Paper ID: MS-06

Investigation on the Feasibility of Padma Sand and Glass Cullet as Potential Raw Materials of Conventional Soda-Lime Glass

Hasnat Jahan Sumona[1*], Md. Golam Mortuza Nion[1], Md. Rahat Al Hassan[1,2], Asrafuzzaman[2], Aungkan Sen[1,2]

[1] Department of Glass & Ceramic Engineering, Rajshahi University of Engineering & Technology, Rajshai-6204.

[2]Department of Materials & Metallurgical Engineering, Bangladesh University of Engineering & Technology, Dhaka-1000.

E-mail: sumona77777@gmail.com

Abstract

Quartz (SiO_2), the staple ingredient of commercial soda lime glass, is being replaced extensively by locally found Padma sand and glass cullet. In this study, 60% quartz, 10% CaO, 15% Na_2O and 15% PbO is taken as the standard soda-lime glass composition. Then, quartz of the standard composition is replaced by 50% and 100% Padma sand (Rajshahi). To check the feasibility of glass cullet, 20% and 30% of the standard composition were replaced by it. All the five samples were fabricated at 1400^0C. The effects of Padma sand and glass cullet were investigated through the measurement of density, porosity, chemical stability, softening point, hardness and optical properties. All the properties were explained in terms of composition and surface morphology. Finally, the authors depicted the possibility of cost-effective commercial production of soda-lime glass with enhanced qualities using Padma sand and glass cullet.

Keywords: Padma Sand, Glass cullet, Soda-lime glass, Optical properties.

1. Introduction

Glass is a non-crystalline amorphous super cooled material [1]. Evaluation of glass-forming ability (GFA) for various glass-forming system approved by experimental data of oxide glasses [2]. Silica is the main raw materials for glass forming, tetrahedral structure of silica gives the basic structure of glass. Each silicon is surrounded by 4 oxygen atoms, Each oxygen atom is bonded to 2 silicon atoms [3].These create skeleton of glass structure. About 60-70% of silica as a raw material used in soda-lime-glass, used for windowpanes and glass containers (bottles and jars) for beverages [4]. Soda-lime glass is often referred to as float glass [5]. Dominant rivers of Bangladesh are the source of sediment rich in silicate mineral, mainly quartz and feldspar. The main silicate mineral, quartz or silica (SiO_2) is the raw material for producing glass [6]. Silica is elevated from these rivers have a need of magnetic separation & calcination. Some paper indicate that river sediment are enriched with 60-70% to 94% silica .For this reason deposits of Bangladeshi river sand used for glass production in glass manufacturing industries [6]. Now a days recycling is one of the major concern for glass production. Glass recycling is the process of use waste glass in different product. These waste glass is called glass cullet. These reduce the consumption of raw materials and saves energy. Recycle glass can be used up to 95% in glass production which is environment friendly and cost efficient [12]. Padma sand (rajshahi) can be a source of silica.

Around 88 to 95 % silicon found in the Padma sand. So this sand can replace the quartz and this silica can give almost same properties and sometimes better properties than quartz [7].In this experiment we used 60% of Padma sand in replace of quartz and found better physical and optical properties . The main objectives of our paper is to use Padma sand & glass cullet as a substitute of silica to eliminate the raw material & melting cost & to attain physical, mechanical & optical properties better than that of Quartz source.

2. Experimental Procedure

The glass samples were prepared by conventional melting method. The raw materials of G1; G2; G3; G4; G5 were weighed into desired amounts and taken to a ceramic crucible used for glass melting. Then, the raw materials were mixed to attain a minimal homogeneity of the mixture. After that, the crucible was placed on a glass melting furnace and heated to 1400° C. The melt was holding for 30 minutes to achieve a liquid with higher fluidity and bubble free. Finally the glass melt was taken to the metal dies, allowed to cool in air. All the characterizations were determined subsequently. The Padma sand was examined by XRF method [7]. Then density (bulk & true Density) were measured by Archimedes law. Porosity (Apparent & true) was measured by pycnometer method [8] , Chemical stability was determined by specific molar solution (0.5M HF & 0.5 M NaOH solution) dipping in hot water bath foe 2 hours then overnight cooled, Softening point was determined by SP-3A Orton Softening point tester,(hearing rate 5° C/ minute), Micro-hardness was determined by Struers Duramin-1/-2 micro-hardness tester To find out the pores, Optical micrscopy was determined & Absorbance was measured by UV-Vis spectroscopy

Table 1. Glass compositions of different sample group

Group name	SiO_2 %	Padma sand %	Glass Cullet %	Na_2O %	CaO %	PbO %
G1	60	-	-	15	10	15
G2	-	60	-	15	10	15
G3	30	30	-	15	10	15
G4	48	-	20	12	8	12
G5	42	-	30	10.5	7	10.5

3. Result & Discussion

3.1 Physical properties (density, porosity, appearance)

It is well known that Soda lime silicate glass has greater density & refractive index & less porosity. [9] The Na_2O, CaO entered into the silica tetrahedral network, fills the interstices so that non bridging oxygen formed. Which is responsible for increasing the weight with no change in volume thus increasing the density[10]. The Na_2O, CaO content & higher amount of PbO is responsible for higher amount of density [11]. **Fig.1** shows, G2 has higher density. This density is responsible for less amount of porosity & water absorption in the G2 composition than G1 & G3 compositions

On the other hand because of the highest particle packing due to use of glass cullet, the G4 & G5 compositions are well graded than rest of the compositions the compositions compaction is better during melting, previously melted glass cullet act as flux, add extra benefit of densification [12].For this reason G4 & G5 compositions have less porosity & no water absorption than other sample

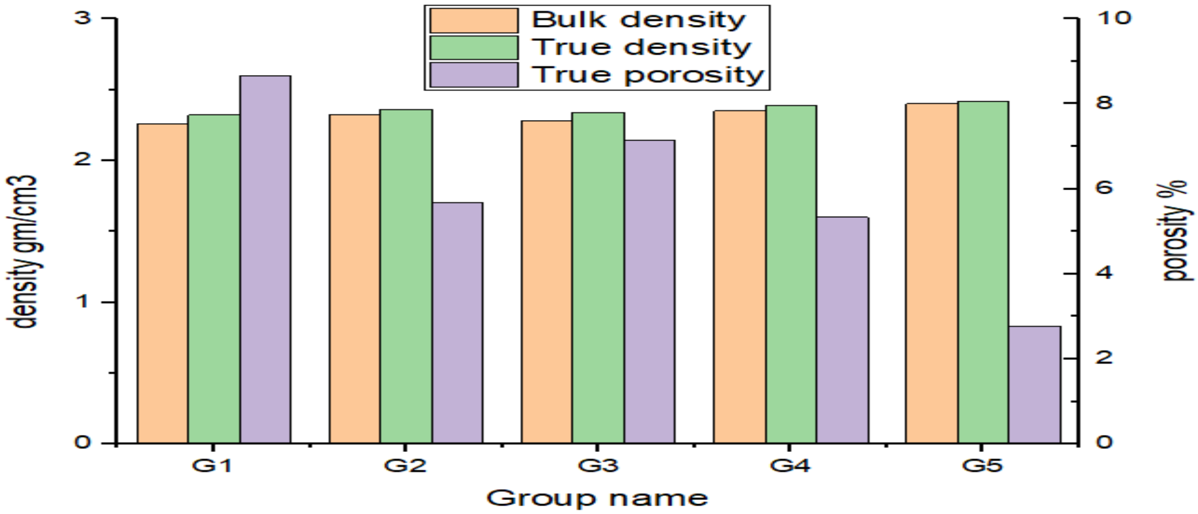

Fig. 1. Density & porosity comparison of different groups

Ordinary soda-lime glass appears colorless to the naked eye when it is thin, Silica gives the transparency in the glass. Contamination & bubbles make the glass opaque, iron oxide impurities produce a green tint which can be viewed in thick pieces. In **fig. 2**. The prepared glass samples are depicted. Our prepared glasses appear greenish color for iron contamination & thick cross section. All of the glasses G2 composition appears less green than others. It contains less bubbles, more transparent. The G4 & G5 cullet containing glasses are more greenish than others as the color of the cullet was greenish as the cullet was thick cross section of float glass

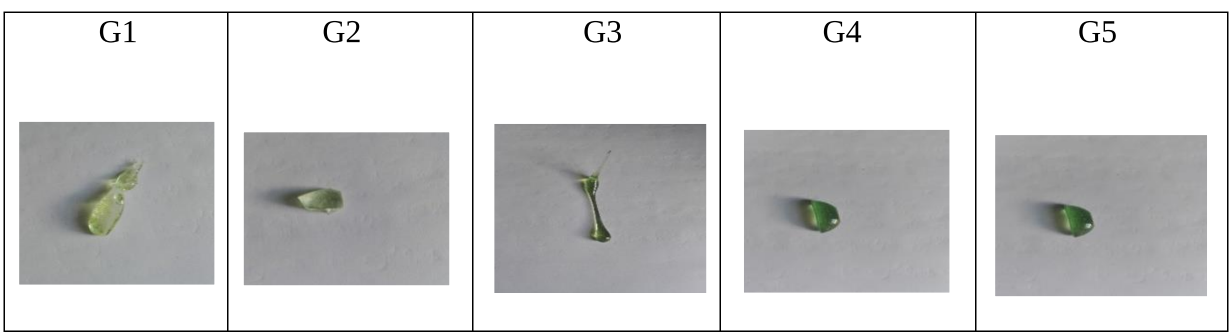

Fig. 2. Appearance of prepared Glass samples

3.2 Thermal property (Softening point)

The softening point, at which the glass may slump under its own weight, is defined by a viscosity of $10^{7.65}$ poise. In **Fig. 3** depicts the softening points of different compositions. Higher amount of Na_2O,CaO,MgO have less softening point.[13] G1 composition is made of pure silica, no extra source of Na_2O have so G1 have highest softening point. G2 & G3 composition, have Padma sand extra Na_2O, CaO ,MgO were added . Na_2O act as the lowering the viscosity & lower the softening point [14]. G4 & G5 compositions have lower Na_2O than G2 & G3 thus G2 softening point is lowest.

3.3 Mechanical property (Hardness)

Hardness is commonly understood as resistance to scratching or abrasion. **Fig. 4** shows the Vickers hardness of different compositions .Glass former SiO_2, give network connectivity, strength of the composition. G4 & G5 composition, high amount of SiO_2, Glass cullet have Source of SiO2 which give network connectivity, Variation of particle sizes increase network packing thus increase hardness ,less amount of high atomic radius element have less tendency to fracture toughness & mobility so hardness increases [15] G2 have MgO & Al_2O_3 in Padma sand so it have higher hardness than G1 & G3 .G3 contains only bigger ionic radius of cation (Ca) decrease the plastic deformation thus it resist less value of Vickers indentation

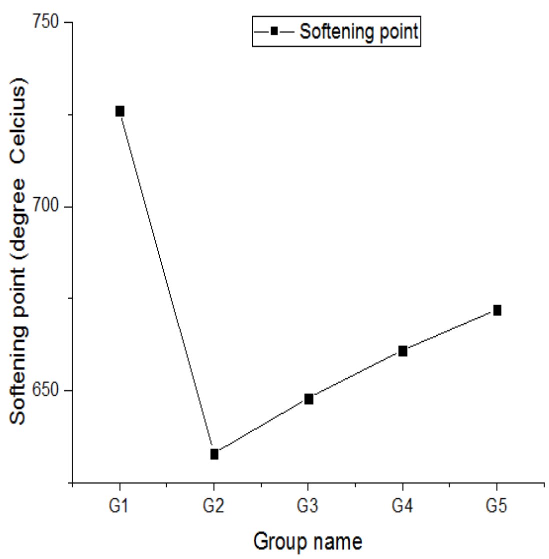

Fig. 3. Softening point comparison of different groups

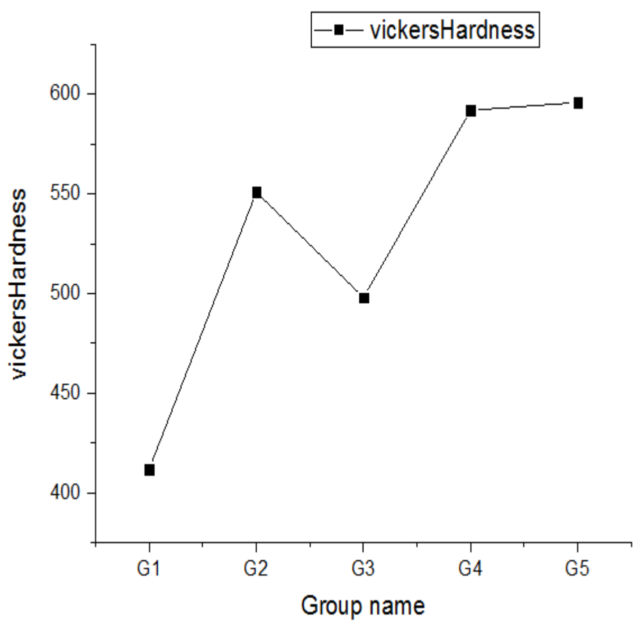

Fig. 4. Hardness comparison of different groups

3.4 Optical properties (Optical micrograph &Absorbance)

Optical properties of glass of most interest in the soda-lime-silica composition field are refractive index, reflection, transmittance and absorption. These properties relate to measurement of internal stress, light protection, heat transmission and visual color. **In Fig.5** depicts G4 & G5 has less bubbles, for higher density & lower porosity. Presence of glass cullet helps to better compaction & well grading of glass structure. On the other hand G1 microscopy shows very large bubbles because of highest porosity & lower density. UV-Vis spectroscopy indicates in **fig. 6** G2 have less absorbance thus the Padma sand contain better transparency. PbO have high-density, high-dispersion, high-refractive-index glasses. Alkaline earth glasses have lower refractive indices comparable to the flints, & have lower dispersions [16]. G2 (Padma sand) composition have alkaline earth materials thus it have lower dispersion & refractive index. It means group 2 have higher transparency[17] . Increasing the amount of Na_2O refractive index increases., replacing Na_2O with Al_2O_3 in aluminosilicate glasses decreases 'n' because polarizable NBO's are replaced by less polarizable Al-O-Si bridging oxygen [18] the group 2 sample contain huge amount of alumina~ 10% determined by XRF of Padma sand [7]. So G2 sample have lower refractive index i.e lower absorbance (< 0.5 %) in the visible range wavelength (~450nm) & higher transparency than other sample. On the other hand for G4 & G5, variation in the particle size distribution of cullet & fine particles occur segregation, optical inhomogeneity. Cullet act as the light absorbing medium, so G5 sample shows higher absorbance with the increase of wavelength

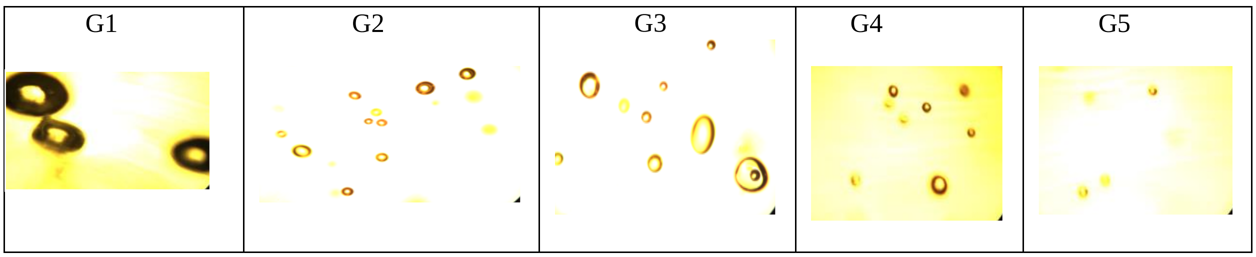

Fig. 5. Optical micrograph image of different groups to find out the pores & bubbles

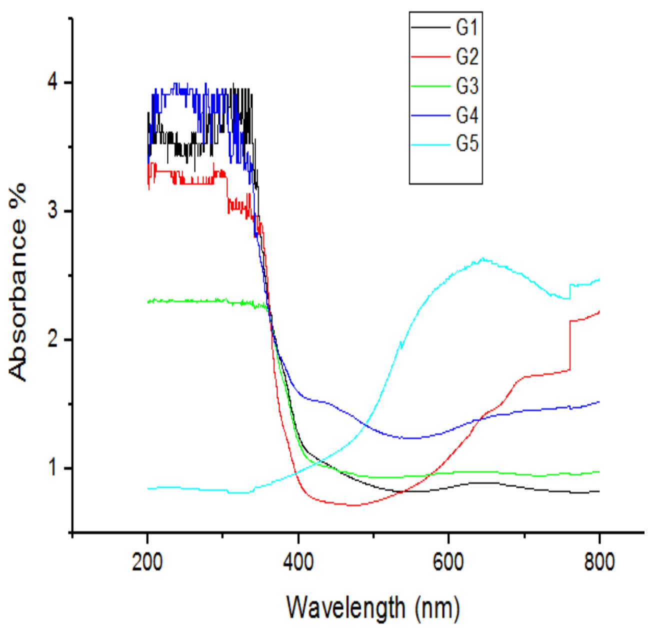

Fig. 6. Absorbance of different groups with wavelength

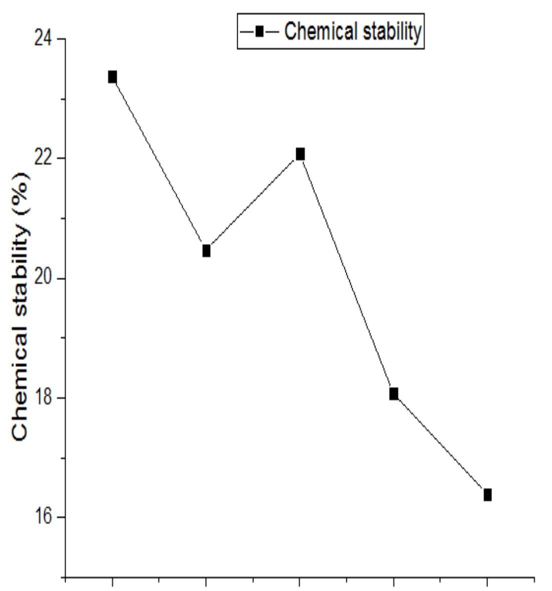

Fig. 7. Chemical Stability comparison of groups

3.5 Chemical Stability (Acidic & basic)

Chemical stability is to be understood as the resistance of the glass surface to chemical attack by defined agents **Fig.7** shows the corrosion of different glass compositions. Higher amount of CaO & lower amount of Na_2O have less corrosion [19]. G2 composition Padma sand have high in maximum Na_2O CaO+MgO content [6],which extensively react with the HF solution than less basic elements containing group That's why G4 & G5 have less corrosion towards acidic solution. But G1 have higher amount of corrosion because it contains large amount of porosity than G3. For this reason G3 is less corrosive. On the other hand, the soda lime silicate glasses are less attractive to basic like NaOH. For this reason the chemical attack with the basic medium is zero for the glass composition.

4. Conclusion

In this work, silicate glasses were made of different silica sources by conventional glass melting method. The method appeared to be quite appropriate for the current work. By altering chemical composition the physical, mechanical & optical properties could be modified described in this work. From all of the samples, G1 sample (60% quartz) have highest corrosion 23.37% & softening point 726 ◦ C but less hardness 412.Replacement of quartz by Padma sand (60%) has showed better properties .It has higher density, transparency, less absorbance of (<3.5%) & hardness with minimal softening point of 633 ◦ C. Thus production of Padma sand is cost effective for its availability & less softening point .The samples with glass cullet sources (20 % & 30% glass cullet of G1 composition) have highest hardness with less corrosion than other samples. 30 % glass cullet have 596 hardness & 16.39 % corrosion .At the end of the experiment ,we assure that Padma sand & glass cullet are the potential raw materials of conventional soda-lime glass.

5. Acknowledgement

The author gratefully acknowledge the Glass & Ceramic Engineering Department, RUET & Rajshahi University for their consistent technical support.

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