the loss of active drug product leading to increased costs. Further, non-catastrophic breakage (i.e., when the glass cracks but does not break) may cause the contents to lose their sterility which, in turn, may result in costly product recalls.

[0005] One approach to improving the mechanical durability of the glass package is to thermally 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 > 2 mm, and glass compositions with high thermal expansion. However, pharmaceutical glass packages typically have complex geometries (vial, tubular, ampoule, etc.), thin walls (~1-1.5 mm), and are produced from low expansion glasses ($30\text{-}55 \times 10^{-7} K^{-1}$) making glass pharmaceutical packages unsuitable for strengthening by thermal tempering.

[0006] 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. However, glass compositions which exhibit a moderate susceptibility to chemical tempering generally exhibit poor chemical durability and vice-versa.

[0007] Accordingly, a need exists for glass compositions which are chemically durable and susceptible to chemical strengthening by ion exchange for use in glass pharmaceutical packages, and similar applications.

SUMMARY

[0008] In one aspect, the present disclosure provides a glass for pharmaceutical packaging having a glass composition comprising: from 70 mol.% to 80 mol.% SiO_2; from 4 mol.% to 8 mol.% alkaline earth oxide, the alkaline earth oxide comprising MgO and CaO; X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein a concentration of K_2O is from 0.01 mol.% to less than 2 mol.%, Y is 9-15 mol.% and a ratio of Y:X is greater than 1.

[0008a] In another aspect, the present disclosure provides a glass for for pharmaceutical packaging having a glass composition comprising: from 74 mol.% to 80 mol.% SiO_2; alkaline earth oxide comprising MgO and CaO and a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is greater than 0 and less than or equal to 0.5 and the CaO is from 0.1 to 1.0 mol. %; X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein Y is greater than 8 mol.%, a ratio of Y:X is greater than or equal to 1, and a ratio of a concentration of B_2O_3 (mol.%) to (Y mol.%-X mol.%) is less than or equal to 0.3.

[0008b] In yet another aspect, the present disclosure provides a glass for pharmaceutical packaging having a glass composition comprising: from 70 mol.% to 80 mol.% SiO_2; from 4 mol.% to 8 mol.% alkaline earth oxide comprising MgO and CaO and a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is greater than 0 and less than or equal to 0.5; X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein Y is 9-14 mol.%, a ratio of Y:X is greater than or equal to 1 and less than or equal to 2, and a ratio of a concentration of B_2O_3 (mol.%) to (Y mol.%-X mol.%) is less than or equal to 0.3.

[0008c] In a further aspect, the present disclosure provides a glass for pharmaceutical packaging having a glass composition comprising: from 70 mol.% to 80 mol.% SiO_2; alkaline earth oxide comprising MgO and CaO and a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is greater than 0 and less than or equal to 0.5; X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein Y is from 9 mol.% to 15 mol.%.

[0008d] According to one example, a glass composition may include: SiO_2 in a concentration greater than about 70 mol.% and Y mol.% alkali oxide. The alkali oxide may include Na_2O in an amount greater than about 8 mol.%. The glass composition may be free of boron and compounds of boron.

[0009] According to another example, a glass composition may include: greater than about 68 mol.% SiO_2; X mol.% Al_2O_3; Y mol.% alkali oxide; and B_2O_3. The alkali oxide may include Na_2O in an amount greater than about 8 mol%. A ratio (B_2O_3 (mol.%)/(Y mol.% – X mol.%) may be greater than 0 and less than 0.3.

CLAIMS

1. A glass for pharmaceutical packaging having a glass composition comprising:

from 70 mol.% to 80 mol.% SiO_2;

from 4 mol.% to 8 mol.% alkaline earth oxide, the alkaline earth oxide comprising MgO and CaO;

X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and

Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein a concentration of K_2O is from 0.01 mol. % to less than 2 mol.%, Y is 9-15 mol.% and a ratio of Y:X is greater than 1.

2. The glass for pharmaceutical packaging of claim 1, wherein the SiO_2 is present in an amount from 74 mol.% to 78 mol.%.

3. The glass for pharmaceutical packaging of claim 1, wherein the alkaline earth oxide comprises a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is less than or equal to 0.5.

4. The glass for pharmaceutical packaging of claim 1, wherein the alkaline earth oxide comprises from 0.1 mol.% to 1.0 mol.% CaO.

5. The glass for pharmaceutical packaging of claim 1, wherein a ratio of Y:X is less than or equal to 2.

6. The glass for pharmaceutical packaging of claim 5, wherein the alkali oxide comprises Na_2O in an amount greater than 8 mol.%.

7. The glass for pharmaceutical packaging of claim 1, wherein the glass composition is free of boron and compounds of boron.

8. The glass for pharmaceutical packaging of claim 1, wherein the glass is ion exchange strengthened and has a compressive stress layer with a depth of layer greater than or equal to 10 μm and a surface compressive stress greater than or equal to 250 MPa.

9. The glass for pharmaceutical packaging of claim 1, wherein the glass has a type HGB1 hydrolytic resistance according to ISO 719.

10. The glass for pharmaceutical packaging of claim 8, wherein the glass has a type HGA1 hydrolytic resistance according to ISO 720 before and after ion exchange strengthening.

11. The glass for pharmaceutical packaging of claim 1, wherein the glass has at least a class S3 acid resistance according to DIN 12116.

12 The glass for pharmaceutical packaging of claim 1, wherein the glass has at least a class A2 base resistance according to ISO 695.

13. A glass for pharmaceutical packaging having a glass composition comprising:

from 74 mol.% to 80 mol.% SiO_2;

alkaline earth oxide comprising MgO and CaO and a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is greater than 0 and less than or equal to 0.5 and the CaO is from 0.1 to 1.0 mol. %;

X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and

Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein Y is greater than 8 mol.%, a ratio of Y:X is greater than or equal to 1, and a ratio of a concentration of B_2O_3 (mol.%) to (Y mol.%-X mol.%) is less than or equal to 0.3.

14. The glass for pharmaceutical packaging of claim 13, wherein the alkaline earth oxide comprises from 3 mol.% to 7 mol.% MgO.

15. The glass for pharmaceutical packaging of claim 13, wherein a ratio of Y:X is less than or equal to 2.

16. The glass for pharmaceutical packaging of claim 13, wherein the alkali oxide comprises Na_2O in an amount greater than 8 mol.%.

17. The glass for pharmaceutical packaging of claim 13, wherein the glass composition is free of boron and compounds of boron.

18. The glass for pharmaceutical packaging of claim 13, wherein the glass is ion exchange strengthened and has a compressive stress layer with a depth of layer greater than or equal to 10 μm and a surface compressive stress greater than or equal to 250 Mpa.

19. The glass for pharmaceutical packaging of claim 13, wherein the glass has a type HGB1 hydrolytic resistance according to ISO 719.

20. A glass for pharmaceutical packaging having a glass composition comprising:

from 70 mol.% to 80 mol.% SiO_2;

from 4 mol.% to 8 mol.% alkaline earth oxide comprising MgO and CaO and a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is greater than 0 and less than or equal to 0.5;

X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and

Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein Y is 9-14 mol.%, a ratio of Y:X is greater than or equal to 1 and less than or equal to 2, and a ratio of a concentration of B_2O_3 (mol.%) to (Y mol.%-X mol.%) is less than or equal to 0.3.

21. The glass for pharmaceutical packaging of claim 20, wherein the alkaline earth oxide comprises from 3 mol.% to 7 mol.% MgO and from 0.1 mol.% to 1.0 mol.% CaO.

22. The glass for pharmaceutical packaging of claim 20, wherein the alkali oxide comprises Na_2O in an amount greater than 8 mol.%.

23. A glass for pharmaceutical packaging having a glass composition comprising:

from 70 mol.% to 80 mol.% SiO_2;

alkaline earth oxide comprising MgO and CaO and a ratio (CaO (mol.%)/(CaO (mol.%)+MgO (mol.%))) is greater than 0 and less than or equal to 0.5;

X mol.% Al_2O_3, wherein X is greater than or equal to 5 mol.% and less than 7 mol.%; and

Y mol.% alkali oxide comprising non-zero amounts of Na_2O and K_2O, wherein Y is from 9 mol.% to 15 mol.%.

24. The glass for pharmaceutical packaging of claim 23, wherein the alkali oxide comprises Na_2O in an amount greater than 8 mol.%.

25. The glass of claim 1, wherein a coefficient of thermal expansion of the glass is less than $70x10^{-7}K^{-1}$.

26. The glass of claim 13, wherein a coefficient of thermal expansion of the glass is less than $70x10^{-7}K^{-1}$.

27. The glass of claim 20, wherein a coefficient of thermal expansion of the glass is less than $70x10^{-7}K^{-1}$.

28. The glass of claim 23, wherein a coefficient of thermal expansion of the glass is less than $70x10^{-7}K^{-1}$.