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EXPERIMENTAL STUDY OF BORATE-BASED GLASS MEDIUM MATERIAL AND HUTA GINJANG QUARTZ SAND THROUGH MELT-QUENCHING TECHNIQUE

Jonny Haratua Pangabean, Juniar Hutahaean, Luli Warty Sihombing, Maryati Dolok Saribu, Juniastel Rajagukguk
Department of Physics, State University of Medan, Indonesia 20221
gabejhp@gmail.com, junhut@gmail.com, juniastel@unimed.ac.id
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ABSTRACT
This research aims to produce a glass material based on quartz sand and borate compounds that can later be applied as a host matrix of rare earth ions as optical amplifiers. The research stages began with exploring quartz sand from Huta Ginjang, cleaning, grinding using a ball-mill and mixing with several other compounds namely Boron oxide ($B_{(2)}O_3$), barium oxide (BaO) and sodium oxide (Na_2) O. The calculation and weighing process is carried out to obtain the mass of each compound to be used. The composition of each compound is shown through the chemical formula (x)Quartz sand + (60- x)$B_{(2)}O_{(3)}$+ 10BaO + 30Na_2O (where x = 0; 2.5; 5; 10; 15; 20 mol%). The next step is the melting and molding process using the melt-quenching method. Through this experiment, a homogeneous and more transparent glass medium with optimum composition for each former and modifier compound was obtained.

Keywords: Quartz sand; borate; glass medium; Huta Ginjang

INTRODUCTION

The development of glass medium research is currently of great interest to researchers because of its excellent application in the fields of optics and telecommunications. The application in the optical field is in the form of a mixture of nature, one of which is quartz sand. Quartz sand or also called white sand is one of the most popular natural materials in Indonesia which has the potential of natural resources to produce pure silica which is widely used in industry. Quartz sand is spread in various regions in Indonesia with different qualities and characteristics depending on regional conditions. The purity of quartz sand is influenced by the content of impurities in the deposition process, these materials can affect the color of quartz sand and the color affects the degree of purity (Prayogo & Budiman, 2012). Quartz sand, also known as white sand or silica sandis the result of weathering of rocks containing major minerals, such as quartz and feldspar.

Quartz sand is a non-metallic mineral that can be utilized for various purposes such as in the industrial sector. In industrial activities, quartz sand is used as the main raw material and many are also used as additional raw materials. As the main raw material, quartz sand is used in the glass, cement, and other industries, while additional raw materials such as the petroleum and mining industries, metal casting, refractory bricks, and others (Fairus et al., 2018). Quartz sand is one of the minerals commonly found in the solid layer that forms the earth's surface consisting of rocks, soil and minerals. Quartz sand or also called white sand is the result of weathering of rocks containing important minerals such as silica. The results of the weathering process are then carried by water or wind and deposited on the banks of rivers, lakes or the sea. The mineral composition of quartz sand consists of silica crystals (SiO_2) and contains impurities that are carried during deposition. Impurity compounds such as iron oxide, calcium oxide and alkali oxide; magnesium or magnesium oxide is generally transported during the deposition process (Falah & Muzaki., 2020)

Researchers suggest quartz sand is mainly used in the glass, optics, ceramics, and abrasive industries where the largest application of quartz sand is in the glassmaking industry. High purity silica sand is used in the glass making industry such as the manufacture of packaging glass, flat glass, special glass and fiberglass (Ramadhan & Suparma, 2018). Quartz sand should not contain more than 0.45% iron when producing glass in the form of glass products, while for optical glass it is not allowed more than 0.015% (Mediastika, 2019). Quartz sand is utilized in the manufacture of optical glass, high quality quartz sand is used for prisms and optical lenses. Borosilicate is one of the most commonly used glass oxides in the thermal and chemical fields. The composition of high-tech glass materials, namely borate oxide (B_2O_3) is widely used as a tissue- forming component due to its contribution to glass formation and low melting point, as well as its optimal impact on thermal, mechanical, and optical properties (Islam et al., 2022) . In terms of the physical properties and mechanical properties of glass, borosilicate glass containing constituent silica and boron oxide contains at least 5% boric oxide ($B_{(2)O3}$). Borosilicate glass has a low impact expansion efficiency and is resistant to chemical attack.

The composition of high-tech glass materials, namely borate oxide (B_2O_3) is widely used as a tissue-forming component due to its contribution to glass formation and low melting point, as well as its optimal impact on thermal, mechanical, and optical properties (Islam et al., 2022). Some oxide glasses that are widely used as active ion hosts are borate oxide glasses (B_2O_3) (Rajagukguk & Fitrilawati, 2018). The main use of borate oxide in glass composition is borosilicate glass. In terms of the physical properties and mechanical properties of glass, borosilicate glass containing constituent silica and boron oxide contains at least 5% boric oxide ($B_{(2)O3}$). Borosilicate glass has a low impact expansion efficiency and is resistant to chemical attack. Borate has low parameters and a higher index of refraction than other glasses, $B_{(2)O3}$ acts as a flux for silica and has a strong flux, this flux has the ability to prevent the formation of oxide layers thereby increasing resistance to chemical reactions [5]. The properties of borate glass such as thermal stability, low melting point, good transparency, ease of manufacturing, low cost, and suitable solvent for various elements, as shown in previous studies here, make it the material of choice for protection. Borate glass has the highest tendency to form glass because it does not crystallize even at slow cooling rates. In addition, borate glass also exhibits high transparency at lower temperatures. Some of the problems and weaknesses of the current laser lasing medium include the inhomogeneous structure of the glass composition that causes the light scattering effect that is less resistant to high heat causing a decrease in the emission intensity of the glass medium. Several studies describe the process of making glass medium using the melt quenching method.

RESEARCH METHOD

The sample preparation method used is the Ball-Mill technique and the Melt-quenching method. Previously, the process of combining several glass forming compounds consisting of former and modifier compounds with the composition of (x quartz sand (QS) + (60-x) B_2O_3+ 10 BaO + 30 Na_2O (where x = 0; 2.5; 5.0; 10; 15; and 20 mol%). Based on the variation of quartz sand composition, the number of samples prepared was 6 as shown in Table 1.

All types of compounds used in this study have a purity level of up to 99%. Furthermore, the melting process was carried out in an electric furnace at 1200°C for 3 hours to obtain a homogeneous medium and high transparency.

Table 1. Sample type based on the composition used

Sample type	Glass composition (mol%)
BBN	$60B_2O_3 – 10BaO – 30Na_2O$
BBNQSand1	$57{,}5B_2O_3 – 10BaO – 30Na_2O – 2{,}5$ QS
BBNQSand2	$55B_2O_3 – 10BaO – 30Na_2O – 5$ QS
BBNQSand3	$50B_2O_3 – 10BaO – 30Na_2O – 10$ QS
BBNQSand4	$45B_2O_3 – 10BaO – 30Na_2O – 15$ QS
BBNQSand5	$40B_2O_3 – 10BaO – 30Na_2O – 20$ QS

Ball Mill Technique

The ball mill technique is a process of grinding materials to obtain very fine sizes from micrometers(μm) to nanometers (nm) (Ichsan et al., 2018) . The ball mill process uses planetary ball mill technology as a process tool to grind the material into a very fine size using mechanical alloying powder techniques to produce material sizes in a fast time (Sirait et al., 2022) . By using the ball mill method the impurities that come with the sand after the ball mill can be separated using a magnet.

Melt-quenching Methode

The melt-quenching technique is the process of melting homogeneously mixed chemicals at a specific temperature. Weighing of chemicals based on the molecular mass and number of moles of the material is adjusted. The mass of the required material has been obtained and then weighing is carried out with a digital balance sheet. Some studies describe the process of making glass medium using the melt-quenching method (Rajagukguk et al., 2015) The quartz sand mixing process used in this study uses the melt-quenching technique. The composition of the materials used is (x) Quartz Sand (QS)+ $(60-x)B_2O_3$+ 10BaO+ $30Na_2O$ where x = 0; 2.5; 5; 10; 15; 20 mol%)) with purity above 99% as much as the total amount of 15 grams. The flow chart of the research stages as shown in Figure 1.

Figure 1. Research Stages of making phosphate based glass base material and quartz sand

RESULT AND DISCUSSION

Research Results

The results obtained from the research are in the form of calculations of the composition of each compound used. In addition to the numerical data results, the results are also obtained in the form of a glass medium that has been successfully printed. In Table 2, the relative atomic mass of each compound element is used to calculate how much compound scale to use.

Table 2. Elemental groupings of each compound former and modifier used

Atomic Name	Element Name	Atomic mass (sma)
Boron	B	10,811
Oxide	O	15,999
Quartz sand (Silicon)	Si	28,085
Sodium	Na	22,990
Barium	Ba	137,34

Based on the data in Table 2, the optimum value of compound to be used can be determined. Furthermore, the relative compound mass for each component of the glass sample is calculated as shown in Table 3. The four compounds used in the formation of this glass medium are Boron trioxide (B(2) O3), Silicon dioxide (SiO2), Barium oxide (BaO) and Sodium dioxide (Na(2) O) with different compound masses through atomic number calculations as shown in Table 3.

Table 3. Relative compound mass of borate glass medium

Atomic name	Compound Name	Mass of compound(sma)
Boron trioxide	B_2O_3	(10,811 x 2) + (15,999 x 3) = 69,619
Silicon	SiO_2	28,085+(15,999 x 2) = 60,083
Barium Oxide	BaO	137.34+15,999 =153,339
Sodium Dioxide	Na_2O	(22,990 x 2) + 15,999 =61,979

After obtaining the relative compound mass, the four compounds are combined in the form of a chemical formula for each sample (which consists of 6 samples). These six samples are differentiated based on the content of quartz sand (QS) which is increased against Boron trioxide as has been done in some previous researchers to determine the effect of increasing new compounds on the shape and

Compound	Composition(mol%)	Molecul Mass (sma)	Component Mass (gram)
QS	2,5	1,502075	0,29858 1313
B_2O_3	57,5	40,03093	7,95732
BaO	10	15,3339	3,04806
Na_2O	30	18,5937	3,69604
Total	100	75,4606	15

The compound composition of the second sample is shown in Table 5. It can be seen that the silica content obtained from quartz sand (QS) is already present at 2.5 mol%. This was done to see the effect of QS addition on the shape and transparency of the prepared glass medium.

Table 6. Mass for each compound required in sample 3 (5QS+ 55B_2O_3 + 10BaO + 30Na_2O (mol%)

Compound	Composition(mol%)	Molecul Mass (sma)	Component Mass (gram)
QS	5	3,00415	0,59905

properties of the glass material to be prepared (Mahrous, E. M. et al. 2024, Alharshan, G. A. et al. 2024, Abouhaswa, A. S et al. 2024)

Table 4. Mass for each compound required in sample 1 (60B_2O_3+ 10BaO+ 30Na_2O (mol%)

Compound	Composition (mol%)	Moleculer Mass (sma)	Component Mass (gram)
B_2O_3	60	41,7714	8,27714
BaO	10	15,3339	3,03846
Na_2O	30	18,5937	3,6844
Total	100	75,699	15

The chemical formula and mass for the first sample with the chemical formula 60B_2O_3 + 10BaO + 30Na_2O (BBNQS0) are shown in Table 4. In this sample, it is known that the quartz sand (QS) content is absent or 0 mol%. This determination is made to see the difference when the glass material is not mixed with silica content (quartz sand) with when mixed.

Table 5. Mass for each compound required in sample 2 (2,5QS+ 57,5B_2O_3 + 10BaO + 30Na_2O (BBNQS1)

B_2O_3	55	38,29045	7,63547
BaO	10	15,3339	3,05772
Na_2O	30	18,5937	3,70776
Total	100	75,2222	15

The chemical formula, composition, molecular mass and mass per component for sample 3 (BBNQS2) are shown in Table 6.

Table 7. Mass for each compound required in sample 4 (10QS+ 50B_2O_3 + 10BaO + 30Na_2O (mol%)

Compound	Composition(mol%)	Molecul Mass (sma)	Component Mass (gram)
QS	10	6,0083	1,20575
B_2O_3	50	34,8095	6,98561
BaO	10	15,3339	3,07723
Na_2O	30	18,5937	3,73141
Total	100	131,9204	15

The chemical formula, composition, molecular mass and mass per component for sample 4 (BBNQS3) are shown in Table 7. The chemical formula for this 10 mol% QS content follows the equation 10QS+ 50B_2O_3 + 10BaO +

30Na_2O (mol%). It is also known that the QS content has increased to 10 mol%.

In the fifth sample (BBNQS4) as shown in Table 8, it is known that the QS composition was increased to 15 mol% so that the Boron oxide content was also decreased to 45 mol%.

Table 8. Mass for each compound required in sample 5 (15QS+ 45B_2O_3 + 10BaO + 30Na_2O (mol%)

Compound	Composition(mol%)	Molecul Mass (sma)	Component Mass (gram)
QS	15	9,01245	1,82025
B_2O_3	45	31,32855	6,32741
BaO	10	15,3339	3,09698
Na_2O	30	18,5937	3,75536
Total	100	74,2686	15

The composition (molecular mass, components) and total mass for sample 6 (BBNQS5) are shown in Table 9. It can be seen that the highest QS content is placed in this sample at 20 mol%. While the Boron oxide (B2O3) content is made to decrease to 40 mol%.

Table 9. Mass for each compound required in sample 6 (20QS+ 40B_2O_3 + 10BaO + 30Na_2O (mol%)

Compound	Composition(mol%)	Molecul Mass (sma)	Component Mass (gram)
QS	20	12,0166	2,44267
B_2O_3	40	27,8476	5,66071
BaO	10	15,3339	3,11699
Na_2O	30	18,5937	3,77963
Total	100	73,7918	15

Table 10. Comparison of the mass of the constituent samples of the glass material (x) Quartz Sand + (60-x) B_2O_3 + 10BaO + 30Na_2O (mol%).

Compoun compiler	Mass of each component in each sample (gr)					
	BBNQS0	BBNQS1	BBNQS2	BBNQS3	BBNQS4	BBNQS5
Quartz sand	0	0,29858	0,59905	1,20575	1,82025	2,44267
B(2) O3	8,27714	7,95732	7,63547	6,98561	6,32741	5,66071
BaO	3,03846	3,04806	3,05772	3,07723	3,09698	3,11699
Na_2O	3,6844	3,69604	3,70776	3,73141	3,75536	3,77963
Total	15	15	15	15	15	15

After calculating the composition, molecular mass and mass content of each sample from sample 1 to 6, data accumulation is carried out as shown in Table 10. From Table 10, it is obtained that there are six samples with each code given, namely BBNQS0; BBNQS1; BBNQS2; BBNQS3; BBNQS4; BBNQS5. Giving this code is to facilitate data analysis as has been done by many previous researchers (Alsaif, N. A., 2024; Ahmadi, M., 2024).

The results of the glass material obtained from this experiment are shown in Figure 1. In the figure, six glass samples with homogeneity and a high level of transparency can be seen.

Discussion

Numerical calculations to obtain the optimal composition of glass materials based on quartz sand and borate compounds have produced six samples with each chemical formula, namely:

Sample 1: 60B_2O_3+ 10BaO+ 30Na_2O
Sample 2: 2,5QS + 67,5B_2O_3 + 10BaO + 30Na_2O
Sample 3: 5QS+55B_2O_3+ 10BaO+ 30Na_2O
Sample 4: 10QS+50B_2O_3+ 10BaO+ 30Na_2O
Sample 5: 15QS+45B_2O_3+ 10BaO+ 30Na_2O
Sample6: 20QS+40B_2O_3+ 10BaO+ 30Na_2O

The total mass of the compound pool for each sample formed was 15 grams. This is in accordance with the optimum composition as shown in several previous studies (Almuqrin, A., 2025; Alzahrani, J. S., 2025). Based on these data, mixing and melting was carried out at 1200 ^{o}C in an electric furnace for 3 hours.

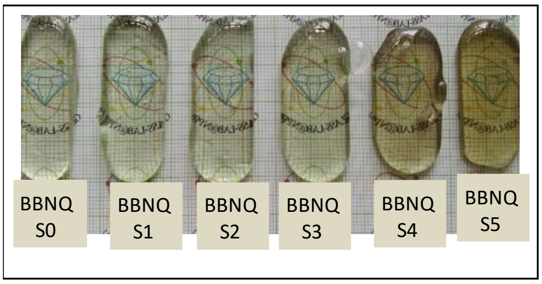

Figure 1. Quartz sand (QS) and B(2)O3based glass materials using melt-quenching method

The results of the molding and cooling process obtained glass materials as shown in Figure 1. It can be seen that the resulting samples have high transparency and good homegenity. There are no spots or defects found in the material that did not dissolve during the melting process (Alfryyan, N., 2025; Lee, S., 2025). Based on the appearance in Figure 1, the resulting glass medium can be continued at the characterization stage and used as a matrix host medium for several rare earth ions.

CONCLUSION AND SUGGESTION

Through this research, it has been explained in full and detailed stages of calculating the composition of glass material compounds. The glass material consists of forming compounds (former) and modifiers (modifier) based on quartz sand from Huta Ginjang and Borate compounds. The calculation stage involves the atomic number of each element content, mass number, relative atomic mass, until the component mass is obtained. Six types of ideal samples have been obtained from the combined composition of quartz sand and borate compounds, namely:

Sample 1: $60B_2O_3$+ 10BaO+ $30Na_2O$
Sample 2: 2,5QS + $67,5B_2O_3$ + 10BaO + $30Na_2O$
Sample 3: 5QS+$55B_2O_3$+ 10BaO+ $30Na_2O$
Sample 4: 10QS+$50B_2O_3$+ 10BaO+ $30Na_2O$
Sample 5: 15QS+$45B_2O_3$+ 10BaO+ $30Na_2O$
Sample 6: 20QS+$40B_2O_3$+ 10BaO+ $30Na_2O$

In addition to the calculation technique that will become a reference for many people, this research also produces a homogeneous and transparent glass medium. By obtaining a glass material based on quartz sand and borate, this combined compound can be continued for the candidate host matrix of rare earth ions.

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