Example		
	Layer Thickness (microns)	Layer Components	Additional Component Details
1 [seal layer]	19	50% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		50% PEP	Density: 0.875 g/cm^3
2	168	75% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% HC	-
		7% PE $CaCO_3$ MB	-
		3% PE white MB	-
3	19	50% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		50% PEP	Density: 0.875 g/cm^3
4	58	90% HDPE	Density: 0.97 g/cm^3
		10% HC	-
5	51	100% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
Overall Film Thickness	315 microns		
WVTR	0.19 g / m^2 / day		

Table 2: Example 1 Details

Base Film Layer	Example 1		
	Layer Thickness (microns)	Layer Components	Additional Component Details

1 [first layer]	19	25% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		75% PEP	Density: 0.875 g/cm^3
2 [fourth layer]	168	75% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% HC	-
		7% PE $CaCO_3$ MB	-
		3% PE white MB	-
3 [additional layer]	19	25% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		75% PEP	Density: 0.875 g/cm^3
4 [second layer]	58	90% HDPE	Density: 0.97 g/cm^3
		10% HC	-
5 [third layer]	51	100% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
Overall Film Thickness	315 microns		
WVTR	0.19 g / m^2 / day		

Table 3: Example 2 Details

Base Film Layer	Example 2		
	Layer Thickness (microns)	Layer Components	Additional Component Details
1 [first layer]	63	25% HDPE	Density: 0.96 g/cm^3 MI: 4 g/10min
		75% PEP	Density: 0.875 g/cm^3

2 [fourth layer]	32	80% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% $CaCO_3$	-
		5% PE white MB	-
3 [second layer]	58	85% HDPE	Density: 0.97 g/cm^3
		15% HC	
4 [fourth layer]	16	95% LLDPE	Density: 0.918 g/cm3 MI: 2 g/10min
		5% PE white MB	-
5 [second layer]	84	85% HDPE	Density: 0.97 g/cm^3
		15% HC	-
6 [fourth layer]	26	80% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% PE $CaCO_3$ MB	-
		5% PE white MB	-
7 [third layer]	36	100% HDPE	Density: 0.96 g/cm^3 MI: 4 g/10min
Overall Film Thickness	315 microns		
WVTR	0.17 g / m^2 / day		

Table 4: Example 3 Details

Base Film Layer	Example 3		
	Layer Thickness (microns)	Layer Components	Additional Component Details

1 [first layer]	63	25% HDPE	Density: 0.96 g/cm^3 MI: 4 g/10min
		75% PEP	Density: 0.875 g/cm^3
2 [fourth layer]	32	85% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% PE $CaCO_3$ MB	-
3 [second layer]	58	85% HDPE	Density: 0.97 g/cm^3
		15% HC	-
4 [additional layer]	16	100% LLDPE	Density: 0.918 g/cm3 MI: 2 g/10min
5 [second layer]	84	85% HDPE	Density: 0.97 g/cm^3
		15% HC	-
6 [fourth layer]	26	85% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% PE $CaCO_3$ MB	-
7 [third layer]	36	100% HDPE	Density: 0.96 g/cm^3 MI: 4 g/10min
Overall Film Thickness	315 microns		
WVTR	0.17 g / m^2 / day		

Table 5: Example 4 Details

Base Film Layer	Example 1		
	Layer Thickness (microns)	Layer Components	Additional Component Information

1 [first layer]	63	25% HDPE	Density: 0.96 g/cm^3 MI: 4 g/10min
		75% PEP	Density: 0.875 g/cm^3
2 [fourth layer]	35	80% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% $CaCO_3$	-
		5% PE white MB	-
3 [second layer]	145	85% HDPE	Density: 0.97 g/cm^3
		15% HC	-
4 [fourth layer]	35	80% HDPE	Density: 0.97 g/cm^3 MI: 6 g/10min
		15% PE $CaCO_3$ MB	-
		5% PE white MB	-
5 [third layer]	37	100% HDPE	Density: 0.96 g/cm^3 MI: 4 g/10min
Overall Film Thickness	315 microns		
WVTR	0.19 g / m^2 / day		

Experimental Results

The above described Comparative Example and Examples 1-4 were tested to determine their sealing performance. The seals were made using 1 heat seal bar, seal time of 0.5 seconds, and sealing pressure of 400 N/20cm^2 against a lidding. The sealing temperature was varied to determine the sealing performance at different sealing temperatures (specifically, at 80 °C, at 90 °C, and 100 °C). The seal force was measured at a sample width of 15 mm, pull speed of 300 mm/min, and a load cell of 250 N. Each

data point in the Tables 6 and 7 provided below is an average of the peak forces recorded in three tests.

Comparative Example and Example 1 were compared as they had similar structure, with different seal layer (or first layer). Comparative Example and Example 1 were tested in both machine direction (MD) and cross direction (CD).

Table 6: Seal Force Comparison

Sealing Temperature (°C)	Comparative Example		Example 1	
	Seal Force (N/15mm)			
	CD	MD	CD	MD
80	6.3	8.4	13.1	10.7
90	16.5	15.7	19.3	19.1
100	19.5	19.2	22.7	18.2

As depicted by Table 6, Example 1 provided improved sealing performance in comparison to Comparative Example. Most notable improvement in the seal force was observed in the cross-direction when the sealing temperature was 80 °C.

Examples 2-4 were tested to determine their sealing performance in the cross direction.

Table 7: Seal Force Details of Examples 2-4

Sealing Temperature (°C)	Example 2	Example 3	Example 4
	Seal Force (N/15mm) in CD		
80	0.4	0.2	0.2
90	2.0	3.2	3.1
100	18.0	16.4	20.2

As depicted by Table 7, Examples 2-4 showcased lower seal strength at the sealing temperatures, but still having an acceptable seal initiation temperature (i.e.,, 100°C).

Each and every document cited in this present application, including any cross referenced, is incorporated in this present application in its entirety by this reference, unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any embodiment disclosed in this present application or that it alone, or in any combination with any other reference or references, teaches, suggests, or discloses any such embodiment. Further, to the extent that any meaning or definition of a term in this present application conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this present application governs.

Unless otherwise indicated, all numbers expressing sizes, amounts, ranges, limits, and physical and other properties used in the present application are to be understood as being preceded in all instances of the term "about." Accordingly, unless expressly indicated to the contrary, the numerical parameters set forth in the present application are approximations that can vary depending on the desired properties sought to be obtained by a person of ordinary skill in the art without undue experimentation using the teachings disclosed in the present application.

As used in the present application, the singular forms "a," "an," and "the" encompass embodiments having plural referents, unless the context clearly dictates otherwise. As used in the present application, the term "or" is generally employed in its sense including "and/or", "unless" the context clearly dictates otherwise.

Spatially related terms, including, but not limited to, "lower," "upper," "beneath," "below," "above," "bottom," and "top," if used in the present application, are used for ease of description to describe spatial relationships of an element(s) to another. Such spatially related terms encompass different orientations of the device in use or operation, in addition to the particular orientations depicted in the figures and described in the present application. For example, if an object depicted in the drawings is turned over or flipped over, elements previously described as below, or beneath other elements would then be above those other elements.

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.

The description, examples, embodiments, and drawings disclosed are illustrative only and should not be interpreted as limiting. The present invention includes the description, examples, embodiments, and drawings disclosed; but it is not limited to such description, examples, embodiments, or drawings. As briefly described above, the reader should assume that features of one disclosed embodiment can also be applied to all other disclosed embodiments, unless expressly indicated to the contrary. Modifications and other embodiments will be apparent to a person of ordinary skill in the packaging arts, and all such modifications and other embodiments are intended and deemed to be within the scope of the present invention.

Clause 1. A thermoformable base film comprising: a first layer comprising at least one polyethylene and having an overall density between about 0.85 g/cm^3 and 0.92 g/cm^3; a second layer comprising a high-density polyethylene and a hydrocarbon resin; and a third layer comprising at least one polyethylene and having an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3; wherein: the second layer is located between the first layer and the third layer; and after thermoforming, the thermoformable base film maintains the shape taken during thermoforming.

Clause 2. The thermoformable base film according to clause 1, wherein the first layer and the third layer each form a surface of the thermoformable base film.

Clause 3. The thermoformable base film according to clause 1 or 2, wherein the first layer comprises an overall density between 0.86 g/cm^3 and 0.92 g/cm^3.

Clause 4. The thermoformable base film according to any of clause 1-3, wherein the first layer comprises a polyethylene plastomer in a range of from 50% to 100%.

Clause 5. The thermoformable base film according to clause 4, wherein the first layer further comprises a low-density polyethylene, a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight.

Clause 6. The thermoformable base film according to any of clauses 1-5, wherein the first layer has a thickness comprising less than 25% of a thickness of the thermoformable base film.

Clause 7. The thermoformable base film according to any of clauses 1-6, wherein the hydrocarbon resin is present from 2.5% to 30% by weight with respect to the second layer.

Clause 8. The thermoformable base film according to any of clauses 1-7, wherein the third layer comprises a medium-density polyethylene or a high-density polyethylene.

Clause 9. A thermoformable base film comprising: a first layer comprising a high-density polyethylene and a polyethylene having a density less than 0.92 g/cm^3; a second layer comprising from 60% to 90%, by weight, of a high-density polyethylene and from 2.5% to 30%, by weight of a hydrocarbon resin; and a third layer comprising at least one polyethylene and having an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3; wherein: the second layer is located between the first layer and the third layer; and the second layer has a thickness that is from 15% to 95% of a thickness of the thermoformable base film.

Clause 10. The thermoformable base film according to clause 9, wherein the first layer and the third layer each form a surface of the thermoformable base film.

Clause 11. The thermoformable base film according to clause 9 or 10, wherein the first layer comprises an overall density between 0.86 g/cm^3 and 0.92 g/cm^3.

Clause 12. The thermoformable base film according to any of clauses 9-11, wherein the first layer comprises a polyethylene plastomer in a range of from 50% to 100% and a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight.

Clause 13. The thermoformable base film according to any of clauses 9-12, wherein the first layer has a thickness of less than 20 microns.

Clause 14. The thermoformable base film according to any of clauses 9-13, wherein the hydrocarbon resin is present from 5% to 10% by weight with respect to the thermoformable base film.

Clause 15. The thermoformable base film according to any of clauses 9-14, wherein the third layer comprises a medium-density polyethylene or a high-density polyethylene.

Clause 16. The thermoformable base film according to any of clauses 9-15, further comprising a fourth layer comprising a high-density polyethylene and an inorganic particle, wherein the inorganic particle is present in the fourth layer at a level of at least 3% by weight, and wherein the fourth layer is located between the first layer and the third layer.

Clause 17. The thermoformable base film according to any of clauses 9-16, wherein the overall density of the thermoformable base film is less than 1.0 g/cm^3.

Clause 18. The thermoformable base film according to any of clauses 9-17, wherein the thermoformable base film is essentially free from polyester, polypropylene, cyclic olefin copolymer, and polyamide.

Clause 19. The thermoformable base film according to any off clauses 9-18, further comprising an oxygen barrier layer comprising an ethylene vinyl alcohol copolymer, wherein the oxygen barrier layer is located between the first layer and the third layer.

Clause 20. A thermoformed base comprising: the thermoformable base film according to any off clauses 1-19; at least one cavity; and a flange surrounding each of the cavities.

Clause 21. The thermoformed base according to clause 20, wherein the thermoformed base maintains the shape taken during thermoforming.

Clause 22. A packaged product comprising: the thermoformed base according to clause 20 or 21; a lid packaging component; and a product; wherein: the lid packaging component is hermetically sealed to the flange of the thermoformed base and the product is enclosed in the at least one cavity of the thermoformed base.

Clause 23. The packaged product according to clause 22, wherein the lid packaging component comprises a heat-sealing layer and a layer comprising at least one of metal and paper.

Clause 24. The packaged product according to clause 22 or 23, wherein the lid packaging component is peelably sealed to the flange of the thermoformed base.

Clause 25. The packaged product according to any of clauses 22-24, wherein the thermoformed base and the lid packaging component are recyclable in the same recycle process.

Clause 26. The packaged product according to any of clauses 22-25, wherein the at least one cavity of the thermoformed base may be depressed manually, and the product may be pushed through the lid packaging component for product dispensing.

Clause 27. The packaged product according to any of clauses 22-26, wherein the seal strength between the thermoformed base and the lid packaging component is at least 2,000 g/25.4mm.

CLAIMS

What is claimed is:

1. A thermoformable base film comprising:

a first layer comprising at least one polyethylene and having an overall density between about 0.85 g/cm^3 and 0.92 g/cm^3;

a second layer comprising a high-density polyethylene and a hydrocarbon resin; and

a third layer comprising at least one polyethylene and having an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3;

wherein:

the second layer is located between the first layer and the third layer; and

after thermoforming, the thermoformable base film maintains the shape taken during thermoforming.

2. The thermoformable base film according to claim 1, wherein the first layer and the third layer each form a surface of the thermoformable base film.

3. The thermoformable base film according to claim 1, wherein the first layer comprises an overall density between 0.86 g/cm^3 and 0.92 g/cm^3.

4. The thermoformable base film according to claim 1, wherein the first layer comprises a polyethylene plastomer in a range of from 50% to 100%.

5. The thermoformable base film according to claim 4, wherein the first layer further comprises a low-density polyethylene, a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight.

6. The thermoformable base film according to claim 1, wherein the first layer has a thickness comprising less than 25% of a thickness of the thermoformable base film.

7. The thermoformable base film according to claim 1, wherein the hydrocarbon resin is present from 2.5% to 30% by weight with respect to the second layer.

8. The thermoformable base film according to claim 1, wherein the third layer comprises a medium-density polyethylene or a high-density polyethylene.

9. A thermoformable base film comprising:

a first layer comprising a high-density polyethylene and a polyethylene having a density less than 0.92 g/cm^3;

a second layer comprising from 60% to 90%, by weight, of a high-density polyethylene and from 2.5% to 30%, by weight of a hydrocarbon resin; and

a third layer comprising at least one polyethylene and having an overall density between about 0.92 g/cm^3 and 0.97 g/cm^3;

wherein:

the second layer is located between the first layer and the third layer; and

the second layer has a thickness that is from 15% to 95% of a thickness of the thermoformable base film.

10. The thermoformable base film according to claim 9, wherein the first layer and the third layer each form a surface of the thermoformable base film.

11. The thermoformable base film according to claim 9, wherein the first layer comprises an overall density between 0.86 g/cm^3 and 0.92 g/cm^3.

12. The thermoformable base film according to claim 9, wherein the first layer comprises a polyethylene plastomer in a range of from 50% to 100% and a medium-density polyethylene or a high-density polyethylene in a range of from 0% to 50%, by weight.

13. The thermoformable base film according to claim 9, wherein the first layer has a thickness of less than 20 microns.

14. The thermoformable base film according to claim 9, wherein the hydrocarbon resin is present from 5% to 10% by weight with respect to the thermoformable base film.

15. The thermoformable base film according to claim 9, wherein the third layer comprises a medium-density polyethylene or a high-density polyethylene.

16. The thermoformable base film according to claim 9, further comprising a fourth layer comprising a high-density polyethylene and an inorganic particle, wherein the inorganic particle is present in the fourth layer at a level of at least 3% by weight, and wherein the fourth layer is located between the first layer and the third layer.

17. The thermoformable base film according to claim 9, wherein the overall density of the thermoformable base film is less than 1.0 g/cm^3.

18. The thermoformable base film according to claim 9, wherein the thermoformable base film is essentially free from polyester, polypropylene, cyclic olefin copolymer, and polyamide.

19. The thermoformable base film according to claim 9, further comprising an oxygen barrier layer comprising an ethylene vinyl alcohol copolymer, wherein the oxygen barrier layer is located between the first layer and the third layer.

20. A thermoformed base comprising:
the thermoformable base film according to claim 1;
at least one cavity; and
a flange surrounding each of the cavities.

21. The thermoformed base according to claim 20, wherein the thermoformed base maintains the shape taken during thermoforming.

22. A packaged product comprising:
the thermoformed base according to claim 20;
a lid packaging component; and
a product;
wherein:
the lid packaging component is hermetically sealed to the flange of the thermoformed base and the product is enclosed in the at least one cavity of the thermoformed base.

23. The packaged product according to claim 22, wherein the lid packaging component comprises a heat-sealing layer and a layer comprising at least one of metal and paper.

24. The packaged product according to claim 22, wherein the lid packaging component is peelably sealed to the flange of the thermoformed base.

25. The packaged product according to claim 22, wherein the thermoformed base and the lid packaging component are recyclable in the same recycle process.

26. The packaged product according to claim 22, wherein the at least one cavity of the thermoformed base may be depressed manually, and the product may be pushed through the lid packaging component for product dispensing.

27. The packaged product according to claim 22, wherein the seal strength between the thermoformed base and the lid packaging component is at least 2,000 g/25.4mm.