# COMPOSITIONAL CLASSIFICATION OF GLASSES, IT'S APPLICATIONS AND PROPERTIES

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***Abstract :***

*Glasses are very crucial scientific material in today's technological era. That is why the glasses have numerous applications in various field. Based on applications and chemical composition they can be classified into seven major groups as Soda-lime glasses, Silicate glasses, Borosilicate glasses, Lead glasses, Aluminosilicate glasses, Chalcogenide glasses and Bioglasses.*

**Introduction :**

A large number of glasses can be classified in several ways. Depending on the criterion for the classification, the glasses can be classified. For example, glasses can be classified on the basis of chemical composition used in the manufacturing, processing behavior, their applications etc. The present paper is based on the **classification of glasses based on their composition.** The most widely used classification is by chemical composition and applications which leads to seven major groups as follows -

1. Soda-lime glass
2. Silicate glasses
3. Borosilicate glasses
4. Lead glasses
5. Aluminosilicate glasses
6. Chalcogenide glasses
7. Bioglasses

| Sr. No. | Glasses | Applications |
|---|---|---|
| 1. | Soda-lime | Glazing, packaging |
| 2. | Silicate | Optical fibres |
| 3. | Borosilicate | High temperatures (cookware, laboratory glassware) |
| 4. | Lead | Lead-crystal tableware ('crystal' glass), protecting panels |
| 5. | Aluminosilicate | Fibres for reinforcement |
| 6. | Chalcogenide | IR optics |
| 7. | Bioglass | Medical |

**Table 1: Different glasses and their applications**

### 1.1 Soda-Lime Glasses :

By far the greatest number of industrially produced glasses belongs to a group of glass types with very similar composition, collectively called soda-lime glasses. As the name indicates, soda and lime play a major role with the main component, sand. A typical soda-lime glass composed of 71-75% by weight sand ($SiO_2$), 12-16% soda ($Na_2CO_3$), 10-15% lime ($CaCO_3$) and lower percentage of other materials for specific properties such as coloring. Sometimes magnesium replaces a portion of the calcium content in the limestone or potassium replaces the sodium in soda. Even so, these glasses are similar to and may be classified as soda-lime glasses. Soda-lime glass is primarily used for bottles, everyday drinking glasses and window glass [9].

The chemical and physical properties of soda-lime glasses are the basis of its wide use. Among the most important is its light transmission which makes it suitable for use as flat window glass. An additional advantage is its smooth, nonporous surface which allows the bottles and packaging glass made from it to be easily cleaned. Soda-lime glass containers filled with drinks and foods do not affect the taste of the contents, nor do they contain any harmful substances [10]. Their resistance to aqueous solutions is sufficient to withstand repeated boiling (preserving jars) without creating negative surface changes.

Indeed, the relatively high alkali content of the glass lowers the melting point as opposed to pure $SiO_2$ glass but also causes an increase in the thermal expansion coefficient, α [11]. With reference to the values α, all glasses are divided into two categories: glass with α values below $6 \times 10^{-6}\ K^{-1}$ are called hard glasses; those with higher α values are called soft glasses [12,13]. Owing to its high thermal expansion, the resistance of soda-lime glass to sudden temperature changes is comparatively poor. Therefore, cautious handling is recommended, for example, when filling this glass with hot liquids.

## 1.2 Silicate Glasses :

Silicate glasses are amorphous and have no crystalline structure. Silicate glass is useful for conducting X-ray crystallography because the X-rays will pass through the silicate pipette holding the sample under examination without being reflected by crystals in the glass itself; thus, the resulting measurement is assured to be from the sample [14].

Silicate glasses have also been commonly used in the field of semiconductor device fabrication as an insulator between active layers of the semiconductor device [15,16]. The silicate glasses are typically formed of phosphosilicate glass (PSG) or borophosphosilicate glass (BPSG). The boron and/or phosphorus impurity levels used can be adjusted to affect the silicate glass's melting point.

Besides these applications, silica glasses doped by ternary semiconductor alloy $Cd\ Se_x\ S_{1-x}$ were widely used for the fabrication of signal red glasses (selenium ruby glass) [17], and nonlinear optical elements [18, 19].

## 1.3 Borosilicate Glasses :

Silicate glasses containing boric oxide comprise the third group, borosilicate glass. These glasses have a higher percentage of $SiO_2$ (70-80%) than the previous two groups. The balance of the composition is as follows: 7-13% $B_2O_3$, 4-8% $Na_2O + K_2O$ and 2-7% $Al_2O_3$. Glasses having such a composition show a high resistance to chemical corrosion and temperature changes [20-23]. For this reason, they are used in the process plants in the chemical industry, in laboratories, as ampoules and vials in the pharmaceuticals industry and as bulb for high-power lamps. Also, borosilicate glass can be used for ceramic boards for large scale integrated circuits used at high temperatures [24].

The family of borosilicate glasses is extremely broad, depending on how the boron compounds within the glass melt interact with other metallic constituents. For this reason, most of these borosilicate glasses are classified as special glasses.

## 1.4 Lead Glasses :

If lead oxide replaces much of the lime in batch, the result is a glass type popularly known as lead crystal. Such glass is composed of 54-65% $SiO_2$, 18-38% PbO, 13-15% $Na_2O$ and $K_2O$ and various other oxides. Glasses with less lead content (less than 18% PbO) are called crystal glass [25]. Different amount of barium, zinc, and potassium oxides can be added to the composition to partially replace some of the lead oxide [26].

Glasses containing lead exhibit a high refractive index [27,28] and are especially suited for decorating by cutting. Their specific gravity is higher than that of soda-lime glass [29,30]. In our daily lives, we usually see them as vases, bowls, ashtrays, or as decorative items [31,32].

**1.5 Aluminosilicate Glasses :**

Aluminosilicate glass has aluminum oxide in its composition. It is similar to borosilicate glass but it has greater chemical durability and can withstand higher operating temperatures. Compared to borosilicate, aluminosilicates are more difficult to fabricate [33-35].

According to British Glass for textiles, an alumino-borosilicate glass with very low sodium oxide content is preferred because of its good chemical durability and high softening point [36-39]. This is also the type of glass fiber used in the reinforced plastics to make protective helmets, boats, piping, car chassis, ropes, car exhausts and many other items.

A small, but important type of glass, aluminosilicate, contains 20% aluminum oxide often including calcium oxide, magnesium oxide and boric oxide in relatively small amounts, but with only very small amounts of soda or potash. It is able to withstand high temperatures and thermal shock and is typically used in combustion tubes, gauge glasses for high-pressure steam boilers, and in halogen-tungsten lamps capable of operating at temperature as high as 923 K [40-43].

**1.6 Chalcogenide Glasses :**

A chalcogenide glass is a glass containing one or more chalcogenide elements (Group VI in the periodic table e.g. sulfur, selenium or tellurium) as a substantial constituent. They are covalently bonded materials and may be classified as molecular solids, that is to say the entire glass matrix may be considered as an infinitely bonded molecule.

The modern technological applications of chalcogenide glasses are widespread specifically as mouldable infrared optics including lenses, and infrared optical fibers as these materials transmit across the full range of the infrared regime of the electromagnetic spectrum [44-48]. The physical properties of chalcogenide glasses (High refractive index, low phonon energy) also make them ideal for incorporation into laser and other active devices when doped with rare earth ions [49,50].

**1.7 Bioglasses :**

Bioglass is a commercially available type of bioactive glass. It is also known as 45S5 glass [51,52]. It is composed of $SiO_2$, $Na_2O$, CaO and $P_2O_5$. Professor Larry Hench developed Bioglass at the University of Florida in the late 1960s [53]. He was challenged by a MASH army officer to develop a material to help regenerate bone, as many Vietnam war veterans suffered badly from bone damage, such that most of them injured in this way lost their limbs.

The key composition features of Bioglass is that it contains less than 60 mol% $SiO_2$, high $Na_2O$ and CaO contents, high $CaO/P_2O_5$ ratio, which makes Bioglass highly reactive to aqueous medium and bioactive. Low bioactivity is the main advantage of Bioglass, while their disadvantage includes mechanical weakness, low fracture resistance due to amorphous 2-dimensional glass network. The bending strength of most Bioglass [54] is in the range of 40-60 MPa, which is not enough for load-bearing application. While it's Young's modulus is 30-35 GPa [55], very close to that of cortical bone. Apart from the above-mentioned groups of glasses there are some special glasses which are discussed in the part B of the paper. The conclusion of Part A and Part B is clubbed together in Part B.

**Conclusion :**

There has been increasing interest in the use of glasses in specific areas, such as daily life, education, and games. The effective use application-oriented glasses require the development of customized technologies and product strategies, such as systems and applications for smart glass-based applications.

In the future, the potential design and development of various radiation shielding and radiation resistant glasses , bioactive glasses, smart glasses may give very satisfactory results in terms of acceleration of technology.

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