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 disclosure refers to a coated pharmaceutical package comprising: a glass body comprising a first surface and a second surface opposite the first surface, wherein the glass body is a glass container formed from a glass composition having a hydrolytic resistance that meets Type I, II or III criteria according to USP 660 or EP 7 and the first surface is an exterior surface of the glass container; 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; and a coupling agent layer disposed between the polymer and the first surface of the glass body, wherein the coefficient of friction of the portion of the coated pharmaceutical package with the low-friction coating is at least 20% less than a coefficient of friction of a surface of an uncoated pharmaceutical package formed from the same glass composition. In another aspect, the present disclosure refers to a coated pharmaceutical package comprising: a glass body comprising a first surface and a second surface opposite the first surface, wherein the glass body is a glass container formed from a glass composition having a hydrolytic resistance that meets Type I, II or III criteria according to USP 660 or EP 7and the first surface is an exterior surface of the glass container; 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 polyimide. In yet another aspect, the present disclosure refers to a pharmaceutical package comprising: a glass body enclosing an interior volume and having an exterior surface, wherein the glass body is formed from a glass composition that meets the Type 1 criteria according to USP <660>; a coupling agent layer having a first thickness less than or equal to 100 nm disposed on the exterior surface of the glass body; and a polymer layer having a second thickness of less than 50 nm positioned over the coupling agent layer, wherein the exterior surface of the glass body with the coupling agent layer and the polymer layer has a coefficient of friction less than or equal to 0.7. In yet another aspect, the present disclosure refers to pharmaceutical package comprising: a glass body having an interior and an exterior surface, wherein the glass body is formed from a glass composition that meets the Type 1 criteria according to USP <660>; a coupling agent layer having a first thickness; and a polymer layer positioned over the coupling agent layer and having a second thickness; wherein the coupling agent layer and the polymer layer together have a total thickness of less than or equal to 200 nm, the first thickness is less than or equal to 100 nm and the exterior surface of the glass body with the coupling agent layer and the polymer layer has a coefficient of friction less than or equal to 0.7.

[0009] According to one 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.

[0010] In another 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 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 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 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 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 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 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 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 composition and the second silane chemical composition may be 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. The coating may be thermally stable at a temperature of at least about 260°C for 30 minutes. A light transmission through the coating may be greater than or equal to about 55%. 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.

[0018] Additional features and advantages of the coated glass articles and methods and processes for manufacturing the same will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the examples described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0019] It is to be understood that both the foregoing general description and the following detailed description describe various examples and are intended to provide an overview or framework for understanding the nature and character of the claimed subject matter. The accompanying drawings are included to provide a further understanding of the various examples, and are incorporated into and constitute a part of this specification. The drawings illustrate the various examples described herein, and together with the description serve to explain the principles and operations of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 schematically depicts a cross section of a glass container with a low-friction coating, according to one or more embodiments shown and described herein;

[0021] FIG. 2 schematically depicts a cross section of a glass container with a low-friction coating comprising a polymer layer and a coupling agent layer, according to one or more embodiments shown and described herein;

[0022] FIG. 3 schematically depicts a cross section of a glass container with a low-friction coating comprising a polymer layer, a coupling agent layer, and an interface layer, according to one or more embodiments shown and described herein,