Advantages of Boron in Glass Mineral Wool Insulation

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Glass Technology Services (GTS) Ltd, based in Sheffield, recently undertook a review on the role of boron in glass mineral wool insulation. The report explored the important benefits boron brings to glass mineral wool insulation, a borosilicate glass, of which it is a major structural component.

Glass fibre is formed when thin strands of molten glass are extruded into many fibres with small diameters suitable for textile processing. Glass is unlike other materials in that, even as a low diameter fibre, it has no crystalline structure. The properties of the structure of glass in its softened stage are very much like its properties when spun into fibre.

In terms of glass formation, it is silica, SiO_2, that forms the basis of all commercial glasses and can be seen as the glass former par excellence. However its high melting point (1723°C or 3133°F) and its high viscosity in the liquid state make it difficult to melt and work.

In general, sodium carbonate is used to lower the melting temperature of the silica to a workable level and lime is added to form the familiar soda-lime silica glass used for both container and flat glass.

Glass then is formed by combining oxides which fall into three basic groups: glass formers as mentioned above, modifiers which are oxides, and generally alkali, added to glass to act as fluxes to reduce the melting temperatures of the formers. Oxides used include sodium oxide, potassium oxide and lithium oxide. Other oxides act as stablisers to improve the durability and stability of glass – generally alkali earth elements such as calcium oxide and magnesium oxide.

Boric oxide has been recognised as a glass former (indeed as far back as 1937) – in that it is able to form a glass on its own – and that it converts to form a vitreous glass network when melted. And even though alkali oxides, such as sodium oxide, modify the boron structure of borate glass, boron remains in the vitreous state.

The interest in boric oxide glasses is twofold: the significant difference in properties between vitreous silica and vitreous B_2O_3 and the change in coordination in borates between three-fold and four-fold depending on the conditions.

Vitreous boric oxide is easy to prepare, as the oxide melts from the boric acid precursor at temperatures as low as 176°C.

Borate glass differs from silicate glass when alkali oxides are added. Small additions of alkali oxide into borate glass cause a decrease in glass transition temperature, an increase in thermal expansion coefficient, an increase in liquidus temperature and can also cause an increase in viscosity. Similar additions into silica glass have the opposite effect.

The trends in silicate glass can be explained by the formation of non-bridging oxygens; the properties of borate glass by boron changing from the three-fold triangular coordination to the four-fold tetrahedral coordination, increasing the connectivity of the network. The result is an increase in glass transition temperature and a decrease in thermal expansion coefficient. At higher alkali oxide concentrations in borate glass ~25 mol %, these property trends reverse due to the formation of non-bridging oxygen atoms.

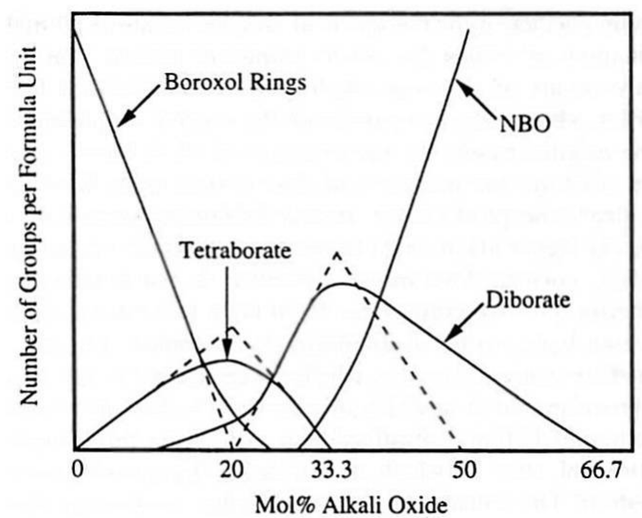

Figure 1 *Effect of alkali oxide on the concentrations of immediate borate structures in alkali borate glass.*

Figure 1 shows graphically how the various intermediate structures in borate glass vary with the addition of alkali oxide. The first structure formed consists of a boroxol ring in which one triangle has been converted to a tetrahedron. Increasing the concentration of alkali oxide leads to complete conversion of the boroxol rings into tetraborate and diboarate groups.

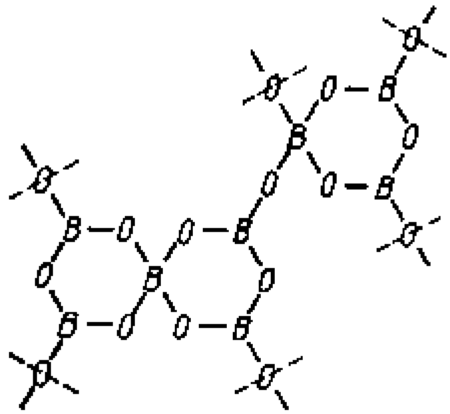

Figure 2 *Tetraborate structure*

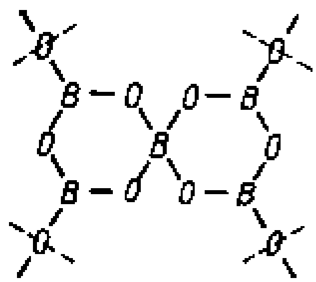

Figure 3 *Pentaborate structure*

A large number of alkali borosilicate glasses, including most of the commercial alkali borosilicate glasses, are phase separated. The phase separation is on such a fine scale that the glasses appear transparent. Sodium borosilicate glasses with less than 20 mole percent of sodium oxide consist of two vitreous phases. One phase will be silica rich and the other alkali and borate rich; Figures 4 and 5 show two example microstructures.

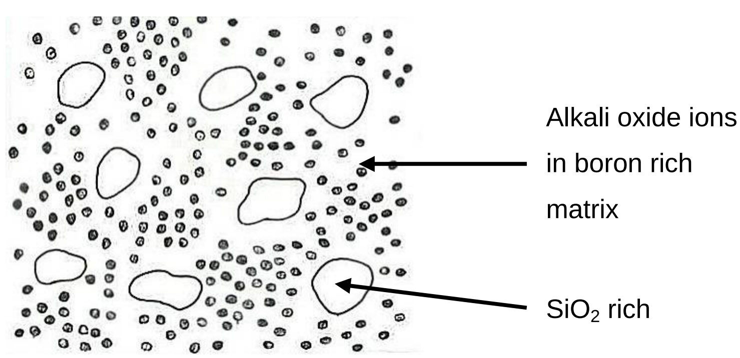

Figure 4 *Schematic representation of a phase separated R_2O – B_2O_3 – SiO_2 phase separated glass with a low SiO_2 content.*

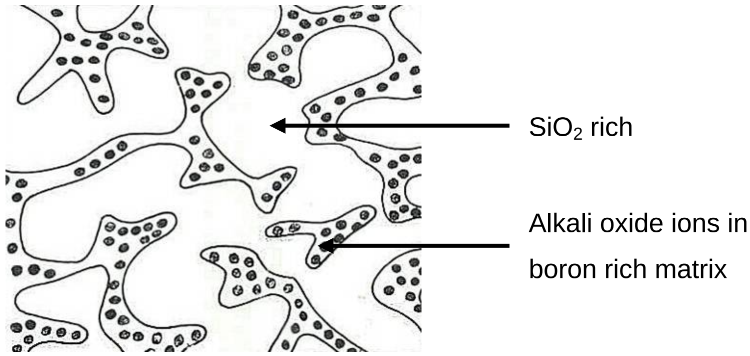

Figure 5 *Schematic Representation of a phase separated R_2O – B_2O_3 – SiO_2 phase separated glass with a high SiO_2 content.*

As in binary alkali borate glasses, the boron rich glass matrix undergoes structural changes when alkali oxide with boron transforming from the three coordinated boroxol rings to the four coordinated tetrahedra. Figure 6 shows how the concentration of four coordinated tetrahedral boron varies with composition.

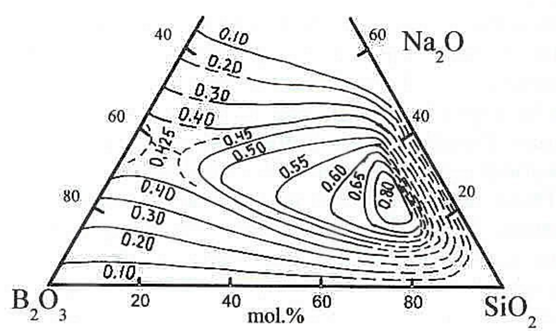

Figure 6 *Concentration of tetrahedral boron in sodium borosilicate glass.*

As glass wool insulation typically contains around 15 mole percent Na_2O, so it is a mixture of the two vitreous phases, as shown in figure X5. The boron in glass wool insulation is present as a vitreous alkali borate glass dispersed in a silicate glass matrix.

As the boron content of glass mineral wool is fairly low, the alkali borate phase will exist as small isolated droplets distributed through the silica-rich matrix. This means the durability of the glass mineral wool will be determined by the rate of dissolution of the predominate silica-rich phase, as any solution will not come into contact with the low durability alkali borate phase until the surrounding glass is removed. If any alkali borate was to leach out the resultant solution would be similar to an ophthalmic solution but with a lower boron concentration.

Boron is beneficial in aiding properties advantageous for production such as viscosity, liquidus temperature and surface tension. Irrespective of the starting materials, once converted to the borate in the glass, the same essential vitreous structures will be formed in the glass. It is also useful in aiding important properties in glass wool insulation for post-production such as thermal conductivity, hydrolytic resistance and biosolubility.

In conclusion, glass wool insulation is a sodium borosilicate glass and is phase separated into two vitreous phases: a vitreous silicate rich phase and a sodium borate rich phase. The alkali borate phase of the glass mineral wool is present as small isolated drops in a silica rich matrix. Glass mineral wool is also very durable due to its fine phase separated microstructure. Vitreous boron, therefore, brings many advantageous properties to glass mineral wool insulation such as improving the biosolubility and thermal conductivity.

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