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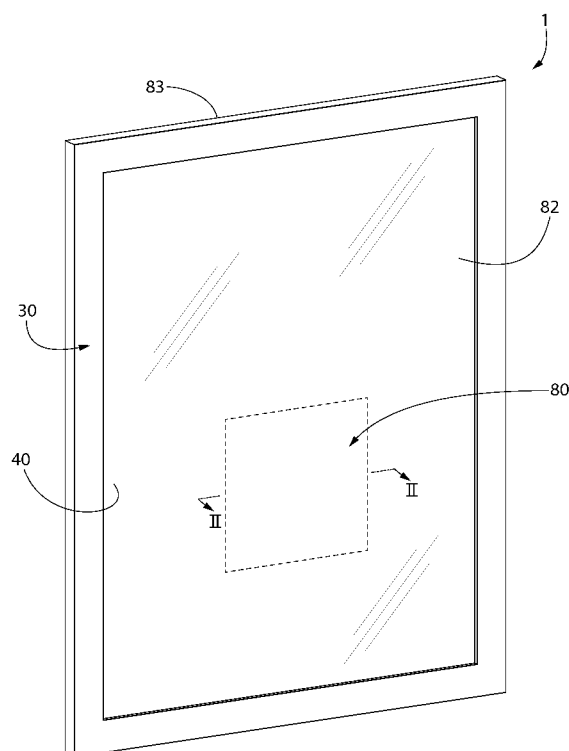


FIG. 1

(57) Abstract: Described herein is a mirror apparatus comprising:
a reflective substrate; and an anti-fog complex comprising: an ad-
hesive layer atop the substrate; a first polymeric layer atop the
pressure sensitive adhesive layer; and a second polymeric layer
atop the first polymeric layer. Methods of making the mirror ap-
paratus are also disclosed.

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ANTI-FOG MIRROR APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a PCT International Application of United States Patent Application No. 14/530,420 filed on October 31, 2014. The disclosure of the above application is incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to aesthetically pleasing reflective surface coverings having anti-fog properties.

BACKGROUND

[0003] Compositions and coatings which provide anti-fog and scratch-resistant surfaces are known. However, when these compositions and coatings are applied to a surface, they can adversely impact the aesthetics and/or functionality of the surface to which they are applied. For example, the application of certain anti-fog compositions and coatings result in surfaces with imperfections and/or discoloration. Surface imperfections and discoloration may not be an issue for some surfaces, e.g. containers or refrigerator doors; however, surface coverings that require a certain level of reflectivity have little tolerance for surface imperfections or discoloration. Thus, there remains a need for reflective surface coverings which avoid discoloration and surface imperfections. Embodiments of the present invention are designed to meet these needs.

SUMMARY

[0004] In some embodiments, the present invention provides a mirror apparatus comprising: a reflective substrate; and an anti-fog complex coupled to the reflective substrate, the anti-fog complex comprising: a thermally activated adhesive layer atop the reflective substrate; a first polymeric layer atop the thermally activated adhesive layer; and a second polymeric layer atop the first polymeric layer; wherein the thickness ratio between the thermally activated adhesive layer and the first thermoplastic polymeric layer is from about 1.25:1 to about 2.75:1.

[0005] Other embodiments of the present invention provide a mirror apparatus comprising: a reflective substrate; and an anti-fog complex comprising: a pressure sensitive adhesive layer atop

the substrate; a first polymeric layer comprising a thermoplastic polymer, the first polymeric layer atop the pressure sensitive adhesive layer; and a second polymeric layer atop the first polymeric layer; wherein the thickness ratio between the pressure sensitive adhesive layer and the first polymeric layer ranges from about 0.25:1 to about 1.25:1.

[0006] Further embodiments provide a method of preparing a mirror apparatus comprising: a) providing a reflective substrate; b) providing a multi-layer film comprising: a protective layer; and an anti-fog complex comprising: a first polymeric layer; an adhesive layer; and a second thermoplastic polymeric layer; c) laminating the multi-layer film and the reflective substrate together to form a laminated composite; d) maintaining the laminated composite in an ambient environment for a time sufficient to permit solidification of the multi-layer film; e) removing the protective layer from the laminated composite to expose the anti-fog complex; and f) performing a post-lamination cleaning phase..

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0008] Figure 1 is a front perspective view of a mirror apparatus 1 comprising a mirror according to the present invention;

[0009] Figure 1A is a cross-sectional view of a portion of the mirror according to the present invention, the portion being identified by the dotted lines in Figure 1 and the cross-sectional view is taken along the II line set forth in Figure 1 – Figure 1A is not drawn to scale;

[0010] Figure 2 is a cross-sectional view of a portion of the mirror according to embodiments of the present invention, the portion being identified by the dotted lines in Figure 1 and the cross-sectional view is taken along the II line set forth in Figure 1 – Figure 2 is not drawn to scale;

[0011] Figure 3 is a side view of an multi-layered film according to the present invention – Figure 3 is not drawn to scale; and

[0012] Figure 4 is a cross-sectional view of a portion of the mirror according to other embodiments of the present invention, the portion being identified by the dotted lines in Figure 1 and the cross-sectional view is taken along the II line set forth in Figure 1 – Figure 4 is not drawn to scale.

DETAILED DESCRIPTION

[0013] As used herein, the term “complex” refers to a plurality of components that are connected. According to the present invention, the terms “substantially” and “about” refers to +/- 5% of the referenced value. According to the present invention, the term “substantially free” refers to less than 0.05 wt. % based on total weight of the referenced composition.

[0014] Referring to Figures 1 and 1A concurrently, a mirror apparatus 1 according to the present invention is disclosed. The mirror apparatus 1 generally comprises an annular frame 30 defining a central opening 40 and a mirror 80. The mirror 80 is supported within the annular frame 30 and is a laminate structure that generally comprises a first major surface 82 opposite a second major surface 83, the laminate structure comprising a reflective substrate 100 and an anti-fog complex 300.

[0015] The reflective substrate 100 may comprise an upper surface 102 opposite a lower surface 103. The reflective substrate 100 may have a thickness t_1 as measured from the upper surface 102 to the lower surface 103 of the reflective substrate 100. The reflective substrate 100 may have a thickness t_1 ranging from about 2 mm to about 6 mm – including all values and sub-ranges there-between. The reflective substrate 100 may have a thickness t_1 ranging from about 2.5 mm to about 3.5 mm – including all values and sub-ranges there-between. The reflective substrate 100 may have a thickness t_1 ranging from about 2.75 mm to about 3.25 mm – including all values and sub-ranges there-between. In some embodiments, the reflective substrate 100 may have a thickness t_1 of about 3 mm.

[0016] The reflective substrate 100 may further comprise a transparent base layer 110 having an upper surface 112 opposite a lower surface 113 and a back coating 120 having an upper surface 122 opposite a lower surface 123. The upper surface 102 of the reflective substrate 100 may comprise the upper surface 112 of the transparent base layer 110 and the lower surface 103 of the reflective substrate 100 may comprise the lower surface 123 of the back coating 120. The upper surface 122 of the reflective back coating 120 may directly contact the lower surface 113 of the transparent base layer 110.

[0017] The back coating 120 may comprise a reflective material. The transparent base layer 110 may be substantially clear and made of glass or a plastic material. For the purposes of this application, the phrases “substantially clear” or “optically clear” refers to materials having an optical transmission of at least about 90%, or even higher, and a haze value of below about 5%,

or even lower. The transparent base layer 110 should be substantially clear such that the underlying back coating 120 forms a reflective surface on the lower surface 113 of the transparent base layer 110 when viewed in a direction extending from at least the upper surface 112 towards the lower surface 113 of the reflective substrate 100. The transparent base layer 110 should be substantially clear such that the underlying back coating 120 forms a reflective surface when viewed from the first major surface 82 of the mirror 80. Stated otherwise, a viewer should see their reflection in the reflective surface when viewing the mirror 80 in the direction of the upper surface 102 towards the lower surface 103 of the reflective substrate 100.

[0018] The anti-fog complex 300 of the present invention is optically clear and comprises an upper surface 302 opposite a lower surface 303. The anti-fog complex 300 may have a thickness t_2 as measured from the upper surface 302 to the lower surface 303 of the anti-fog complex 300. The anti-fog complex 300 may comprise an adhesive layer 220, a first polymeric layer 240, and a second polymeric layer 260. The second polymeric layer 260 may be atop the first polymeric layer 240. The first polymeric layer 240 may be atop the adhesive layer 220. The adhesive layer 200 may be atop the reflective substrate 100.

[0019] The adhesive layer 220 may comprise an upper surface 222 opposite a lower surface 223. The adhesive layer 220 may have a thickness t_3 as measured from the upper surface 222 to the lower surface 223 of the adhesive layer 223. The lower surface 303 of the anti-fog complex 300 may comprise the lower surface 223 of the adhesive layer 220. The adhesive layer 220 is optically clear.

[0020] The first polymeric layer 240 may comprise an upper surface 242 opposite a lower surface 243. The first polymeric layer 240 may have a thickness t_4 as measured from the upper surface 242 to the lower surface 243 of the polymeric layer 240. The first polymeric layer 240 is optically clear.

[0021] The first polymeric layer 240 may comprises a polymer selected from: polymethyl methacrylate; a polyamide; polybenzamidazole; polyethylene; polypropylene; polystyrene; polyvinyl chloride; polyethylene terephthalate; and polytetrafluoroethylene. In some embodiments, the polymer of the first polymeric layer 240 is a thermoplastic polymer. The first polymeric layer 240 may be formed from a thermoplastic polymer of polyethylene terephthalate. The first polymeric layer 240 may be substantially free of UV additives. In some embodiments, the first polymeric layer 240 may be completely free of UV additives.

[0022] The second polymeric layer 260 may comprise an upper surface 262 opposite a lower surface 263. The second polymeric layer 260 may have a thickness t_5 as measured from the upper surface 262 to the lower surface 263 of the second polymeric layer 260. The thickness t_5 of the second polymeric layer 260 may range from about 5 μm to about μm – including all values and sub-ranges there-between. The thickness t_5 of the second polymeric layer 260 may be about 10 μm . The upper surface 302 of the anti-fog complex 300 may comprise the upper surface 222 of the second polymeric layer 260.

[0023] The second polymeric layer 260 comprises polyurethane. The polyurethane of the second polymeric layer may be hydrophilic. The polyurethane based layer may be formed from a resin composition comprising an isocyanate prepolymer having free isocyanate groups, and an organic solvent solution of a hydrophilic polyol and a surfactant having isocyanate-reactive functionality. In some embodiments, the hydrophilic polyol and the surfactant react with the free isocyanate groups in the isocyanate prepolymer to form the polyurethane backbone having both the hydrophilic moiety and the surfactant moiety chemically reacted therein and attached thereto. Suitable polyurethane based layers are described, for example, in U.S. Patent No. 5,877,254.

[0024] In some embodiments, the surfactant has distinct hydrophilic and hydrophobic regions such that the desired interfacial tension between the surface and the condensing moisture is effectively reduced.

[0025] Cationic and anionic surfactants are preferred; however, non-ionic surfactants may also be useful, provided they are equipped with the reactive group functionality and exhibit the distinct hydrophilic and hydrophobic regions. In certain applications where non-ionic surfactants are used, they may be selected from ethoxylated or propoxylated alcohols, phenols, amides and amines. Non-ionic surfactants, however, are known to typically include isocyanate reactive groups such as hydroxyl groups.

[0026] Anionic and cationic surfactants rarely contain free, reactive groups. In some embodiments, wherein anionic and cationic surfactants are properly modified to include free reactive hydroxyl groups, or other groups which are reactive with isocyanate groups, such modifications will provide the necessary reaction site to incorporate into the polyurethane structure.

[0027] Ionic surfactants are preferred because they are often more effective wetting agents than non-ionic surfactants due to their ionic character. In the present invention, the surfactant anionics

are free to migrate throughout the polymer complex since they are bound to the reacted cations by electrostatic interaction rather than covalent bonding.

[0028] The isocyanate-reactive surfactant may be selected from an anionic surfactant, a cationic surfactant, and a mixture thereof. Although hydroxyl-bearing surfactants are preferred, a number of other reactive groups on the surfactant are contemplated, including amino, carboxyl and thiol groups. The surfactant may bear more than one or one-type of isocyanate-reactive group. The ionic surfactants are preferably quaternary cationic surfactants or anionic surfactants having hydroxyl groups in the cation portion. More preferably, the surfactant is a non-ethoxylated hydrocarbon chain with greater than 16 carbon atoms. A non-limiting list of examples of suitable anionic surfactants includes monoethanolamine salts of sulfonic acids, diethanolamine salts of sulfonic acids, triethanolamine salts of sulfonic acids and mixtures thereof.

[0029] Typically, anionic surfactants rarely contain free, reactive hydroxyl groups in their structure. As such, these substances must be prepared to incorporate free hydroxyl or other isocyanate-reactive groups. Hydroxylation is accomplished by neutralizing a hydroxyl bearing quaternary ammonium base such as choline hydroxide with an acid such as dodecylbenzene sulfonic acid, as further described herein in the examples. Other hydroxyl-bearing ammonium compounds include but are not limited to triethylethanol-, diethyldiethano-, and ethyltriethanolammonium salts. A non-limiting list of suitable sulfonic acids from which the salts are prepared includes dodecylbenzene sulfonic acid, naphthalene sulfonic acid, lignin sulfonic acids, petroleum sulfonic acids and paraffin sulfonic acids.

[0030] Examples of hydroxyl-containing cationic-surfactants include, without limitation, ricinoleamidopropyl dimethylethylammonium ethosulfate, stearamidopropyl dimethylethanolammonium methasulfate and octadecylmethol diethanolammonium chloride.

[0031] The polyol that may be suitable for use in the present invention are of a hydrophilic character, and are capable of reacting with an isocyanate prepolymer to form a polyurethane chain. Non-limiting examples of suitable polyol for use in the present invention includes polyethylene glycol and ethylene glycol/propylene glycol copolymers and mixtures thereof. Other suitable hydrophilic polyol include polybutylene glycol, polyethylene imine, amine-terminated polyethers and certain polyester polyol.

[0032] The isocyanate prepolymers contemplated for use with the present invention include those isocyanates containing reactive isocyanate groups and which are capable of forming

polyurethane polymer chains as is well known to those skilled in the art. In preferred embodiments, the isocyanate prepolymer is a biuret or an isocyanurate of a diisocyanate. Most preferably, the diisocyanate is hexamethylene diisocyanate. Other useful diisocyanates include prepolymers of diisophorone diisocyanate, diphenylmethane diisocyanate, bis(methylcyclohexyl) diisocyanate and toluenediisocyanate. Blocking of the isocyanate group, for example with an oxime or phenol, and later removal of the protective group prior to reaction is also contemplated. When blocked isocyanates are employed, it is possible to use solvents or other compounds which, but for the protective group in the isocyanate, would react with and consume the isocyanate groups.

[0033] The second polymeric layer 260 may be substantially free of UV additives. In other embodiments, the second polymeric layer 260 is completely free of UV additives.

[0034] The anti-fog complex 300 of the present invention may have a thickness t_2 that is calculated as follows:

$$t_2 = t_3 + t_4 + t_5$$

[0035] The anti-fog complex 300 may be formed by the upper surface 222 of the adhesive layer 220 contacting the lower surface 243 of the first polymeric layer 240 and the upper surface 242 of the first polymeric layer 240 contacting the lower surface 263 of the second polymeric layer 260.

[0036] The mirror 80 may be formed by the lower surface 263 of the second polymeric layer 260 contacting the upper surface 242 of the first polymeric layer 240, the lower surface 243 of the second polymeric layer 240 contacting the upper surface 222 of the adhesive layer 220, the lower surface 223 of the adhesive layer 220 contacting the upper surface 112 of the transparent base layer 110, and the lower surface 113 of the transparent base layer 110 contacts the upper surface 122 of the back coating 120.

[0037] The mirror 80 of the present invention may have a thickness t_0 that is calculated as follows:

$$t_0 = t_1 + t_3 + t_4 + t_5$$

[0038] The mirror 80 of the present invention may comprise the lower surface 303 of the anti-fog complex 300 contacting the upper surface 102 of the reflective substrate 100 – wherein the lower surface 303 of the anti-fog complex 300 comprises the lower surface 223 of the adhesive

layer 200 – such that the lower surface 303 of the anti-fog complex 300 is adhesively bonded (by the adhesive layer 220) to the upper surface 102 of the reflective substrate 100.

[0039] Referring now specifically to the embodiments exemplified in Figure 2, a mirror apparatus 1 comprising a mirror 80a will be described. The mirror 80a is similar to the mirror 80 except for the differences described herein below. The features of the mirror 80a that are described above with regard to the mirror 80 will not be repeated herein in the interest of brevity, it being understood that the description above with regard to the mirror 80 applies. Furthermore, features of the mirror 80a will be similarly numbered as similar features on the mirror 80 except that the a suffix of “a” will be used. For features of the mirror 80a that are numbered but not described, it should be understood that the description of the similar feature in the mirror 80 applies.

[0040] The present invention is directed to a mirror apparatus comprising a mirror 80a having an anti-fog complex 300a comprising an adhesive layer 220a, a first polymeric layer 240a, and a second polymeric layer 260a, wherein the adhesive layer 220a is formed from a thermally activated adhesive composition.

[0041] The anti-fog complex 300a may have a thickness t_{2a} ranging from about 250 μm to about 300 μm . In some embodiments, the anti-fog complex 300a has a thickness t_{2a} ranging from about 255 μm to about 295 μm . In some embodiments, the anti-fog complex 300a has a thickness t_{2a} ranging from about 260 μm to about 290 μm . In some embodiments, the anti-fog complex 300a has a thickness t_{2a} ranging from about 265 μm to about 285 μm . In some embodiments, the anti-fog complex 300a has a thickness t_{2a} ranging from about 270 μm to about 280 μm . In some embodiments, the anti-fog complex 300a has a thickness t_{2a} of about 275 μm .

[0042] A ratio of adhesive layer 220a thickness t_{3a} to the first polymeric layer 240a thickness t_{4a} may range from about 1.25:1 to about 2.75:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220a thickness t_{3a} to the first polymeric layer 240a thickness t_{4a} may range from about 1.25:1 to about 2.5:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220a thickness t_{3a} to the first polymeric layer 240a thickness t_{4a} may range about 1.25:1 to about 2.25:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220a thickness t_{3a} to the first polymeric layer 240a thickness t_{4a} may range from about 1.25:1 to about 2:1 – including all ratios and sub-ranges there-between. The ratio of

adhesive layer 220a thickness t_{3a} to the first polymeric layer 240a thickness t_{4a} may be about 1.5:1.

[0043] The adhesive layer 220a may be formed from a thermally activated adhesive composition and comprises an adhesive available from Akron Coating and Adhesives, Inc., e.g. ACA-40-004. Other suitable thermally activated adhesives are described in U.S. Patent No. 6,753,379 to 3M Innovative Properties Company. In some embodiments, the thermally activated adhesive is in the form of a film. In some embodiments, the thermally activated adhesive is water-based. In some embodiments, the thermally activated adhesive is solvent-based. According to such embodiments, the adhesive layer 220a may be substantially free of UV additives. In other embodiments, the thermally activated adhesive layer may be completely free of UV additives.

[0044] The adhesive layer 220a formed from the thermally activated adhesive composition may have a thickness t_{3a} ranging from about 140 μm to about 175 μm – including all values and sub-ranges there-between.

[0045] The first polymeric layer 240a may have a thickness t_{3a} ranging from about 75 μm to about 125 μm – including all values and sub-ranges there-between. In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of from about 80 μm to about 120 μm – including all values and sub-ranges there-between. In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of from about 85 μm to about 115 μm – including all values and sub-ranges there-between. In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of from about 90 μm to about 110 μm – including all values and sub-ranges there-between. In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of from about 95 μm to about 105 μm – including all values and sub-ranges there-between. In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of about 100 μm . In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of about 101 μm . In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of about 102 μm . In some embodiments, the first polymeric layer 240a has a thickness t_{3a} of 101.6 μm .

[0046] The adhesive layer 220a formed from the thermally activated adhesive composition may comprise from about 52 wt.% to about 65 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The adhesive layer 220a formed from the thermally activated adhesive composition may comprise from about 55 wt.% to about 59 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The adhesive layer 220a

formed from the thermally activated adhesive composition may comprise about 57 wt.% of the anti-fog complex 300a. The adhesive layer 220a According to the embodiments of may comprises 58 wt.% of the anti-fog complex 300a.

[0047] The first polymeric layer 240a may comprise from about 28 wt.% to about 48 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The first polymeric layer 240a may comprise from about 33 wt.% to about 43 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The first polymeric layer 240a may comprise about 38 wt.% of the anti-fog complex 300a.

[0048] The second polymeric layer 260a may comprise from about 1 wt.% to about 10 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The second polymeric 260a layer may comprise from about 2 wt.% to about 7 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The second polymeric layer 260a may comprise from about 3.5 wt.% to about 5.5 wt.% of the anti-fog complex 300a – including all values and sub-ranges there-between. The second polymeric layer 260a may comprise about 4.5 wt.% of the anti-fog complex 300a.

[0049] Referring now specifically to the embodiments exemplified in Figure 4, a mirror apparatus 1 comprising a mirror 80b will be described. The mirror 80b is similar to the mirror 80 except for the differences described herein below. The features of the mirror 80b that are described above with regard to the mirror 80 will not be repeated herein in the interest of brevity, it being understood that the description above with regard to the mirror 80 applies. Furthermore, features of the mirror 80b will be similarly numbered as similar features on the mirror 80 except that the a suffix of “b” will be used. For features of the mirror 80b that are numbered but not described, it should be understood that the description of the similar feature in the mirror 80 applies.

[0050] The present invention is directed to a mirror apparatus comprising a mirror 80b having an anti-fog complex 300b comprising an adhesive layer 220b, a first polymeric layer 240b, and a second polymeric layer 260b, wherein the adhesive layer 220b is formed a pressure sensitive adhesive composition.

[0051] The anti-fog complex 300b may have a thickness t_{2b} ranging from about 50 μm to about 125 μm – including all values and sub-ranges there-between. In some embodiments, anti-fog complex 300b has a thickness t_{2b} ranging from about 65 μm to about 110 μm – including all

values and sub-ranges there-between. In some embodiments, anti-fog complex 300b has a thickness t_{2a} ranging from about 75 μm to about 95 μm – including all values and sub-ranges there-between. In some embodiments, the anti-fog complex 300b has a thickness t_{2b} ranging from about 80 μm to about 90 μm – including all values and sub-ranges there-between. In some embodiments, the anti-fog complex 300b has a thickness t_{2b} of about 86 μm .

[0052] A ratio of adhesive layer 220b thickness t_{3b} to the first polymeric layer 240b thickness t_{4b} may range from about 0.2:1 to about 1.25:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220b thickness t_{3b} to the first polymeric layer 240b thickness t_{4b} may range from about 0.25:1 to about 1:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220b thickness t_{3b} to the first polymeric layer 240b thickness t_{4b} may range from about 0.5:1 to about 1:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220b thickness t_{3b} to the first polymeric layer 240b thickness t_{4b} may range from about 0.65:1 to about 1:1 – including all ratios and sub-ranges there-between. The ratio of adhesive layer 220b thickness t_{3b} to the first polymeric layer 240b thickness t_{4b} may be about 0.5:1.

[0053] According such embodiments, the adhesive layer 220b is formed from a pressure sensitive adhesive composition. The pressure sensitive composition is optically clear. The pressure sensitive adhesive composition may comprise one or more acrylic polymers, vinyl polymers, mixtures, or copolymers thereof. Non-limiting examples of acrylic polymer may include homopolymers or co-polymers of one or more acrylate monomer such as C1 to C10 esters of acrylic acid. Non-limiting examples acrylate monomer may include such as butyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, ethyl (meth)acrylate, methyl (meth)acrylate, n-propyl (meth)acrylate, isopropyl (meth)acrylate, t-butyl (meth)acrylate, pentyl (meth)acrylate, n-octyl (meth)acrylate, isooctyl (meth)acrylate, isononyl (meth)acrylate and 2-ethylbutyl (meth)acrylate. In some embodiments, acrylic polymer may be a copolymer of an acrylate monomer and other monomers, such as ethylene.

[0054] In some embodiments, the pressure sensitive adhesive composition is in the form of a film. The adhesive layer 220b may be substantially free of UV additives. In other embodiments, the adhesive layer 220b may be completely free of UV additives.

[0055] The adhesive layer 220b may be formed from a pressure sensitive adhesive composition and have a thickness t_{3b} ranging from about 10 μm to about 40 μm – including all values and

sub-ranges there-between. The adhesive layer 220b may be formed from a pressure sensitive adhesive composition and have a thickness t_{3b} ranging from about 20 μm to about 30 μm – including all values and sub-ranges there-between. The adhesive layer 220b may be formed from a pressure sensitive adhesive composition and have a thickness t_{3b} of about 25 μm .

[0056] The first polymeric layer 240b may have a thickness t_{3b} ranging from about 35 μm to about 90 μm – including all values and sub-ranges there-between. The first polymeric layer 240b may have a thickness t_{3b} of from about 20 μm to about 75 μm – including all values and sub-ranges there-between. The first polymeric layer 240b may have a thickness t_{3b} of from about 25 μm to about 65 μm – including all values and sub-ranges there-between. The first polymeric layer 240b may have a thickness t_{3b} of from about 35 μm to about 60 μm – including all values and sub-ranges there-between. The first polymeric layer 240b may have a thickness t_{3b} of from about 45 μm to about 55 μm – including all values and sub-ranges there-between. The first polymeric layer 240b may have a thickness t_{3b} of about 50 μm . The first polymeric layer 240b may have a thickness t_{3b} of about 51 μm . The first polymeric layer 240b may have a thickness t_{3b} of about 50.8 μm .

[0057] The adhesive layer 220b may comprise from about 20 wt.% to about 40 wt.% of the anti-fog complex 300b – including all values and sub-ranges there-between. The adhesive layer 220b may comprise from about 25 wt.% to about 35 wt.% of the anti-fog complex 300b – including all values and sub-ranges there-between. The adhesive layer 220b may comprise about 29 wt.% of the anti-fog complex 300b. According to the embodiments of Figure 3, the adhesive layer 220b may comprises 30 wt.% of the anti-fog complex 300b.

[0058] The first polymeric layer 240b may comprise from about 50 wt.% to about 70 wt.% of the anti-fog complex 300b – including all values and sub-ranges there-between. The first polymeric layer 240b may comprise from about 55 wt.% to about 65 wt.% of the anti-fog complex 300b – including all values and sub-ranges there-between. The first polymeric layer 240b may comprise about 57 wt.% to about 59 wt. % of the anti-fog complex 300b. The first polymeric layer 240b may comprise about 58 wt.% of the anti-fog complex 300b.

[0059] The second polymeric layer 260b may comprise from about 8 wt.% to about 16 wt.% of the anti-fog complex 300b – including all values and sub-ranges there-between. The second polymeric 260b layer may comprise from about 10 wt.% to about 14 wt.% of the anti-fog

complex 300b – including all values and sub-ranges there-between. The second polymeric layer 260b may comprise about 12 wt.% to about 13 wt. % of the anti-fog complex 300b.

[0060] Referring now to Figure 3, the present invention may be a multi-layer film 200b having an upper surface 202b opposite a lower surface 203b. The multi-layer film 200b may comprise a top protective layer 280b, the anti-fog complex 300b, and, optionally, a bottom protective layer 290b, wherein the anti-fog complex 300b includes the adhesive layer 220b formed from the pressure sensitive adhesive composition, as previously discussed. Specifically, the multi-layer film 200b comprises a top protective layer 280b positioned atop the second polymeric layer 260b, the second polymeric layer 260b being positioned atop the first polymeric layer 240b, the first polymeric layer 240b being positioned atop the bottom protective layer 290b.

[0061] The top protective layer 280b may comprise an upper surface 282b opposite a lower surface 283b. The top protective layer 280b may have a thickness t_{6b} as measured from the upper surface 282b to the lower surface 283b of the top protective layer 280b. The thickness t_{6b} of the top protective layer 280b may range from about 10 μm to about 38 μm – including all values and sub-ranges there-between. The top protective layer 280b may comprise a polymer such as polyethylene terephthalate. The upper surface 202b of the multi-layer film 200b may comprise the upper surface 282b of the top protective layer 280b.

[0062] The bottom protective layer 290b may comprise an upper surface 292b opposite a lower surface 293b. The bottom protective layer 290b may have a thickness t_{9b} as measured from the upper surface 292b to the lower surface 293b of the bottom protective layer 290. The thickness t_{9b} of the bottom protective layer 290b may range from about 10 μm to about 38 μm – including all values and sub-ranges there-between. The bottom protective layer 290b may comprise a polymer such as polyethylene terephthalate. The lower surface 203b of the multi-layer film 200b may comprise the lower surface 293b of the bottom protective layer 290b.

[0063] The anti-fog complex 300b may comprise about 60 to about 70 wt. % of the multi-layer film 200b. The top protective layer 280b and the bottom protective layer 290b may each comprise about 15 wt. % to about 20 wt. % of the multi-layer film 200b.

[0064] The multi-layer film 200b may have a thickness t_{7b} that is calculated as follows:

$$t_{7b} = t_{3b} + t_{4b} + t_{5b} + t_{6b} + t_{9b}$$

[0065] The multi-layer film 200b may have the following layer organization: the lower surface 283 of the top protective layer 280 may contact the upper surface 262 of the second polymeric

layer 260, the lower surface 263 of the second polymeric layer 260 may contact the upper surface 242 of the first polymeric layer 240, the lower surface 243 of the first polymeric layer 240 may contact the upper surface 222 of the adhesive layer 220, and the lower surface 223 of the adhesive layer 220 may contact the upper surface 292 of the bottom protective layer 290.

[0066] During application, the bottom protective layer 290 may be removed, thereby exposing the lower surface 303 of the anti-fog complex 300, which is then brought in contact with the upper surface 102 of a reflective substrate 100. Specifically, removing the bottom protective layer 290 exposes the lower surface 223 of the adhesive layer 200, which may then be contacted with the upper surface 102 of the reflective substrate 100 such that the lower surface 303 of the anti-fog complex 300 is adhesively bonded (by the adhesive layer 220) to the upper surface 102 of the reflective substrate 100. Before or during application of the lower surface 303 of the anti-fog complex 300 onto the upper surface 102 of the reflective substrate 100, the adhesive layer 220 may be heated (e.g., by heated roller) to a temperature ranging from about 48 °C to about 60 °C to help facilitate the application of the pressure sensitive adhesive composition of the adhesive layer 220 onto the reflective substrate 100. Specifically, by using the addition of heat from the heated roller at a temperature ranging from about 48 °C to about 60 °C, the resulting anti-fog complex 300b (which uses the pressure sensitive based adhesive layer 220) results in superior optical properties that include the anti-fog complex 300b being substantially clear (i.e. “optically clear”), thereby providing a superior mirror 80.

[0067] After application, downward pressure may be applied to the upper surface 283 of the top protective layer 280. The top protective layer 280 may then be removed, thereby exposing the top surface 302 of the anti-fog complex 300 and the top surface 262b of the second polymeric layer 260 to the surrounding environment. The exposed upper surface 302b of the anti-fog complex 300 may then be cleaned by a post-lamination cleaning cycle, described further herein..

[0068] Other embodiments provide a method of manufacturing a mirror including an adhesive layer formed from the thermally-activated adhesive composition comprising: a) providing a reflective substrate and a multi-layer film, the multi-layer film comprising a top protective layer atop an anti-fog complex, the anti-fog complex comprising: a first polymeric layer; an adhesive layer; a second polymeric layer; b) laminating the multi-layer film and the reflective substrate together to form a laminated composite; c) maintaining the laminated composite in ambient conditions for a time sufficient to permit solidification of the multi-layer film; d) removing the

top protective layer from the laminated composite to expose the anti-fog complex; and e) performing a post-lamination cleaning cycle.

[0069] Referring now generally to the present invention, the post-lamination cleaning phase comprises a first cleaning step and a second cleaning step. In some embodiments, the second cleaning step is performed within 24 hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed at least 24 hours after the first cleaning step is completed.

[0070] In some embodiments, the second cleaning step is performed 30 minutes after completion of the first cleaning step. In some embodiments, the second cleaning step is performed one hour after completion of the first cleaning step. In some embodiments, the second cleaning step is performed two hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed four hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed 8 hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed twelve hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed eighteen hours after completion of the first cleaning step.

[0071] In some embodiments, the second cleaning step is performed from about 30 minutes to 24 hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed from about 1 hour to 18 hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed from about 2 hours to 12 hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed from about 4 hours to 10 hours after completion of the first cleaning step. In some embodiments, the second cleaning step is performed from about 6 hours to 8 hours after completion of the first cleaning step.

[0072] In some embodiments, exposure of the reflective surface covering to an environment having a relative humidity of greater than about 60% causes leaching or blooming of certain elements to the surface of the reflective surface covering, resulting in a white haze on that surface. Conventional methods of preparing reflective surface coverings have, heretofore, not been able to eliminate formation of this white haze.

[0073] In some embodiments, the anti-fog complex may be referred to as an anti-fog matrix. In those embodiments wherein the anti-fog complex is referred to as an anti-fog matrix, it is

believed that one or more components of the anti-fog matrix releases one or more elements which present on the top surface of the reflective surface covering, under certain environmental conditions. In some embodiments, it is believed that these elements reach the top surface by permeating through the first polymeric layer. In other embodiments, it is believed that the presentation of these elements on the top surface is the result of a chemical reaction between an element of the second polymeric layer and an environmental constituent, which causes the element to emanate from the first polymeric layer.

[0074] In some embodiments, the first cleaning step comprises applying an alcohol based composition to the anti-fog complex. In some embodiments, the alcohol based composition is manually applied to the anti-fog complex. In some embodiments, the alcohol based composition is applied to the anti-fog complex using a roller. In some embodiments, the alcohol based composition is applied to the anti-fog complex using a paint roller.

[0075] In some embodiments, the first cleaning step further comprises removing the alcohol based composition from the anti-fog complex. In some embodiments, the first cleaning step further comprises removing the alcohol based composition from the anti-fog complex using a towel. In some embodiments, the towel comprises a natural fiber. In some embodiments, the towel is a cloth towel.

[0076] In some embodiments, the first cleaning step further comprises applying an alkaline solution to the anti-fog complex. In some embodiments, the alkaline solution is an ammonia based solution. In some embodiments, the alkaline solution is manually applied to the anti-fog complex. In some embodiments, the first cleaning step further comprises removing the alkaline solution from the anti-fog complex. In some embodiments, the alkaline solution is removed from the anti-fog complex using a cellulosic substrate. In some embodiments, the cellulosic substrate is a paper towel.

[0077] In some embodiments, the second cleaning step comprises applying an alcohol based composition to the anti-fog complex. In some embodiments, the second cleaning step further comprises removing the alcohol based composition from the anti-fog complex. In some embodiments, the second cleaning step further comprises removing the alcohol based composition from the anti-fog complex using a towel. In some embodiments, the towel comprises a natural fiber. In some embodiments, the towel is a cloth towel.

[0078] In some embodiments, the second cleaning step further comprises applying an alkaline solution to the anti-fog complex. In some embodiments, the alkaline solution is an ammonia based solution. In some embodiments, the alkaline solution is manually applied to the anti-fog complex. In some embodiments, the second cleaning step further comprises removing the alkaline solution from the anti-fog complex. In some embodiments, the alkaline solution is removed from the anti-fog complex using a cellulosic substrate. In some embodiments, the cellulosic substrate is a paper towel.

[0079] In some embodiments, the first cleaning step and/or the second cleaning step are automated.

[0080] In some embodiments, the step of laminating the multi-layer film and the reflective substrate together to form a laminated composite is performed in a cleanroom. As used herein, the term “clean room” is intended to refer to an environment having an ISO 14644-1 cleanroom standard of between ISO 1 and ISO 8.

[0081] In some embodiments, the laminated composite is maintained in an ambient environment for from about 48 to about 72 hours. In some embodiments, the laminated composite is maintained in an ambient environment for about 48 hours. In some embodiments, the laminated composite is maintained in an ambient environment for about 72 hours. In some embodiments, the laminated composite is maintained in an ambient environment for at least 84 hours. In some embodiments, the laminated composite is maintained in an ambient environment for at least 96 hours.

[0082] In some embodiments, the reflective substrate and the multi-layer film are laminated together using a hot roll laminator. In some embodiments, the reflective substrate and the multi-layer film are laminated together in a cleanroom. In some embodiments, the hot roll laminator has a run speed of between about 1 foot/minute and about 10 feet/minute. In some embodiments, the hot roll laminator has a run speed of between about 2 feet/minute and about 9 feet/minute. In some embodiments, the hot roll laminator has a run speed of between about 3 feet/minute and about 8 feet/minute. In some embodiments, the hot roll laminator has a run speed of between about 4 feet/minute and about 7 feet/minute. In some embodiments, the hot roll laminator has a run speed of between about 4 feet/minute and about 6 feet/minute. In other embodiments, the hot roll laminator has a run speed of about 3 feet/minute. In other embodiments, the hot roll

laminator has a run speed of about 4 feet/minute. In other embodiments, the hot roll laminator has a run speed of about 5 feet/minute.

[0083] In some embodiments, the reflective substrate is inspected for defects prior to laminating the multi-layer film and the reflective substrate together.

[0084] In some embodiments, the multi-layer film and the reflective substrate are laminated together at a pressure of from about 10 pounds per square inch (psi) to about 40 psi. In some embodiments, the multi-layer film and the reflective substrate are laminated together at a pressure of from about 15 psi to about 35 psi. In some embodiments, the multi-layer film and the reflective substrate are laminated together at a pressure of from about 20 psi to about 30 psi. In some embodiments, the multi-layer film and the reflective substrate are laminated together at a pressure of about 25 psi.

[0085] In some embodiments, the multi-layer film is maintained at a tension of from about 15 pounds to about 30 pounds during the laminating step. In other embodiments, the multi-layer film is maintained at a tension of from about 20 pounds to about 25 pounds during the laminating step.

[0086] In some embodiments, the hot roll laminator is maintained at a temperature of from about 105 °C to about 130 °C during the laminating step. In some embodiments, the hot roll laminator is maintained at a temperature of from about 110 °C to about 125 °C during the laminating step. In some embodiments, the hot roll laminator is maintained at a temperature of from about 115 °C to about 120 °C during the laminating step.

[0087] Referring now generally to the present invention, the mirror 80 has a scratch/dig ratio between 120/80 and 10/5. In some embodiments, the mirror 80 has a scratch/dig ratio between 80/50 and 20/10. In some embodiments, the mirror 80 has a scratch/dig ratio between 60/40 and 40/20. The mirror 80 may have a Yellow Index Rating of greater than 3. In other embodiments, the mirror 80 of the present invention has a Yellow Index Rating of greater than or equal to 4.

[0088] In some embodiments, the reflective surface has a visible light reflectance of greater than 75%. In some embodiments, the reflective surface has a visible light reflectance of greater than 80%. In some embodiments, the reflective surface has a visible light reflectance of greater than 85%. In some embodiments, the reflective surface has a visible light reflectance of greater than 90%. In some embodiments, the reflective surface has a visible light reflectance of greater than 95%. In some embodiments, the reflective surface has a visible light reflectance of greater than

97.5%. In some embodiments, the reflective surface has a visible light reflectance of greater than 98%. In some embodiments, the reflective surface has a visible light reflectance of greater than 99%.

[0089] In some embodiments, each layer of the multi-layer film has a particular arrangement. In some embodiments, the first polymeric layer is positioned between the adhesive layer and the second polymeric layer. In those embodiments wherein the multi-layer film further comprises a protective layer, the protective layer is adjacent to the second polymeric layer. In some embodiments wherein the multi-layer film further comprises a protective layer, there are no intervening layers between the protective layer and the second polymeric layer.

[0090] In some embodiments, the second polymeric layer forms the top surface of the multi-layer film. In those embodiments wherein the multi-layer film comprises a protective layer, the protective layer forms the top surface of the multi-layer film.

[0091] In some embodiments, the first polymeric layer is positioned between the adhesive layer and the second polymeric layer, such that there are no intervening layers between the first polymeric layer and the adhesive layer. In some embodiments, the first polymeric layer is positioned between the adhesive layer and the second polymeric layer, such that there are no intervening layers between the first polymeric layer and the second polymeric layer. In some embodiments, the first polymeric layer is positioned between the adhesive layer and the second polymeric layer, such that there are no intervening layers between the first polymeric layer and the second polymeric layer or any intervening layers between the first polymeric layer and the adhesive layer.

[0092] In some embodiments, each layer of the anti-fog complex has a particular arrangement. In some embodiments, the first polymeric layer is positioned between the adhesive layer and the second polymeric layer of the anti-fog complex. In some embodiments, the second polymeric layer forms the top surface of the anti-fog complex. In some embodiments, the anti-fog complex does not contain any intervening layers between the first polymeric layer and the adhesive layer. In some embodiments, the anti-fog complex does not contain any intervening layers between the first polymeric layer and the second polymeric layer. In some embodiments, the anti-fog complex does not contain any intervening layers between the first polymeric layer and the second polymeric layer or any intervening layers between the first polymeric layer and the adhesive layer.

[0093] The invention will be described in greater detail by way of specific examples. The following examples are offered for illustrative purposes and are not intended to limit the invention in any manner. Those skilled in the art will readily recognize a variety of noncritical parameters, which can be changed or modified to yield essentially the same results.

EXAMPLES

Example 1

[0094] Table 1 (below) describes the results of evaluations performed on exemplary reflective surface coverings of the present invention and comparative surface coverings. All surface coverings are evaluated for discoloration, quality of lamination and functionality; and an aggregate pass/fail rating is assigned. A surface covering which does not meet the standard for discoloration, quality of lamination or functionality receives a “Fail” rating.

[0095] Discoloration (e.g. yellowing of the product) and quality of lamination are assessed by visual inspection; and functionality is assessed by visible light reflectance.

Table 1

Example	Thickness (μm)		Adhesive	Pass/Fail
	Adhesive	PET		
Ex. I	152.4	101.6	A*	Pass
Ex. II	152.4	101.6	A	Pass
Comp. Ex. I	152.4	50.8	A	Fail
Comp. Ex. II	152.4	50.8	B**	Fail
Comp. Ex. III	152.4	101.6	B	Fail
Comp. Ex. IV	177.8	50.8	A	Fail
Comp. Ex. V	177.8	101.6	B	Fail
Comp. Ex. VI	152.4	50.8	A	Fail
Comp. Ex. VII	152.4	50.8	A	Fail
Comp. Ex. VIII	152.4	101.6	C***	Fail
Comp. Ex. IX	88.9	101.6	B	Fail
Comp. Ex. X	63.5	101.6	B	Fail
Comp. Ex. XI	114.3	101.6	B	Fail
Comp. Ex. XII	38.1	101.6	B	Fail

* Thermally activated adhesive

** Hot melt adhesive

*** Adhesive + UV additive

[0096] The results described in Table 1 (above) demonstrate that exemplary reflective surface coverings of the present invention meet the quality standards for discoloration, quality of lamination and functionality, while the comparative reflective surface coverings fail to meet at least one of these quality standards.

Example 2

[0097] Reflective surface coverings prepared according to exemplary methods of the present invention and reflective surface coverings prepared in accordance with comparative methods are evaluated. The exemplary methods of the present invention included first and second cleaning steps, while the comparative methods did not. The surface coverings are visually inspected for the presence of white haze on the top surface. Remarkably, reflective surface coverings prepared by comparative methods possess a white haze on the top surface; whereas reflective surface coverings prepared in accordance with exemplary methods of the present invention are free of white haze.

[0098] It is intended that any patents, patent applications or printed publications, including books, mentioned in this patent document be hereby incorporated by reference in their entirety.

[0099] As those skilled in the art will appreciate, numerous changes and modifications may be made to the embodiments described herein, without departing from the spirit of the invention. It is intended that all such variations fall within the scope of the invention.

CLAIMS

1. A mirror apparatus comprising:
 - a reflective substrate; and
 - an anti-fog complex coupled to the reflective substrate, the anti-fog complex comprising:
 - a thermally activated adhesive layer atop the reflective substrate;
 - a first polymeric layer comprising a thermoplastic polymer, the first polymeric layer being atop the thermally activated adhesive layer; and
 - a second polymeric layer atop the first polymeric layer;wherein the thickness ratio between the thermally activated adhesive layer and the first polymeric layer is from about 1.25:1 to about 2.75:1.
2. The mirror apparatus according to claim 1, wherein the mirror apparatus has a scratch/dig ratio between 120/80 and 10/5.
3. The mirror apparatus according to claim 1 or claim 2, wherein the anti-fog complex has a thickness of from about 250 μm to about 300 μm .
4. The mirror apparatus according to any foregoing claim, wherein the thermally activated adhesive layer is substantially free of a UV additive.
5. The mirror apparatus according to any foregoing claim, wherein the anti-fog complex is substantially free of a UV additive.
6. The mirror apparatus according to any foregoing claim, wherein the first polymeric layer has a thickness of from about 75 μm to about 125 μm .
7. The mirror apparatus according to any foregoing claim, further comprising a protective layer atop the second polymeric layer.

8. The mirror apparatus according to any foregoing claim, wherein the second polymeric layer comprises a polyurethane.
9. The mirror apparatus according to claim 8, wherein the second polymeric layer further comprises a hydrophilic polymer.
10. The mirror apparatus according to any foregoing claim, having a Yellow Index Rating of greater than 3.
11. The mirror apparatus according to any foregoing claim, having a Yellow Index Rating of greater than or equal to 4.
12. The mirror apparatus according to any foregoing claim, wherein the anti-fog complex is optically clear.
13. The mirror apparatus according to any foregoing claim, having a visible light reflectance of greater than 85%.
14. A mirror apparatus comprising:
 - a reflective substrate; and
 - an anti-fog complex comprising:
 - a pressure sensitive adhesive layer atop the substrate;
 - a first polymeric layer comprising a thermoplastic polymer, the first polymeric layer atop the pressure sensitive adhesive layer; and
 - a second polymeric layer atop the first polymeric layer;wherein the thickness ratio between the pressure sensitive adhesive layer and the first polymeric layer ranges from about 0.25:1 to about 1.25:1.
15. The mirror apparatus according to claim 14, wherein the pressure sensitive adhesive layer has a thickness ranging from about 10 μm to about 40 μm .

16. The mirror apparatus according to claim 14 or claim 15, wherein the second polymeric layer comprises a polyurethane.
17. A method of preparing a mirror apparatus comprising:
 - a) providing a reflective substrate
 - b) providing a multi-layer film comprising:
 - a protective layer; and
 - an anti-fog complex comprising:
 - a first polymeric layer;
 - an adhesive layer; and
 - a second polymeric layer;
 - c) laminating the multi-layer film and the reflective substrate together to form a laminated composite;
 - d) maintaining the laminated composite in an ambient environment for a time sufficient to permit solidification of the multi-layer film;
 - e) removing the protective layer from the laminated composite to expose the anti-fog complex; and
 - f) performing a post-lamination cleaning phase.
18. The method according to claim 17, wherein the post-lamination cleaning phase comprises a first cleaning step and a second cleaning step.
19. The method according to claim 18, wherein the second cleaning step is performed at least 24 hours after completion of the first cleaning step.
20. The method according to claim 18, wherein the second cleaning step is performed from about 30 minutes to about 24 hours after completion of the first cleaning step.
21. The method according to any one of claims 18 to 20, wherein the first cleaning step comprises applying an alcohol based composition to the anti-fog complex.

22. The method according to any one of claims 18 to 21, wherein the first cleaning step further comprises removing the alcohol based composition from the anti-fog complex.
23. The method according to claim 21 or claim 22, wherein the first cleaning step further comprises applying an alkaline solution to the anti-fog complex.
24. The method according to claim 23, wherein the first cleaning step further comprises removing the alkaline solution from the anti-fog complex.
25. The method according to any one of claims 18 to 24, wherein the second cleaning step comprises applying an alcohol based composition to the anti-fog complex.
26. The method according to claim 25, wherein the second cleaning step further comprises removing the alcohol based composition from the anti-fog complex.
27. The method according to claim 25 or claim 26, wherein the second cleaning step further comprises applying an alkaline solution to the anti-fog complex.
28. The method according to claim 27, wherein the second cleaning step further comprises removing the alkaline solution from the anti-fog complex.
29. The method according to any one of claims 17 to 28, wherein the laminated composite is maintained in an ambient environment for from about 48 to about 72 hours.
30. The method according to any one of claims 17 to 29, wherein the reflective substrate and the multi-layer film are laminated together using a hot roll laminator.
31. The method according to any one of claims 17 to 30, wherein the reflective substrate and the multi-layer film are laminated together to form a laminated composite in a cleanroom.

32. The method according to any one of claims 17 to 31, wherein the reflective substrate is inspected for defects prior to laminating the multi-layer film and the reflective substrate together to form a laminated composite.
33. The method according to any one of claims 30 to 32, wherein the hot roll laminator has a run speed of from about 1 foot/minute to about 10 feet/minute.
34. The method according to any one of claims 30 to 33, wherein the hot roll laminator has a run speed of about 3 feet/minute.
35. The method according to any one of claims 30 to 34, wherein the hot roll laminator has a run speed of about 5 feet/minute.
36. The method according to any one of claims 17 to 35, wherein the multi-layer film and the reflective substrate are laminated together to form a laminated composite at a pressure of from about 10 psi to about 40 psi.
37. The method according to any one of claims 17 to 36, wherein the multi-layer film and the reflective substrate are laminated together to form a laminated composite at a pressure of from about 20 psi to about 30 psi.
38. The method according to any one of claims 17 to 37, wherein the multi-layer film and the reflective substrate are laminated together to form a laminated composite at a pressure of about 25 psi.
39. The method according to any one of claims 17 to 38, wherein the multi-layer film is maintained at a tension of from about 15 pounds to about 30 pounds during the laminating step.

40. The method according to any one of claims 17 to 39, wherein the multi-layer film is maintained at a tension of from about 20 pounds to about 25 pounds during the laminating step.
41. The method according to any one of claims 30 to 40, wherein the hot roll laminator is maintained at a temperature of from about 105 °C to about 130 °C during the laminating step.
42. The method according to any one of claims 30 to 41, wherein the hot roll laminator is maintained at a temperature of from about 110 °C to about 125 °C during the laminating step.

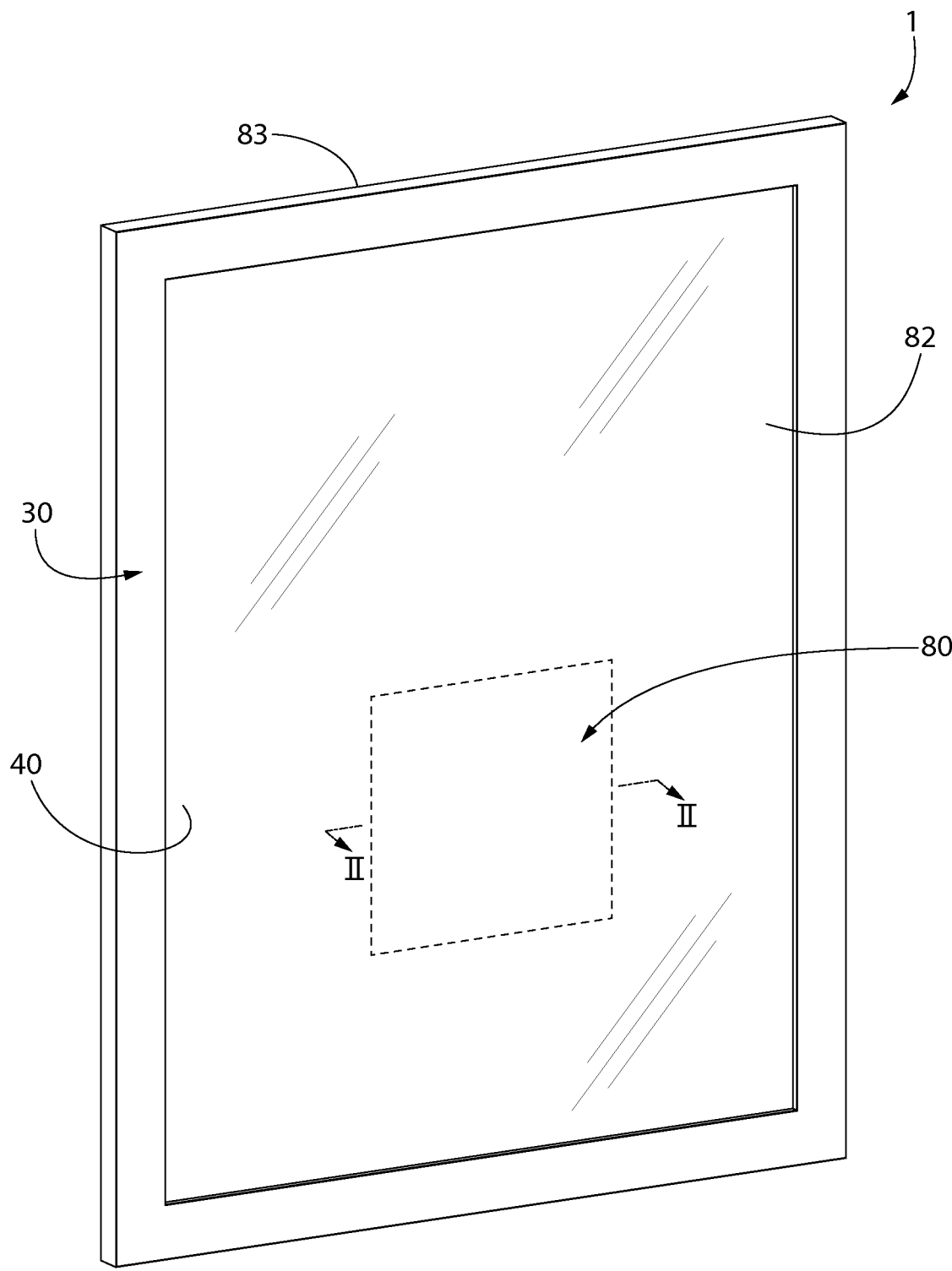


FIG. 1

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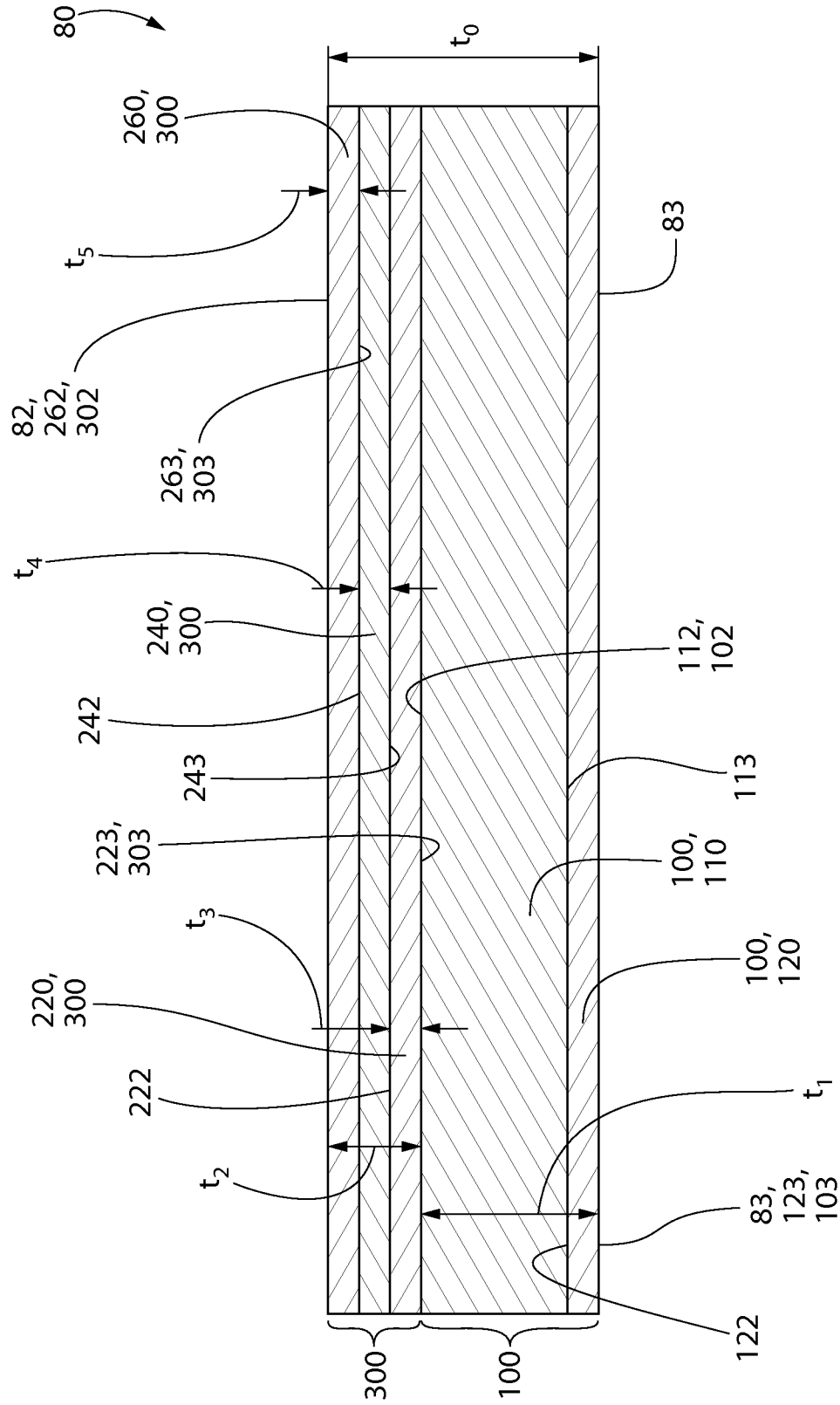


FIG. 1A

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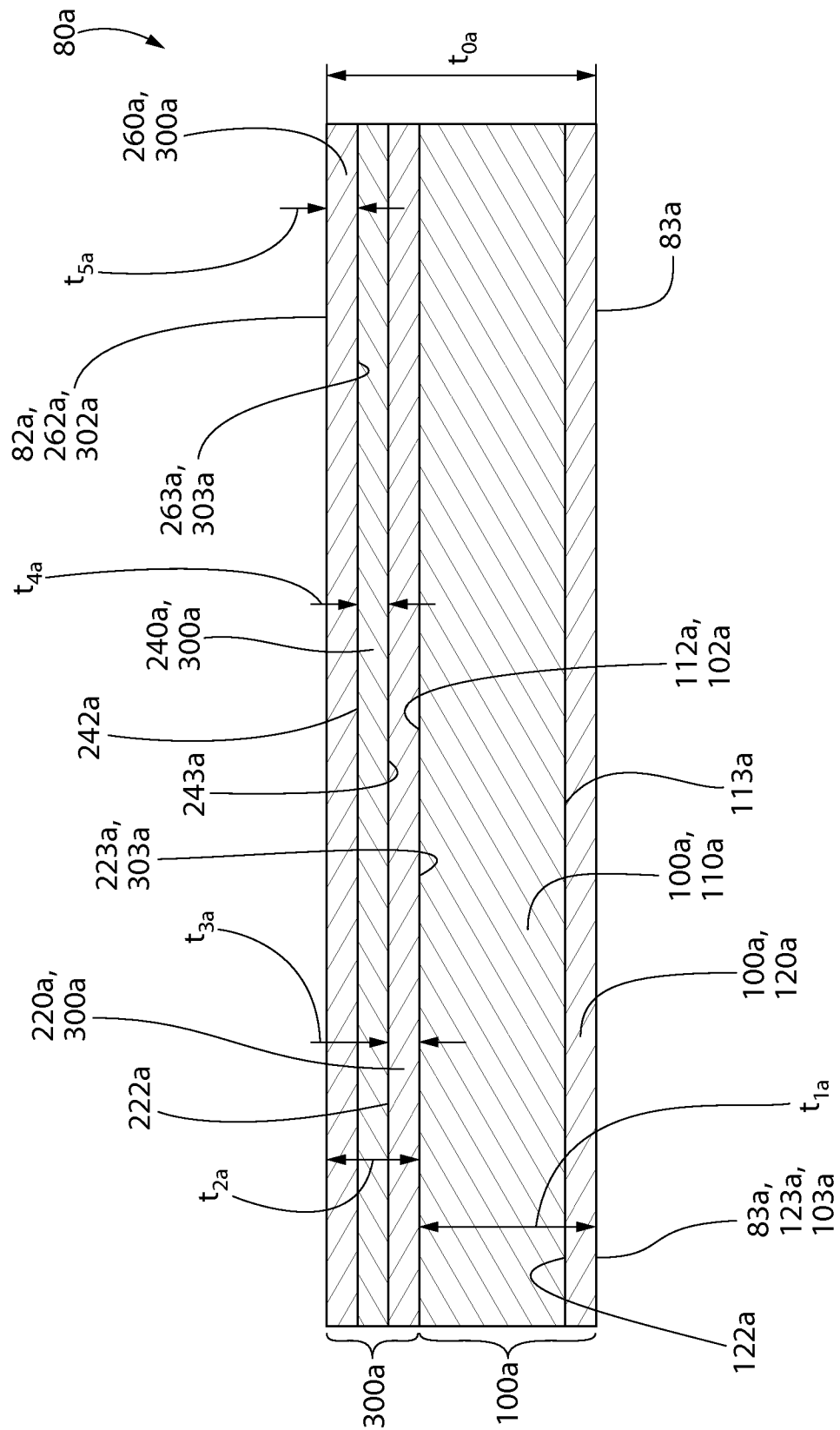


FIG. 2

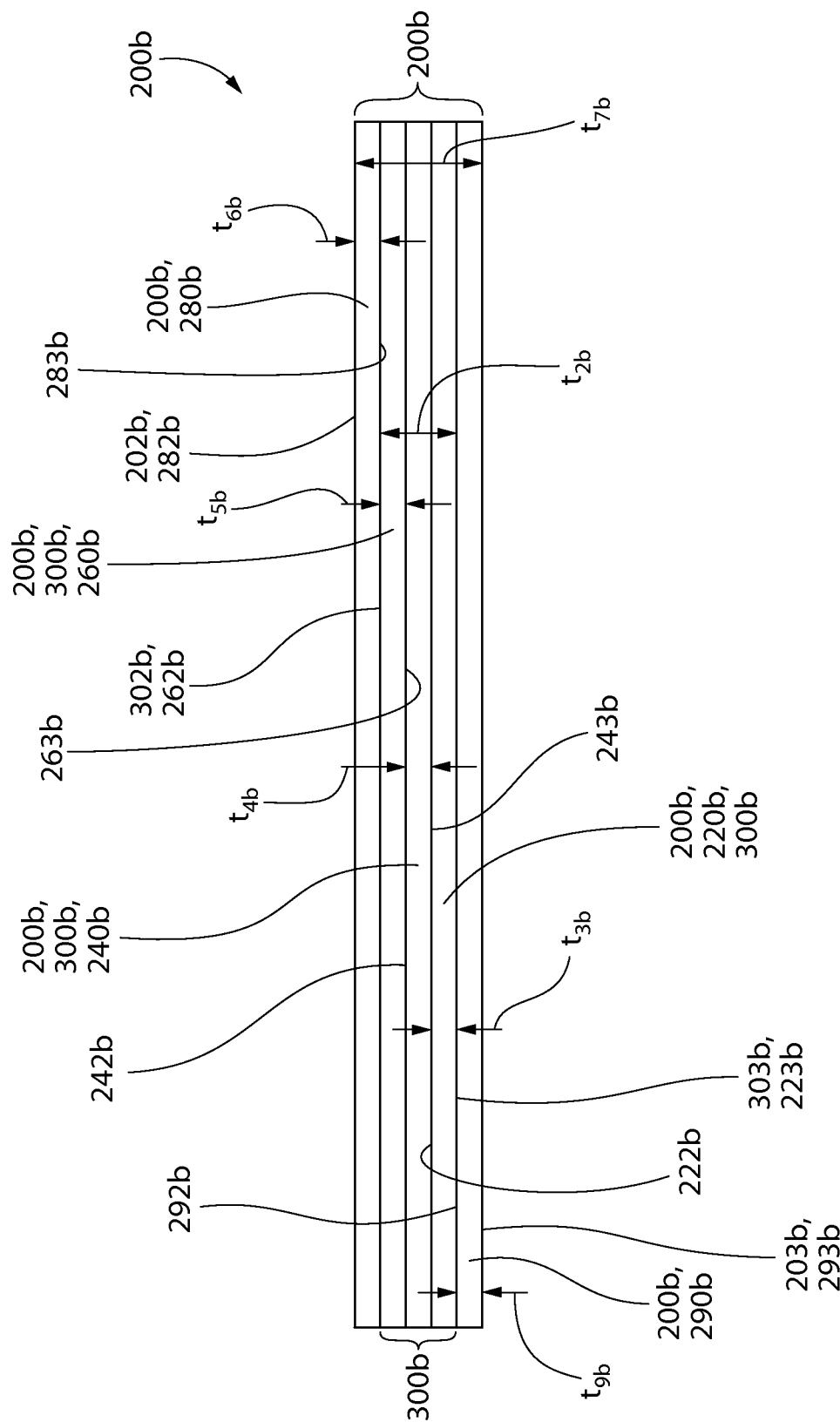


FIG. 3

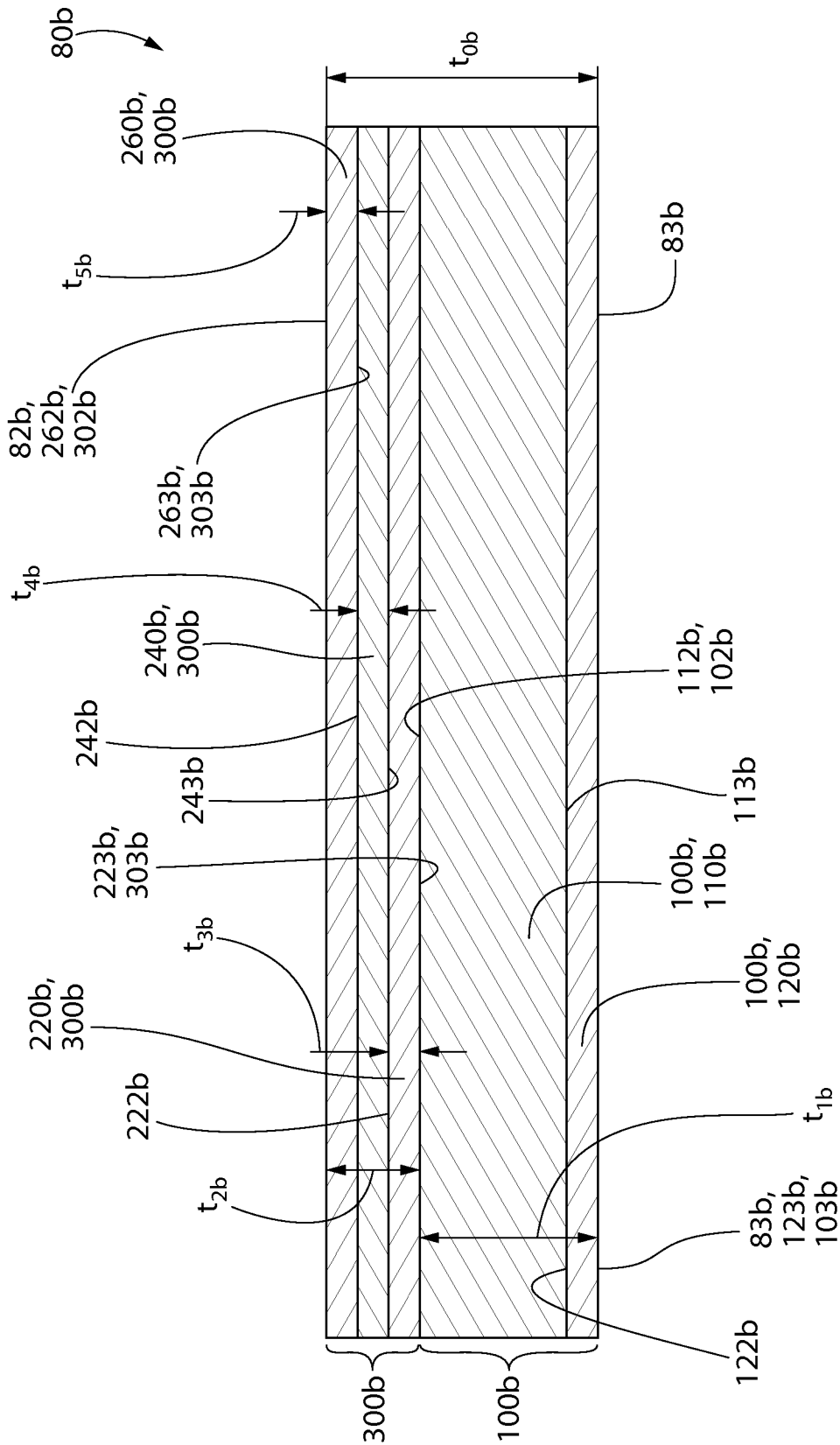


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2015/058582

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G02B 5/08 (2015.01)

CPC - G02B 5/0808 (2015.12)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A45D 42/00, 42/08; A47G 1/00, 1/02; G02B 5/08 (2015.01)

CPC - A45D 42/00, 42/08; A47G 1/00, 1/02; G02B 5/08, 5/0808 (2015.12)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 359/507, 512; IPC(8) - A45D 42/00, 42/08; A47G 1/00, 1/02; G02B 5/08; CPC - A45D 42/00, 42/08; A47G 1/00, 1/02; G02B 5/08, 5/0808 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar.

Search terms used: anti, fog, reflective, mirror, coating, laminate, polymer, thermoplastic.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0187728 A1 (BOROWIEC et al) 07 August 2008 (07.08.2008) entire document	1, 3, 14-16
A	US 6,455,142 B1 (HEBERGER et al) 24 September 2002 (24.09.2002) entire document	1-3, 14-21
A	US 5,402,265 A (JAHODA et al) 28 March 1995 (28.03.1995) entire document	1-3, 14-21

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14 December 2015

Date of mailing of the international search report

27 JAN 2016

Name and mailing address of the ISA/

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Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2015/058582

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-13, 22-42
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.