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 borosilicate 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 borosilicate 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 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 borosilicate glass composition that meets the Type 1 criteria according to USP <660>; and a low friction coating comprising: 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 borosilicate glass composition that meets the Type 1 criteria according to USP <660>; and a low friction coating comprising: 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

CLAIMS

1. 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 borosilicate 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.

2. The coated pharmaceutical package of claim 1, wherein a thickness of the low friction coating is less than or equal to 1 μm.

3. The coated pharmaceutical package of claim 1, wherein a thickness of the low friction coating is less than or equal to 100 nm.

4. The coated pharmaceutical package of claim 1, wherein the coupling agent layer comprises a coupling agent; and

wherein the low-friction coating comprises a polymer layer positioned over the coupling agent layer, the polymer layer comprising the polymer.

5. The coated pharmaceutical package of claim 4, wherein the coupling agent comprises at least one of:

a first silane, a hydrolysate thereof, or an oligomer thereof; or

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

6. The coated pharmaceutical package of claim 5, wherein the first silane is an aromatic silane.

7. The coated pharmaceutical package of claim 1, wherein the coupling agent layer comprises a silsesquioxane comprising an aromatic moiety and an amine moiety.

8. The coated pharmaceutical package of claim 1, wherein the coupling agent layer comprises at least one of:

a mixture of a first silane and a second silane; or

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

9. The coated pharmaceutical package of claim 8, wherein the first silane is an aromatic silane.

10. The coated pharmaceutical package of claim 1, wherein the polymer is a polyimide.

11. The coated pharmaceutical package of claim 1, wherein the coated pharmaceutical package is thermally stable at a temperature of at least about 260°C for 30 minutes.

12. The coated pharmaceutical package of claim 1, wherein the glass body comprises ion-exchanged glass.

13. 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 borosilicate 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 polyimide.

14. A pharmaceutical package comprising:

a glass body enclosing an interior volume and having an exterior surface, wherein the glass body is formed from a borosilicate glass composition that meets the Type 1 criteria according to USP <660>; and

a low friction coating comprising:

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.

15. The pharmaceutical package of claim 14, wherein the first thickness is less than 90 nm.

16. The pharmaceutical package of claim 14, wherein the first thickness is less than 80 nm.

17. The pharmaceutical package of claim 14, wherein the first thickness is less than 70 nm.

18. The pharmaceutical package of claim 14, wherein the first thickness is less than 60 nm.

19. The pharmaceutical package of claim 17, wherein the second thickness is less than 25 nm.

20. The pharmaceutical package of claim 14, wherein the second thickness is less than 25 nm.

21. The pharmaceutical package of claim 14, wherein:

the portion of the exterior surface of the pharmaceutical package with the coupling agent layer and the polymer layer has a coefficient of friction of less than or equal to 0.6 relative to a like-coated glass pharmaceutical package; and

a light transmission through the pharmaceutical package is greater than or equal to about 55% of a light transmission through an uncoated pharmaceutical package for each wavelength from about 400 nm to about 700 nm.

22. The pharmaceutical package as recited in claim 14, wherein a coefficient of friction of the portion of the exterior surface of the pharmaceutical package with the coupling agent layer and the polymer layer is less than or equal to 0.6 after undergoing a depyrogenation cycle at a temperature of from 250°C to 380°C for a time period of from 30 seconds to 72 hours.

23. The pharmaceutical package of claim 22, wherein the depyrogenation cycle comprises heating the pharmaceutical package to a temperature of 250°C for 30 minutes.

24. The pharmaceutical package of claim 22, wherein the depyrogenation cycle comprises heating the pharmaceutical package to a temperature of 300°C for 30 minutes.

25. The pharmaceutical package of claim 22, wherein the depyrogenation cycle comprises heating the pharmaceutical package to a temperature of from about 260°C to about 400°C for a time period of 30 minutes.

26. The pharmaceutical package of claim 14, wherein the polymer layer comprises a polyimide.

27. The pharmaceutical package of claim 14, wherein the coupling agent layer comprises an inorganic material.

28. The pharmaceutical package of claim 14, wherein the coupling agent layer comprises at least one of titanates, zirconates, tin, titanium, tin oxide, or titanium oxide.

29. The pharmaceutical package of claim 14, wherein the coupling agent layer comprises a silane comprising an amine moiety.

30. The pharmaceutical package of claim 14, wherein:

the portion of the exterior surface of the pharmaceutical package with the coupling agent layer and the polymer layer has a coefficient of friction of less than or equal to 0.6, wherein the coefficient of friction is a maximum coefficient of friction measured relative to a second pharmaceutical package in a vial-on-vial testing jig under a normal load of 30 N, the second pharmaceutical package formed from the same glass composition and comprising the coupling agent layer and the polymer layer on at least a portion of a second exterior outer surface of the second pharmaceutical package and subjected to the same environmental conditions prior to measurement of the coefficient of friction; and

the portion of the exterior surface of the pharmaceutical package with the coupling agent layer and the polymer layer contains less than 6 glass checks

per 5mm length when abraded along a length of about 20mm with the second pharmaceutical package in the vial-on-vial testing jig under the normal load of 30 N after exposure of the pharmaceutical package and the second pharmaceutical package to a temperature of at least about 260°C for 30 minutes.

31. The pharmaceutical package of claim 14, wherein a coefficient of friction of the portion of the pharmaceutical package with the coupling agent layer and the polymer layer is at least 20% less than a coefficient of friction of a surface of an uncoated pharmaceutical package formed from the same glass composition.

32. A pharmaceutical package comprising:

a glass body having an interior and an exterior surface, wherein the glass body is formed from a borosilicate glass composition that meets the Type 1 criteria according to USP <660>; and

a low friction coating comprising:

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.

33. The pharmaceutical package of claim 32, wherein the first thickness is 90 nm.

34. The pharmaceutical package of claim 32, wherein the second thickness is less than 50 nm.

35. The pharmaceutical package of claim 32, wherein the portion of the exterior surface of the pharmaceutical package with the coupling agent layer and the polymer layer has a coefficient of friction of less than or equal to 0.6 relative to a like-coated glass pharmaceutical package.