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(54) Title: ENERGY EFFICIENT SODA LIME SILICATE GLASS COMPOSITIONS USING BORAX PENTAHYDRATE

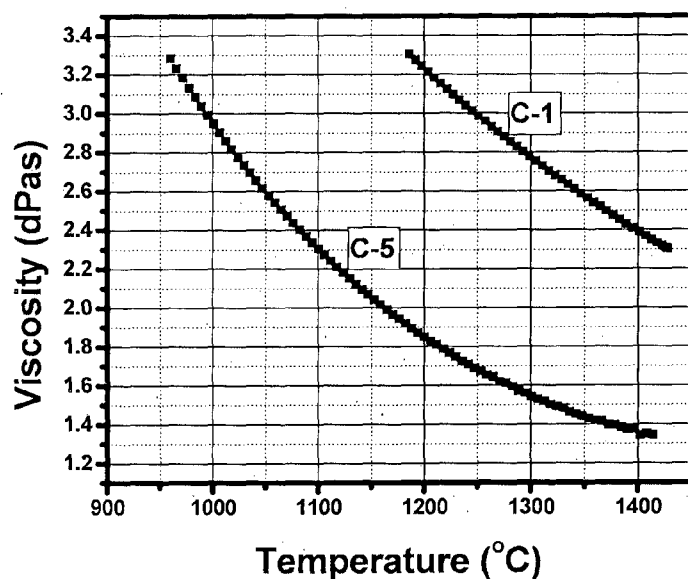


Figure - 2

(57) Abstract: The invention is directed to energy efficient soda lime silicate glass compositions using borax pentahydrate. The invented glasses have the compositions in the ranges: $B_2O_3 = 7.19-51.74$ wt.%, $SiO_2 = 22.68-74.62$ wt.%, $Na_2O = 13.0-23.5$ wt.%, $CaO = 0.0-10.5$ wt.%, $K_2O = 0.03-0.3$ wt.%, $Al_2O_3 = 0.15-1.3$ wt.%, $MgO = 0.43-4.0$ wt.%, and $Fe_2O_3+TiO_2 = 0.05-0.12$ wt.%. The evaluated properties of the glasses have revealed that these invented glasses are suitable for manufacturing improved quality container glasses, float glasses and glasses for ophthalmic lens blanks as well. The addition of borax pentahydrate originated B_2O_3 at its optimum level (28.5 - 30.3 wt.% B_2O_3) is found to reduce the glass melting temperature by 150-200°C. This lowering of glass melting temperature substantially saves energy and reduces the production cost; hence the compositions are energy efficient and cost effective. It eliminates the use of soda ash and limestone, so it reduces the carbon dioxide (CO_2) emission and thereby global warming; thus these compositions are environmentally friendly as well.



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**“ENERGY EFFICIENT SODA LIME SILICATE GLASS COMPOSITIONS
USING BORAX PENTAHYDRATE”**

5 The following specification particularly describes the invention and the manner in which it is to be performed:

FIELD OF THE INVENTION

The present invention relates to energy efficient soda lime silicate glass compositions using borax pentahydrate. In particular, the invention relates to
10 incorporation of boron oxide using low cost borax pentahydrate ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$; 47-48 wt. % B_2O_3 , 21-22 wt. % Na_2O and 30-31 wt. % H_2O) as raw materials in producing the above mentioned different industrial glasses with simultaneous substitution of the use of soda ash as a source of Na_2O by the incorporation of Na_2O
15 from borax pentahydrate. Here soda lime silicate glass was manufactured by replacing soda ash raw material with borax pentahydrate in the range 25-100 wt%. In addition the CaO component was also replaced by the Na_2O of borax pentahydrate. This activity results in simultaneous incorporation of B_2O_3 in the glass matrix by replacing SiO_2 content. Characterization of the invented glasses
20 were done by the evaluation of their different properties such as coefficient of thermal expansion (CTE), glass transition temperature (T_g), glass deformation temperature (T_d), refractive index, transmission spectrum, and mechanical properties, etc. The effects of addition of borax pentahydrate at its optimum level (28.5 - 30.3 wt.% B_2O_3) on the glass melting temperature of soda lime silicate glass
25 was also evaluated by viscosity measurement and heating stage microscopic studies, and found to be reduced by 150-200°C. This lowering of glass melting temperature substantially saves energy and reduces the production cost. It eliminates the use of soda ash and limestone, so it reduces the carbon dioxide (CO_2) emission and thereby global warming; thus it is environmentally friendly.
30 Further, it offers a great benefit to the glass industry and opens up a new application of borax pentahydrate. It is observed that the incorporation of boron oxide in the invented silicate glasses reduces their coefficient of thermal expansion, increases their refractive index and hardness. Thus, the evaluated

properties of the glasses revealed that these invented glasses are suitable for manufacturing improved quality of container glasses, float glasses and glasses for ophthalmic lens blanks.

5 BACKGROUND OF THE INVENTION

The present invention relates to an improved soda-lime-silicate float and container glass composition that yields economic advantages in melting and forming, superior properties such as mechanical, thermal and physical properties. The compositions of commercially produced float and container glass have been
10 standardized over a narrow range in order to achieve a set of properties that are desired for manufacture and subsequent processing of flat/container glass products. Changing the composition by varying one or more constituent in order to tailor one property usually has adverse effects on at least one or more other properties. Glass compositions for production of flat and container glasses are
15 standardized considering minimized melting temperature, surface abrasion resistance, surface weather durability, lower corrosion to refractories, temperability and most importantly the production cost. It is established that reducing the amount of silica and or increasing the alkali content in the glass can lower the melting temperature of the glass and lower the energy consumption for
20 melting, but doing so surface durability of glass product reduces. Loss of glass durability can be compensated by adjusting other constituents but which will result in reduction of working range i.e. the reduction in temperature range in which the glass can be formed without devitrification of the glass. Hence, it has become impractical for flat glass manufacturer, particularly float glass producers
25 to alter the composition in order to achieve melting advantages and energy savings and maintaining and or improving the properties. The glass industry has many segments employing different production processes.

The use of commercial soda lime silicate glasses are increasing tremendously along with the increase in real estate as these glasses has become inevitable to augment
30 the aesthetics of the commercial/ domestic buildings. Other than aesthetics, these glasses are used to protect from the natural calamities, to protect from sunlight etc. in order to control the atmosphere within the house. These glasses are

generally used in the flat glass (automotive and construction), glass container (foods, beverages, perfumes and pharmaceuticals) and many other glass industries. The flat glass sector (also commonly referred to as the float glass sector, based on the name of the manufacturing process involved in making flat glass) produces about five million tons of glass per year, with residential and commercial construction and automotive industries comprising about 80 % of the market. The flat glass industry produces glass primarily for the automotive (laminated and tempered glass), and construction (windows and doors) markets. These segments account for 60% and 30% of all flat glass shipments, respectively. The balance is used in sectors such as mirrors, solar panels, signs and optical glass.

The container glass sector is the glass industry's largest producer. Demand in the container glass industry is predicted to expand at a rate of 2.2% annually. The glass container industry represents a very robust market. Beverage bottles account for the lion's share of this industry, with beer bottles leading the way, followed by wine and non-alcoholic drinks bottles. The food container market also has a strong share and other sectors include toiletries and cosmetics, and laboratory glassware. Colored glasses are prominent in this industry, with amber (dark brown) containers for beer and many shades of green containers used for wine. Clear, flint glasses are used for food and drink products.

Other glass industries include lighting; technical glass for video screens, televisions and solar panels; insulation glass (fibers); foam glass; and many other "specialty" glasses.

The glass industry is an ever growing market where state-of-the-art technologies are continually being improved to ensure faster and cheaper production of more sophisticated products. Further, new technical specialty and functionality glasses are continually being introduced to the market, e.g. security, multi-laminated and self-cleaning glasses. Soda-lime silica glass produced by float process and having a strain point of about 510⁰C is also used as a substrate for plasma display (US patent no. 5780373 and 5858987).

As the construction, automotive and consumer packaged goods industries employ new technical and functional requirements for their glass products, the demand

for the high quality soda lime silicate glass will continue to grow - now and for the foreseeable future.

Hence, researchers worldwide are engaged in developing commercial glasses based on soda lime silicate glasses with improved properties at a cheaper cost.

5 Presently to manufacture soda lime silicate glass soda ash, lime stone and silica is used. The present invention relates to substitution of soda ash and lime stone (Na_2O and CaO) of commercially available soda lime silicate glass by low cost borax pentahydrate raw material for producing glasses with improved properties, in terms of thermal, mechanical, durability and most importantly to reduce the
10 melting temperature in order to achieve production energy savings.

US Patent No. 5,071,796 (James V. Jones and S. M. Ohlberg) discloses flat glass compositions with improved melting and tempering properties. These glasses are having low melting temperatures than standard commercial soda lime silicate glasses and these are achieved by partially replacing high melting alumina with
15 silica. However, the drawbacks of the invention are that the most important, i.e. optical properties which are essential for the application in optical areas and particularly in window glass are not addressed. Coefficient of thermal expansion (CTE) of the glasses developed by them is higher ($10.44 \times 10^{-6} / ^\circ\text{C}$) compared to the standard float glass ($8.62 \times 10^{-6} / ^\circ\text{C}$). This will eventually impair the thermal
20 shock resistance of the glass.

Reference may be made to US Patent No. 346768 (Ernst Winter et. al) wherein development of soda-lime silicate glass containing vanadium has been reported which demonstrates high UV absorption for wavelengths below 350 nm and this can be used for manufacturing glass containers, such as bottles in which UV-sensitive
25 food stuffs, such as, for example, milk, yogurt, juices containing vitamins or the like, are transported and stored. It has been claimed that this glass can be produced by cost effective manner but details about how this cost effectiveness is achieved has not been elaborated. However, main shortcomings of this invention are that it did not compare other essential properties, such as thermal,
30 mechanical, optical transmission properties etc. with standard commercially available soda-lime silicate glasses.

Reference may be made to US Patent No. 5362689 (Shigeki Morimoto et. al) which is related to the invention of a well balanced visible light transmittance and infrared and ultraviolet ray absorbing glass suitable for use in building and vehicle window, which comprises of a modified soda-lime silicate glass composition incorporated with relatively small and strictly specified amounts of iron oxide, cerium oxide, and titanium oxide together with a very small amount of manganese oxide. As per their claim the invented glass is having high Young's modulus, Poisson's ratio and thermal expansion co-efficient. However, exact data related to these properties have not been reported and optical transmittance has been reported as about 70 % which is low if considered for window applications. High thermal expansion of this glass will also lead to the poor thermal shock resistance. US Patent no. 5364820 (Shigeki Morimoto et. al) discloses the invention of neutral gray-colored infrared and ultra violet radiation absorbing glass by modifying the composition of soda-lime silicate glasses by incorporating limited amounts of iron oxide, CeO_2 and trace amounts of CoO and Se in order to modify the coloration and optical characteristics of the glass. Though optical properties and temper ability are reported, however, other essential properties such as physical, thermal, melting temperature, mechanical properties, durability etc. are not mentioned. Reference may be made to US Patent No. 5478783 (P. L. Higby and B. E. Penrod) wherein compositions based on soda-lime-silica modified by incorporating cobalt oxide, iron oxide, nickel oxide and TiO_2 to achieve infrared and ultraviolet absorbing glass for use in windows of vehicles have been reported. Though optical transmittance properties are reported but other essential properties of the invented glass are not been discussed. Reference may be made to US patent no. 5558942 (M. Itoh and T. Kijima) wherein soda-lime-silica based compositions have been modified by incorporating V_2O_5 and Fe_2O_3 to develop ultraviolet ray absorbent colored glass for buildings and vehicles has been reported. Only luminous transmittance and ultra-violet ray transmittance properties are evaluated, however, other essential physical, thermal, mechanical properties, durability etc. are not discussed. This patent also did not mention about effect of such alternation of composition on melting temperatures.

US patent no. 6063718 (N. E. Khilati et. al) discloses soda-lime-silica glass compositions and their applications. They invented glass compositions which are suitable for production of glass ribbons from which panes can be cut. According to their claim these glasses are fire resistant; hence, these can be used to make fire-resistant glazing or can serve as substrates for the manufacture of plasma screens, electroluminescent screens and cold cathode screens. However, main shortcomings of this patent are that it did not mention about the effect of these compositions on melting temperatures and optical, mechanical properties.

US patent no.7754631 mentioned about invention of alkali-free glass substrate, which has a high Young's modulus, a low linear expansion coefficient, a high strain point and a low density, does not devitrify in the float forming process and possesses excellent acid resistance property. The composition of the glass invented by the group is having melting temperature of up to 1630°C which is quite high in respect to the manufacturing cost point of view.

Borax pentahydrate ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$) is the refined form of sodium borate minerals such as borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) and kernite ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 4\text{H}_2\text{O}$). Borax pentahydrate consists of 47-48 wt. % B_2O_3 , 21-22 wt. % Na_2O and 30-31 wt. % H_2O . It is an important multifunctional source of B_2O_3 , particularly processes in which the simultaneous presence of Na_2O is beneficial. Borax pentahydrate, therefore, seems to be a potential raw material which could beneficially be used in manufacturing of several industrial glasses.

In summary, the major problems of the hitherto known glasses as described herein above for the incorporation of borax pentahydrate raw materials in industrial soda-lime-silica glass are:

a) As far our knowledge goes, there is no report available in patents, literature and public domain regarding incorporation of B_2O_3 replacing SiO_2 by borax pentahydrate as a raw material with simultaneous substitution of the use of soda ash as a source of Na_2O by the incorporation of Na_2O from borax pentahydrate in soda-lime-silica glasses.

b) All the above mentioned reports are mainly related to the development of new composition and or change of minor constituents of the existing

composition of standard soda-lime-silica glass to achieve a particular set of properties. However, incorporation of cheaper varieties of raw materials abundantly available are not exploited for reducing the melting temperature of soda-lime-silica glass in order to radically reduce the production cost by obtaining the similar or even improved properties.

c) None of these patents mentioned about all essential properties of soda-lime-silica glass such as, optical, thermal, mechanical and physical properties which are essential in order to assess their suitability for various applications.

Hence, there is an obvious need to develop new compositions by incorporating low cost borax pentahydrate raw materials abundantly available by replacing Na_2O and CaO of soda-lime-silicate glass in order to substantially reduce melting temperature of the glass which in turn will drastically reduce the production cost and to achieve at least similar or better set of properties of soda-lime-silica glass.

OBJECTS OF THE INVENTION

Main objective of the present invention is to incorporate boron oxide (B_2O_3) and invent the composition by replacing silicon dioxide (SiO_2) of soda-lime silicate glass composition using borax pentahydrate as raw material for manufacturing different industrial glasses.

Another object of the present invention is to substitute soda ash source of Na_2O simultaneously using the available Na_2O from borax pentahydrate as raw material.

Yet another object of the present invention is to establish the composition of soda lime silicate glass by replacing soda ash raw material with borax pentahydrate in the range 25-100%.

Yet another object of the present invention is to establish the composition of soda lime silicate glass by replacing CaO with Na_2O of borax pentahydrate and simultaneous replacement of SiO_2 by B_2O_3 of borax pentahydrate.

Still another object of the present invention is to lowering of melting temperature of soda lime silicate glass by addition of borax pentahydrate at its optimum level and ascertain the maximum lowering of melting temperature by measurement of high temperature molten glass viscosity.

Yet another object of the present invention is to establish the properties of new glass compositions which ascertain the improvement of container and float glasses. Still another object of the present invention is to establish the glass chemical composition for the most popular "white crown" type ophthalmic glass of refractive index 1.523.

SUMMARY OF THE INVENTION

- Accordingly, present invention provides energy efficient soda lime silicate glass composition using borax pentahydrate comprising (wt.%) $B_2O_3 = 7.19-51.74$ wt.%, $SiO_2 = 22.68-74.62$ wt.%, $Na_2O = 13.0-23.5$ wt.%, $CaO = 0.0-10.5$ wt.%, $K_2O = 0.03-0.3$ wt.%, $Al_2O_3 = 0.15-1.3$ wt.%, $MgO = 0.43-4.0$ wt.%, and $Fe_2O_3+TiO_2 = 0.05-0.12$ wt.%.
- In an embodiment of the present invention, the said glasses have density in the range of $2.312-2.575 \text{ g.cm}^{-3}$.
- In another embodiment of the present invention said composition is useful for manufacturing container, float and ophthalmic glasses.
- In yet another embodiment of the present invention, the said glasses have coefficient of thermal expansion (CTE, $50-300^\circ\text{C}$) in the range of $(71.4-90.6) \times 10^{-7} \text{ K}^{-1}$.
- In yet another embodiment of the present invention, the said glasses have glass transition temperature (T_g) in the range of $506-595^\circ\text{C}$.
- In yet another embodiment of the present invention, the said glasses have dilatometric softening point or temperature (T_d) in the range of $540-634^\circ\text{C}$.
- In yet another embodiment of the present invention, the said glasses have dielectric constant in the range of $7.41-10.23$.
- In yet another embodiment of the present invention, the said glasses have refractive index in the range of $1.5058-1.5337$.
- In yet another embodiment of the present invention, the said glasses have optical transmission at 550 nm for the glass thickness of 2.0 mm in the range of $83-90\%$.
- In yet another embodiment of the present invention, the said glasses have viscosity in the range of $1.36-1.85 \text{ dPa.s}$ in the temperature range of $1150-1400^\circ\text{C}$.
- In yet another embodiment of the present invention, the said glasses have the Vicker's hardness in the range of $5.54 - 6.50 \text{ GPa}$.

In yet another embodiment, present invention provides a process for the preparation of borax pentahydrate originated B_2O_3 incorporated soda lime silicate glasses as claimed in claim 1 and the said process comprising the steps of:

- i. mixing 12.45 to 79.35% by weight Borax pentahydrate, 0.31 to 3.41% by weight Feldspar, 16.75 to 54.51% by weight Quartz, 0.0 to 15.20% by weight Soda ash, 0.08 to 0.63% by weight Alumina, 0.0 to 15.46% by weight Calcium carbonate, 0.32 to 3.32% by weight Magnesium oxide and 0.008 to 0.017% by weight Titanium dioxide for a period in the range of 10 to 20 minutes to obtain a uniform mixture;
- ii. melting the mixture as obtained in step (i) at temperature in the range of 1500 to 1600°C for period in the range of 1.0 to 2.0 h with 1 to 2 intermittent stirring for 0.4 to 0.6 min each to obtain homogenize glass melt;
- iii. quenching the glass melt as obtained in step (ii) at temperature in the range of 1500 to 1600°C followed by casting and annealing to obtain borax pentahydrate originated boron oxide (B_2O_3) incorporated soda lime silicate glasses.

In yet another embodiment of the present invention, the addition of borax pentahydrate originated boron oxide (B_2O_3) at its optimum level (28.5 - 30.3 wt.%) in the soda lime silicate glass reduce the glass melting temperature by at least 150-200°C.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 represents transmission spectra of container glass samples C-1 to C-9 as a function of wavelength.

Figure 2 represents variation of viscosity of glass sample C-1 (blank container glass, 0.0 wt.% B_2O_3) and C-5 (100 % Na_2O is replaced by Na_2O of BP, 28.5 wt.% B_2O_3) as a function of temperature.

Figure 3 represents variation of shrinkage and starting of batch melting of glass sample C-1 (blank container glass, 0.0 wt.% B_2O_3) and C-5 (100 % Na_2O is replaced by Na_2O of BP, 28.5 wt.% B_2O_3) as a function of temperature.

Figure 4 represents transmission spectra of container glass samples F-1 to F-8 as a function of wavelength.

Figure 5 represents variation of viscosity of glass sample F-1 (blank float glass) and F-5 (100 % Na₂O is replaced by Na₂O of BP) as function of temperature.

- 5 Figure 6 represents variation of shrinkage and starting of batch melting of glass sample F-1 (blank container glass, 0.0 wt.% B₂O₃) and F-5 (100 % Na₂O is replaced by Na₂O of BP, 30.3 wt.% B₂O₃) as a function of temperature.

DETAILED DESCRIPTION OF THE INVENTION

- 10 The present invention relates to energy efficient soda lime silicate glass compositions using borax pentahydrate. In particular, the invention relates to incorporation of boron oxide using low cost borax pentahydrate (Na₂B₄O₇·5H₂O; 47-48 wt. % B₂O₃, 21-22 wt. % Na₂O and 30-31 wt. % H₂O) as raw materials in producing the above mentioned different industrial glasses with simultaneous
- 15 substitution of the use of soda ash as a source of Na₂O by the incorporation of Na₂O from borax pentahydrate. Here soda lime silicate glass was manufactured by replacing soda ash raw material with borax pentahydrate in the range 25-100 wt%. In addition the CaO component was also replaced by the Na₂O of borax pentahydrate. This activity results in simultaneous incorporation of B₂O₃ in the
- 20 glass matrix by replacing SiO₂ content. Characterization of the invented glasses were done by the evaluation of coefficient of thermal expansion (CTE), glass transition temperature (T_g), glass deformation temperature (T_d), deformation behaviour of glass blocks at elevated temperatures, refractive index, transmission spectrum, and mechanical properties. The effect of addition of borax
- 25 pentahydrate at its optimum level on the melting temperature of soda lime silicate glass was also evaluated by viscosity measurement and heating stage microscopic studies, and found to be reduced by 150-200°C. This lowering of glass melting temperature substantially reduces the production cost and saves energy. It offers a great benefit to the glass industry and opens up a new application of borax
- 30 pentahydrate. It is observed that the incorporation of boron oxide in the invented silicate glasses reduces their coefficient of thermal expansion, increases their refractive index and hardness. Thus, the evaluated properties of the glasses

revealed that these invented glasses are suitable for manufacturing improved quality of container glasses, float glasses and glasses for ophthalmic lens blanks. In an embodiment, the present invention provides a process for preparing the energy efficient container and float glass of superior quality, wherein the steps comprising:

a) Borax pentahydrate originated boron oxide (B_2O_3) incorporated soda lime silicate glasses, wherein the glasses have the compositions in weight percent (wt.%) in the ranges: B_2O_3 = 7.19-51.74 wt.%, SiO_2 = 22.68-74.62 wt.%, Na_2O = 13.0-23.5 wt.%, CaO = 0.0-10.5 wt.%, K_2O = 0.03-0.3 wt.%, Al_2O_3 = 0.15-1.3 wt.%, MgO = 0.43-4.0 wt.%, and $Fe_2O_3+TiO_2$ = 0.05-0.12 wt.%;

b) Glass preparation activity were carried out following a typical soda lime silicate container glass composition as provided in Table 2 (Sample C-1) and a typical soda lime silicate float glass composition as provided in Table 5 (Sample F-1).

c) Melting of soda lime silicate glass (container and float glasses) by replacing soda ash raw material using borax pentahydrate in the range 25-100%, and the glass composition is provided in Table 2 for container glass (sample C-2, C-3, C-4 and C-5 respectively) and in Table 5 for float glass (sample F-2, F-3, F-4 and F-5 respectively).

d) The glasses were prepared by melting in the range 1500^0 to 1600^0C in a platinum crucible for 1 to 2 h with intermittent 1 to 2 stirrings for 0.5 - 1.0 minute followed by casting on an iron mould and subsequently annealed properly.

e) They were sized and polished as required for different property evaluation. The set of glass compositions of borax pentahydrate originated sodium oxide (Na_2O) incorporated soda lime silicate container glasses, wherein the said glasses having melting temperature (T_m) of 899^0C compared to commercial container glass which shows melting behaviour at 1153^0C . A huge reduction in melting temperature of 254^0C has been observed for the glasses obtained by replacing 100 % of Na_2O of soda ash with Na_2O of BP. In the case of float glass remarkable melting temperature drop of 240^0C has been observed in the borax pentahydrate

originated sodium oxide (Na_2O) incorporated soda lime silicate container glasses (melting temperature, 874°C), compared to the commercial float glass (1114°C).

The set of glass compositions of borax pentahydrate originated boron oxide (B_2O_3) incorporated soda lime silicate glasses, wherein the said glasses eliminate the use of soda ash (Na_2CO_3), so it reduces the carbon dioxide (CO_2) emission and global warming; thus these compositions are environmentally friendly.

The set of glass compositions the addition of borax pentahydrate originated boron oxide (B_2O_3) at its optimum level (28.5 - 30.3 wt.%) in the soda lime silicate glass reduce the glass melting temperature by at least $150\text{-}200^\circ\text{C}$. Thus it saves energy; hence the glass compositions are energy efficient and cost effective.

Raw Materials

The raw materials used were borax pentahydrate, quartz, feldspar, soda ash, calcium carbonate and magnesium oxide. Since the chemical composition of the starting materials has the predominant role, so their chemical compositions are given below in Table 1.

Table 1. Chemical Composition (wt.%) of Borax Pentahydrate (BP) and other raw materials

Component	Borax Pentahydrate	Quartz	Feldspar	Soda Ash	Calcium Carbonate	Magnesium Oxide
B_2O_3	47.8 - 48.5	-	-	-	-	-
SiO_2	0.023	99.24	74.40	-	-	-
Fe_2O_3	0.0035	0.04	0.08	0.04	0.02	0.05
Al_2O_3	0.024	-	13.13	-	-	-
CaO	0.025	-	0.67	-	99.00	-
MgO	0.008	-	-	-	-	99.00
NaCl	0.003	-	-	-	-	-
Na_2SO_4	0.015	-	-	-	-	-
Na_2O	21.6	-	2.87	56.12	-	-
K_2O	-	-	7.28	-	-	-
CO_2	-	-	-	42.82	-	-
Moisture	30.4885- 29.7885	0.72	1.57	1.02	0.98	0.95
Insolubles in water	0.01	-	-	-	-	-

Glass Preparation

Glass preparation activity were carried out following a typical soda lime silicate container glass composition as provided in Table 2 (Sample C-1) and a typical soda lime silicate float glass composition as provided in Table 5 (Sample F-1). The glasses were prepared by melting at 1500⁰-1600°C in a platinum crucible for 1-2 h with intermittent 1-2 stirrings for 0.5 - 1.0 minute followed by casting onto an iron mould and subsequently annealed properly. They were sized and polished as required for different property evaluation.

Soda lime silicate based container glasses

The detailed compositions of the glasses were provided in Table 2. Here soda (Sodium oxide, Na₂O) content of these glasses was gradually replaced by soda (Sodium oxide, Na₂O) as incorporated from borax pentahydrate instead of using soda ash. At the same time, silica content of glass was replaced by boron oxide (B₂O₃) of borax pentahydrate (BP) equivalent to soda content. Similarly lime (Calcium oxide, CaO) was gradually replaced by soda (Sodium oxide, Na₂O) obtained from borax pentahydrate and at the same time, silica content of glass was replaced by boron oxide of borax pentahydrate (BP) equivalent to soda content. Their evaluated properties are shown in Table 3. It is seen that density (increases then decreases) varies in the range 2.312-2.575 g.cm⁻³, coefficient of thermal expansion (CTE) (decreases): (71.4 - 89.8) x 10⁻⁷ K⁻¹ (50-300°C), T_g : 506 - 595°C (increases then decreases), T_d : 540 - 634°C (increases then decreases), dielectric constant: 7.41-8.18 (increases then decreases), refractive index (increases then decreases): 1.5058-1.5300, and transmission: 83-89%. Their transmission spectra are shown in Figure - 1. The plot of viscosity as a function of temperature of glass samples is shown in Figure - 2 and summarized in Table 4. It is seen that the similar viscosity value could be obtained nearly 150-200°C lower temperature in the glasses after replacement of soda and silica by BP. Under this replacement the glass preserves its stability. This viscosity data indicates that the glasses could be melted at least 100°C lower temperature (if not more) which results in energy saving in industry and obviously reduction in production cost. To further, confirm this phenomenon of change in melting behaviour, experiments

using heating microscope was conducted with glass block/batch. The glass compositions of borax pentahydrate originated sodium oxide (Na_2O) incorporated soda lime silicate container glass shows melting temperature (T_m) of 899°C compared to commercial container glass which shows melting behaviour at 1153°C .

- 5 A huge reduction in melting temperature of 254°C has been observed for the glasses obtained by replacing 100% of Na_2O of soda ash with Na_2O of BP. A reduction of batch melting temperature of 296°C is also observed in the heating microscope experiment, which is shown in Fig. 3.

10 Table 2. Composition (wt.%) of container glasses and replacement done by borax pentahydrate (BP)

Sample No.	B_2O_3	SiO_2	Na_2O	CaO	K_2O	Al_2O_3	MgO	$\text{Fe}_2\text{O}_3 + \text{TiO}_2$	Total	Replacement of silica by B_2O_3 of BP (wt.%)	Replacement of Na_2O by Na_2O of BP (wt.%)	Replacement of CaO by Na_2O of BP (wt.%)
C-1	--	74.42	13.00	10.50	0.30	1.30	0.43	0.05	100	0.0	0.0	0.0
C-2	7.19	67.23	13.00	10.50	0.30	1.30	0.43	0.05	100	9.66	25	0.0
C-3	14.39	60.03	13.00	10.50	0.30	1.30	0.43	0.05	100	19.34	50	0.0
C-4	21.58	52.84	13.00	10.50	0.30	1.30	0.43	0.05	100	29.00	75	0.0
C-5	28.50	45.92	13.00	10.50	0.30	1.30	0.43	0.05	100	38.30	100	0.0
C-6	36.25	38.17	16.50	7.00	0.30	1.30	0.43	0.05	100	48.71	100	33.3
C-7	44.00	30.42	20.00	3.50	0.30	1.30	0.43	0.05	100	59.12	100	66.67
C-8	51.74	22.68	23.50	00.00	0.30	1.30	0.43	0.05	100	69.52	100	100

15 Table 3. Evaluated properties of container glasses and replacement done by borax pentahydrate (BP)

Sample No.	Density, g.cm^{-3}	CTE, $\times 10^{-7} \text{K}^{-1}$ (50-300°C)	T_g ($^\circ\text{C}$)	T_d ($^\circ\text{C}$)	Dielectric Constant	Refractive Index, n (at 633 nm)	Transmission (%T), at 550 nm (t=2 mm)
C-1	2.490	89.8	573	608	8.01	1.5106	89
C-2	2.538	84.8	588	634	8.18	1.5243	89
C-3	2.575	79.5	595	628	7.99	1.5277	83
C-4	2.513	74.9	595	628	7.87	1.5300	83
C-5	2.491	71.4	589	633	7.53	1.5291	87
C-6	2.463	74.6	568	604	7.59	1.5266	89

C-7	2.391	81.4	536	572	7.41	1.5180	86
C-8	2.312	82.6	506	540	7.56	1.5058	89
Effect	Increase then decrease	Decrease	Increase then decrease	Increase then decrease	Increase then decrease	Increase then decrease	Decrease

CTE : Coefficient of thermal expansion; T_g : Glass transition temperature; T_d : Dilatometric softening point

- 5 **Table 4.** Viscosity at various temperature of glass samples C-1 (blank container glass, 0.0 wt.% B_2O_3) and C-5 (100 % Na_2O is replaced by Na_2O of BP, 28.5 wt.% B_2O_3)

Temperature ($^{\circ}C$)	Viscosity of C-1 (dPas)	Viscosity of C-5 (dPas)
1200	3.2365	1.8496
1250	2.9948	1.6821
1300	2.7735	1.5426
1350	2.5706	1.4383
1400	2.3923	1.3587

10 **Soda lime silicate based float glasses**

- The detailed compositions of the glasses were provided in Table 5. Here soda (Sodium oxide, Na_2O) content of these glasses was gradually replaced by soda (Sodium oxide, Na_2O) as incorporated from borax pentahydrate instead of using soda ash. At the same time, silica content of glass was replaced by boron oxide (B_2O_3) of borax pentahydrate (BP) equivalent to soda content. Similarly lime (calcium oxide, CaO) was gradually replaced by soda (Sodium oxide, Na_2O) obtained from borax pentahydrate and at the same time, silica content of glass was replaced by boron oxide of borax pentahydrate (BP) equivalent to soda content. Their evaluated properties are shown in Table 6. It is seen that density (increases then decreases) varies in the range $2.375-2.545 \text{ g.cm}^{-3}$, coefficient of thermal expansion (CTE) (decreases): $(74.3-90.6) \times 10^{-7} \text{ K}^{-1}$ ($50-300^{\circ}C$), T_g : $526-586^{\circ}C$ (increases then decreases), T_d : $562-632^{\circ}C$ (increases then decreases), dielectric constant: 9.08-10.23 (decreases), refractive index (increases then decreases): 1.5168-1.5337, and transmission: 86-90%. Their transmission spectra are shown in Figure - 4. The plot of viscosity as a function of temperature of glass samples is shown in Figure - 5 and summarized in Table 7. It is seen that the similar viscosity value could be obtained nearly $150-200^{\circ}C$ lower temperature in

the glasses after replacement of soda and silica by BP. Under this replacement the glass preserves its stability. This viscosity data indicates that the glasses could be melted at least 100°C lower temperature (if not more) which results in energy saving in industry and obviously production cost reduction. To further, confirm this phenomenon of change in melting behaviour, experiments using heating microscope was conducted with glass block/batch. The glass compositions of borax pentahydrate originated sodium oxide (Na₂O) incorporated soda lime silicate float glass shows melting temperature (T_m) of 874°C compared to commercial float glass which shows melting behaviour at 1114°C. A huge reduction in melting temperature of 240°C has been observed for the glasses obtained by replacing 100 % of Na₂O of soda ash with Na₂O of BP. A reduction of batch melting temperature of 422°C is also observed in the heating microscope experiment, which is shown in Fig. 6.

Table 5. Composition (wt.%) of float glasses and replacement done by borax pentahydrate (BP)

Sample ID	B ₂ O ₃	SiO ₂	Na ₂ O	CaO	K ₂ O	Al ₂ O ₃	MgO	Fe ₂ O ₃ +TiO ₂	Total	Replacement of silica by B ₂ O ₃ of BP (wt.%)	Replacement of Na ₂ O by Na ₂ O of BP (wt.%)	Replacement of CaO by Na ₂ O of BP (wt.%)
F1	-	73.00	13.70	9.00	0.03	0.15	4.00	0.12	100	0.0	0.0	0.0
F2	7.58	65.42	13.70	9.00	0.03	0.15	4.00	0.12	100	10.38	25	0.0
F3	15.16	57.84	13.70	9.00	0.03	0.15	4.00	0.12	100	20.77	50	0.0
F4	22.74	50.26	13.74	9.00	0.03	0.15	4.00	0.12	100	31.15	75	0.0
F5	30.30	42.70	13.70	9.00	0.03	0.15	4.00	0.12	100	41.51	100	0.0
F6	36.94	36.06	16.70	6.00	0.03	0.15	4.00	0.12	100	50.60	100	33.33
F7	43.58	29.42	19.70	3.00	0.03	0.15	4.00	0.12	100	59.70	100	66.67
F8	50.21	22.79	22.70	0.00	0.03	0.15	4.00	0.12	100	68.78	100	100

Table 6. Evaluated properties of float glasses and replacement done by borax pentahydrate (BP)

Sample ID	Density, g.cm ⁻³	CTE, x10 ⁻⁷ K ⁻¹ (50-300°C)	T _g (°C)	T _d (°C)	Dielectric Constant	Refractive Index, n (at 633 nm)	Transmission (%T), at 550 nm (t=2 mm)
F1	2.505	90.6	563	612	10.23	1.5182	90
F2	2.530	85.7	578	621	10.12	1.5228	88
F3	2.534	80.9	586	631	10.00	1.5297	88
F4	2.545	77.4	584	632	9.85	1.5333	88
F5	2.517	74.3	579	616	9.33	1.5337	86
F6	2.494	77.5	564	604	9.08	1.5332	90
F7	2.404	77.7	551	587	9.64	1.5261	89
F8	2.375	82.1	526	562	9.49	1.5168	89

Effect	Increase then decrease	Decrease	Increase then decrease	Increase then decrease	Decrease	Increase then decrease	Decrease
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CTE : Coefficient of thermal expansion; T_g : Glass transition temperature; T_d : Dilatometric softening point

Table 7. Viscosity at various temperature of glass samples F-1 (blank float glass, 0.0 wt.% B_2O_3) and F-5 (100 % Na_2O is replaced by Na_2O of BP, 30.3 wt.% B_2O_3)

Temperature ($^{\circ}C$)	Viscosity of F-1 (dPas)	Viscosity of F-5 (dPas)
1150	3.2671	1.8290
1200	3.0132	1.6783
1250	2.7757	1.5615
1300	2.5637	1.4786
1350	2.3667	1.4192

EXAMPLES

The following examples are given by way of illustration only and therefore should not be construed to limit the scope of the present invention.

EXAMPLE-1

The starting raw materials were mixed in such a proportion that the resultant batch comprises the composition of sample C-2 as mentioned in Table 2. Glass batch (Borax pentahydrate = 15.05 g, Feldspar = 4.12 g, Quartz = 64.66 g, Alumina = 0.76 g, Calcium carbonate = 18.70 g, Soda ash = 17.16 g, Magnesium oxide = 0.43 g, and Titanium dioxide = 0.01 g) for 100 g of glass was mixed thoroughly in a porcelain bowl using white fiber spoons. The mixing was done for 15 minutes to ensure uniform mixing of raw materials. The glasses were prepared by melting in a 100 ml platinum crucible. Melting was carried out in an electrically heated raising hearth electric furnace (Heating element: Kanthal) at $1600^{\circ}C$ for 2h in air atmosphere with 2 intermittent stirrings for 0.5 minute each. Stirring was carried out using SiO_2 glass rod for homogenizing the glass melt. The molten glass was quenched at 25 degree Celsius followed by casting onto an iron mould and subsequently annealed properly. They were sized and polished as required for different property evaluation. The CTE of the of 6 mm dia. glass cylinders were

measured with an accuracy of $\pm 1\%$ in the temperature range 50° - 350°C using a horizontal-loading dilatometer (Netzsch, Model 402 PC) and the CTE value measured to be $89.8 \times 10^{-7}/\text{K}$. The T_g value obtained from dilatometer curve was 588°C . The refractive index was measured by a Prism Coupler (Model: 2010/M, Metriton Corporation, Pennington, NJ) at wavelength 633 nm and the value was 1.5243. Optical transmission spectrum was recorded on UV-Vis-NIR spectrophotometer (Perkin-Elmer, Lambda 20) at 25 degree Celsius and the transmission of 2 mm thick glass sample at 550 nm was measured to be 89% .The dielectric constant (ϵ_r) was measured with an accuracy of $\pm 1\%$ at a frequency of 1MHz using a LCR meter (Hioki, Model 3532-50 LCR Hitester) at 25 degree Celsius and the measured ϵ_r value to be 8.18. Other properties of the glass of this composition has been mentioned Table 3.

EXAMPLE-2

The starting raw materials were mixed in such a proportion that the resultant batch comprises the composition of sample C-5 as mentioned in Table 2. Glass batch (Borax pentahydrate = 59.63 g, Feldspar = 4.12 g, Quartz = 43.19 g, Alumina = 0.76 g, Calcium carbonate = 18.70 g, Magnesium oxide = 0.43 g, and Titanium dioxide = 0.01 g) for 100 g of glass was mixed thoroughly in a porcelain bowl using white fiber spoons. The mixing was done for 15 minutes to ensure uniform mixing of raw materials. The glasses were prepared by melting in a 100 ml platinum crucible. Melting was carried out in an electrically heated raising hearth electric furnace (Heating element: Kanthal) at 1500°C for 2h in air atmosphere with 2 intermittent stirrings for 1 minute each. Stirring was carried out using SiO_2 glass rod for homogenizing the glass melt. The molten glass was quenched at 25 degree Celsius followed by casting onto an iron mould and subsequently annealed properly. They were sized and polished as required for different property evaluation. The CTE of the of 6 mm dia. glass cylinders were measured with an accuracy of $\pm 1\%$ in the temperature range 50° - 350°C using a horizontal-loading dilatometer (Netzsch, Model 402 PC) and the CTE value measured to be $71 \times 10^{-7}/\text{K}$. The T_g value obtained from dilatometer curve was 589°C . The refractive index was measured by a Prism Coupler (Model: 2010/M, Metriton Corporation, Pennington,

NJ) at wavelength 633 nm and the value was 1.5291. The viscosity of the glass was measured by a viscometer (Vis 403, Bahr GmbH.) and the viscosity value measured at 1400°C was 1.3587 dPas. Optical transmission spectrum was recorded on UV-Vis-NIR spectrophotometer (Perkin-Elmer, Lambda 20) at 25 degree Celsius and the transmission of 2 mm thick glass sample at 550 nm was measured to be 87%. The dielectric constant (ϵ_r) was measured with an accuracy of $\pm 1\%$ at a frequency of 1MHz using a LCR meter (Hioki, Model 3532-50 LCR Hitester) at 25 degree Celsius and the measured ϵ_r value to be 7.5. Other properties of the glass of this composition has been mentioned Table 3. The deformation behaviour of the block of glasses/batches were observed using a heating microscope (Expert System Solutions S.r.l, Misura 3 HSM, Modena, Italy). The glass compositions of borax pentahydrate originated sodium oxide (Na_2O) incorporated soda lime silicate container glass shows melting temperature (T_m) of 899°C compared to commercial container glass which shows melting behaviour at 1153°C. A huge reduction in melting temperature of 254°C has been observed for the glasses obtained by replacing 100 % of Na_2O of soda ash (C-5) with Na_2O of BP.

EXAMPLE-3

The starting raw materials were mixed in such a proportion that the resultant batch comprises the composition of sample C-8 as mentioned in Table 2. Glass batch (Borax pentahydrate = 108.24 g, Feldspar = 4.12 g, Quartz = 22.85 g, Alumina = 0.76 g, Magnesium oxide = 0.43 g, and Titanium dioxide = 0.01 g) for 100 g of glass was mixed thoroughly in a porcelain bowl using white fiber spoons. The mixing was done for 15 minutes to ensure uniform mixing of raw materials. The glasses were prepared by melting in a 100 ml platinum crucible. Melting was carried out in an electrically heated raising hearth electric furnace (Heating element: Kanthal) at 1500°C for 1h in air atmosphere with 2 intermittent stirrings for 0.5 minute each. Stirring was carried out using SiO_2 glass rod for homogenizing the glass melt. The molten glass was quenched at 25 degree Celsius followed by casting onto an iron mould and subsequently annealed properly. They were sized and polished as required for different property evaluation. The CTE of the of 6 mm dia. glass cylinders were measured with an accuracy of $\pm 1\%$ in the temperature

range 50°-350°C using a horizontal-loading dilatometer (Netzsch, Model 402 PC) and the CTE value measured to be $82.6 \times 10^{-7}/K$. The T_g value obtained from dilatometer curve was 589°C. The refractive index was measured by a Prism Coupler (Model: 2010/M, Metricon Corporation, Pennington, NJ) at wavelength 633 nm and the value was 1.5058. Optical transmission spectrum was recorded on UV-Vis-NIR spectrophotometer (Perkin-Elmer, Lambda 20) at 25 degree Celsius and the transmission of 2 mm thick glass sample at 550 nm was measured to be 89%. The dielectric constant (ϵ_r) was measured with an accuracy of $\pm 1\%$ at a frequency of 1MHz using a LCR meter (Hioki, Model 3532-50 LCR Hitester) at 25 degree Celsius and the measured ϵ_r value to be 7.56. Other properties of the glass of this composition has been mentioned Table 3.

EXAMPLE-4

The starting raw materials were mixed in such a proportion that the resultant batch comprises the composition of sample F-2 as mentioned in Table 5. Glass batch (Borax pentahydrate = 15.86 g, Feldspar = 0.41 g, Quartz = 65.61 g, Alumina = 0.10 g, Calcium carbonate = 16.07 g, Soda ash = 18.29 g, Magnesium oxide = 4.00 g, and Titanium dioxide = 0.02 g) for 100 g of glass was mixed thoroughly in a porcelain bowl using white fiber spoons. The mixing was done for 15 minutes to ensure uniform mixing of raw materials. The glasses were prepared by melting in a 100 ml platinum crucible. Melting was carried out in an electrically heated raising hearth electric furnace (Heating element: Kanthal) at 1600°C for 2h in air atmosphere with 2 intermittent stirrings for 0.5 minute each. Stirring was carried out using SiO₂ glass rod for homogenizing the glass melt. The molten glass was quenched at 25 degree Celsius followed by casting onto an iron mould and subsequently annealed properly. They were sized and polished as required for different property evaluation. The CTE of the of 6 mm dia. glass cylinders were measured with an accuracy of $\pm 1\%$ in the temperature range 50°-350°C using a horizontal-loading dilatometer (Netzsch, Model 402 PC) and the CTE value measured to be $85.7 \times 10^{-7}/K$. The T_g value obtained from dilatometer curve was 578°C. The refractive index was measured by a Prism Coupler (Model: 2010/M,

Meticon Corporation, Pennington, NJ) at wavelength 633 nm and the value was 1.5228. Optical transmission spectrum was recorded on UV-Vis-NIR spectrophotometer (Perkin-Elmer, Lambda 20) at 25 degree Celsius and the transmission of 2 mm thick glass sample at 550 nm was measured to be 88%. The dielectric constant (ϵ_r) was measured with an accuracy of $\pm 1\%$ at a frequency of 1MHz using a LCR meter (Hioki, Model 3532-50 LCR Hitester) at 25 degree Celsius and the measured ϵ_r value to be 10.12. Other properties of the glass of this composition has been mentioned Table 6.

EXAMPLE-5

The starting raw materials were mixed in such a proportion that the resultant batch comprises the composition of sample F-5 as mentioned in Table 5. Glass batch (Borax pentahydrate = 63.38 g, Feldspar = 0.41 g, Quartz = 42.71 g, Alumina = 0.10 g, Calcium carbonate = 16.07 g, Magnesium oxide = 4.00 g, and Titanium dioxide = 0.02 g) for 100 g of glass was mixed thoroughly in a porcelain bowl using white fiber spoons. The mixing was done for 15 minutes to ensure uniform mixing of raw materials. The glasses were prepared by melting in a 100 ml platinum crucible. Melting was carried out in an electrically heated raising hearth electric furnace (Heating element: Kanthal) at 1500°C for 2h in air atmosphere with 2 intermittent stirrings for 1.0 minute each. Stirring was carried out using SiO₂ glass rod for homogenizing the glass melt. The molten glass was quenched at 25 degree Celsius followed by casting onto an iron mould and subsequently annealed properly. They were sized and polished as required for different property evaluation. The CTE of the of 6 mm dia. glass cylinders were measured with an accuracy of $\pm 1\%$ in the temperature range 50°-350°C using a horizontal-loading dilatometer (Netzsch, Model 402 PC) and the CTE value measured to be $74.3 \times 10^{-7}/K$. The T_g value obtained from dilatometer curve was 579°C. The refractive index was measured by a Prism Coupler (Model: 2010/M, Meticon Corporation, Pennington, NJ) at wavelength 633 nm and the value was 1.5337. The viscosity of the glass was measured by a viscometer (Vis 403, Bahr GmbH.) and the viscosity value measured at 1350°C was 1.4192 dPas. Optical transmission spectrum was recorded on UV-Vis-NIR spectrophotometer (Perkin-Elmer, Lambda 20) at 25

degree Celsius and the transmission of 2 mm thick glass sample at 550 nm was measured to be 86%. The dielectric constant (ϵ_r) was measured with an accuracy of $\pm 1\%$ at a frequency of 1 MHz using a LCR meter (Hioki, Model 3532-50 LCR Hitester) at 25°C and the measured ϵ_r value to be 9.33. Other properties of the glass of this composition has been mentioned Table 6. The deformation behaviors of the blocks of glass/batch pellets were observed using a heating microscope (Expert System Solutions S.r.l, Misura 3 HSM, Modena, Italy). The glass compositions of borax pentahydrate originated sodium oxide (Na_2O) incorporated soda lime silicate float glass shows melting temperature (T_m) of 874°C compared to commercial float glass which shows melting behaviour at 1114°C. A huge reduction in melting temperature of 240°C has been observed for the glasses obtained by replacing 100 % of Na_2O of soda ash with Na_2O of BP.

EXAMPLE-6

The starting raw materials were mixed in such a proportion that the resultant batch comprises the composition of sample F-8 as mentioned in Table 5. Batch for 100 g of glass was prepared by mixing Borax pentahydrate = 105.05 g, Feldspar = 0.41 g, Quartz = 22.65 g, Alumina = 0.10 g, Magnesium oxide = 4.00 g, and Titanium dioxide = 0.02 g in a porcelain bowl using white fiber spoons. The mixing was done for 15 minutes to ensure uniform mixing of raw materials. The glasses were prepared by melting in a 100 ml platinum crucible. Melting was carried out in an electrically heated raising hearth electric furnace (Heating element: Kanthal) at 1500°C for 1h in air atmosphere with 2 intermittent stirrings for 0.5 minute each. Stirring was carried out using SiO_2 glass rod for homogenizing the glass melt. The molten glass was quenched at 25 degree Celsius followed by casting onto an iron mould. As-cast glass block was subsequently annealed properly. Annealed glass block was sized and polished as required for different property evaluation. The CTE of the of 6 mm dia. glass cylinders were measured with an accuracy of $\pm 1\%$ in the temperature range 50°-350°C using a horizontal-loading dilatometer (Netzsch, Model 402 PC) and the CTE value measured to be $82.1 \times 10^{-7}/\text{K}$. The T_g value obtained from dilatometer curve was 579°C. The refractive index was measured by a Prism Coupler (Model: 2010/M, Metricon Corporation, Pennington, NJ) at

wavelength 633 nm and the value was 1.5168. Optical transmission spectrum was recorded on UV-Vis-NIR spectrophotometer (Perkin-Elmer; Lambda 20) at 25 degree Celsius and the transmission of 2 mm thick glass sample at 550 nm was measured to be 89% .The dielectric constant (ϵ_r) was measured with an accuracy of $\pm 1\%$ at a frequency of 1MHz using a LCR meter (Hioki, Model 3532-50 LCR Hitester) at 25 degree Celsius and the measured ϵ_r value to be 9.49. Other properties of the glass of this composition has been mentioned Table 6.

ADVANTAGES OF THE INVENTION

The main advantages of the present invention are:

- (a) The addition of borax pentahydrate originated boron oxide (B_2O_3) at its optimum level (28.5-30.3 wt.%) in the soda lime silicate glass reduce the glass melting temperature by 150-200°C.
- (b) This lowering of glass melting temperature substantially saves energy. Thus these glass compositions are energy efficient.
- (c) Due to saving energy, it reduces the production cost. So compositions are cost effective.
- (d) It offers a great benefit to the glass industry and opens up a new application of borax pentahydrate.
- (e) It eliminates the use of soda ash (Na_2CO_3) and limestone ($CaCO_3$), so it reduces the carbon dioxide (CO_2) emission and thereby global warming; thus these compositions are environmentally friendly.
- (f) The incorporation of boron oxide in the invented silicate glasses reduces their coefficient of thermal expansion, increases their refractive index and hardness. Thus, it offers several technical benefits and improves the glass quality.
- (g) The evaluated properties of the glasses have revealed that these invented glasses are suitable for manufacturing improved quality of container glasses, float glasses and glasses for ophthalmic lens blanks.

THE CLAIM:

- 5 1. Energy efficient soda lime silicate glass composition using borax pentahydrate comprising (wt.%) B_2O_3 = 7.19-51.74 wt.%, SiO_2 = 22.68-74.62 wt.%, Na_2O = 13.0-23.5 wt.%, CaO = 0.0-10.5 wt.%, K_2O = 0.03-0.3 wt.%, Al_2O_3 = 0.15-1.3 wt.%, MgO = 0.43-4.0 wt.%, and $Fe_2O_3+TiO_2$ = 0.05-0.12 wt.%.
10 2. Soda lime silicate glass composition as claimed in claim 1, wherein said composition is useful for manufacturing container, float and ophthalmic glasses.
3. Soda lime silicate glass composition as claimed in claim 1, wherein the said glasses have density in the range of $2.312-2.575\text{ g.cm}^{-3}$.
4. Soda lime silicate glass composition as claimed in claim 1, wherein the said
15 glasses have coefficient of thermal expansion (CTE, 50-300°C) in the range of $(71.4-90.6) \times 10^{-7}\text{ K}^{-1}$.
5. Soda lime silicate glass composition as claimed in claim 1, wherein the said glasses have glass transition temperature (T_g) in the range of 506-595°C.
6. Soda lime silicate glass composition as claimed in claim 1, wherein the said
20 glasses have dilatometric softening point or temperature (T_d) in the range of 540-634°C.
7. Soda lime silicate glass composition as claimed in claim 1, wherein the said glasses have dielectric constant in the range of 7.41-10.23.
8. Soda lime silicate glass composition as claimed in claim 1, wherein the said
25 glasses have refractive index in the range of 1.5058-1.5337.
9. Soda lime silicate glass composition as claimed in claim 1, wherein the said glasses have optical transmission at 550 nm for the glass thickness of 2.0 mm in the range of 83-90%.
10. Soda lime silicate glass composition as claimed in claim 1, wherein the said
30 glasses have viscosity in the range of 1.36-1.85 dPa.s in the temperature range of 1150-1400°C.

11. Soda lime silicate glass composition as claimed in claim 1, wherein the said glasses have the Vicker's hardness in the range of 5.54 - 6.50 GPa.

12. A process for the preparation of borax pentahydrate originated B_2O_3 incorporated soda lime silicate glasses as claimed in claim 1 and the said process comprising the steps of:

i. mixing 12.45 to 79.35% by weight Borax pentahydrate, 0.31 to 3.41% by weight Feldspar, 16.75 to 54.51% by weight Quartz, 0.0 to 15.20% by weight Soda ash, 0.08 to 0.63% by weight Alumina, 0.0 to 15.46% by weight Calcium carbonate, 0.32 to 3.32% by weight Magnesium oxide and 0.008 to 0.017% by weight Titanium dioxide for a period in the range of 10 to 20 minutes to obtain a uniform mixture;

ii. melting the mixture as obtained in step (i) at temperature in the range of 1500 to 1600°C for period in the range of 1.0 to 2.0 h with 1 to 2 intermittent stirring for 0.4 to 0.6 min each to obtain homogenize glass melt;

iii. quenching the glass melt as obtained in step (ii) at temperature in the range of 1500 to 1600°C followed by casting and annealing to obtain borax pentahydrate originated boron oxide (B_2O_3) incorporated soda lime silicate glasses.

13. The process as claimed in claim 12, wherein the addition of borax pentahydrate originated boron oxide (B_2O_3) at its optimum level (28.5 - 30.3 wt.%) in the soda lime silicate glass reduce the glass melting temperature by at least 150-200°C.

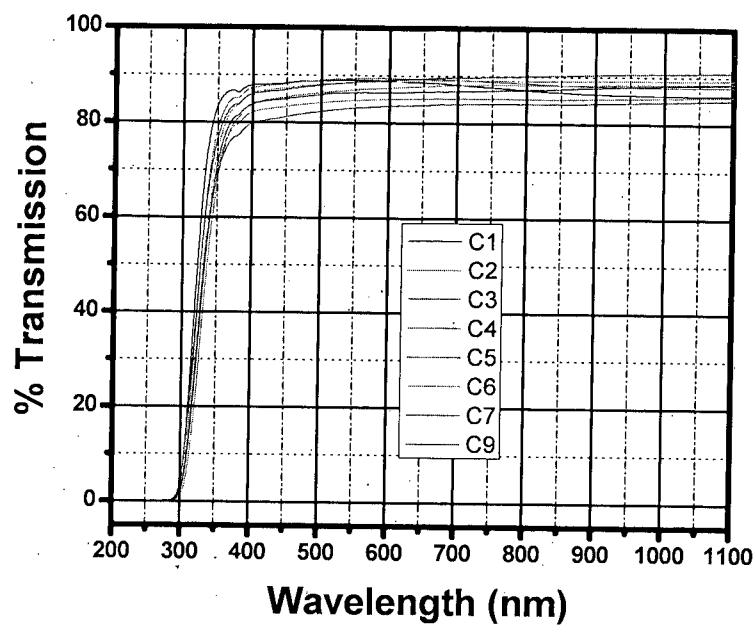


Figure - 1

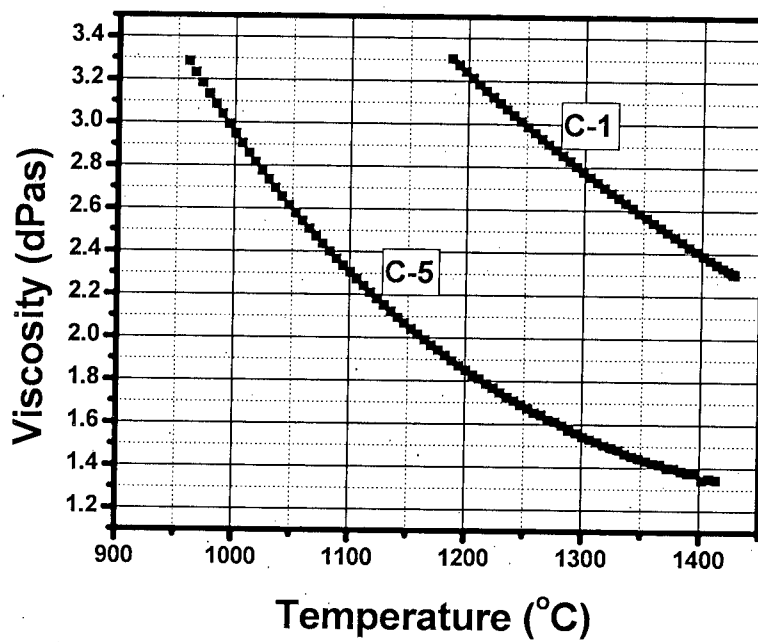


Figure - 2

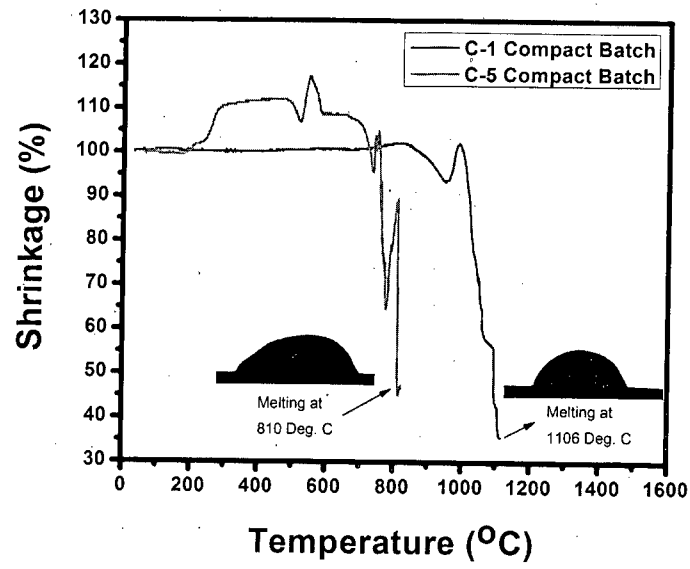


Figure - 3

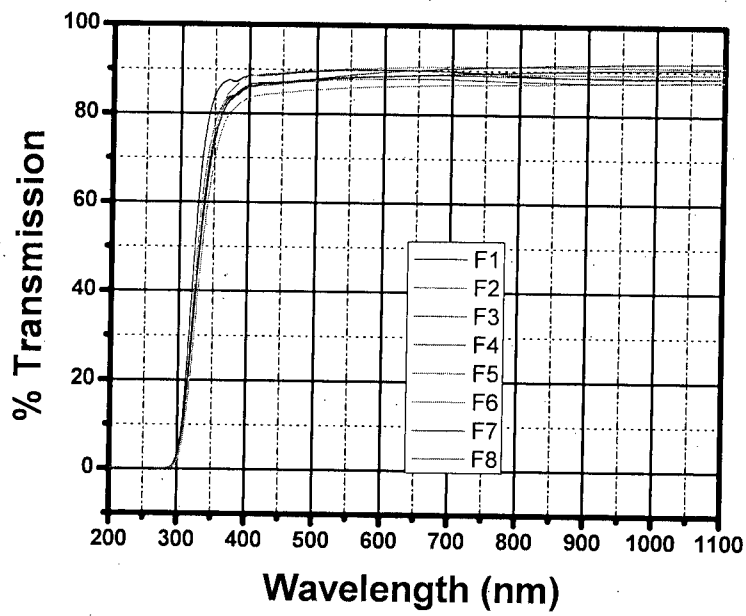


Figure - 4

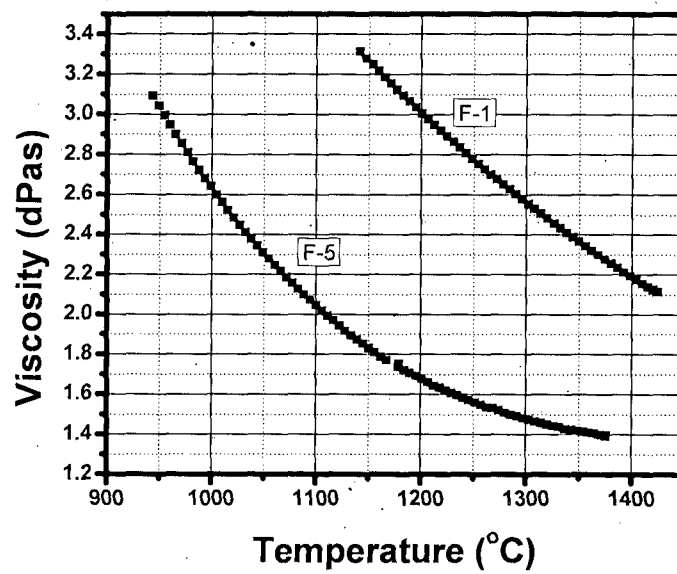


Figure - 5

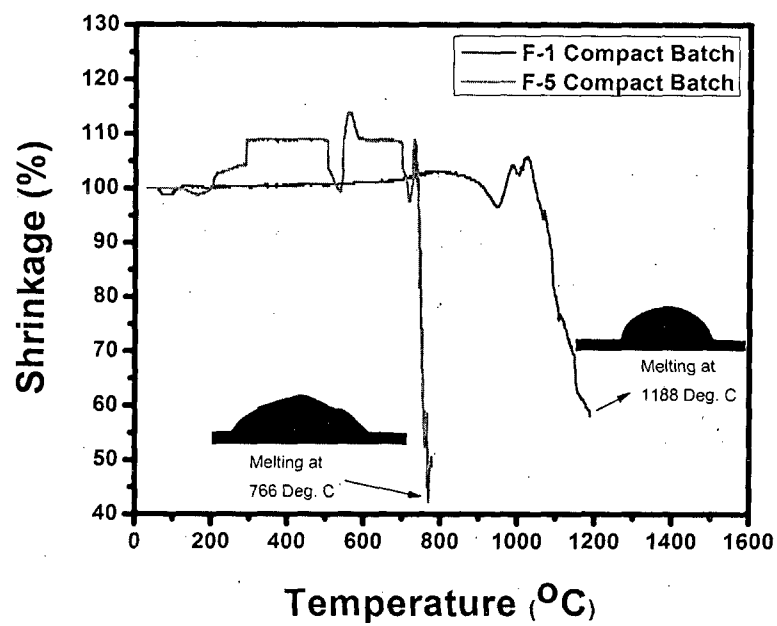


Figure - 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2014/000027

A. CLASSIFICATION OF SUBJECT MATTER INV. C03C1/02 C03C3/064 C03C3/087 C03C3/091 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C03C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 523 264 A (MATTSON STEPHANIE M [US]) 4 June 1996 (1996-06-04) abstract; table: examples 1, 4, 5, 7, 10, 14-16	1-12
Y	----- "In vitro dynamic solubility test: influence of various parameters", ENVIRONMENTAL HEALTH PERSPECTIVES, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES, US, vol. 435, no. 3353, 10 October 2008 (2008-10-10), pages 91-96, XP009106999, ISSN: 0091-6765 paragraph "Introduction; table 2: example CM44 ----- -/--	1-12
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 20 May 2014		Date of mailing of the international search report 30/05/2014
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Deckwerth, Martin

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2014/000027

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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