International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 9 Issue 2 Series. I || Feb.2020 || PP 56-67

Production And Characterization Of Soda-Lime Silica Glass Using Silica Sand.

Zainul'abideen Abbati[1] and Ibrahim Abdullahi[2]
[1]*Department of Welding and Fabrication, Kano State Polytechnic, Kano Nigeria.*
[2] *Mechanical engineering Department, Faculty of Engineering, Bayero University Kano.*
Corresponding Author: Zainul'abideen Abbati

ABSTRACT. *This work production and characterization of soda-lime silica glass using silica sand was processed. Sand Sample deposit was assessed for glass makingthrough analytical method i.e X- Ray fluorescence spectroscopy (XRF), after it undergoes chemical pretreatment. The result reveals the presence of silicon oxide SiO_2at a higher percentage of 98.03%. The following oxides were also fond from the sand: Al_2O_3 0.81%, K_2O 0.047%, Na_2O 0.034%, CaO 0.26%, MgO 0.061%, Fe_2O_3 0.07%, CuO 0.260%, ZnO 0.170%, BaO 0.023%, TiO3 0.08%, MnO 0.017% and L.O.I 0.110%. The sand physical properties (such as density, specific gravity, grain size and grain morphology), standard method for testing sand sample density was followed for three times and found densities of 1.144g/cm3, 0.984gcm3 and 0.964g/cm3 which indicates the average density of sand sample was 1.03g/cm3. The specific gravity was also determined as 1.749, 1.894 and 1.869 at different times which signifies the possibility of using the sand sample for glass making because all the specific gravities are less than 2.65 which is the recommended sand sample specific gravity. Particle size and distribution and grain morphology were carried out using manually operated mechanical shaker (sieving method) and electronic microscope (SEM) respectively. The result reveals that the highest percentage of retention occurred at sieve number 20, 30, 50 70 and 140 correspond to standard requirement for sieve size retention fraction for glass making. Grain shape was found to be angular with sharp corner which also satisfies the standard requirement for glass making.The silica sand when properly processed may be used for production of higher temperature engineering materials such as; glass which will provide job opportunities to the youth in the area and the country at large.*

KEY WORDS*- Amorphous, Crystals, Glass, Soda-Lime, Silica,*

Date of Submission: 04-02-2020 Date of Acceptance: 20-02-2020

I. Introduction

Glass is defined as an amorphous solid usually formed by the solidification of a melt without crystallization (Azom, 2001). It is an engineering material widely used for various purposes such as packaging of food item in solid form or liquid (beverages) and produced at higher temperature above 1675C (Sara, B et. al 2015). Glass is an engineering material made by man and used in the production of jewellery, knifes and arrow tips right from the olden days. Glass production increases during industrial revolution due to availability of the major raw-material (i.e silica, soda-ash) and at affordable price. The advantage of glass product over other engineering materials led to the mass production of glass in the 20th century (Rechard E. et.al, 2008). Modern or float glass was in use for many applications such as domestic, medical, structural and so on (Naimeh K, 2004).

Methods of production of glass are many depending on its type (i.e. Vitreous Silica Glass, Sodium Silicate or Water Glass, Sheet and Container Glass or Soda-Lime-Silica glass, Borosilicate Glasses, White Opaque – Opal Glass, Special Glasses, Ceramic Glasses, Sealing and Solder Glasses and Phosphate Glasses) to be produced for various applications such as flat and container glass, glass fibers, glass tubing, bulbs, TV screens, tableware, insulators, electrical components, pharmaceuticals and so on,(Azom, 2001). Soda-lime silica glass is produced as a result of chemical reaction between silica, alkali (NaO), and alkali earth oxide (MgO) at higher melting temperature that break the crystal structure formed by individual constituent oxide and undergoes fast cooling which result in producing irregular and rigid structure (Rehren, T. 2007). Decrease in silica content and increase in fluxes content lower the melting temperature and the properties of soda-lime glass constitute the properties of the constituent raw-material (Sara, B et. al 2015). Different geological materials such as sand, rock, clay and other Agricultural commodities shells (such as ground-nut, rise-host, beans etc.) contain abundance silica content that can be extracted through different method of beneficiation (i.e chemical method). The extracted silica can be used in production of soda-lime silica glass after it undergoes chemical analysis using XRF that make it possible in formulating the glass batch with different raw-material composition. Thus, Soda-lime silica is a soft glass which is prepared by fusing the composition of sodium carbonate, calcium carbonate

and silica through heating that decomposes the carbonate and solidified through fast cooling without crystallization. The present of soda-ash and limestone is to lower the high temperature and add chemical durability to the produced glass respectively. According to Sintali and Egbo (2007), the suitability of sand for glass making depends on three basic parameters; sand chemical composition, sand grain size distribution and percentage of trace contaminant. A sand with 70% $SiO_2$and above is suitable for making glass. Glass making sand should not be too coarse or too fine, because coarser grains cannot form homogenous glass batch while too fine grain size will create air bubbles in the glass (Kovacecet, et.al., (2011). Silica sand that is used for glass making falls into two groups; the natural physical state of sand and the degree of purity of the sand which is indicated by its chemical composition (Sintali and Egbo, 2007). Industrial uses of silica sand depend on its purity and physical characteristics which include; grain shape, sphericity, grain size and distribution (Kamar, 2004).

Silica sand has many advantages that can improve the nation's economy due to its potential application in many areas such as dishware, stoneware, earthenware, porcelain, white wires, bricks making, building (wall and floor), ceramics composite and glass of different types. There is high deposit of silica sand in Nigeria especially areas with river flow (Edem et.al, 2014).

II. Material And Method.

Collection and Pretreatment of the Sand Sample

Ten Sand Samples was sourced from Yanbarau River beach deposit of sand from different position of the river (as shown in Plate I) located at latitude 11.83^o N and longitude 8.59^o E in Dawakin Kudu Local Government of Kano State Nigeria.

Plate I. Deposit of Sand in River Yanbarau Beach of Dawakin Kudu.

The sand sample was pretreated by washing thoroughly using tap water to remove dust until clean water started to flow out. 250ml of hydrofluoric acid was poured into the sample and stirred for 5minutes followed by 250ml of distil water and stirred for 5minutes, until it drains out. Tap water was used to wash the sand properly, for the second time in order to reduce the iron content and to stop further reaction. The sand sample was then spread on a mat to dry under the sun as shown in Plate II and then oven dried at temperature of 110^{o}C for seven hours as shown in Plate III. The same procedure was repeated to the rest of samples.

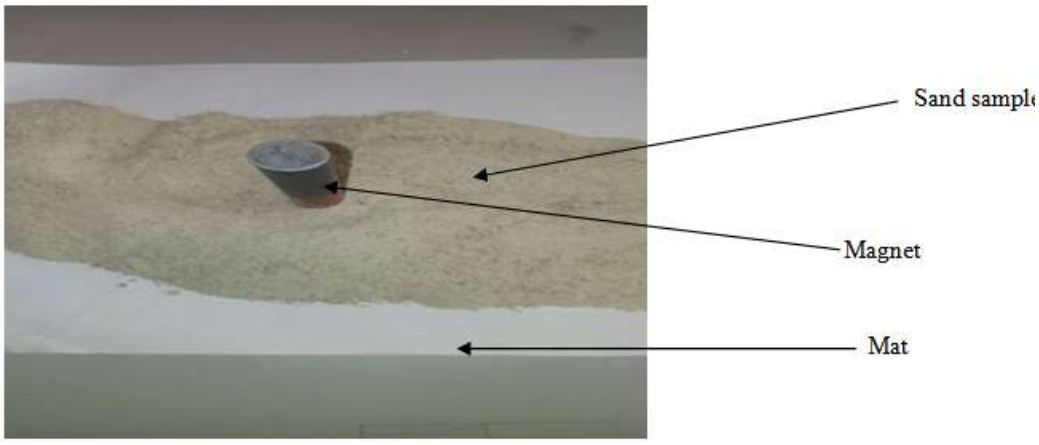

Plate II. Sand after Undergoing Pretreatment.

Plate III. Sand under Oven dried.

Determination of Chemical Composition of the sand

XRF was conducted according to ASTM C146-94a (2014), using EDXRF Spectrometer "Minimal 4" model for determination of the constituent element or oxide present, the analysis was conducted at National Geosciences Research Laboratory (NGRL) Kaduna, Kaduna state. 5g of this sample was weighted in a beaker using macular balance, and thoroughly mixed with 1g of soluble starch that gave homogeneous mixture and pressed to high pressure at 12,000Psi (6 tsi) to produce pellets. The pallets were leveled and packaged for analysis.

The machine was switched on and the selection of filters was guided by a given periodic table used for elemental analysis. 100 seconds was used as measurement time for the sample, and air was used as a medium throughout. The machine was then calibrated by the machine gain control, after which the sample was measured by clicking the position of the sample charger. Loss on ignition was determined gravimetrically by heating 1g of the powdered sample in a cleaned weighted crucible at 1000^{o}C. After which the crucible and the content was weighted to get the differences in weight before and after heating, and automatically released the result on the computer attached to the XRF machine as shown in Plate IV. The rest of the samples undergoes the same procedure.

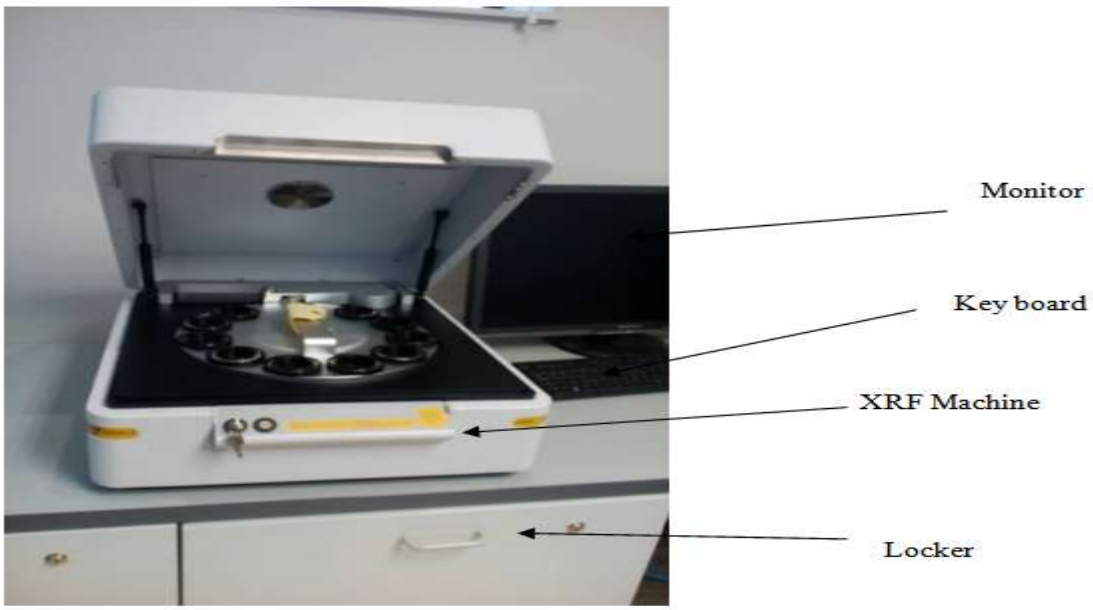

Plate IV. XRF Machine

Determination of Density of the Sand

The density test was conducted according to ASTM C127-07 (2007) each sand sample was consider as a batch; each batch was immersed in water for 24 hours to essentially fill the pores. It was then removed from

the water and allowed to dry in an oven at a temperature of 110 ± 5^{o}C as shown in Plate V. The mass of the sample was determined by weighing and subsequently the volume of the sample was determined by displacement method and recorded. Finally, the density was calculated using the Density equation;

$\rho = \frac{m}{v}$----------1.

Where ρ is the density m (g) is the mass, v (m^3) is the volume

Plate V. An Electric Oven for Sample Drying.

Grain Size Analysis of the Sand

Grain size analysis was conducted to each sample according to ASTM D422-63 (2007). Sample to be tested was dried using oven dryer. 100g of dried sample was measured, recorded and the weighted sample was placed in the top most sieve of the selected sieve as in the required specification, which was arranged in a mechanical vibrator. The sieve shaker vibrated the sample inside the sieve series for 15 minutes as shown in Plate VI. The sieves were separated and the cumulative percentage by weight of the particles retention on each sieve was found, weighted and recorded. This is repeated to the rest of the samples.

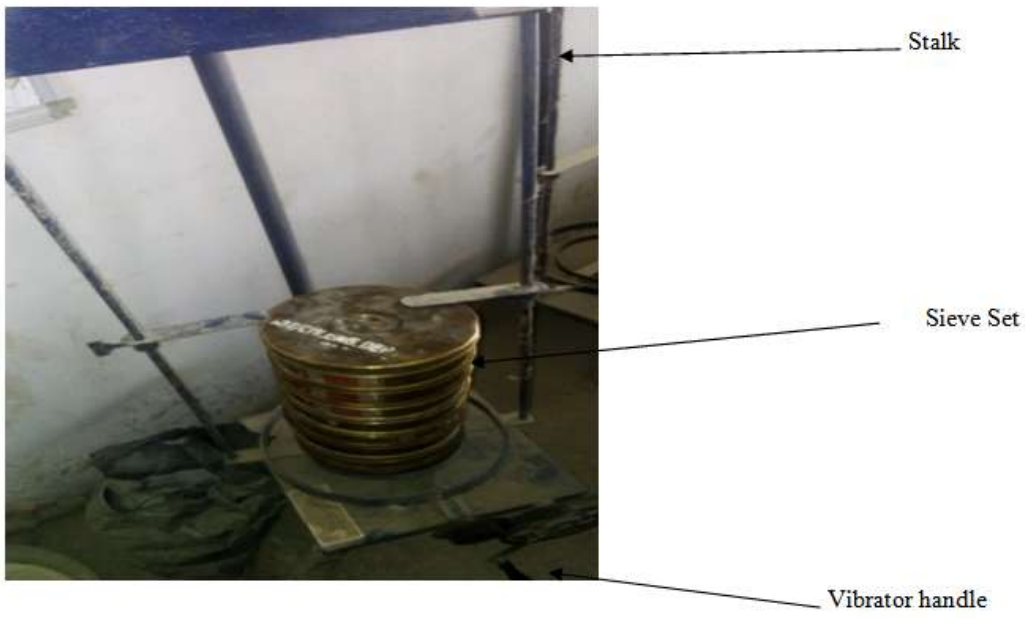

Plate. VI. Sand Sample inside Sieves

Determination of Specific gravity of the Sand

The sand sample specific gravity was determined using density bottle, starting by weighing empty density bottle using weight balance and recorded as (M_1). Sample of 10g was weighted and poured into the bottle and the bottle was weighed and recorded as (M_2).Water was added into the bottle and heated in order to expel air bubbles and then allowed to cool. The bottle and its content were weighed after it has cooled and recorded as (M_3). The content inside density bottle was poured away and distil water was used to clean it, then filled with water, weighed and recorded as (M_4). The specific gravity of the sand was evaluated using Rudolp and Lubes equation (2). (Sintali and Egbo, 2007). This procedure was repeated to each sample.

$$SG = (M_2 - M_1)\left\{\frac{1}{M_4 - M_2}\right\} + (M_3 - M_2) \text{----------2.}$$

where:

SG is the specific gravity of the sand sample.

M_1 is the weight of empty density bottle.

M_2 is the weight of sand sample and density bottle.

M_3 is the weight of heated sand sample and water inside density bottle after cooling.

M_4 is the weight of bottle filled with water.

Grain Morphology Examination of the Sand Sample.

Grain morphology of the sand Sample was analysed by a scanning electron microscope SEM (Model: PhenonProx) at Umaru Musa Yar'adua University laboratory (UMYU) Katsina. SEM was used to view each sample of sand in order to find out the sand shape. The sample was oven dried at 60^{o}C for at least 3 hours, it was then loaded into the SEM holder and the SEM was turned ON, also the monitor was ON. The sample was then bombarded with a beam of hot tungsten filament electron at an acceleration potential of 30 kV, which emit electrons that pass through a series of electromagnetic lenses. Magnification was chosen starting from lower 100X and TV scan mode was also chosen. The sample was found using trackball, slow scan mode was used to increase the magnification slowly up to 370X and 500X. Variable button was pressed were it opened small window on the monitor screen, the size of the screen was adjusted and overlaid it on the region of interest, then the image was focused within the small screen using outer focus ring followed by using inner focus ring which looked more fine than using outer focus ring. The spirit icon in the computer was double clicked and the image was saved by clicking file menu, sample name and photo I.D was imported as shown in Plate VII. The produced silica sand morphological image was also analyzed using imagej software were the particle average size, grain size distribution and particle shape were determined. It involves converting the SEM image to binary by using the pixels information, the image with resolution 176x204 pixels 8 bits at 370x719 magnification was analyzed by drawing a straight line on the image along the length of the scale by using line tool from the tool bar, analyze tab was selected from the menu bar and the length of the straight line was entered. Region of interest was selected in the image by drawing a box in the region using box tool in the tool bar. Region of interest was crop under the image tab and threshold was applied. Set measurement under analyze tab was set and analyze particles where selected by pointing on select tab which resulted on displaying result.

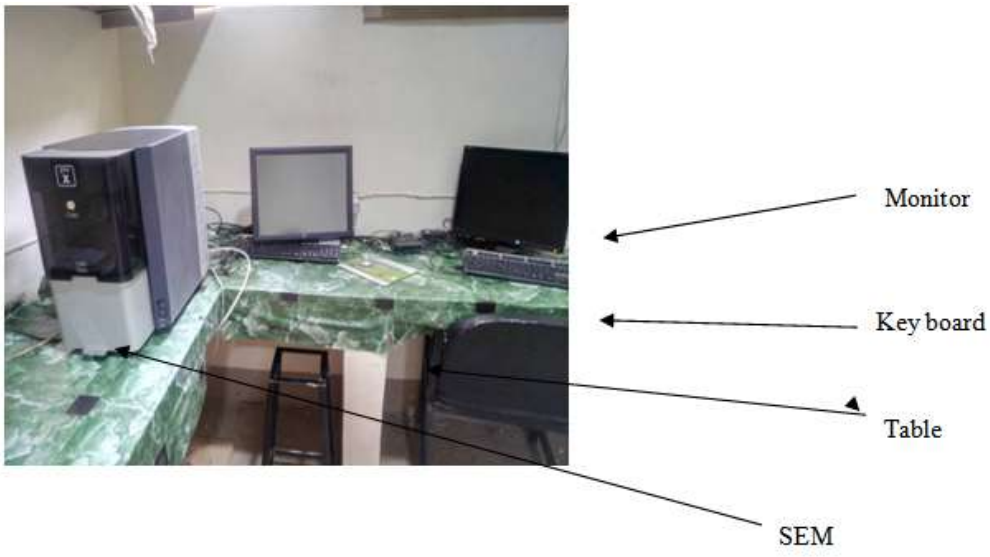

Plate VII. Scanning Electron Microscope

III. Results And Discussion

Experimental Results

The result of the experiments or tests conducted was presented in this chapter as follows:

Chemical Composition of Sand Sample

Table 1 shows the detail oxides composition of one of the sand Sample obtained from chemical analysis using XRF "Minimal 4" model. The result shows silicon dioxide (SiO_2) known as silica is the constituent with highest percentage composition of (98.03%) while TiO_2 has the lowest percentage composition of 0.008%. This sand sample was selected due to its higher percentage of silica and low percentage of iron oxide, which are the major factors for a sand to produce colorless soda-lime silica glass.

Table 1: Chemical Composition of the Sand Sample.

Oxide composition	(%) Content
SiO_2	98.03
Al_2O_3	0.81
K_2O	0.047
Na_2O_3	0.034
CaO	0.26
MgO	0.061
Fe_2O_3	0.07
CuO	0.260
ZnO	0.170
BaO	0.023
TiO_2	0.008
MnO	0.017
Loss on Ignition	0.110

Density of the Sand Sample

Table 2 shows the result for density test of sand sample. The result of density test was obtained from the test conducted and average density is calculated. The result shows the value of mass for three samples and their various volumes. It also indicates negligible variation of mass against density as shown in figure 1.0. The figure shows a graph of density against mass of sand sample, the graph shows that 4.589g of sand sample has a density of 1.147g/cm^3, next sample of 4.839g attained a density of 0.988g/cm^3, and the last mass of the sample was recorded as 4.819g with density of 0.964g/cm^3. The differences in the densities of the three sand samples are negligible which is probably due to the negligible change in mass of the sample.

Table 2: Density of the Sand.

Sample	Mass (g)	Volume (cm^3)	Density(g/cm^3)
1	4.589	4.00	1.147
2	4.839	4.90	0.988
3	4.819	5.00	0.964
Average Density			1.033

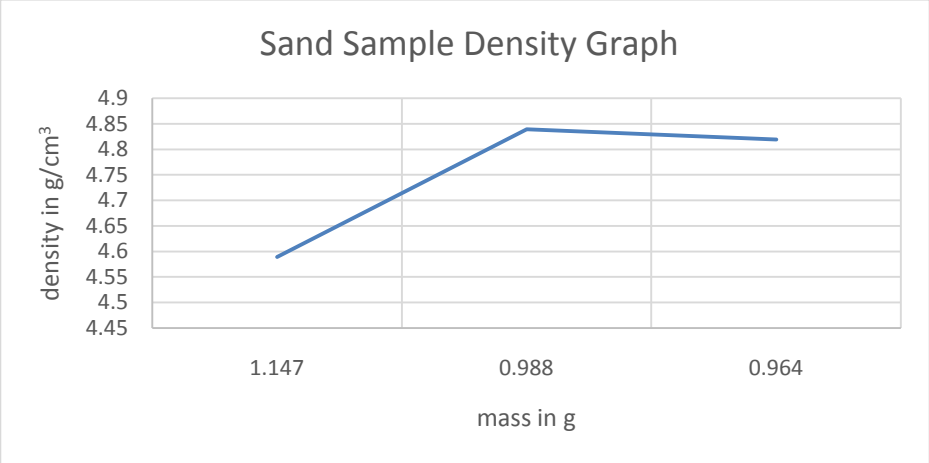

Fig 1.0 Variation of Sand Sample density with mass.

Sand Sample Grain Size and Distribution Analysis Result

Table 3 shows the mass of sand obtained from the grain size and distribution analysis for a sand of 100g. The analysis was conducted for three round using mesh number 20, 30, 40, 50, 70, and 140, mean value

was obtained at each mesh number and cumulative mean value was also obtained which shows that 99.41g of the sand was collected after the analysis of 100g of the sand. The result shows high percentage of retention at mesh number 30 with mesh size 0.595mm as shown in Figure 1.1. The figure shows the variation of cumulative mean percentage of retained with mesh size of each sieve.

Table 3: Sand Sample Grain Size and Distribution Analysis Result.

s/n	Mesh no.	Mesh size(mm)	1st (g)	2nd (g)	3rd (g)	Mean (g)	Cumulative mean(g)
1.	20	0.840	13.5	10.7	11.5	11.9	11.9
2.	30	0.600	37.1	32.4	35.5	35.0	46.9
3.	40	0.425	5.1	5.7	5.1	5.3	52.2
4.	50	0.300	12.0	10.7	12.0	11.56	63.76
5.	70	0.212	17.1	17.7	16.4	17.06	80.82
6.	100	0.150	5.2	6.1	5.1	5.46	86.28
7.	140	0.105	11.3	14.6	13.5	13.13	99.41

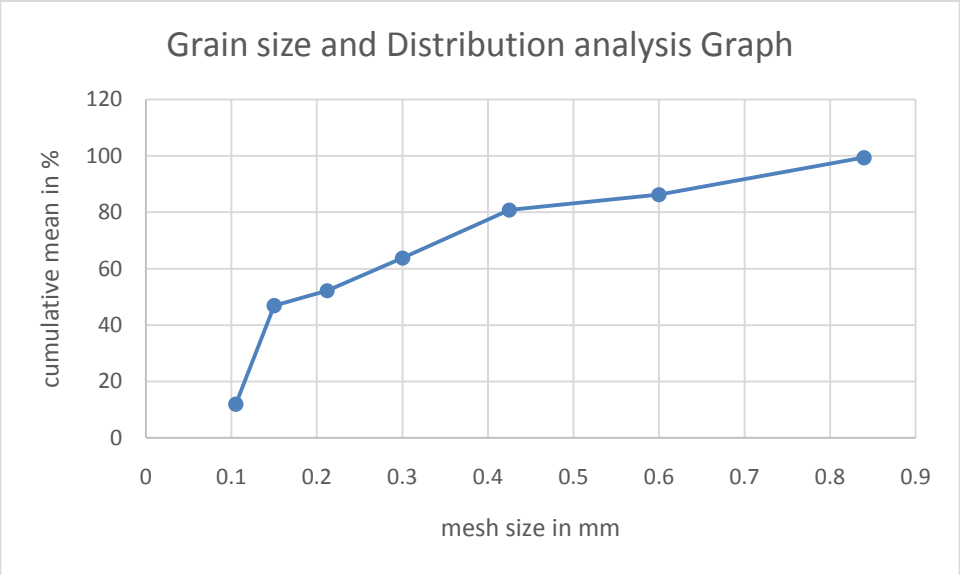

Figure 1.1 Variation of Cumulative mean percentage retained with mesh size of sand Sample.

Sand Sample Specific Gravity Test Result

Table 4 shows the result for specific gravity of sand obtained using Rudolp and Lubes equation. The result shows all the specific gravity of the sand samples are less than 2.5 which correspond to the sand specific gravity for glass making (Duvuna and Ayuba 2015).

Table 4: Sand Sample Specific Gravity Test Result.

Sample	Mass (g)	Specific gravity
1	M_1=18.101 M_2=28.066 M_3=45.840 M_4=43.919	1.749
2	M_1=18.101 M_2=28.171 M_3=47.936 M_4=43.935	1.892
3	M_1=18.101 M_2=28.112 M_3=46.099 M_4=43.092	1.869

Sand Sample Grain Morphology Result

The results of the morphological examination for sand sample are presented as SEM micrograph as shown in Plate VIII and Plate IX at 500x and 370x magnification respectively. Plate VIII shows SEM morphology of the sand at 500x magnification. The image shows homogeneity of sand grain size by visual

inspection also the sand grains boundary indicates angular edges with sharp corner. These properties of the image show that sand sample can probably use for glass making.

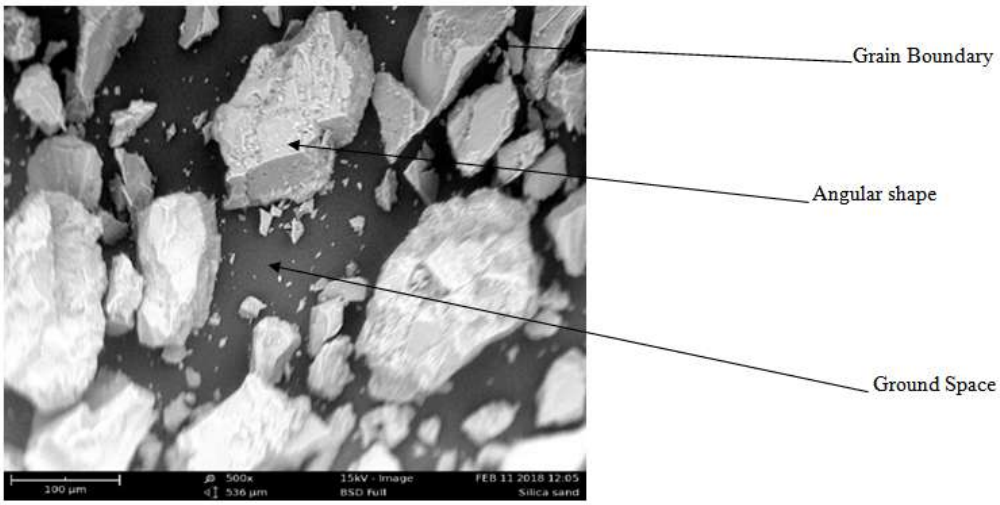

Plate VIII Sand Sample Morphology at Magnification 500x

Plate IX shows SEM morphology of the SandSample at 370x magnification. The image shows merely homogeneity in grain size, and also shows the shape of grain boundary which look angular in shape with sharp corners, these indicate that the sandsample is good for glass making.

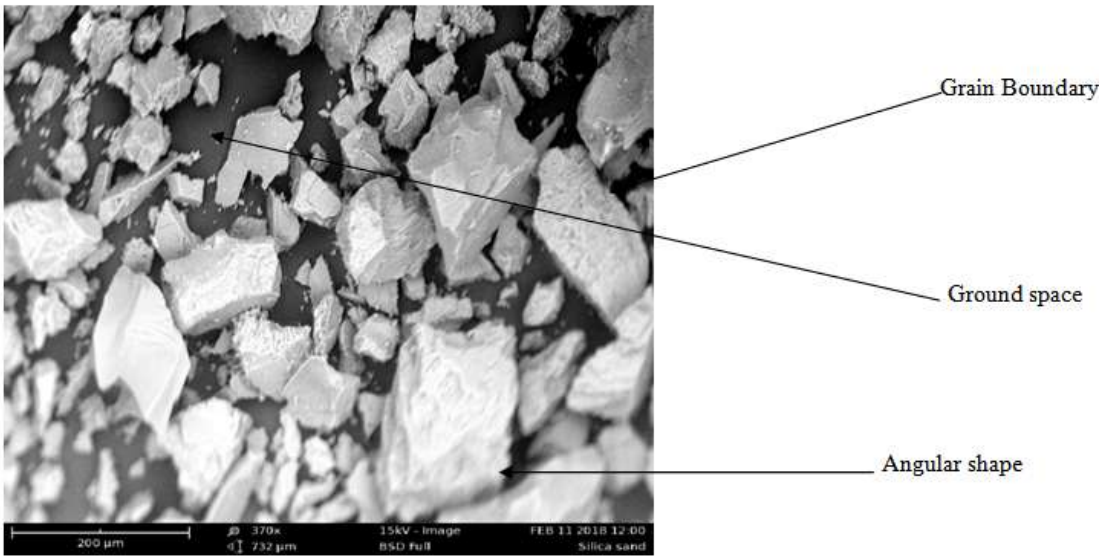

Plate IX Sand Sample Morphology at Magnification 370x

Particle Sharp Analysis Result of the Sand Sample by Imagej

Table 5 is the result of particle shape analysis for the Sand sample using imagej software. The result shows the values of circularity, roundness, length of ferret X and Y, ferret angle and solidity for the grains which indicate the possibility of using the sand for glass making- as per Benson and Wilson, (2015), grain shape that is well-rounded and spherical is greater than or equal to ≥ 0.6 and cannot be used for glass making.

S/N	Area	BX	BY	Width	Height	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR	Round	Solidity
1	7	422	2	3	5	0.496	5.831	422	7	59.036	2.849	2.499	0.4	0.609
2	14	264	9	5	8	0.333	9.434	264	9	122.005	3.8	3.312	0.302	0.519
3	15	243	26	8	6	0.255	8.544	243	32	20.556	6	1.456	0.687	0.429
4	21	241	34	8	9	0.271	10.817	242	34	123.69	5.662	2.094	0.478	0.452
5	263	399	50	20	30	0.195	30.265	415	50	97.595	20	1.492	0.67	0.597
6	9	167	58	5	6	0.344	7.211	168	64	56.31	3.536	2.677	0.373	0.545
7	22	171	58	7	10	0.239	10.44	175	58	106.699	6.753	1.673	0.598	0.44
8	18	163	68	6	6	0.38	7.81	163	74	39.806	6	1.199	0.834	0.6
9	19	155	76	10	8	0.286	12.207	155	84	34.992	4.418	4.351	0.23	0.475
10	22	210	76	7	9	0.465	10.817	211	85	56.31	4.537	3.399	0.294	0.595
11	112	552	100	18	21	0.375	23.431	555	100	129.806	8.751	3.705	0.27	0.624
12	180	122	101	41	53	0.073	62.482	122	149	50.194	11.404	8.578	0.117	0.289
13	29	207	111	9	17	0.212	19.235	207	128	62.103	4.715	5.478	0.183	0.45
14	92	173	123	14	25	0.148	25.962	174	148	74.358	10.27	3.099	0.323	0.443
15	36	196	128	11	10	0.257	12.083	196	135	24.444	9.068	1.271	0.787	0.468
16	181	25	129	19	26	0.361	27.514	29	155	70.907	13.621	2.216	0.451	0.633
17	33	165	129	5	15	0.256	15.133	168	129	97.595	5	3.992	0.25	0.589
18	9	191	129	2	8	0.331	8.246	191	137	75.964	2	4.974	0.201	0.692
19	33	383	134	11	8	0.236	12.083	383	141	24.444	7.034	1.754	0.57	0.55
20	5	378	137	5	4	0.388	6.403	378	141	38.66	1.947	5	0.2	0.526
21	9	387	147	6	5	0.393	7.071	388	147	135	3.905	2.175	0.46	0.5
22	8	167	171	4	6	0.335	6.325	167	171	108.435	4	1.935	0.517	0.485
23	6	196	188	3	5	0.484	5.831	196	193	59.036	2.239	3.374	0.296	0.667
24	6	325	203	2	6	0.404	6.325	325	209	71.565	1.902	4.833	0.207	0.667
25	46	262	209	17	7	0.287	17.263	262	212	10.008	6.886	3.577	0.28	0.532
26	79	121	211	11	17	0.38	17.464	127	211	103.241	10.29	1.946	0.514	0.65
27	51	237	214	15	6	0.314	15.524	237	215	165.069	5.916	2.626	0.381	0.638
28	12	279	222	5	10	0.259	11.18	279	232	63.435	2.346	6.976	0.143	0.533
29	7	224	225	2	6	0.472	6.325	224	231	71.565	2	3.982	0.251	0.737
30	298	564	255	19	40	0.215	40.608	567	295	80.074	18.598	2.266	0.441	0.57
31	13	132	264	5	10	0.28	11.18	132	264	116.565	2.69	5.906	0.169	0.553
32	6	581	280	4	5	0.425	6.403	581	285	51.34	2.121	4.116	0.243	0.571
33	21	562	282	5	10	0.225	10.296	562	291	60.945	5	2.294	0.436	0.506
34	8	583	284	3	6	0.429	6.083	584	284	99.462	3	2.467	0.405	0.593
35	158	348	312	24	34	0.098	37.162	348	346	66.194	17.665	2.612	0.383	0.378

Table: 5. Sand Sample Particle Shape Analysis Result.

Table 6 is the summary result of particle shape analysis for the sand using imagej software. The result summarized the values of the grain shape parameters such as circularity, solidity, feret angle and feret length, which indicates that the grain shape is angular with sharp corner.

Table 6: Summary Result Table for Particle Size Analysis.

Slice	Count	Total Area	Average Size	%Area	Circ.	Solidity	Feret	FeretX	FeretY	FeretAngle	MinFeret
Silica Sand	35	1848	52.8	0.622	0.311	0.546	15.171	281.143	155.6	75.069	6.455

IV. Discussion

All the analysis and experimental result about chemical properties, physical properties and morphological exermination are discussed as follows. The result of the properties like chemical composition, density, specific gravity, grain size and distribution and morphological structure.

From the result of the chemical composition in Table 1. The XRF analysis result indicates the presence of high SiO_2 content of 98.03% by weight composition with twelve (12) oxide component, some act as impurities (such as iron oxide) while some act as fluxes (such as sodium oxide). The high percentage of silica in the sand may likely be due to the following reasons. Firstly, geographical location, river flow area and sand treatment with Hydrofluoric acid (Hf) which reduces the content of impurities. The concentration of silica in the sand indicated the suitability of using the sand for glass making, because for any sand to be used for glass making, it must contain at least 70% silicon oxide (SiO_2) (Edem et, al, 2014). The content of iron oxide affects the formation of colorless glass that is when the iron content exceeds 0.1%, the sand may be used for glass making but it will be colored glass, so also, if the iron content is below 0.1% colorless glass may be formed. The purity of the sand can be increased by leaching the sand with Hf. Moreover, glass making sand should not have

iron oxide above 0.1% by weight, in order to produce colorless glass and it is found from Table 1, the content of iron oxide was 0.07% by weight which indicated the possibility of making colorless glass with the sand. The result obtained agreed with the findings Meechoowas, et.al (2013). According to Duvuna and Ayuba. (2015), for sand to be suitable for glass making, CaO and MgO should be between 4-5% by weight, Na_2O and K_2O should be between 2-9% by weight, these two-oxide act as fluxes, when their content reach the required percentage, they likely reduce the melting temperature of the glass batch. Although, the content of the above oxides as shown in Table 1 are not up to the requirement, the oxide can be added as a supplement to the glass batch since they act as a flux. Therefore, the Sand sample has high potential for glass making.

Density Test

From the result of sand density as shown in Table 2 there is negligible variation in the density of the sand after it's pretreatment. The variation in density of the sand is obtained probably due to little change in mass of the sand as shown in Figure 1.0. The figure shows insignificant changes in the densities of sand as a result of negligible changes of its mass in gram. This is probably due to the change in volume. Moreover, the density of pure silica is within the range of (2-2.3g/cm^3) while cristobalite and tridymite have much lower densities Marzia (2014), therefore, the collected sample of sand is likely to be a cristobalite or tridymite, when we consider the values of densities found in Table 2.

Grain size and distribution analysis

From Table 3, there is variation in mass of sand retention in each sieve after sieving. These variations in mass of sand obtained are likely attributed to non-homogeneity of the sand grain size. Grain size and distribution is an important factor that effects the glass formation, because large grain does not properly mix with other grain in a glass batch while too fine grains create air bubbles on the glass product Edem et.al,. (2014). Also, according to Duvuna and Ayuba (2015), ideal grain size should be between 15-100 mesh number and it should have percentage retention of at least 75%. The result shows that there are higher percentage of retention of sand sample at sieve number 30, because when we consider Table 3 majority of the particles are found in mesh number 30 which is 0.595mm size that consist of minimal air bubble between the grains of the sand, because the smaller grains fill the gaps in between the big ones during glass melting. If we analyses Table 3, it can be observed that the sand sample are found in mesh number 30, 50 and 70, more than 70% of the sand are sized within 0.595mm, to 0.210mm. The result shows homogeneity in size which will likely result in melting the glass batch. As a result of the grain size and distribution analysis of the sand sample, the percentage retention and screen mesh number correspond to the standard requirement of silica sand for glass making.

Specific Gravity Test

From the result of specific gravity of sand samples as shown in Table 4. After it was tested for three times and found their various specific gravity at 1.749, 1.892 and 1.869. Silica exist in different crystalline form that indicate different specific gravity, example quartz is having approximately 2.651 specific gravity Rajappa, et.al., (2014).The result reveals that the values of the specific gravities in Table 4 is very close to the quartz specific gravity, the closest of the values probably indicate that the sand can be used for glass making, because a silica sand with specific gravity above 2.65 cannot be suitable for glass making (Duvuna and Ayuba 2015).

Grain Morphology Examination using SEM

Grain shape play an important role in the glass making process. Plate VIII and IX are the result of morphology examination scanned at Magnification of 500x and 370x respectively, from visual inspection the result revealed that the grain shape of the sand is angular in shape with sharp corner as shown in the Plate VIII and Plate IX, because each grain is having a boundary that almost look straight and then turn to other boundary through sharp corner. In a nutshell the grain shape is not spherical or round in shape. These correspond to the requirement for a sand to be suitable for glass making (Duvuna and Ayuba, 2015).

Grain Shape Analysis.

The morphology of the collected sand sample was observed with microscope and analysed using imagej software as shown in Plate X and Plate XI. Grain parameters such as area, circularity, feret angle, roundness, width, height, feretX, feretY and solidity was found as shown in Table 5and also, summarized in Table 6 as shown. The analysis showed that circularity value is less than 0.6 as shown in Table 5 and is summarized as 0.311 as shown in Table 6. So also, from Table 5 sphericity or roundness is less than 0.6 and the average grain size was 0.595mm. Table 5shows the result of the sand particle shape analysis, from the result it was observed that most of the values for circularity, roundness or sphericity of the particles is less than 0.6 which signifies that the particle shape is not circular or round in shape because it analyzed measurement is not up to unity. According to Blott, and Pye, (2008), circularity for an irregular object is closer to zero while

circularity for perfect circle is 1 and it is stated by Duvuna and Ayuba, (2015), that sand sample with angular or semi angular shape and with sharp corner is suitable for glass making while sandsample with circular shape is not suitable for glass making. Also, the sharp corner is found due to the values of feret angle, which is at an acute angle and obtuse angle as shown in Table 5 and Table 6, these indicate that the shape is not circular, since the feret angle is not up to reflex angle and full angle. Moreover, the shape analysis result of the sand sample using imagej software as shown in Table 5 and Table 6, agreed with the result for morphological image of the sand sample and can probably be used for glass making.

V. Conclusion

Based on these work findings, it can be concluded that:

- The chemical composition of the sand sample was found to have 98.03% SiO_2 as its highest composition which is adequate for glass making and the iron oxide percentage was also within the standard requirement for making colorless glass, i.e. less than 0.1%.
- The physical properties test show that, the average density of the sand sample is 1.033g/cm^3 and its specific gravity is less than 2.65, so it is suitable for glass making.
- The grain size and distribution of the sand sample fall within the recommended sieve number (20-100) and the average grain size was found to be0.595mm.
- The grain shape from the grain morphology was found to be angular or semi angular with sharp corner by visual inspection and also, angular or semi angular by particle analysis using imagej. This signified that the sand deposit investigated and is suitable for soda-lime silica glass making and it should be utilized for many other applications such as flat and container glass, glass fibers, glass tubing, bulbs, TV screens, tableware, insulators, electrical components, pharmaceuticals and so on.

VI. Recommendations

Based on the results discussed and concluded it could be recommended that:

- Sand sample need additional oxide (such as CaO, Na_2O and MgO) to act as a flux which reduce the melting temperature of the glass batch.
- It is recommended that the Sand sample should be subjected to melting in order to determine its thermal property, and final production of soda-lime silica glass which will then progress to characterization of the produced soda lime glass.

VII. Acknowledments.

This research was possible through the financial assistance of TETFUND (TETFUND/DESS/POLY/KANO/2017/RP/VOL.1) provided to the corresponding author. Immeasurable thanks goes to Professor Ibrahim Abdullahi of Bayero University Kano who proof read the manuscript. My appreciation goes to Prof. M. A Kurawa and Prof. A Dan'isah of Chemistry Dept. and Elect. Engn Dept. BUK respectively. Thanks to chemistry laboratory Technologist SLT Dept. SOT Sabo Isyaku and Munzali Mustapha who assisted me during the laboratory and fieldwork. Your technical support is highly commended.

References

[1]. ASTM C1110-03 (2008). "Standard practice for sample preparation for X-ray emission spectrometric analysis of sand using pressed powder method.
[2]. ASTM C127-07(2007). "Standard test method for density, relative density (specific gravity) and absorption of sand. West Conshohocken, PA 19428-2959, United states.
[3]. ASTM C146-94a (2014). "Standard test methods for chemical analysis of glass sand. West Conshohocken, PA. ASTM international.
[4]. ASTM D422-63 (2007). "Standard test method for particle size analysis of sand. West Conshohocken, PA. ASTM International United states.
[5]. Azom, N. (2001). Glass- an overview, an article, www.azom.com/article.aspx.
[6]. Benson, M. E., & Wilson, A. B. (2015). Frac Sand Sources in the United States. *Rock Products*, *118*(5), 34.
[7]. Blott, S. J., & Pye, K. (2008). Particle shape: a review and new methods of characterization and classification. *Sedimentology*, *55*(1), 31-63.
[8]. Duvuna. G. A and Ayuba. A. (2015). "A study on silica sand quality in Yazaram and Mugulbudeposits for glass making", *Nigerian journal of technology*, faculty of engineering, university of Nigeria Nsukka, vol. 39, No. 1 pp109-112.
[9]. Edem, C. A., Malu, S. P., & Ita, B. I. (2014). Characterization and beneficiation of the glass making potentials of silica sand deposit from River Benue North Central Nigeria. *Journal of Natural Sciences Research*, *4*(19), 49-58.*Geochemistry and Material Applications Review in Mineralogy* Vol. 29 pp 500.
[10]. Kamar S. A, (2004). Silica, C. A. S., & MINED, W. I. S. What is Silica?. "Geology and occurrence of industrial silica" EBS 425 *Mineral Per industrian* pp1-7.
[11]. Kovacec, M., Pilipovic, A., & Stefanic, N. (2011). Impact of glass cullet on the consumption of energy and environment in the production of glass packaging material. *Recent Researches in Chemistry, Biology, Environment and Culture. Monteux, Switzerland*.

[12]. Marzia Hoque, T. (2014). "Upgradation of locally available silica for the production of solar grade silicon". *Dissertation research of philosophy in material science*, Department of material and metallurgical engineering, Bangladesh University of engineering and technology.
[13]. Meechoowas, E., Tapasa, K., & Jitwatcharakomol, T. (2013). Alternative soda-lime glass batch to reduce energy consumption. In *Key Engineering Materials* (Vol. 545, pp. 24-30). Trans Tech Publications.
[14]. Richaed, E., Sun, K.H and Debels, E. (2008). Fundamental condition of Glass formation, *Journal of American ceramic society*, pp (90-93)
[15]. Rajappa, C., Sringeri, S. B., Subramanian, Y., & Gopalakrishnan, J. (2014). A molecular dynamics study of ambient and high pressure phases of silica: Structure and enthalpy variation with molar volume. *The Journal of chemical physics*, *140*(24), 244512.
[16]. Sintali. I.S and Egbo G, (2007). "Investigation on the chemical and physical properties of Dapchi, Ngala and Gwoza silica sand for glass making" *Journal of Engineering and Technology (JET).* Vol.2, No.2 pp 13-18.

Zainul'abideen Abbati"Production And Characterization Of Soda-Lime Silica Glass Using Silica Sand." International Journal of Engineering Science Invention (IJESI), Vol. 09(02), 2020, PP0 56-67.