strength of the glass pharmaceutical package resulting in an increased likelihood that cracks will develop in the glass, potentially compromising the sterility of the pharmaceutical contained in the package or causing the complete failure of the package.

[0006] One approach to improving the mechanical durability of the glass package is to thermally and/or chemically temper the glass package. Thermal tempering strengthens glass by inducing a surface compressive stress during rapid cooling after forming. This technique works well for glass articles with flat geometries (such as windows), glass articles with thicknesses greater than about 2 mm, and glass compositions with high thermal expansion. However, pharmaceutical glass packages typically have complex geometries (vial, tubular, ampoule, etc.), thin walls (sometimes between about 1-1.5 mm), and are produced from low expansion glasses, making glass pharmaceutical packages unsuitable for strengthening by thermal tempering. Chemical tempering also strengthens glass by the introduction of surface compressive stress. The stress is introduced by submerging the article in a molten salt bath. As ions from the glass are replaced by larger ions from the molten salt, a compressive stress is induced in the surface of the glass. The advantage of chemical tempering is that it can be used on complex geometries, thin samples, and is relatively insensitive to the thermal expansion characteristics of the glass substrate.

[0007] However, while the aforementioned tempering techniques improve the ability of the strengthened glass to withstand blunt impacts, these techniques are less effective in improving the resistance of the glass to abrasions, such as scratches, which may occur during manufacturing, shipping and handling.

[0008] Accordingly, a need exists for alternative glass articles which have improved resistance to mechanical damage.

SUMMARY

[0008a] In one aspect, the present invention provides a coated glass article comprising: a glass container comprising a first surface and a second surface opposite the first surface, wherein the first surface is an exterior surface of the glass container; a low-friction coating positioned on at least a portion of the first surface of the glass container, the low-friction coating comprising a polymer chemical composition, the low-friction coating having a thickness of less than or equal to 1 micron and a coefficient of friction of less than or equal to

0.7 relative to a like coated glass article, wherein: the polymer chemical composition is selected from the group consisting of polyimides, polybenzimidazoles, polysulfones, polyetheretherketones, polyetherimides, polyamides, polyphenyls, polybenzothiazoles, polybenzoxazoles, polybisthiazoles, polyaromatic heterocyclic polymers, fluoropolymers, silsesquioxane-based polymers, and silicone resins; the coated glass article is thermally stable after depyrogenation at a temperature of at least 280°C for 30 minutes in air; a light transmission through the coated glass article is greater than or equal to 55% of a light transmission through an uncoated glass article for wavelengths from 400 nm to 700 nm; the low-friction coating has a mass loss of less than 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of 10°C/minute; and the low-friction coating has a mass loss of less than 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of 10°C/minute; and the coated glass article is a pharmaceutical package.

[0009] ~~According to~~In one ~~embodiment~~example, a coated glass article may include a glass body comprising a first surface and a low-friction coating positioned on at least a portion of the first surface of the glass body, the low-friction coating comprising a polymer chemical composition. The coated glass article may be thermally stable at a temperature of at least

about 260°C for 30 minutes. A light transmission through the coated glass article may be greater than or equal to about 55% of a light transmission through an uncoated glass article for wavelengths from about 400 nm to about 700 nm. The low-friction coating may have a mass loss of less than about 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of about 10°C/minute.

[0009a] In another aspect, the present invention provides a coated glass article comprising: a glass container comprising an exterior surface; and a low-friction coating positioned on at least a portion of the exterior surface of the glass container and having a coefficient of friction of less than or equal to 0.7 relative to a like coated glass article, the low-friction coating comprising: a coupling agent layer positioned on the exterior surface of the glass container, the coupling agent layer comprising a coupling agent, the coupling agent comprising at least one of: a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition; and a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition; and a polymer layer positioned over the coupling agent layer, the polymer layer comprising a polyimide chemical composition, wherein: the first silane chemical composition and the second silane chemical composition are different chemical compositions; the coated glass article is thermally stable after depyrogenation at a temperature of at least 280°C for 30 minutes in air; a light transmission through the coated glass article is greater than or equal to 55% of a light transmission through an uncoated glass article for wavelengths from 400 nm to 700 nm; and the coated glass article is a pharmaceutical package.

[0010] In another ~~embodiment~~example, a coated glass article may include a glass body comprising an exterior surface and a low-friction coating positioned on at least a portion of the exterior surface, the low-friction coating comprising a polymer chemical composition. A coefficient of friction of an abraded area of the portion of the exterior surface with the low-friction coating may be less than 0.7 after exposure to an elevated temperature of 280°C for 30 minutes and abrasion under a 30 N load and does not have observable damage. A retained strength of the coated glass article in horizontal compression may not decrease by more than about 20% after exposure to an elevated temperature of 280°C for 30 minutes abrasion under a 30 N load.

[0011] In yet another ~~embodiment~~example, a coated glass article may include a glass body having a first surface. A low-friction coating may be positioned on at least a portion of the first surface of the glass body. The low-friction coating may include a polymer chemical composition and a coupling agent comprising at least one of: a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition; and a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition. The first silane chemical composition and the second silane chemical composition may be different chemical compositions. The coated glass article may be thermally stable at a temperature of at least about 260°C for 30 minutes. A light transmission through the coated glass article is greater than or equal to about 55% of a light transmission through an uncoated glass article for wavelengths from about 400 nm to about 700 nm. The low-friction coating may have a mass loss of less than about 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of about 10°C/minute.

[0012] In another ~~embodiment~~example, a coated glass article may include a glass body comprising a first surface and a low-friction coating positioned on at least a portion of the first surface of the glass body. The low-friction coating may include a coupling agent comprising an oligomer of one or more silane chemical compositions. The oligomer may be a silsesquioxane chemical composition and at least one of the silane chemical compositions comprises at least one aromatic moiety and at least one amine moiety. The low friction coating may also include a polyimide chemical composition formed from the polymerization of at least a first diamine monomer chemical composition, a second diamine monomer chemical composition, and a dianhydride monomer chemical composition. The first diamine monomer chemical composition may be different than the second diamine monomer chemical composition.

[0013] In another ~~embodiment~~example, a coated glass article may include a glass body comprising a first surface and a low-friction coating positioned on at least a portion of the first surface. The low-friction coating may include a polymer chemical composition. The coated glass article may be thermally stable at a temperature of at least about 300°C for 30 minutes. A light transmission through the coated glass article may be greater than or equal to about 55% of a light transmission through an uncoated glass article for wavelengths from about 400 nm to about 700 nm.

[0014] In another ~~embodiment~~example, a coated glass article may include a glass body comprising a first surface and a second surface opposite the first surface. The first surface may be an exterior surface of a glass container. A low-friction coating may be bonded to at least a portion of the first surface of the glass body. The low-friction coating may include a polymer chemical composition. The coated glass article may be thermally stable at a temperature of at least about 280°C for 30 minutes. A light transmission through the coated glass article may be greater than or equal to about 55% of a light transmission through an uncoated glass article for wavelengths from about 400 nm to about 700 nm.

[0015] In another ~~embodiment~~ example a coated glass article may include a glass body comprising a first surface and a low-friction coating bonded to at least a portion of the first surface of the glass body. The low-friction coating may include a coupling agent layer positioned on the

first surface of the glass body. The coupling agent layer may include a coupling agent comprising at least one of: a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition; and a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition. A polymer layer may be positioned over the coupling agent layer. The polymer layer may include a polyimide chemical composition. The first silane chemical composition and the second silane chemical composition may be different chemical compositions. The coated glass article may be thermally stable at a temperature of at least about 280°C for 30 minutes. A light transmission through the coated glass article may be greater than or equal to about 55% of a light transmission through an uncoated glass article for wavelengths from about 400 nm to about 700 nm.

[0016] In another ~~embodiment~~example, a coated glass article may include a glass body having a first surface and a low-friction coating bonded to at least a portion of the first surface of the glass body. The low-friction coating may include a coupling agent layer comprising a coupling agent comprising an oligomer of one or more silane chemical compositions. The oligomer may be a silsesquioxane chemical composition and at least one of the silane chemical compositions comprises at least one aromatic moiety and at least one amine moiety. The low friction coating may further comprise a polymer layer comprising a polyimide chemical composition formed from the polymerization of at least a first diamine monomer chemical composition, a second diamine monomer chemical composition, and a dianhydride monomer chemical composition. The first diamine monomer chemical composition may be different than the second diamine monomer chemical composition. The low-friction coating may also include an interface layer comprising one or more chemical compositions of the polymer layer bound with one or more of the chemical compositions of the coupling agent layer.

[0017] In another ~~embodiment~~example, a low-friction coating for a substrate may include a polyimide chemical composition and a coupling agent. The coupling agent may include at least one of: a mixture of a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, and a second silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition may be an aromatic silane chemical

for about 15 min, or any time and temperature sufficient to adequately liberate the water and/or other organic solvents present on the exterior surface 108 of the glass container wall 104.

[0089] Referring to FIG. 2, in one embodiment, the coupling agent is positioned on the glass container as a coupling agent layer 180 and is applied as a solution comprising about 0.5 wt% of a first silane and about 0.5 wt% of a second silane (total 1 wt% silane) mixed with at least one of water and an organic solvent, such as, but not limited to, methanol. However, it should be understood that the total silane concentration in the solution may be more or less than about 1 wt%, such as from about 0.1 wt% to about 10 wt%, from about 0.3 wt% to about 5.0 wt%, or from about 0.5 wt% to about 2.0 wt%. For example, in one embodiment, the weight ratio of organic solvent to water (organic solvent:water) may be from about 90:10 to about 10:90, and, in one embodiment, may be about 75:25. The weight ratio of silane to solvent may affect the thickness of the coupling agent layer, where increased percentages of silane chemical composition in the coupling agent solution may increase the thickness of the coupling agent layer 180. However, it should be understood that other variables may affect the thickness of the coupling agent layer 180 such as, but not limited, the specifics of the dip coating process, such as the withdraw speed from the bath. For example, a faster withdraw speed may form a thinner coupling agent layer 180.

[0090] In another embodiment, the coupling agent layer 180 may be applied as a solution comprising 0.1 vol% of a commercially available aminopropylsilsesquioxane oligomer. Coupling agent layer solutions of other concentrations may be used, including but not limited to, 0.01-10.0 vol% aminopropylsilsesquioxane oligomer solutions.

[0091] As noted herein, the low friction coating also includes a polymer chemical composition. The polymer chemical composition may be a thermally stable polymer or mixture of polymers, such as but not limited to, polyimides, polybenzimidazoles, polysulfones, polyetheretherketones, polyetherimides, polyamides, polyphenyls, polybenzothiazoles, polybenzoxazoles, polybisthiazoles, and polyaromatic heterocyclic polymers with and without organic or inorganic fillers. The polymer chemical composition may be formed from other thermally stable polymers, such as polymers that do not degrade at

CLAIMS

1. A coated glass article comprising:

a glass body comprising a first surface and a second surface opposite the first surface, wherein the first surface is an exterior surface of the glass article; and

a low-friction coating positioned on at least a portion of the first surface of the glass body, the low-friction coating comprising a polymer chemical composition, the low-friction coating having a thickness of less than or equal to about 1 micron and a coefficient of friction of less than or equal to 0.7 relative to a like coated glass article, wherein:

the coated glass article is thermally stable after depyrogenation at a temperature of at least 280°C for 30 minutes in air;

a light transmission through the coated glass article is greater than or equal to 55% of a light transmission through an uncoated glass article for wavelengths from 400 nm to 700 nm;

the low-friction coating has a mass loss of less than 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of 10°C/minute; and

the coated glass article is a pharmaceutical package.

2. The coated glass article of claim 1 wherein the low-friction coating further comprises a coupling agent positioned on the first surface of the glass body and the polymer chemical composition is positioned over the coupling agent.

3. The coated glass article of claim 2, wherein the coupling agent comprises at least one of:

a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof; and

a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition, wherein the first silane chemical composition and the second silane chemical composition are different chemical compositions.

4. The coated glass article of claim 1, wherein the low-friction coating comprises:

a polyimide chemical composition; and

a coupling agent positioned between the polyimide chemical composition and the first surface of the glass body, the coupling agent comprising at least one of:

a mixture of a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, and a second silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition and the second silane chemical composition is an aliphatic silane chemical composition; and

a chemical composition formed from the oligomerization of at least the first silane chemical composition and the second silane chemical composition.

5. A coated glass article comprising:

a glass body comprising a first surface; and

a low-friction coating positioned on at least a portion of the first surface of the glass body and having a coefficient of friction of less than or equal to 0.7 relative to a like coated glass article, the low-friction coating comprising:

a coupling agent layer positioned on the first surface of the glass body, the coupling agent layer comprising a coupling agent, the coupling agent comprising at least one of:

a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition; and

a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition; and

a polymer layer positioned over the coupling agent layer, the polymer layer comprising a polyimide chemical composition, wherein:

the first silane chemical composition and the second silane chemical composition are different chemical compositions;

the coated glass article is thermally stable after depyrogenation at a temperature of at least 280°C for 30 minutes in air;

a light transmission through the coated glass article is greater than or equal to 55% of a light transmission through an uncoated glass article for wavelengths from 400 nm to 700 nm; and

the coated glass article is a pharmaceutical package.

6. The coated glass article of claim 3 or claim 5, wherein the first silane chemical composition is an aromatic alkoxysilane chemical composition comprising at least one amine moiety and the second silane chemical composition is an aliphatic alkoxysilane chemical composition comprising at least one amine moiety.

7. The coated glass article of claim 3 or claim 5, wherein the first silane chemical composition is aminophenyltrimethoxy silane and the second silane chemical composition is 3-aminopropyltrimethoxy silane.

8. The low-friction coating of claim 4 or claim 5, wherein the polyimide chemical composition is formed from the polymerization of:

at least one monomer chemical composition comprising at least two amine moieties; and

at least one monomer chemical composition comprising at least two anhydride moieties and having a benzophenone structure.

9. The low-friction coating of claim 4 or claim 5, wherein the polyimide chemical composition is formed from the polymerization of at least benzophenone-3,3',4,4'-tetracarboxylic dianhydride, ortho-Tolidine, and 4,4'-methylene-bis(2-methylaniline).

10. The coated glass article according to claim 5, wherein the low-friction coating has a mass loss of less than about 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of about 10°C/minute.

CLAIMS

1. A coated glass article comprising:

a glass container comprising a first surface and a second surface opposite the first surface, wherein the first surface is an exterior surface of the glass container;

a low-friction coating positioned on at least a portion of the first surface of the glass container, the low-friction coating comprising a polymer chemical composition, the low-friction coating having a thickness of less than or equal to 1 micron and a coefficient of friction of less than or equal to 0.7 relative to a like coated glass article, wherein:

the polymer chemical composition is selected from the group consisting of polyimides, polybenzimidazoles, polysulfones, polyetheretherketones, polyetherimides, polyamides, polyphenyls, polybenzothiazoles, polybenzoxazoles, polybisthiazoles, polyaromatic heterocyclic polymers, fluoropolymers, silsesquioxane-based polymers, and silicone resins;

the coated glass article is thermally stable after depyrogenation at a temperature of at least 280°C for 30 minutes in air;

a light transmission through the coated glass article is greater than or equal to 55% of a light transmission through an uncoated glass article for wavelengths from 400 nm to 700 nm;

the low-friction coating has a mass loss of less than 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of 10°C/minute; and

the coated glass article is a pharmaceutical package.

2. The coated glass article of claim 1 wherein the low-friction coating further comprises a coupling agent positioned on the first surface of the glass container and the polymer chemical composition is positioned over the coupling agent.

3. The coated glass article of claim 2, wherein the coupling agent comprises at least one of:

a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof; and

a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition, wherein the first silane chemical composition and the second silane chemical composition are different chemical compositions.

4. The coated glass article of claim 1, wherein the low-friction coating comprises:

a polyimide chemical composition; and

a coupling agent positioned between the polyimide chemical composition and the first surface of the glass container, the coupling agent comprising at least one of:

a mixture of a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, and a second silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition and the second silane chemical composition is an aliphatic silane chemical composition; and

a chemical composition formed from the oligomerization of at least the first silane chemical composition and the second silane chemical composition.

5. A coated glass article comprising:

a glass container comprising an exterior surface; and

a low-friction coating positioned on at least a portion of the exterior surface of the glass container and having a coefficient of friction of less than or equal to 0.7 relative to a like coated glass article, the low-friction coating comprising:

a coupling agent layer positioned on the exterior surface of the glass container, the coupling agent layer comprising a coupling agent, the coupling agent comprising at least one of:

a first silane chemical composition, a hydrolysate thereof, or an oligomer thereof, wherein the first silane chemical composition is an aromatic silane chemical composition; and

a chemical composition formed from the oligomerization of at least the first silane chemical composition and a second silane chemical composition; and

a polymer layer positioned over the coupling agent layer, the polymer layer comprising a polyimide chemical composition, wherein:

the first silane chemical composition and the second silane chemical composition are different chemical compositions;

the coated glass article is thermally stable after depyrogenation at a temperature of at least 280°C for 30 minutes in air;

a light transmission through the coated glass article is greater than or equal to 55% of a light transmission through an uncoated glass article for wavelengths from 400 nm to 700 nm; and

the coated glass article is a pharmaceutical package.

6. The coated glass article of claim 3 or claim 5, wherein the first silane chemical composition is an aromatic alkoxysilane chemical composition comprising at least one amine moiety and the second silane chemical composition is an aliphatic alkoxysilane chemical composition comprising at least one amine moiety.

7. The coated glass article of claim 3 or claim 5, wherein the first silane chemical composition is aminophenyltrimethoxy silane and the second silane chemical composition is 3-aminopropyltrimethoxy silane.

8. The low-friction coating of claim 4 or claim 5, wherein the polyimide chemical composition is formed from the polymerization of:

at least one monomer chemical composition comprising at least two amine moieties; and

at least one monomer chemical composition comprising at least two anhydride moieties and having a benzophenone structure.

9. The low-friction coating of claim 4 or claim 5, wherein the polyimide chemical composition is formed from the polymerization of at least benzophenone-3,3',4,4'-tetracarboxylic dianhydride, ortho-Tolidine, and 4,4'-methylene-bis(2-methylaniline).

10. The coated glass article according to claim 5, wherein the low-friction coating has a mass loss of less than 5% of its mass when heated from a temperature of 150°C to 350°C at a ramp rate of 10°C/minute.