MULTILAYER CLEAR OVER COLOR POLYOLEFIN SHEETS AND LAYERED BACKING STRUCTURE

Inventor: Dennis C. Smith, Norwalk, OH (US)

Correspondence Address:
PATENT GROUP 2N
JONES DAY
NORTH POINT, 901 LAKESIDE AVENUE
CLEVELAND, OH 44114 (US)

Assignee: A. SCHULMAN, INC., Akron, OH (US)

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ABSTRACT
A multilayer structure includes a clear polyolefin layer, a colored polyolefin layer, and a random polyolefin backing layer. The colored and backing layers are coextruded and are permanently bonded at a layer interface, which is exclusive of an adhesive. The structure has a DOI of 70 or greater and passes a gravelometer impact test per the GM9508P standard, with a 10 pint load, at a −30°C. temperature, and at an impact angle of 30 degrees. Among other uses, the structures are appropriate for use as body panels in the motor vehicle industry. The structures display a "class A" finish and meet a variety of requirements for durability and weatherability. An ABA structured backing layer and a method of making it are also described herein.
Fig. 10

Fig. 11
MULTILAYER CLEAR OVER COLOR POLYOLEFIN SHEETS AND LAYERED BACKING STRUCTURE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of PCT application No. PCT/US09/42704, which was filed on May 4, 2009, which in turn claimed the benefit of priority from U.S. Provisional Application No. 61/050,465, filed on May 5, 2008. These prior applications, including the written description and drawing figures, are hereby incorporated into the present application by reference.

BACKGROUND

[0002] Many different types of articles produced today are formed from coextruded or laminated sheets. For the composition of these sheets there are several different types of competing technologies, such as painted plastic, solvent cast fluoro-acrylic film, coextruded ionomer decorative sheet, painted metal, & coextruded acrylic/ABS sheet.

[0003] For many polymeric articles of manufacture, optical and durability characteristics are very important. Particularly in the transportation industry, the qualities of distinction of image, gloss, imprint resistance, scratch resistance, mar resistance, and corrosion resistance are highly desirable among other measures of durability and optical quality. Achieving a balance of excellent optical qualities and excellent durability qualities is a difficult endeavor and is complicated by the unpredictability of chemical interactions between various materials used in such compositions. It is particularly difficult to achieve an excellent balance of properties in a final formed product that has been subjected to heat and/or elongation.

[0004] In addition, sheet formed thermoplastic polyolefin (TPO) typically includes a mixture of both virgin polymer and regrind polymer. TPO is a blend of an olefin, an elastomer, and a filler such as talc. The addition of regrind polymer is considered a necessary practice within the sheet extrusion industry in order to control costs by minimizing waste and reducing the overall raw material cost of the final part. Although the economics improve with the addition of regrind, the added regrind contributes to a lower melt strength and the sag resistance of the sheet is significantly reduced. A low sag resistance can cause defects such as excessive “webbing” in tight corners, surface tears in areas of high stretch, and non-uniform wall thickness. Significant variation in wall thickness throughout a part can cause excessive warping and/or deterioration of physical properties.

SUMMARY

[0005] This application describes novel multilayer structures that include a clear polyolefin layer, a colored polyolefin layer, and a random polyolefin backing layer. The colored and backing layers are coextruded and are permanently bonded at a layer interface. In another embodiment, the clear polyolefin layer is also coextruded and permanently bonded over the colored backing layer. These structures have a DOI of 70 or greater and pass a gravellometer impact test per the GM9508P standard, with a 10 pint load, at a ~30°C temperature, and at an impact angle of 30 degrees. The multilayer structures retain DOI and gravellometer impact standards as stated above even after being subjected to heat and/or elongation to make a final formed product. Among other uses, the structures are appropriate for use as vehicle body panels.

[0006] A formed product is described that includes a coextruded clear isotactic polypropylene/ethylene copolymer layer of 1 mil to 20 mils in thickness, alternatively 2.5 mils to 20 mils in thickness; a coextruded colored isotactic polypropylene/ethylene copolymer layer of 3 mils to 20 mils in thickness, alternatively 1 mil to 20 mils in thickness; and a polyolefin backing layer with a random microstructure. The clear and color layers are coextruded and are permanently bonded at a layer interface. The formed product has a DOI of 70 or greater. The formed product is substantially non-oriented by stretching. The formed product has a gloss of 75 or greater at a 60° angle and a gloss of 60 or greater at a 20° angle. The clear polyolefin layer has a light transmittance of 90% or greater. The clear polyolefin layer has a haze of 10 or less. The formed product exhibits no gauze imprint at 70°C. Minimum under a 500 g load applied over a 40 mm diameter for two hours. The formed product passes a gravellometer impact test per the GM9508 standard, with a 10 pint load, at a ~30°C temperature, and at an impact angle of 30 degrees.

[0007] A vehicle body panel is described herein that includes a multilayer structure. The multilayer structure includes a coextruded clear isotactic polypropylene/ethylene copolymer layer of 1 mil to 10 mils in thickness, alternatively 2.5 mils to 10 mils in thickness; a coextruded colored isotactic polypropylene/ethylene polyolefin layer of 1 mils to 10 mils thick, alternatively 3 mils to 20 mils in thickness; and a polyolefin backing layer with a random microstructure. The clear and color layers are coextruded and are permanently bonded at a layer interface. The structure has a DOI of 70 or greater. The structure is substantially non-oriented by stretching. The structure has a gloss of 75 or greater at a 60° angle and a gloss of 60 or greater at a 20° angle. The clear polyolefin layer has a light transmittance of 90% or greater. The clear polyolefin layer has a haze of 10 or less. The structure exhibits no gauze imprint at 70°C. Minimum under a 500 g load applied over a 40 mm diameter for two hours. The structure passes a gravellometer impact test per the GM9508P standard, with a 10 pint load, at a ~30°C temperature, and at an impact angle of 30 degrees. Furthermore, the clear and/or color layers include an additive selected from the group consisting of: antioxidants, UV stabilizers, slip agents, and combinations of these.

[0008] In another embodiment, a multilayer structure includes a clear polyolefin layer, and a colored polyolefin backing layer with a random microstructure. The clear and backing layers are coextruded and are permanently bonded at a layer interface. The interface is exclusive of an adhesive layer, and the structure has a DOI of 70 or greater. In addition, the structure passes a gravellometer impact test per the GM9508P standard, with a 10 pt load, at a ~30°C temperature, and at an angle of 30 degrees.

[0009] A method of forming the above structures is also described.

[0010] This application further describes a multilayer structure that includes a first thermoplastic layer having a polymeric component consisting essentially of virgin polyolefin, a second thermoplastic layer including regrind polyolefin, and an optional third thermoplastic layer having a polymeric component consisting essentially of virgin polyolefin. The second thermoplastic layer is adjacent to the first thermoplastic layer and the third thermoplastic layer, if present.
A method for forming a multilayered polymeric structure is also described. The method includes: coextruding a first thermoplastic layer having a polymeric component that consists essentially of a virgin polyolefin with a second thermoplastic layer that includes regrind polyolefin, and optionally with a third thermoplastic layer having a polymeric component that consists essentially of a virgin polyolefin. The second thermoplastic layer is adjacent to the first thermoplastic layer and the third thermoplastic layer, if present.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of an example coextruded three-layer film.
FIG. 2 is a cross-sectional view of an example three-layer film for lamination.
FIG. 3 is a cross-sectional view of an example coextruded four-layer film.
FIG. 4 is a cross-sectional view of an example four-layer film for lamination.
FIG. 5 is a cross-sectional view of an example coextruded two-layer film.
FIG. 6 is a cross-sectional view of an example vehicle body panel.
FIG. 7 is a cross-sectional view of a second example vehicle body panel.
FIG. 8 is a cross-sectional view of an example multilayer structure with an ABA backing layer.
FIG. 9 is a cross-sectional view of an example multilayer structure with an AB backing layer.
FIG. 10 is a cross-sectional view of a mono-layer virgin/regrind blended backing layer and an ABA backing layer.
FIG. 11 is a graph comparing the “bag time” of a mono-layer virgin/regrind blended backing layer and an ABA backing layer.

DETAILED DESCRIPTION

The example multilayer structures disclosed herein provide a paint-free plastic sheet structure that may be designed to simulate the appearance of painted metal or plastic. Example multilayer structures include a clear polyolefin layer over a colored polyolefin layer. Another example is a multilayer structure with a clear polyolefin layer over a translucent polyolefin layer, over a color polyolefin layer. For each of these examples the multi-layer structures are provided with a thermoplastic polyolefin backing layer. Yet another example includes a clear polyolefin layer over a colored backing layer. Preferably, there is no adhesive layer at the interface between the clear layer and the color layer and there is no adhesive layer at the interface between the layer attached to the backing layer. Most preferably, the interface between all layers of the multilayer structures is free of all adhesives. An additional disposable mask layer may be provided on each of the example structures. Furthermore, in some examples, more than one color layer, more than one clear layer, and/or more than one backing layer may be employed.

The example multilayer structures may be formed into an article or laminated onto a substrate to produce an article. Example articles include a vehicle body panel, bumper fascia, and rocker panel.

In the field of polymeric multilayer sheets, compositional design changes that result in improvements in one or more optical or material characteristics typically result in a deterioration in another optical or material characteristic. For example, modifying a product to make it more durable will likely result in a deterioration in optical qualities. This is partly due to the unpredictable nature of the chemical interactions, differences in refractive indexes of the blended components, and component compatibilities. This makes it quite difficult to achieve a balance of excellent properties across several categories of optical and durability characteristics.

The example multilayer structures display an excellent balance of properties. Improvements in durability and weatherability were realized without sacrificing the appearance requirements needed (DOL—70 min, 85 min preferred; Gloss—75 min @ 60 degrees, 60 min @ 20 degrees) in order to achieve a “Class A” finish on parts of 0% stretch or greater. These improvements enable the multilayer structures to be used by auto manufacturers and others as vehicle panels, bumper fascias, and/or rocker panels, among other uses.

In the example multilayer structures, a combination of several design elements produces the desired balance of excellent properties. An efficient, reduced-layer structure is employed that does not require an adhesive to bond the layers of the structure together. Like chemistries in the bonded layers allow the layers to bond to each other at the layer interface. Coextrusion technology promotes the bonding of layers and provides a smooth finish. Appropriate selection of polyolefins, additives, and pigmentation for each layer also contributes to the balance of properties. In addition, further processing techniques and additives are also used to optimize the optical and durability characteristics of the multilayer structures.

The clear layer, the color layer, and the backing layer of the example multilayer structures are permanently bonded by using like chemistries. Like chemistries in this application means belonging to same family of olefinic hydrocarbons. Each layer is coextruded from like olefinic material. This results in permanent bonding at each layer interface between the like olefinic materials. By eliminating the adhesive at the interface, the durability of the multilayer structures is improved. As mentioned above, the bond at each layer interface is permanent which results in a product that does not delaminate when exposed to heat, sunlight, extreme cold, humidity, water immersion, chemicals, and grovel impact. In contrast, if there were a coextruded adhesive layer interspersed between the layers without a structure that inherently has a “weak link” that could fail and result in delamination. In addition, the example multilayer structures have a ΔL of 2 or less, according to the GM9302P stress whitening resistance standard. An added benefit to the adhesive-layer-free structures is that the sheet product becomes less complex to manufacture.

The clear layer, the color layer, and the backing layer of the multilayer structures are primarily composed of an olefinic material. For example, polypropylene/ethylene copolymer may be used as the olefinic material for each layer.

FIGS. 1 and 2 both show example three-layer coextruded olefinic sheet structures.

FIG. 1 illustrates an example sheet structure 1 that can be used to make both thick and thin sheets. A multilayer structure as thin as 3 mils to as thick as 540 mils may be created according to this sheet structure 1. Multilayer structures of intermediate thicknesses may also be created, for example, 8.5 mils to 540 mil, 20 mils to 450 mil, 50 mils to 300 mil, or 150 mils to 250 mils. Relatively thick sheets may be used in applications where it is desired to thermoform a...
part directly from the sheet itself, or thinner sheets may be desirable to thermoform a shell that is suitable to be backfilled via injection molding to achieve the final thickness. Other processes that can be used with this type of sheet/film structure include compression molding and simultaneous in-mold thermoforming/injection backfill processes.

[0032] The clear layer 3 is 1 to 20 mils in thickness, for example, 2.5 to 20 mils, 3.0 to 15 mils, or 5.0 to 10 mils. It is primarily made of a polyolefin, such as a polypropylene/ethylene copolymer. An example propylene/ethylene copolymer for use in the clear layer 3 has a monomer ratio of 0.5-12% ethylene, such as 1-7%, 2-10%, or 3-7% ethylene. The example propylene/ethylene copolymer may be isotactic, such as greater than 70%, greater than 80%, or greater than 90% isotactic and have a random microstructure. The crystallinity of the example propylene/ethylene copolymer may be greater than 60%, such as greater than 70%, or greater than 90%. The example copolymer may have a Rockwell hardness of R80 or greater, such as R100 or greater, or R105 or greater. The melting point of the example copolymer is greater than 155° C., such as 156° C. to 300° C., 156° C. to 170° C., or 156° C. to 165° C. The example propylene/ethylene copolymer may have a flexural modulus of greater than 1850 MPa, such as 1900 to 2500 MPa, or 2000 to 2100 MPa. A blend of polyolefins may also be employed in the clear layer 3, for example, a blend of majority isotactic polyolefin and a minority of syndiotactic polyolefin or atactic polyolefin. Example isotactic polyolefins include those sold under the following trade names: INSPIRE 404 polypropylene (Dow), CLYRELL RC514 L (LyondellBasell), INSPIRE 117 polypropylene (Dow), SR257M (LyondellBasell), 6289MZ (Total), 6D83K (Dow), and PRISMA 3410 polypropylene (Braskem). Example syndiotactic polyolefins include those sold under the following trade names: Polypropylene 1251 (Total Petrochemicals) (2 MI, 6.9% Haze, 130° C. melt point) and Polypropylene 1471 (Total Petrochemicals) (4 MI, 4.8% Haze, 130° C. melt point). Another example polyolefin is NOITO from Mitsui Chemicals (Haze 4-7%, melt point 100° C.-135° C.). An example atactic polypropylene is FF018F from Sunoco (1.8 Melt Flow g/10 min at 230° C with 2.16 kg weight). A metalloocene-based homopolymer or copolymer of propylene may also be used.

Additives, such as UV stabilizer, e.g. CYASORB THT 7001 (Cytce Industries), Antioxidants, e.g. HOSTANOX PEP-Q (Clariant), and slip agents, e.g. CRODAMIDE ER (Croda), may also be added to the polyolefin.

[0033] The clear layer 3 should have a light transmittance of 85-100%, such as 88-100%, or 90-100%. It should also have a haze of no greater than 10%, such as no greater than 8%, no greater than 5%, no greater than 2.5%, or no greater than 1.0%. For certain applications it may be desirable to include a small amount of pigment or special effects in the clear layer 3.

[0034] The color layer 5 is 1 to 20 mils in thickness, for example, 3.0 to 20 mils, 4.0 to 15 mils, or 5.0 to 10 mils. The color layer 5 is primarily made of a polyolefin, such as propylene/ethylene copolymer. Preferably, the clear layer 3 and the color layer 5 will have like chemistries, that is, they will be of the same type of polyolefin and similar enough in properties that when coextruded as layers they will become chemically bonded at the clear/color layer interface 4. As such, an example propylene/ethylene copolymer for use in the color layer 5 has a monomer ratio of 0.5-12% ethylene, such as 2-10%, or 3-7% ethylene. The example propylene/ethylene copolymer may also be isotactic, such as 60-90%, or 70-85% isotactic and have a random microstructure. The crystallinity of the example propylene/ethylene copolymer may be greater than 60%, such as greater than 70%, or greater than 90%. The example copolymer may have a Rockwell hardness of greater than 100, such as greater than 105, or greater. The melting point of the example copolymer is greater than 155° C., such as 156° C. to 300° C., 156° C. to 170° C., or 156° C. to 165° C. The example propylene/ethylene copolymer may have a flexural modulus of greater than 1000 MPa, such as greater than 1850 MPa, for example as 1900 to 2500 MPa, or 2000 to 2100 MPa. A blend of polyolefins may also be employed in the color layer 5, for example, a blend of majority isotactic polyolefin and a minority of syndiotactic or atactic polyolefin. Example isotactic polyolefins include those sold under the following trade names: INSPIRE 404 polypropylene (Dow), CLYRELL RC514 L (LyondellBasell), INSPIRE 117 polypropylene (Dow), SR257M (LyondellBasell), 6289MZ (Total), 6D83K (Dow), and PRISMA 3410 polypropylene (Braskem). Example syndiotactic polyolefins include those sold under the following trade names: Polypropylene 1251 (Total Petrochemicals) (2 MI, 6.9% Haze, 130° C. melt point) and Polypropylene 1471 (Total Petrochemicals) (4 MI, 4.8% Haze, 130° C. melt point). Another example polyolefin is NOITO from Mitsui Chemicals (Haze 4-7%, melt point 100° C.-135° C.). An example atactic polypropylene is FF018F from Sunoco (1.8 Melt Flow g/10 min at 230° C with 2.16 kg weight). A metalloocene-based homopolymer or copolymer of propylene may also be used.

Additives, such as UV stabilizer, e.g. CYASORB THT 7001, Antioxidants, e.g. HOSTANOX PEP-Q (Clariant), and slip agents, e.g. CRODAMIDE ER (Croda), may also be added to the polyolefin.
ethylene/acrylic acid copolymer resins, ethyl methyl acrylate copolymer, and propylene/ethylene copolymers, such as TC-110 EMA (Exxon Mobil), AC540 wax (Honeywell), INSPIRE 404, and PRIMACOR 1410 (Dow).

[0037] Many factors can affect the choice of a carrier resin for use in a pigment pre-dispersion. Specifically at issue is the compatibility of a carrier resin with the polyolefin into which it will be blended. The refractive index of a carrier resin compatible with a polyolefin may be very close to the refractive index of the polyolefin, e.g., within 0.005 of the refractive index of the polyolefin (sodium-D filter at 20° C.). Typically, it is advantageous to select a carrier resin with a melt flow rate that is greater than or equal to the melt flow rate of the polyolefin when measured at the same temperature and load as the polyolefin. Melt flow rate may be measured, for example, according to ASTM D1238. Furthermore, a carrier resin should also be compatible and miscible with the polyolefin into which it will be blended. The appearance properties of the final product improve as the compatibility between the carrier resin and the polyolefin increases.

[0038] The particle size of the pigment should generally be minimized to optimize dispersion of the pigment in the polyolefin. As different pigments are unique compounds having widely varying sizes and properties, there is no single size that can be suggested as optimal. Generally, the quality of the dispersion achieved upon mixing a pigment pre-dispersion with a polyolefin will be improved with smaller pigment particles. Typically, pigment particle sizes in a pigment pre-dispersion of less than or equal to about 25 micrometers are capable of being well dispersed. Thus, the pigments used in the multilayer structure should have a particle size of less than or equal to about 25 micrometers, such as 25 micrometers, 15 micrometers, or 10 micrometers.

[0039] The pre-dispersion may be made as described in the co-owned U.S. application Ser. No. 11/592,883, titled, “Ionomer Pigmentation,” which is hereby incorporated by reference.

[0040] The pigment pre-dispersion may be added to the polyolefin as the polyolefin is processed in an apparatus such as an extruder. The pigment pre-dispersion can be pre-mixed with polyolefin pellets or powder prior to the polyolefin being added to the processing apparatus. Additionally, the pigment pre-dispersion can be let down into an intermediate carrier and this intermediate mixture can then be blended with the polyolefin. If let down into an intermediate carrier, the pigment pre-dispersion level can be, for example, about 25% to about 50% of the intermediate mixture. The intermediate mixture may then be mixed with a polyolefin at a level, for example, of about 2% to about 10% of the polyolefin.

[0041] The example backing layer 7 of FIG. 1 is to 500 mils in thickness, for example 3 to 500 mils, 10 to 300 mils, or 100 to 200 mils. The example backing layer 7 is primarily composed of a thermoplastic polyolefin, such as polypropylene/ethylene copolymer. The thermoplastic polyolefin is preferably of a random microstructure, and may be exclusive of block copolymers. Example random isotactic polyolefins include high-impact copolymers, for example those having 7 to 30% ethylene homo or copolymer content, such as Pro-Fax 7823 PP (LyondellBasell). Other example random isotactic polyolefins include those sold under the following trade names: INSPIRE 404 polypropylene (Dow), CLEYRELL RC514 L (LyondellBasell), INSPIRE 117 polypropylene (Dow), SR257M (LyondellBasell), 6289MIZ (Total), 6D83K (Dow), and PRISMA 3410 polypropylene (Braskem).

Example random syndiotactic polyolefins include those sold under the following trade names: Total Polypropylene 1251 (2 ML, 6.9% Haze, 130° C. melt point) and Total Polypropylene 1471 (4 ML, 4.8% Haze, 130° C. melt point). Another example polyolefin is NOTIO from Mitsui Chemicals (Haze 4-7, melt point 100° C.-135° C.). A metalloene-based homopolymer or copolymer of propylene may also be used.

[0042] The example backing layer also may contain an elastomer, such as, for example, ethylene alpha-olefin copolymers where the alpha-olefin portion can contain 3-20 carbon atoms. Examples of such materials include but are not limited to ethylene octene copolymer, ethylene butene copolymer, ethylene hexene copolymer, ethylene heptene copolymer. These type of alpha olefins represent the following PE families: LDPE, VLDPE, ULDPE. Additional elastomers include, but are not limited to, ethylene propylene copolymer, ethylene propylene diene terpolymer, ethylene alpha-olefin diene terpolymer, styrene block copolymer including styrene-butadiene-styrene and styrene-ethylene-propylene-styrene. The very low density polyethylene rubber may have a density of 0.75 to 0.95 g/cm³, such as about 0.88 g/cm³. Preferably, the backing layer 7 and the color layer 5 will have like chemistries, e.g. olefinic.

[0043] A filler, such as talc may constitute 0-40%, such as 20-30%, or 22-28% of the example backing layer. Furthermore, various other additives such as process aids, dispersing aids, UV stabilizers, antioxidants, and nucleators may also be utilized in the backing layer in small amounts, such as 0.001% to 10%, 0.01% to 5.0%, or 0.1 to 3.5%. Examples of such additives include TR016 wax (Struktol) (process aid & dispersing aid), CHIMASSORB 119 (Ciba) (UV stabilizer), SYNPRO 128 calcium stearate (Ferro) (process aid & dispersing aid), IRGANOX 3114 (Ciba) (antioxidant), HOSTANOX PEP-Q (Clariant) (antioxidant), VANOX ZMTI (R.T. Vanderbilt) (antioxidant), and HPN 20E (Milliken) (nucleator). The backing layer 7 may also include pigment and/or effect materials in some applications.

[0044] FIG. 2 shows an example sheet structure that is similar to example structure 1 shown in FIG. 1, however, the sheet structure of FIG. 2 is a multilayer tape structure 10. Although the example multilayer tape structure 10 itself is coextruded, the tape structure 10 may be applied to a substrate during a laminating process. In this case, the multilayer tape structure 10 would be laminated to another substrate prior to, during, or after the forming of an article. In order to achieve good adhesion after laminating, the backing layer 17 in this structure may contain an additional adhesive component that will have a lower melting point compared to the other existing olefinic ingredients. The laminating may be by melt laminating or by an additional laminated adhesive layer. Examples of laminated adhesive layer include pressure-sensitive tape, roll-applied adhesive, and two-sided tape. It is also possible to omit the adhesive component if the backing layer 17 will adhere to a desired substrate sufficiently without the adhesive. As adhesive components are added to the backing layer 17, the addition of a release liner, such as the mask layers described in the commonly owned WIPO Publication WO 2006/014281, titled “Co-extruded Mask Layer,” which is
hereby incorporated by reference, may be helpful in order to prevent the roll from sticking to itself. A multilayer tape structure 10 as thin as 3 mils to as thick as 25.0 mils, such as 5.0 mils to 25.0 mils may be created. Multilayer tape structures 10 of intermediate thicknesses may also be created, for example, 10.0 to 20.0 mil, or 12.0 to 18.0 mils.

[0045] The example clear layer 13 of FIG. 2 is 1 to 10.0 mils in thickness, for example 2.0 to 10.0 mils, 3.0 to 8.0 mils, or 4.0 to 6.0 mils. Otherwise, the example clear layer 13 of the tape structure 10 is essentially the same as the example clear layer 3 of FIG. 1, described above.

[0046] The example color layer 15 of FIG. 2 is 1 to 10.0 mils in thickness, for example 2.0 to 10.0 mils, 3.0 to 8.0 mils, or 4.0 to 6.0 mils. Otherwise, the example color layer 15 of the tape structure 10 is essentially the same as the example color layer 5 of FIG. 1, described above.

[0047] The example backing layer 17 of FIG. 2 is 1 to 5.0 mils in thickness, for example 1.5 to 4.5 mils, or 2.0 to 4.0 mils. The example backing layer 17 of the tape structure 10 is essentially the same as the example backing layer 7 of FIG. 1, described above, except it contains an adhesive as part of the polymeric blend. The adhesive component may be used in practically any weight percentage in the backing structure, for example, 60 to 100%, 20-60%, 30-50%, or 35-45%. The adhesive component may be olefin polymers, or copolymers such as polypropylene/ethylene copolymers with a high level of ethylene monomer content, and a low melting point, for example, ethylene alpha-olefin copolymers where the alpha-olefin portion can contain 3-20 carbon atoms. Examples of such materials include, but are not limited to, ethylene octene copolymer, ethylene butene copolymer, ethylene hexene copolymer, ethylene heptene copolymer. These type of alpha olefins represent the following polyethylene families: LDPE, VLDPE, ULDPE. Additional elastomers include, but are not limited to, ethylene propylene copolymers, ethylene propylene diene terpolymer, ethylene alpha-olefin diene terpolymer, styrenic block copolymers including styrene-butadiene-styrene, styrene-ethylene-propylene-styrene and the like, a particular example of ethylene-propylene elastomer is VERSIFY 2300 (Dow). The adhesive component could also include, but is not limited to, other olefinic or non-olefinic materials such as ethylene-acrylate-GMA terpolymers, ethylene butyl (or methyl or hexyl)acrylate copolymers, EVA, ester and other bis adhesives, ethylene acid copolymers, and maleic anhydride grafted copolymers.

[0048] Varying the type of adhesive component in polymeric blend allows the multilayer structure to be laminated to different substrates, including, but not limited to: polypropylene, TPO, polyethylene, a polymeric blend or alloy containing polypropylene or polyethylene in it, ABS, ABS containing blends or alloys, acrylic, polycarbonate, polycarbonate containing blends or alloys, metal, glass, wood, ceramic, thermoset plastics, and composites. The adhesive layer 17 may be provided with pigment and/or effect material.

[0049] FIGS. 3 and 4 depict the four-layer structure 20, 30 counterparts of the three-layer structures 1, 10 of FIGS. 1 and 2. As such, the four-layer structures 20, 30 are used in substantially the same manner as described for FIGS. 1 and 2, respectively, and are similar in composition, except as noted below. The four-layer structures 20, 30 in FIGS. 3 and 4 each have a clear layer 23, 33, a color layer 25, 35, and a backing layer 27, 37. The structures of FIGS. 3 and 4, however, differ from the structure of FIGS. 1 and 2 in that each has a translucent color layer 29, 39 between the clear 23, 33 and color layers 25, 35. The translucent color layer 29, 39 is typically made of a polyolefin, such as polypropylene/ethylene copolymer. An example polypropylene/ethylene copolymer for use in the translucent color layer 29, 39 has a monomer ratio of 0.5-12% ethylene, such as 2-10%, or 3-7% ethylene. The example polypropylene/ethylene copolymer may also be isotactic, such as 60-90%, or 70-85% isotactic and have a random microstructure. The crystallinity of the example polypropylene/ethylene copolymer may be greater than 60%, such as greater than 70%, or greater than 90%. The example copolymer may have a Rockwell hardness of greater than R100, such as R105 or greater. The melting point of the example copolymer is greater than 155° C., such as 156° C. to 300° C., 156° C. to 170° C., or 156° C. to 165° C. The example polypropylene/ethylene copolymer may have a flexural modulus of greater than 1000 MPa, such as greater than 1850 MPa, 1900 to 2500 MPa, or 2000 to 2100 MPa. A blend of polyolefin may also be employed in the translucent color layer 29, 39; for example, a blend of majority isotactic polyolefin and a minority of syndiotactic or atactic polyolefin. Example random isotactic polyolefins include those sold under the following trade names: INSPIRE 404 polypropylene (Dow), CLYRELLI RC514 L (LyondellBasell), INSPIRE 117 polypropylene (Dow), SR257M (LyondellBasell), 6289MZ (Total), 6083K(Dow), and PKISMA 3410 polypropylene (Braskem). Example random syndiotactic polyolefins include those sold under the following trade names: Polypropylene 1251 (Total), MI 6.9% Haze, 130 C melt point) and Polypropylene 1471 (Total), MI 4.8% Haze, 130 C melt point). Another example polyolefin is NOTIO from Mitsui Chemicals (Haze 4-7%, Melt point 100 C-135 C). An example atactic polypropylene is FF018F from Sunoco (1.8 Melt Flow g/10 min at 230 C with 2.16 kg weight). A metalloocene-based homopolymer or copolymer of propylene may also be used. This translucent color layer may be used to create various special effects such as metal flake, pearlescent, fluorescent, phosphorescent, and mirrored glass and/or improve the depth of color for the underlying opaque color layer. The polyolefin that makes up the translucent color layer may be of the same chemistry as the clear 23, 33 and color layers 25, 35 to promote adhesive-free bonding at the layer interfaces 24, 34, 26, 36, 28, 38.

[0050] The translucent color layer 29, 39 does not require that only translucent pigments are used therein. In this case, “translucent” is meant to refer to the percent loading of color used in the translucent layer 29, 39. All pigments used in the color layer 25, 35 can also be used in the translucent layer 29, 39, but are used in lower amounts (relative to the underlying essentially opaque color layer 25, 35) in order to maintain some level of the base resin clarity.

[0051] Regarding the example four-layer structure of FIG. 3, the structure 20 may be as thin as 4.0 mils to as thick as 560 mil, such as 11 mils to 560 mils. Multilayer structures of intermediate thicknesses may also be created, for example, 20 mils to 450 mil, 50 mils to 300 mil, or 150 mils to 250 mils. Relatively thick sheets may be used in applications where it is desired to thermoform a part directly from the sheet itself, or thinner sheets may be desirable to thermoform a sheet that is suitable to be backfilled via injection molding to achieve the final thickness. The translucent layer 29 may be 1 to 20 mils in thickness, such as 2.5 to 20 mils, 5.0 to 15 mils, or 7.0 to 12.0 mils.

[0052] Regarding the example four-layer tape structure 30 of FIG. 4, the structure 30 may be as thin as 4 mils to as thick
as 35.0 mils. Multilayer structures of intermediate thicknesses may also be created, for example, 7 mils to 35 mils, 8.0 mils to 30.0 mils, 10 mils to 20.0 mils, or 12.0 mils to 18.0 mils. The translucent layer 39 is 1 to 10 mils in thickness, for example 2.0 to 10 mils, 3.0 to 8.0 mils, or 4.0 to 6.0 mils. As with the tape structure 10 of FIG. 2, the four-layer tape structure 30 would be laminated to another substrate prior to or during the forming of an article. In order to achieve good adhesion after lamination, the backing layer 37 in this structure 30 may contain an additional adhesive component that will have a lower melting point compared to the other existing olefinic ingredients.

FIG. 5 depicts an example two layer structure 40 that includes a clear polyolefin layer 43 over a colored backing layer 47. The clear layer 43 has the same characteristics as the example clear layer 3 of FIG. 1, except that it is coextruded with and permanently bonded directly to the colored backing layer 47 at a layer interface 44. The colored backing layer 47 is the same as the backing layer 7 of FIG. 1, except it is provided with pigment and/or effect materials. Carrier resins may also be used to incorporate the pigment and/or effect materials into the colored backing layer 47. Example carrier resins, pigments, and effect materials may be selected from those listed above in the discussion of the color layer 7 of FIG. 1. The carrier resin, however, should be carefully selected to be compatible with the majority component polymer of the colored backing layer 47. That is, the carrier resin should have similar melt flow rate, refractive index, and be miscible in the majority component polymer. The pigment and/or effect materials may be incorporated into the colored backing layer 47 in an amount of 0.0001% to 30%, for example, 0.01% to 20%, 1.0% to 10%, or 0.0001% to 0.01%.

In an alternative example, the clear polyolefin layer 43 may be replaced with a colored layer as described above having pigments and/or effect materials.

Some examples of different formed products in which this two layer structure is used include: RV exterior wall panels, heavy truck and RV air cones, fenders or body panels for agricultural vehicles, and truck fenders.

The structures 1, 10, 20, 30, 40 shown in FIGS. 1-15 may be used with or without a mask layer, such as a protective mask, forming mask, or combination of protective/forming mask, for example, the mask layers described in WIPO Publication WO 2006/014281. The mask layer could be laminated onto or coextruded with the structures illustrated in FIGS. 1-4.

In order to improve or modify the performance of an individual layer or the structure as a whole, each layer shown in FIGS. 1-5 may contain additive ingredients from the following list in any combination. The list is as follows:

- Antioxidants
- UV stabilizers
- Waxes as Property Modifiers
- Lubricants
- Antistats
- Process Aids
- Dispersion Aids
- Flame Retardants
- Smoke Suppressors
- Foaming Agents
- Colorants (pigments, dyes, all special effect additives)
- Antimicrobials
- Antifog Agents
- Clarifying Agents
- Nucleating Agents
- Acid Scavengers
- Low Temperature Impact Modifiers
- Fillers (inorganic & wood)
- Gloss Agents
- Gloss Reducing Agents
- Scratch Mar Additives
- Stress Whitening Modifiers
- Surfactants
- Silicone, Siloxanes, Organo-Modified Siloxanes, or Silicone Graft Copolymers (e.g., Evonik Tegomer which may contain alkyl, epoxide, hydroxy, amino, carboxyl, and/or acrylate organic substituents)
- Functional grafted polypropylene modifiers (e.g., acid grafted polypropylene, maleic anhydride grafted polypropylene, and ionic functional grafted polypropylene)
- In particular, one or more clarifying agents may be added to polymers that are already clarified by various methods or the clarifying agents may be added to non-clarified polymers. Stress whitening agents may be added to improve gloss resistance.
- The aforementioned additives may also be utilized in each layer in relatively small amounts, such as 0.001% to 10%, 0.0001% to 0.001%, 0.0001% to 1%, 1% to 5%, and 5% to 10%, and for fillers, fibers, retardants, functional grafted polypropylene modifiers, and smoke suppressor additives, up to 50%, such as up to 40%, or 10-30%.
- The example multilayer structures are not substantially oriented either axially or biaxially by stretching. By not substantially oriented, it is meant that the polymers are not purposely stretched to induce orientation that would affect the physically properties of the material. The multilayer structure may have a flexural modulus of 1000 MPa or greater, such as 1500 to 7000 MPa, 1700 to 3000 MPa, 3000 to 6000 MPa, or 2500 to 5500 MPa.
- The example multilayer structures display excellent optical qualities. The example multilayer structures have a distinguished appearance (DOI) of at least 70, such as 75 or greater, 85 or greater, 90 or greater, and 95 or greater. Furthermore, the multilayer structures have a gloss of 75 or greater at a 60° angle, such as 85 or greater, 90 or greater, and 95 or greater. The multilayer structures also have a gloss of 60 or greater at a 20° angle, such as 70 or greater, 80 or greater, and 85 or greater.
- The example multilayer structures also possess excellent durability and mar resistance, exemplified by several tests required by auto manufacturers (see Table 2 below). For instance, the multilayer structures will pass a five-finger scratch and mar resistance test defined by GMW 3943. The structures also exhibit no gauze imprint at 70°C. minimum under a 500 g load applied over a 40 mm diameter for two hours. Furthermore, the multilayer structures show no signs of gloss loss, staining, or surface swelling at 70°C. with exposure to methanol, motor oil, lithium grease, and egg albumin.
- The multilayer structures can be thermoformed into formed products, such as, for example, an automobile bumper or other exterior trim panel. Such a part can be made from a multilayer structure that is thick enough to provide sufficient
structural stability to be used alone. Furthermore, the multilayer structure can be injection molded from behind with additional polymer material to provide support to the multilayer structure. The pigmented polyolefins with their minimized pigment particle size are able to maintain color uniformity and opacity in high draw regions created during thermoforming.

[0092] The layers of the multilayer structures are coextruded and include those layers shown in FIGS. 1-5 and described herein. Additional coextruded layers can include, but are not limited to, polymers such as polypropylene, polypropylene copolymer, polyethylene, polyethylene copolymer, polystyrene, ABS, styrene terpolymer, and polyurethane.

[0093] The polyolefin layers and multilayer films as described herein may be exposed to various structure modifying treatments to further enhance aspects of physical performance. These products may, for example, be subjected to corona discharge treatment, ozone treatment, low temperature plasma treatment which incorporates either oxygen or nitrogen gas, glow plasma treatment, reverse sputtering treatment, oxidation treatment using chemicals, UV curing, e-beam irradiation, gamma beam irradiation, x-rays and the like. Such treatments may, among other things, cross-link the polymer structure of the polyethylene layers and the multilayer films. As an example, the multilayer films could be exposed to gamma beam, electron beam, or x-ray radiation at dosing levels of between 0.1 and 50 meg-rads. These treatments can improve the surface hardness, scratch resistance, mar resistance, chemical resistance and/or oxygen/air barrier efficiency of the multilayer structures while maintaining low haze, high gloss, transparency, and distinction of image. Additionally, weathering performance can be maintained or enhanced and material memory can be maintained. These treatments may also improve the adhesion properties of the tape structures 10, 30 to various substrates.

[0094] The improvements realized in the multilayer structures described herein in both design and durability performance allow them to be used in a variety of markets which require a “Class A” finish, such as:

- Motor Vehicles
- Light/Consumer Automotive
- Heavy Trucks
- RV
- Agriculture
- ATV’s
- Motorcycles
- Snowmobiles
- Jet Skis
- Marine
- Farm Machinery
- Signage
- Appliances
- Consumer Electronics.

[0099] Example articles the multilayer sheets could be formed into include:

- Bumper fascias
- Rocker panels
- Cell-Phone covers
- Computer housings
- Motor covers
- Fenders
- Heavy truck fairings

[0107] Running boards
[0118] RV wall panels
[0119] Appliance housings.

[0120] FIGS. 6 and 7 show example cross-sections of vehicle body panels constructed of the multilayer structure of the present disclosure. In FIG. 6, the multilayer film has a clear layer 53, a color layer 55, and a backing layer 57, and the multilayer film is laminated onto a rigid substrate 59. In FIG. 7, the multilayer structure 60 has a clear layer 63, a color layer 65, and a backing layer 67. The multilayer structure 60 is thick and rigid enough to be a vehicle body panel without an additional rigid substrate. The translucent layer discussed above may also be used in combination with or in place of the colored layer on vehicle body panels. Also, the colored backing layer may be used in place of the backing layer and with only a clear layer on top in vehicle body panels.

[0121] In an additional example, the structures 1, 10, 20, 30 in FIGS. 1-4 and structures 40, 50, and 60 in FIGS. 5-7 utilize regrind as an additional layer adjacent to the backing layer or as a component of the backing layer. As explained below, the example backing layer provides significant and unexpected advantages over backing layers that mix regrind and virgin polymer in one layer.

[0122] Thermoforming TPO sheet is typically difficult due to the material’s inherently weak melt strength. Inadequate melt strength during heating results in excessive “sheet sag,” which in turn can cause various defects during forming of the part. Defects include excessive “webbing” in tight corners, surface “tears” in areas of high stretch, and non-uniform wall thickness. Significant variation in wall thickness throughout a part can cause excessive warping and/or reduced physical properties.

[0123] During sheet production, the melt strength of TPO is further compromised due to the addition of regrind which causes an increase in the severity of the above mentioned defects. The addition of regrind is performed in order to control costs by minimizing waste and reducing the overall raw material cost of the final part. Although the economics improve with the addition of regrind, the melt strength, sag resistance, and other properties of the sheet are significantly reduced.

[0124] It was unexpectedly discovered that the reduction of melt strength and sag resistance due to the addition of regrind can be significantly reduced by changing the structure of the TPO sheet.

[0125] As shown in FIGS. 8 and 9 the thermoplastic polyolefin backing layer has multiple layers as components. There is a separate layer of virgin thermoplastic polyolefin material (Layer A) and a separate layer of regrind thermoplastic polyolefin material (Layer B). FIG. 8 shows an example sheet structure 70 with an ABA multilayered backing layer structure and FIG. 9 shows an example sheet structure 80 with an AB backing layer structure 80.

[0126] The example sheet structure 70 in FIG. 8 has an ABA backing layer made up of a first A layer 71, a second A layer 73, and a B layer 72 disposed between the first and second A layers 71, 73. First A layer 71 is adjacent to one side of the B layer 72 and the second A layer 73 is adjacent to the opposite side of the B layer 72. The ABA backing layer is combined with an upper section 75 that comprises a clear layer and optionally a translucent and/or color layer, as those layers are described above and are depicted in structures 1, 10, 20, 30, 40, 50, 60 shown in FIGS. 1-7. The first A layer 71 is adjacent to the upper section 75.
The polymeric base for first A layer 71 and the second A layer 73 of the example sheet structure 70 of FIG. 8 is 100% virgin thermoplastic polyolefin. Virgin thermoplastic means a thermoplastic that has not been reprocessed and/or previously used in another product. The thermoplastic polyolefin may be selected from the thermoplastic polyolefins described above for the backing layer 7 of FIG. 1. Additives may also be included as described herein for the backing layer.

The first A layer 71 is, for example, 5% to 45% of the total thickness of the ABA backing layer, such as 10 to 35%, 5 to 20%, or 25 to 45% of the total backing layer thickness. The entire example ABA backing layer structure is 3.0 to 500 mils, so the first A layer 71 may be 0.15 mils to 225 mils, such as 5 to 10 mils, 10-80 mils, or 20 to 150 mils. The second A layer 73 has the same range of thicknesses, however, its thickness is independently selected from the thickness of the first A layer 71.

The polymeric base for the B layer 72 is 100% regrind polyolefin material (meaning a polyolefin that has been previously used and/or reprocessed). If desired for certain applications, the B layer 72 may also be a mixture of regrind and virgin polymeric material. For example, the polymeric base for the B layer may comprise 10 to 99% regrind, such as 10 to 49%, 51 to 99%, or 25 to 75% regrind material, whereas the remainder of the polymeric base is virgin polyolefin material.

The regrind material is produced from sources such as trim scrap, products that do not meet quality control or specifications, or various other sources that would otherwise be waste materials. The original polymer used in the regrind material may, for example, be selected from the thermoplastic polyolefins described above for the backing layer 7 of FIG. 1. The original material used for the regrind material may also include additives as described herein for the backing layer. In one example, the regrind material is miscellaneous polypropylene homopolymers and copolymers with talc filler, colorants, and stabilizers.

The B layer 72 is, for example, 10-90% of the total thickness of the ABA backing layer, such as 10 to 49%, 51 to 90%, or 20 to 60% of the total backing layer thickness. The entire example ABA backing layer structure is 3.0 to 500 mils, so the B layer 72 may be 0.3 mils to 450 mils, such as 5 to 20 mils, 20-120 mils, or 40 to 300 mils.

In an alternate example, the first A layer 71 and optionally the second A layer 73 also include a pigment to supply the layer with a desired color. This colored backing layer is particularly suitable for use with an upper section 75 that includes only a clear layer. This can be considered a two-layer structure as described above and shown in FIG. 5, although the backing layer is divided into three separate layers.

The example sheet structure 80 shown in FIG. 9 has an AB backing layer made up of a A layer 81 and a B layer 83. The AB backing layer is combined with an upper section 85 that comprises a clear layer and optionally a translucent and/or color layer, as those layers are described above, and are depicted in structures 1, 10, 20, 30, 40, 50, 60 shown in FIGS. 1-7. The A layer 81 is adjacent to the B layer 83 on one side and is adjacent to the upper section 85 on the other side.

The A layer 81 and B layer 83 are composed of the same materials as disclosed for the ABA layer example shown in FIG. 8. Coloring may also be added to the A layer 81 as described above, particularly when the AB backing layer is used in conjunction with just a clear layer in the upper section 85.

The A layer 81 is, for example, 10-90% of the total thickness of the AB backing layer, such as 20-60%, 10 to 49%, or 51-90% of the total backing layer thickness. The entire example AB backing layer structure is 3.0 to 500 mils, so the A layer 81 may be 0.3 mils to 450 mils, such as 5 to 20 mils, 20-120 mils, or 40 to 300 mils.

The B layer 83 is, for example, 10-90% of the total thickness of the AB backing layer, such as 20-60%, 10 to 49%, or 51-90% of the total backing layer thickness. The entire example AB backing layer structure is 3.0 to 500 mils, so the B layer 83 may be 0.3 mils to 450 mils, such as 5 to 20 mils, 20-120 mils, or 40 to 300 mils.

The ABA and AB backing layers may be formed by coextrusion. The AB and ABAB backing layers can be coextruded with the upper section that includes a clear layer and optionally a color and/or translucent layer. In another example, further thermoplastic polyolefin layers may be added. For example, the backing layer may be structured as an ABABA layered structure.

The example sheet structure 70, 80 may also be used in conjunction with upper sections 75, 85 that comprise chemistries other than the polyolefin layers described above. For example, the upper sections 75, 85 may comprise polymeric components such as acrylic, ionomer, fluorocrylic, fluoropolymers, cast-fluoroacrylic, polyethylene, polypropylene, polycarbonate, acrylic styrene acrylonitrite (ASA), or mixtures thereof. These alternative upper section chemistries could also be extruded or laminated onto the ABAB backing layer. In certain embodiments the upper sections 75, 85 could even be paint.

Examples 1-6

Example 1 is a prospective, generic example, and is set forth to demonstrate an example range of different ingredients that may be added to each layer of the multilayer structure. The optimal concentration and presence of these ingredients will vary based on the color and type of pigment desired. Other application specific parameters may also affect the composition of the multilayer structure.

Prospective Generic Example 1

**Clear Layer**

**70-100% Inspire 404 Clear PP**

*Inspire 404 PP is a highly isotactic, highly crystalline polypropylene-ethylene copolymer containing about 1.7% ethylene monomers, and having a flexural modulus of 2070 MPa (84 inch bar), 156°C. melting point, 95.6 J/g enthalpy of melting, Rockwell C hardness*

**0.3-0.7% UV Stabilizer e.g. Cysorb THT 7001**

**0-10.0% Slip Agent e.g. Crodamide ER (an effective amount that does not impact haze detrimentally)**

**0-3% Clarifier, e.g. NX20**

**0-1.0% Antioxidant, e.g. Hostanox Pep-Q**

**0-1.0% Second Antioxidant, e.g. Iriganol 3114**

**Translucent Color Layer (this layer is Optional & the Formula Varies with Color & Special Effects)**

**60.000-99.000% Polypropylene, e.g. Inspire 404 PP**

**0-1.0% Antioxidant, e.g. Hostanox Pep-Q**

**0-3% Clarifier, e.g. NX20**

**>0-10.000% pigment &/or special effects**
Example 2
Three-Layer Structure

[0181] Clear Layer
[0182] 96.1% Inspire 404 Clear PP*
[0183] 00.3% Cytosorb THT 7001 (UV stabilizer)
[0184] 00.3% Crodamide ER (slip agent)
[0185] 3% NX20 (Milliken Chemical) (clarifier)
[0186] 0.300% Hostanox Pep-Q (antioxidant)
[0187] Color Layer
[0188] 90.280% Inspire 404 PP*
[0189] 3% NX20 (clarifier)
[0190] 4.000% AC540 Wax (organic pigment carrier)
[0191] 0.560% TC-110 EMA (inorganic pigment carrier)
[0192] 0.040% Red Iron Oxide 116M (Nubiola) (pigment)
[0193] 0.720% Perylene Red 179 229-8436 (Sun Chemical) (pigment)
[0194] 1.000% DPP Red 254 Cromophil 2030 (Ciba) (pigment)
[0195] 0.300% Cytosorb THT 7001 (UV stabilizer)
[0196] 0.300% Hostanox Pep-Q (antioxidant)
[0197] Backing Layer
[0198] 61.944% Pro-Fax 7823 PP**
[0199] 28.690% DFD 1088 NT VLDPE (Dow Chemical)
[0200] 18.890% Premium HTP Ultra 5 L (talc filler) (Fibracel)
[0201] 1.186% TR016 Wax (process aid & dispersing aid)
[0202] 0.550% Chimassorb 119 (UV stabilizer)
[0203] 0.048% Synpro 12B Calcium Stearate (process aid & dispersing aid)
[0204] 0.288% Irganox 3114 (antioxidant)
[0205] 0.288% Hostanox Pep-Q (antioxidant)
[0206] 0.288% Vanox ZMTI (antioxidant)
[0207] 0.120% HPN 20E (Milliken Chemical) (nucleator)
[0208] 4.000% Schulman Gray Color Concentrate (A. Schulman)

Example 3
Four-Layer Structure

[0209] Clear Layer
[0210] 99.1% Inspire 404 Clear PP*
[0211] 00.3% Cytosorb THT 7001 (UV stabilizer)
[0212] 0.300% Crodamide ER (slip agent)
[0213] 0.300% Hostanox Pep-Q (antioxidant)
[0214] Translucent Color Layer
[0215] 98.700% Inspire 404 PP*
[0216] 0.490% AC540 Wax (organic pigment carrier)
[0217] 0.210% DPP Red 254 Cromophil 2030 (pigment)
[0218] 0.300% Cytosorb THT 7001 (UV Stabilizer)
[0219] 0.300% Hostanox Pep-Q (antioxidant)
[0220] Color Layer
[0221] 79.400% Inspire 404 PP* 14.000% R104 TiO2 (pigment) (DuPont)
[0222] 4.796% HB9200 propylene homopolymer (Ineos USA LLC) (pigment carrier)
[0223] 1.204% Profx 6301 polypropylene (Lyondell Basell) (pigment carrier)
[0224] 0.300% Cytosorb THT 7001 (UV Stabilizer)
[0225] 0.300% Hostanox Pep-Q (antioxidant)
[0226] Backing Layer
[0227] 61.944% Pro-Fax 7823 PP**
[0228] 7.680% DFD 1088 NT VLDPE
[0229] 24.480% Premium HTP Ultra 5 L (talc filler) (Fibracel)
[0230] 0.576% TR016 Wax (process aid & dispersing aid)
[0231] 0.288% Chimassorb 119 (UV stabilizer)
[0232] 0.048% Synpro 12B Calcium Stearate (process aid & dispersing aid)
[0233] 0.288% Irganox 3114 (antioxidant)
[0234] 0.288% Hostanox Pep-Q (antioxidant)
[0235] 0.288% Vanox ZMTI (antioxidant)
[0236] 0.120% HPN 20E (nucleator)
[0237] 4.000% Schulman Gray Color Concentrate (A. Schulman)

Example 4
Four-Layer Structure

[0238] Clear Layer
[0239] 96.1% Inspire 404 Clear PP*
[0240] 3% NX20 (clarifier)
[0241] 00.3% Cytosorb THT 7001 (UV Stabilizer)
[0242] 00.3% Crodamide ER (Slip Agent)
[0243] 0.30% Hostanox Pep-Q (antioxidant)
Example 6

Two-Layer Structure with Colored TPO

<table>
<thead>
<tr>
<th>Layer 1</th>
<th>Clear Layer with Colorant</th>
</tr>
</thead>
<tbody>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>1.000% Hostavin PR-31 (Clariant)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>0.150% Hostavin VSU (Clariant)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>0.300% Hostanox Pep-Q (antioxidant)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>0.300% Ingastab FS-042 (Ciba)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>0.350% Tinuvin 328 (Ciba)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>1.000% Crodamide ER (slip agent)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>0.120% HPN 20E (nucleator)</td>
</tr>
<tr>
<td>96.000% Pristene RM2091***</td>
<td>4.000% Schulman Gray Color Concentrate (A. Schulman)</td>
</tr>
</tbody>
</table>

Example 5

Three-Layer Structure

<table>
<thead>
<tr>
<th>Layer 1</th>
<th>Clear Layer with Colorant</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>9.4000% Inspire 404 PP**</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>3% NXC400 (clarifier)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>1.120% AC540 Wax (organic pigment carrier)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.480% PR177 (DIC) (pigment)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.240% Primacor 1410 (pigment carrier)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.160% 93202 Hi-Lite Sparkle Orange (BASF) (special effects pigment)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.300% Cyasorb THT 7001 (UV Stabilizer)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.300% Hostanox Pep-Q (antioxidant)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.300% Hostanox Pep-Q (antioxidant)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.300% Vanox ZMT1 (antioxidant)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>0.120% HPN 20E (nucleator)</td>
</tr>
<tr>
<td>90.000% Inspire 404 PP**</td>
<td>4.000% Schulman Gray Color Concentrate (A. Schulman)</td>
</tr>
</tbody>
</table>

(All Percentages are by Weight.)

Process for Example 2

[0321] Clear Layer

[0322] First, an additive concentrate was made by feeding the UV stabilizer and slip agent along with about 2.4% by weight (based upon the total weight of the clear layer) of the INSPIRE 404 polypropylene copolymer to a twin screw extruder. The INSPIRE 404 polypropylene copolymer acts as a carrier resin in this stage of the process. The extruded product is a pelleted additive concentrate.

[0323] The clear layer was then fabricated by feeding the remaining approximately 93.7% of the INSPIRE 404 polypropylene copolymer to a single screw extruder along with the additive concentrate, the clarifier, and the antioxidant. The additive concentrate makes up 3% of the total weight of the clear layer.

[0324] Color Layer

[0325] An additive concentrate was made for the color layer, just as described above for the clear layer, except no slip agent is present.

[0326] Additionally, a first color concentrate was made by combining water, the organic pigments (Perylene Red 179 229-8436 and DPP Red 254 CROMOPHTAL 2030) and organic pigment carrier (AC540 Wax). The water is displaced by the addition of the organic pigment carrier during a flashing process, as described in U.S. patent publication 2005/
0282962, which is herein incorporated by reference. A second color concentrate was made by adding the inorganic pigment and inorganic carrier resin to a mill.

[0327] The color layer was then fabricated by feeding the INSPIRE 404 polypropylene copolymer to a single screw extruder along with the additive concentrate and the first and second color concentrates.

[0328] Backing Layer
[0329] In a separate process, a Farrell Continuous Mixer was loaded with Pro-Fax 7823 polypropylene and the DFDB 1088NT very low density polyethylene. Talc and the other additives listed in the formula for Example 2 were added also. The product of the mixer was natural TPO in pellet form.

[0330] The color concentrate pellets and the natural TPO pellets were then added to a single screw extruder, which produced the backing layer.
[0331] Coextrusion Setup
[0332] The single screw extruders for the clear, color, and backing layers were positioned so that each layer would be coextruded in a multilayer stack.

Process for Example 3

[0333] Clear Layer
[0334] The clear layer was made by the process described above in Example 2, but with the formula for Example 3.
[0335] Translucent Layer
[0336] The color concentrate was made by the same process used to make the color layer as described in Example 2, but with the pigment and carrier resin given in the formula above for Example 3.
[0337] The translucent layer was then fabricated by feeding the INSPIRE 404 polypropylene copolymer to a single screw extruder along with the color concentrate, the antioxidant, and the UV additive.

[0338] Color Layer
[0339] The color layer was fabricated by feeding the INSPIRE 404 polypropylene copolymer to a single screw extruder along with the two carrier resins and one pigment, the antioxidant, and the UV additive.
[0340] Backing Layer
[0341] The backing layer was made by the process described above in Example 2.
[0342] Coextrusion Setup
[0343] The single screw extruders for the clear, translucent, color, and backing layers were positioned so that each layer would be coextruded in a multilayer stack.

Process for Example 4

[0344] Clear Layer
[0345] The clear layer was made by the process described above in Example 2, but with the formula for Example 4.
[0346] Translucent Layer
[0347] The translucent layer was made by the same process used to make the translucent layer as described in Example 3, but with the formula for Example 4.
[0348] Color Layer
[0349] An additive concentrate was made for the color layer, just as described above for the clear layer, except no slip agent is present.
[0350] Additionally, a color concentrate was made by combining water, the carbon black pigment BP1300 and organic pigment carrier (AC540 Wax). The water is displaced by the addition of the organic pigment carrier during the flushing process, as described in U.S. patent publication 2005/0282962.

[0351] The color layer was then fabricated by feeding the INSPIRE 404 polypropylene copolymer to a single screw extruder along with the additive concentrate, the color concentrate, and the aluminum flake.

[0352] Backing Layer
[0353] The backing layer was made by the process described above in Example 2.
[0354] Coextrusion Setup
[0355] The single screw extruders for the clear, translucent, color, and backing layers were positioned so that each layer would be coextruded in a multilayer stack.

Process for Example 5

[0356] Clear Layer
[0357] First, an additive concentrate was made by feeding the UV stabilizer, antioxidant, and slip agent along with about 6.9% by weight (based upon the total weight of the clear layer) of the INSPIRE 404 polypropylene copolymer to a twin screw extruder. The INSPIRE 404 polypropylene copolymer acts as a carrier resin in this stage of the process. The extruded product is a pelletized additive concentrate.
[0358] The clear layer was then fabricated by feeding the remaining approximately 90% of the INSPIRE 404 polypropylene copolymer to a single screw extruder along with the additive concentrate. The additive concentrate makes up about 10% of the total weight of the clear layer.

[0359] Color Layer
[0360] An additive concentrate was made for the color layer, just as described above for the clear layer of Example 5.
[0361] Additionally, a first color concentrate was made by combining water, the organic pigments (Perylene Red 179 229-8436 and DPP Red 254 Cromophot 2050) and organic pigment carrier (AC540 Wax). The water is displaced by the addition of the organic pigment carrier during a flushing process, as described in U.S. patent publication 2005/0282962.

[0362] A second color concentrate was made by adding the inorganic pigment and inorganic carrier resin (LLDPE) to a mill.
[0363] The color layer was then fabricated by feeding the INSPIRE 404 polypropylene copolymer to a single screw extruder along with additive concentrate and the first and second color concentrates in the amounts shown in the formula above.

[0364] Backing Layer
[0365] In a separate process, a Farrell Continuous Mixer was loaded with Pro-Fax 7823 polypropylene and the DFDB 1088NT very low density polyethylene. Talc and the other additives listed in the formula for Example 5 were added also. The product of the mixer was natural TPO in pellet form.
[0366] The color concentrate pellets and the natural TPO pellets were then added to a single screw extruder, which produced the backing layer.
[0367] Coextrusion Setup
[0368] The single screw extruders for the clear, color, and backing layers were positioned so that each layer would be coextruded in a multilayer stack.

Process for Example 6

[0369] Clear Layer
[0370] The clear layer was made by the process described above in Example 2, but with the formula for Example 6.
[0371] Colored Backing Layer
[0372] The colored backing layer was made by the process described above in Example 2, but with the formula for Example 6.
Coextrusion Setup

The single screw extruders for the clear and colored backing layers were positioned so that each layer would be coextruded in a multilayer stack.

Results

Table 1 summarizes the advantages over competitive technologies in terms of design simplification, design flexibility, process flexibility, & environmental friendliness. Table 2 shows that the multilayer sheets in olefinic Examples 2-6 display the best overall durability performance in comparison to competitive designs. The comparative example of a polyolefin material with block copolymer base and no slip additive is prospective based on known polypropylene examples with no additives.

### TABLE 1

<table>
<thead>
<tr>
<th>Paint</th>
<th>Free/Recyclable</th>
<th>Solvent Cast</th>
<th>Painted Plastic</th>
<th>Painted Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
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</table>

### TABLE 1-continued

<table>
<thead>
<tr>
<th>Test</th>
<th>Standard</th>
<th>Olefinic Examples 2-6</th>
<th>Ionomer</th>
<th>Acrylic/ABS</th>
<th>Solvent Cast</th>
<th>Painted Plastic</th>
<th>Painted Metal</th>
<th>Pass/Fail Criteria</th>
<th>Prospective Comparative Example</th>
<th>Olefinic Examples 2-6</th>
<th>Ionomer</th>
<th>Acrylic/ABS</th>
<th>Solvent Cast</th>
<th>Plastic</th>
<th>Painted Plastic</th>
<th>Painted Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imprint Resistance @ 70°C</td>
<td>Honda #16</td>
<td>No Imprint, No Adhesion</td>
<td>Pass</td>
<td>Pass</td>
<td>Fail</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Oil Resistance @ 70°C</td>
<td>GM3953P</td>
<td>Compare to Control</td>
<td>Pass (8-10)</td>
<td>Pass</td>
<td>Fail (4)</td>
<td>Pass (10)</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass (8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease Resistance @ 70°C</td>
<td>GM3953P</td>
<td>Compare to Control</td>
<td>Pass (8-10)</td>
<td>Pass</td>
<td>Fail (4)</td>
<td>Pass (10)</td>
<td>Pass</td>
<td>Pass</td>
<td>Fail (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Egg Albumin Resistance @ 70°C</td>
<td>GM3953P</td>
<td>Compare to Control</td>
<td>Pass (10)</td>
<td>Pass</td>
<td>Fail (4)</td>
<td>Pass (10)</td>
<td>Fail</td>
<td>Fail (6-8)</td>
<td>Pass (8)</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol Resistance @ RT</td>
<td>GM3950P</td>
<td>1 maximum</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scratch &amp; Mar Resistance Gravelometer</td>
<td>GM39508P</td>
<td>5 pints/90°</td>
<td>7 or greater</td>
<td>9</td>
<td>Fail</td>
<td>9</td>
<td>Fails (cracks)</td>
<td>&lt;7</td>
<td>&lt;7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravelometer</td>
<td>GM39508P</td>
<td>10 pints/30°</td>
<td>7 or greater</td>
<td>9</td>
<td>Fail</td>
<td>7 but failed due to delamination</td>
<td>Fails (cracks)</td>
<td>&lt;7</td>
<td>&lt;7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravelometer</td>
<td>GM39508P</td>
<td>15 pints/30°</td>
<td>7 or greater</td>
<td>9</td>
<td>Fail</td>
<td>7 but failed due to delamination</td>
<td>Fails (cracks)</td>
<td>&lt;7</td>
<td>&lt;7</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
TABLE 2-continued

<table>
<thead>
<tr>
<th>Test</th>
<th>Prospective</th>
<th>Olefinic Examples</th>
<th>Compare to Control</th>
<th>GMPEP Impact Failures</th>
<th>GM503P Impact Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temp Impact</td>
<td>Pass</td>
<td>Pass</td>
<td>Fail</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>Crock Mar</td>
<td>Pass</td>
<td>Fail</td>
<td>Fail</td>
<td>Fail</td>
<td>Fail</td>
</tr>
</tbody>
</table>

GM503P Scale: 0 = no change, 1 = Slight, 3 = Moderate, 5 = Severe
GM9509P Scale: 0 = Fail, 1 = Poor, 2 = Fair, 3 = Fair, 4 = Fair, 7 = Good, 8 = Good, 9 = Good, 10 = no damage/no chipping

The test standards used above are available from General Motors, Honda, and Chrysler. Testing was performed by Ghesquire Plastic Testing, Inc. of Harper Woods, MI and A. Schulman Invention of Sharon Center, OH.

[0376] In summary, the favorable results for the example olefinic multilayer structures shown in both tables were made without sacrificing the high gloss and DOI requirements that are needed in order to achieve a Class “A” surface.

Examples 1A-8A

Examples 1A-8A illustrate the unexpected results obtained by using a multi-layered virgin/regrind/virgin backing layer instead of a blended regrind and virgin monolayer backing layer. FIG. 10 shows an ABA backing layer 90 that corresponds to Examples 1A-4A. FIG. 10 also shows a monolayer backing layer 100 that corresponds to Examples 5A-8A. Both structures 90, 100 were 100 mils in thickness in all the Examples 1A-8A.

Example 1A is a control showing a single A layer that is not blended with regrind.

In Examples 2A-4A, the A layers are coextruded with the B layer adjacent to them. The A layer is composed of the materials as specified in Table 3. Percentages are given in weight percentages. Though fillers, colorants, stabilizers and other additives are present, the polymeric base is 100% virgin polymer. The B layer is composed of regrind miscellaneous polypropylene homo- and copolymers with talc, filler, colorants, and stabilizers. The polymeric base of the B layer is 100% regrind polymer. Examples 1A-4A vary in the thickness of the A layers and the B layers. In Examples 2A-4A the two A layers in each Example are of equal thicknesses, in values of 40 mil, 30 mil, and 20 mil, respectively.

In Examples 5A-7A a regrind is blended with the virgin polymer and other additives in the amounts disclosed in Table 4. Example 8A is a control using 100% regrind. The same type of regrind material was used in Examples 5A-7A as was used in Examples 2A-4A. The structure in Examples 5A-8A is a single-layer extruded sheet.

TABLE 3-continued

<table>
<thead>
<tr>
<th>Example</th>
<th>A Layer Composition</th>
<th>A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pro-Fax 7823 PP (%)</td>
<td>64.301</td>
<td>64.301</td>
<td>64.301</td>
<td>64.301</td>
</tr>
<tr>
<td></td>
<td>DFDB 1088 NT VLDPE (%)</td>
<td>7.920</td>
<td>7.920</td>
<td>7.920</td>
<td>7.920</td>
</tr>
<tr>
<td></td>
<td>Premium HTP Ultra 5L (talc filler) (%)</td>
<td>25.245</td>
<td>25.245</td>
<td>25.245</td>
<td>25.245</td>
</tr>
<tr>
<td></td>
<td>TR016 wax (process aid &amp; dispersing aid) (%)</td>
<td>0.594</td>
<td>0.594</td>
<td>0.594</td>
<td>0.594</td>
</tr>
<tr>
<td></td>
<td>Chinnasorb 119 (UV stabilizer) (%)</td>
<td>0.297</td>
<td>0.297</td>
<td>0.297</td>
<td>0.297</td>
</tr>
<tr>
<td></td>
<td>Sympro 12B Calcium Stearate (process aid &amp; dispersing aid) (%)</td>
<td>0.049</td>
<td>0.049</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td></td>
<td>Evanstat 18 DSTDP (Evans Chemetics) (antioxidant) (%)</td>
<td>0.198</td>
<td>0.198</td>
<td>0.198</td>
<td>0.198</td>
</tr>
<tr>
<td></td>
<td>Irganox B225 (Ciba) (antioxidant) (%)</td>
<td>0.396</td>
<td>0.396</td>
<td>0.396</td>
<td>0.396</td>
</tr>
<tr>
<td></td>
<td>Polyblak 3123B (A. Schulman) (black color concentrate) (%)</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

TABLE 4

<table>
<thead>
<tr>
<th>Example</th>
<th>Mono-Layer Composition</th>
<th>A/B/A Layer Thicknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pro-Fax 7823 PP (%)</td>
<td>51.440</td>
</tr>
<tr>
<td></td>
<td>DFDB 1088 NT VLDPE (%)</td>
<td>6.336</td>
</tr>
<tr>
<td></td>
<td>Premium HTP Ultra 5L (talc filler) (%)</td>
<td>20.196</td>
</tr>
<tr>
<td></td>
<td>TR016 wax (process aid &amp; dispersing aid) (%)</td>
<td>0.475</td>
</tr>
<tr>
<td></td>
<td>Chinnasorb 119 (UV stabilizer) (%)</td>
<td>0.238</td>
</tr>
<tr>
<td></td>
<td>Sympro 12B Calcium Stearate (process aid &amp; dispersing aid) (%)</td>
<td>0.040</td>
</tr>
<tr>
<td></td>
<td>Evanstat 18 DSTDP (Evans Chemetics) (antioxidant) (%)</td>
<td>0.158</td>
</tr>
<tr>
<td></td>
<td>Irganox B225 (Ciba) (antioxidant) (%)</td>
<td>0.317</td>
</tr>
</tbody>
</table>
TABLE 4-continued

<table>
<thead>
<tr>
<th>Example</th>
<th>5A</th>
<th>6A</th>
<th>7A</th>
<th>8A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyblak 3123B (black color concentrate) (%)</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Regrind (%)</td>
<td>19.800</td>
<td>39.600</td>
<td>59.400</td>
<td>99.000</td>
</tr>
</tbody>
</table>

[0381] The A layers of Examples 1A-4A were made by the following process. The Pro-Fax 7823 polypropylene and the DFDB 1088NT very low density polyethylene were fed into a Farrell Continuous Mixer. Talc and the other additives listed in Tables 3 were also added. The product of the mixer was natural TPO in pellet form. In the next step, pelletized black color concentrate and the natural TPO pellets were added to a single screw extruder.

[0382] The mono-layer Example 1A was the product of extruding the A layer as a mono-layer sheet.

[0383] The B layers of Examples 2A-4A were made by feeding pelletized and ground up regrind to a single screw extruder.

[0384] In Examples 2A-4A, the extruders were positioned so that each layer would be coextruded in a multilayer stock.

[0385] In Examples 5A-7A Pro-Fax 7823 polypropylene and the DFDB 1088NT very low density polyethylene were fed to a Farrell Continuous Mixer. Talc and the other additives listed in Table 4 were also added. The product of the mixer was a virgin TPO in pellet form. In the next step, pelletized black color concentrate, the virgin TPO pellets, and regrind were added to a single screw extruder and extruded as a mono-layer sheet.

[0386] Example 8A was made by the same process as Examples 4A-7A, except no virgin polymer “Pro-Fax 7823 polypropylene” was added.

Results

[0387] FIG. 11 compares the virgin backing layer of Example 1 and the virgin/regrind/virgin ABA structured backing layers of Examples 2A-4A to the mono-layer structured backing layers of Examples 5A-8A. In particular, FIG. 11 shows the impact of varying amounts of regrind on sag resistance for each type of structure. In these Examples, sag resistance was measured in terms of “bag time,” which is the amount of time required to reach a bag depth of seven inches after heating of the sheet is initiated. The sheet sample size was 40 inches by 20 inches. The sample was heated at 340°F on a thermoformer. As the data shows, the “bag time” decreases (decreasing sag resistance) as the % regrind increases in both sets of Examples. However, Examples 2A to 4A show improved sag resistance versus Examples 5A to 7A. For example, improvements of 3.5% or greater in terms of time to bag, such as 5% and greater are exhibited by Examples 2A to 4A over Examples 5A to 7A.

[0388] In addition, other properties of the ABA structured backing layer show unexpected improvement compared to the blended mono-layer structure. Table 5 summarizes the results of additional testing performed on Examples 1A-8A. The columns are offset so that Examples that are directly comparable in terms of regrind percentage are in vertical alignment.

TABLE 5

<table>
<thead>
<tr>
<th>Example</th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex Mod (MPa)</td>
<td>2520</td>
<td>2612</td>
<td>2559</td>
<td>2391</td>
</tr>
<tr>
<td>% Elong @ Break</td>
<td>327</td>
<td>311</td>
<td>251</td>
<td>199</td>
</tr>
<tr>
<td>Tensile @ Yield (MPa)</td>
<td>19</td>
<td>19.3</td>
<td>19.8</td>
<td>21</td>
</tr>
<tr>
<td>Ductile/Brittle Pt (°C)</td>
<td>-20</td>
<td>-20</td>
<td>-20</td>
<td>-10</td>
</tr>
<tr>
<td>Energy to Max Load (J)</td>
<td>29</td>
<td>29</td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>Total Energy (J)</td>
<td>49</td>
<td>49</td>
<td>51</td>
<td>49</td>
</tr>
</tbody>
</table>

[0389] The flexural modulus was tested according ISO 178 at 2 mm/min and a 64 mm span. The elongation at break and tensile at yield parameters were tested according to ISO 527 at 50 mm/min. The ductile/brittle point, energy to Max Load, and total energy measurements were tested according to GM9004P at 2.2 m/s. For the flexural modulus, percent elongation at break, and tensile at yield tests, the samples were cut parallel to the direction of the extrusion flow.

[0390] This written description sets forth the best mode of the invention, and describes the invention so as to enable a person skilled in the art to make and use the invention, by presenting examples. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art.

It is claimed:

1. A multilayer structure comprising:
   a first thermoplastic layer having a polymeric component consisting essentially of virgin polyolefin;
   a second thermoplastic layer including regrind polyolefin; and
   a third thermoplastic layer having a polymeric component consisting essentially of virgin polyolefin;
   the second thermoplastic layer being adjacent to the first thermoplastic layer and the third thermoplastic layer.

2. The multilayer structure of claim 1 wherein the multilayer structure includes a clear polymer layer.

3. The multilayer structure of claim 1 wherein the polymeric component of the second layer consists essentially of regrind.

4. The multilayer structure of claim 3 wherein the bag strength of the first, second, and third layer is at least 5% greater than a control sample that is identical to the first, second, and third layer in formulation and dimension, but has a mono-layer structure that incorporates a blend of the regrind and the virgin polymer instead of a multi-layered structure.

5. The multilayer structure of claim 2 wherein the multilayer structure further comprises a colored polymeric layer adjacent to the clear layer.

6. The multilayer structure of claim 1 wherein the virgin polyolefin comprises a propylene homopolymer or a copolymer including polypropylene, and further comprises a very low density polyethylene.
7. A backing layer for a multilayered polymeric structure comprising:
   a first thermoplastic layer including a polymeric component, wherein the polymeric component consists essentially of a virgin polyolefin;
   a second thermoplastic layer including regrind polyolefin; a third thermoplastic layer having a polymeric component, wherein the polymeric component consists essentially of a virgin polyolefin;
   the second thermoplastic layer being adjacent to the first thermoplastic layer and the third thermoplastic layer, if present.

8. The backing layer of claim 7 wherein the polymeric component of the second layer consists essentially of regrind.

9. The backing layer of claim 7 wherein the bag strength of the backing layer is at least 3% higher in terms of the time to bag, than a control sample that is identical to the backing layer in formulation and dimension, but has a mono-layer structure that incorporates a blend of the regrind and the virgin polymer instead of a multi-layered structure.

10. The backing layer of claim 7 wherein the virgin polyolefin comprises a propylene homopolymer or a copolymer including polypropylene, and further comprises a very low density polyethylene.

11. A method for forming a multilayered polymeric structure, the method comprising coextruding a first thermoplastic layer having a polymeric component that consists essentially of a virgin polyolefin, with a second thermoplastic layer including regrind polyolefin, and a third thermoplastic layer having a polymeric component that consists essentially of a virgin polyolefin; the second thermoplastic layer being adjacent to the first thermoplastic layer and the third thermoplastic layer.

12. The method of claim 11 wherein the coextrusion step further comprises coextruding a clear polymeric layer with the first, second, and third thermoplastic layers.

13. The method of claim 11 wherein the coextrusion step further comprises coextruding a clear polymeric layer and a colored polymeric layer with the first, second, and third thermoplastic layers.

14. The method of claim 11 further comprising forming the coextruded multilayered polymeric structure to make a formed product.

15. The method of claim 11 wherein the polymeric component of the second layer consists essentially of regrind.

16. The method of claim 11 wherein the virgin polyolefin comprises a propylene homopolymer or a copolymer including polypropylene, and further comprises a very low density polyethylene.

17. The method claim of 11 wherein the formed product is a backing layer for a vehicle body panel.

18. The method of claim 11 wherein the bag strength of the multilayered polymeric structure after coextrusion is at least 3% higher in terms of the time to bag, than a control sample that is identical to the backing layer in formulation and dimension but has a mono-layer structure that incorporates a blend of the regrind and the virgin polymer instead of a multi-layered structure.

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