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TESTS WITH FOAM GLASS FOR GLASS ART AND DESIGN

Bachelor of Culture and Arts thesis

Smart and Sustainable Design

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Opinnäytetyön päämääränä oli suunnitella ja valmistaa teos vaahtolasista sekä syventyä vaahtolasitekniikan tutkimiseen. Tämä saavutettiin testaamalla erilaisia lasijauheiden ja vaahdotusagenttien yhdistelmiä. Tavoitteena oli ymmärtää reaktioita lasin ja vaahdotusaineiden välillä ja löytää niihin sopiva uuniohjelma.

Tutkimus toteutettiin pääasiassa käytännön kokeilujen avulla, koska vaahtolasi on suhteellisen tuntematon materiaali lasitaiteessa ja -suunnittelussa. Työn perustana toimivat aikaisemmin kerätty tieto lasista ja vaahtolasitekniikasta, sekä haastattelut. Prosessi dokumentoitiin työpäiväkirjan avulla ja tutkimus perustui omaan kokeelliseen tutkimukseen, jota täydennettiin kuvilla ja kirjallisilla kuvauksilla.

Lopputuloksena syntyi teos. Joustavuuden avulla perinteisen lasitaiteen rajat laajenivat, edistäen samalla innovaatiota ja luovuutta. Työskentely vaahtolasin parissa tarjosi sekä haasteita että palkitsevia kokemuksia, paljastaen materiaalin valtavan potentiaalin monipuolisena ja vaikuttavana aineena taiteen ja suunnittelun alalla.

Avainsanat Vaahtolasi, vaahdotusagentti, lasijauhe, kestävä muotoilu

Sivut 39 sivua ja liitteitä 1 sivu

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Name of Degree Programme	Smart and Sustainable Design	Abstract
Author	Eveliina Tahvanainen	Year 2024
Subject	Foam Glass in Glass Art and Design	
Supervisors	Auli Rautiainen	

The aim of the thesis was to design and create a work from foam glass while delving deeper into foam glass technology. This was achieved by designing experimental setups and testing various combinations of glass powders and foaming agents. The goal was to comprehend the interactions between them and to identify a suitable kiln program for it.

The research primarily involved practical experiments, given the relatively unfamiliar nature of foam glass in glass art and design. Information was being collected about glass and foam glass technique, which formed the basis of the work, along with interviews. The process was documented using a work diary, relying on personal experimental research supplemented with images and written descriptions.

The outcome was an artwork. Through flexibility in experimentation the boundaries of traditional glass art were being pushed, driving innovation and creativity. The journey of working with foam glass presented both challenges and rewards, offering a glimpse into its vast potential as a versatile material in art and design.

Keywords Foam glass, foaming agent, glass powder, sustainable design
Pages 39 pages and appendices 1 page

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1 Introduction

In the thesis, the focus is on testing the manufacturing process of foam glass. The project focuses on exploring innovative applications of foam glass, particularly in artistic and functional contexts. My aim is to contribute new insights to the fields of glass art and materials science by investigating foam glass technology and its potential applications.

Information about glass and foam glass techniques has been collected which I use as the base of the work. Previous experiments have involved using recycled glass powder made of jars and bottles and calcium carbonate to create wall pieces and functional objects. However, for the thesis, the plan is to use glass powders used for firing, which offer more color options and better accessibility.

The main goal is to produce a foam glass work by designing experimental setups and testing various combinations of glass powders and foaming agents. This involves acquiring materials, such as different foaming agents and glass powders used for firing, and considering factors like temperature, mixing rations, and mold usage.

The process will be documented, and results will be analyzed to improve foam glass quality, enhance foaming efficiency, and achieve desired characteristics in the final piece. Overall, the project seeks to expand knowledge in the field and advance understanding of foam glass technology.

1.1 Starting points and topicality

The thesis topic is very current because there is limited existing knowledge on the subject. I will expand knowledge in the field by contributing new findings and insights to the field of glass art and design and materials science, advancing understanding of foam glass technology and its potential applications. For me it is interesting to investigate innovative applications for foam glass beyond traditional uses, exploring its potential in various artistic and functional contexts.

My previous experiments with foam glass have been primarily with recycled float glass powder and calcium carbonate. I have successfully produced wall pieces and functional design objects such as bowls and candleholders. A challenge for my thesis is finding a suitable kiln program for glass powders used for firing together with foaming agents.

1.2 Goals

The goal is to test and produce a foam glass work by designing experimental setups for creating foam glass samples using various combinations of glass powders and foaming agents. Acquiring necessary materials including different types of foaming agents (e.g., calcium carbonate & sodium bicarbonate) and Bullseye glass powders. Considering factors such as temperature, pressure, mixing ratios and the use of molds.

1.3 Research questions

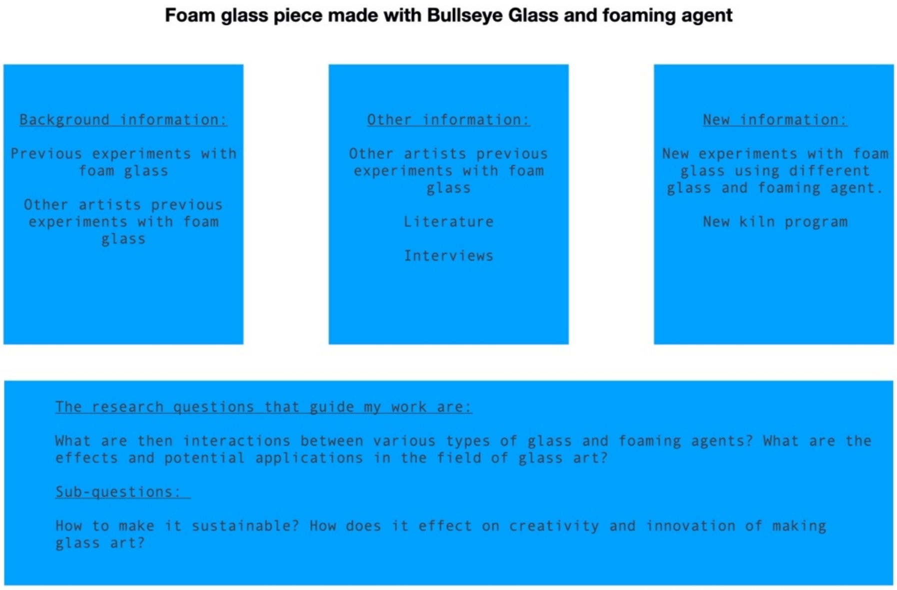
The research questions that guide the work are: What are the interactions between mainly Bullseye glass powders and foaming agents? What are the effects and potential applications in the field of glass art and design?

The sub-questions are: How can foam glass production be made sustainable? Does it effect on creativity and innovation of making glass art and how?

1.4 Frame of reference

The aim is to explore innovative uses for foam glass beyond its traditional applications, such as in infrastructure and building construction, by examining its potential in various artistic and functional contexts. Through experimentation with different compositions of foam glass and foaming agents, its properties are sought to be optimized for specific artistic or practical purposes. By meticulously documenting and analyzing the process of working with foam glass and foaming agents, the aim is to provide valuable insights into techniques, challenges, and successful outcomes for future reference (Figure 1).

Figure 1 Frame of reference



2 Background of the project

The background of the project revolves around mastering the manufacturing process of foam glass, with a focus on experimentation and improvement. Previous experiments involved using recycled glass powder and calcium carbonate to create wall pieces and functional objects (Figure 2).

Figure 2 Example of a wall piece “Volcanic Home” made with recycled glass powder and calcium carbonate

However, for this thesis, the approach shifts to utilizing Bullseye glass powders due to their wider range of color options and better accessibility.

The utilization of a foaming agent is pivotal in this project, as it plays a crucial role in creating the desired lightweight and textured surface characteristic of foam glass. By documenting the manufacturing process and analyzing the results, the aim is to enhance foam glass quality, optimize foaming efficiency, and achieve specific characteristics in the final piece.

Overall, the project aims to advance the understanding and capabilities of foam glass production, paving the way for more versatile and aesthetically appealing applications in wall pieces, functional objects, and potentially other artistic endeavors.

3 Key concepts of foaming agents

In this section, I will define key concepts related to foaming agents.

In the book Rifolasi – Innovations in Recycled Glass, Jari Vesterinen describes the process of foam glass as explained. Mastery of this process is crucial for comprehending the reactions that transpire at varying temperatures, with different types of glass, and using diverse foaming agents. The foaming reaction encompasses two primary mechanisms: chemical and physical. In the chemical process, foaming gas forms within the sintered powdered glass mass, instigated by a chemical reaction induced by the foaming agent. This reaction prompts the growth of bubbles and the consequent foaming of the glass. Conversely, the physical expansion of bubbles occurs as the temperature escalates and gas is generated during the chemical reaction. This augmentation in temperature increases the pressure inside the glass-agent mixture, fostering bubble growth. Successful foam glass formation hinges on achieving internal gas pressure levels that surpass the force exerted by the surface tension of the bubble, thus inducing foaming. The foaming agent plays a pivotal role in this process, influencing parameters such as the requisite temperature and the quantity of gas released. (Mirja Niemelä, 2014, p. 88)

Calcium carbonate ($CaCO_3$) is a chemical compound composed of one atom of calcium, one of carbon, and three of oxygen. It serves as a primary component of various natural substances such as limestone, marble, chalk, eggshells, bivalve shells, and corals. Typically appearing as a white powder or colorless crystal, calcium carbonate undergoes decomposition upon heating, yielding carbon dioxide and calcium dioxide, commonly referred to as quicklime. (The Editors of Encyclopaedia Britannica, 2024)

Sodium bicarbonate, also recognized as baking soda or bicarbonate of soda, boasts the chemical formula $NaHCO_3$. This compound manifests as a white solid, typically crystalline in structure but frequently presenting as a finely powdered form. (Wikipedia, n.d.) In its natural state, sodium bicarbonate occurs as nahcolite, a constituent of the mineral natron, and is frequently encountered in solution within numerous mineral springs. (BRP Adhikary, 2024)

4 Glass as a material

The manufacturing process of glass involves melting raw materials at high temperatures, primarily comprising silica (sand) along with additives like soda ash and limestone, followed by rapid cooling to solidify. Glass is used in various applications including architecture, transportation, packaging, electronics and household items. (Bullseye Glass Co., 2012) This section delves into the multifaceted world of glass as a material, examining its origins, properties, and diverse applications.

4.1 Bullseye Glass Co.

Bullseye Glass was founded by three recent art school graduates in 1974, in Portland, Oregon. Ray Ahlgren, Dan Schwoerer, and Boyce Lundstrom built their factory with scraps repurposed from a shipyard. Their products were made from recycled bottle cullet to produce hand-rolled sheets for the stained-glass trade.

In the company’s website they tell how a chance encounter with artist Klaus Moje in 1979 inspired them to do something that changed the company’s course and the history of glass art. They produced a palette of tested-compatible glasses for creating works in a kiln. Bullseye embarked on a long-term program of research and education by working together with artists to expand and share the technical, aesthetic, and conceptual possibilities of what is now called “kiln-glass”.

Bullseye Glass continues its tradition of crafting glass one sheet at a time, a practice dating back to 1974. They also offer a range of fusible accessory glasses, including powder, frit, ribbon, and stringer. With worldwide shipping, Bullseye Glass facilitates the creation of diverse and stunning glassworks for makers across the globe. (Bullseye Glass Co. n.d.)

In a video from Bullseye Glass Co., the question “What is Glass?” is explored, revealing that art glass possesses a unique quality: it transitions from behaving like a solid to behaving like a liquid. This characteristic enables artisans to shape it through blowing or kiln forming techniques. While various forms of glass serve diverse purposes, each has its commonly associated methods of use.

Sheet glass, for instance, is primarily utilized for creating fused panels or slumped plates. Frits and powders, finely ground grains of glass, find application in casting methods such as pate de verre and kiln casting, as well as for achieving painterly effects. Rods and stringers, typically manipulated in a flame, can also be incorporated directly into kiln forming processes. Billets, on the other hand, are block-shaped and commonly employed in kiln casting. (Bullseye Glass Co., 2012)

4.2 Foam Glass

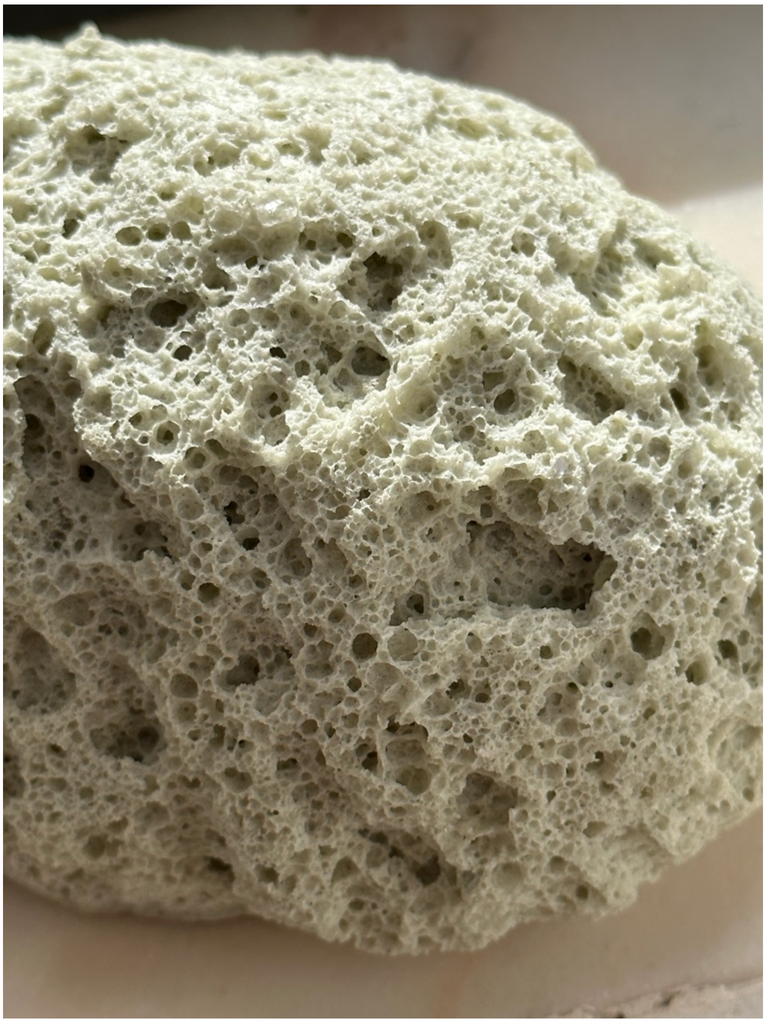
Foam glass, also referred to as cellular glass, was originally manufactured from a specially formulated glass composition using virgin glass only. Currently, there are several foam glass production plants that are using up to 98% post-consumer waste glass in their product. (El-Haggar PE, 2007, chapter 5)

The foam glass boasts several desirable properties, including low thermal conductivity, high compression strength, exceptional frost resistance, and enhanced durability. These characteristics make it suitable for various applications such as wall construction, heat regulation in refrigeration units, and utilization as a floating and filtering material. Renowned for its advanced heat insulation capabilities, foam glass is also easy to cut and cement, further expanding its potential uses. (Haimei Zhang, 2011, chapter 12)

Foamit foam glass aggregate, manufactured by Uusioaines Oy in Finland, utilizes recycled glass sourced from various sources like car windscreens and packaging glass. This process involves purifying and sorting the glass chips, some of which are then used to produce Foamit foam glass. Once the Foamit structure completes its life cycle, it can be recycled similar to pure mineral materials. (Uusioaines Oy, 2024)

Foam glass is made by heating a mixture of powdered glass and a foaming agent. When the glass mixture is at a temperature between 700°C and 900°C, near the melting point of the glass, the glass powder turns into a viscous liquid and the blowing agent releases a gas, the gas expands and produces a structure of cells or bubbles which forms the porous body of foam glass. (What is foam glass?, 2019) (Figure 3)

Figure 3 Close up of a foam glass texture made with recycled glass powder and calcium carbonate



“Foam glass isn’t as widely known as an art material and challenges traditional perceptions of glass making and glass aesthetics.” (Charlott Rodgers, 2023) There is not much of information available on foam glass concerning art and design, and the artists I’ve consulted have largely relied on self-discovery through experimentation and testing.

5 Process of creating foam glass

In this section I will describe the process of creating foam glass. I select suitable glass powders to begin work with foaming agents, like sodium bicarbonate and calcium carbonate. Then I conduct initial firing tests using the chosen glass powders and foaming agents, closely monitoring the temperature to identify the optimal temperature for foam expansion.

Following the initial firings, I evaluate the results, focusing on foam expansion levels and any visible irregularities, documenting my observations. I will evaluate the results of the calcium carbonate test firing, comparing its effectiveness to sodium bicarbonate. Throughout the process, I iterate the firing process, adjusting parameters such as temperature, mixing rations, and foaming agent concentration, to refine my experimental setup based on observations and analysis.

Once I've determined the optimal firing parameters and glass-foaming agent combinations, I'll finalize the process plan for producing foam glass work, incorporating lessons learned from experimentation. I'll document each step of the process, including materials used, firing parameters, and observations, compiling my findings into a comprehensive report.

5.1 Work stages

5.1.1 1st test transparent glass

Based on my initial firings, I discovered that only transparent glass gave satisfactory results. Therefore, I focused on using specific types of transparent glass powders that I had available from previous order from Bullseye Glass Co., including Yellow Transparent Powder, Light Plum Transparent, and Light Green Transparent, along with sodium bicarbonate and calcium carbonate as foaming agents (Table 1).

Table 1 Test 1 glass powder, foaming agent, total weight

Test 1

Yellow Transparent 117,60g	2,4g (2%) calcium carbonate	120g
Light Plum Transparent 98g	2g (2%) calcium carbonate	100g
Light Green Transparent 48g	2g (2%) calcium carbonate	50g

First, I weighted the glass powder and foaming agent on a scale (Figure 4) and mixed them in a cup by using a wooden a stick.

Figure 4 Weighting the glass powder

I put kiln paper on top of kiln shelf in the kiln and used molds available to at the studio to see if it makes a difference with more air flowing underneath. I applied the mix of glass powder and foaming agents in different forms and finished shaping them with a small brush.

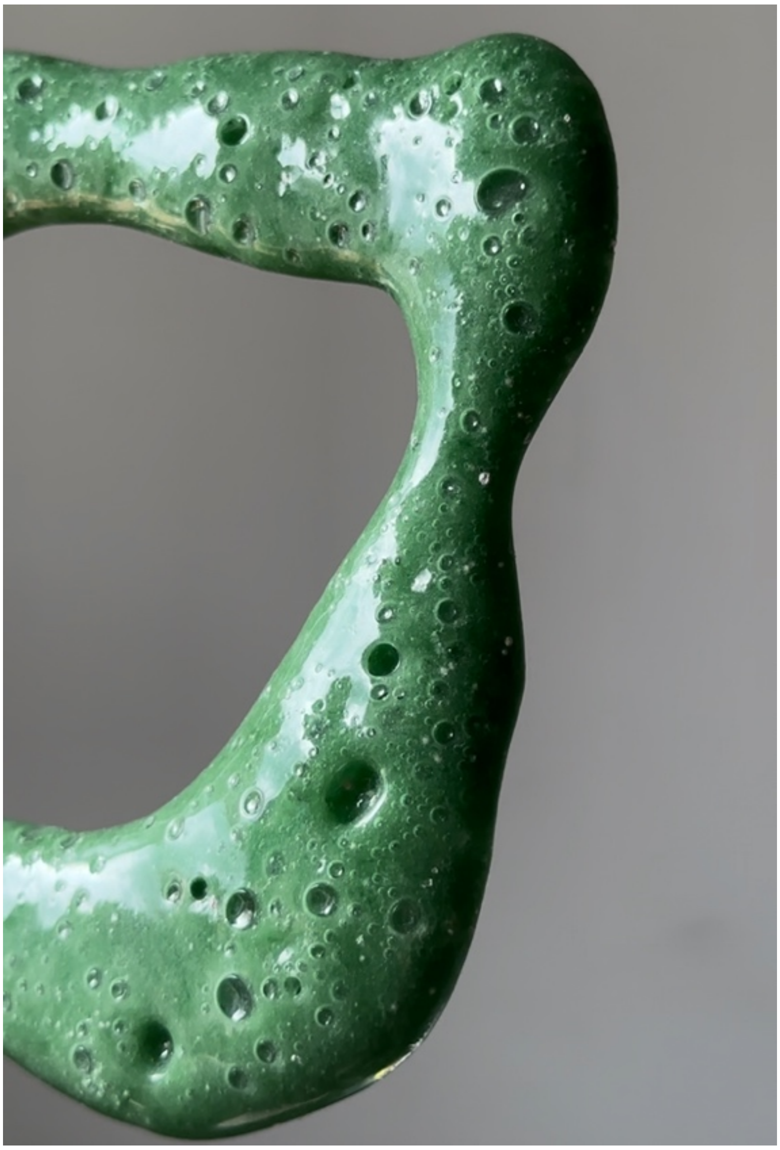
I calculated the kiln program by altering the previous one I used with float glass to be more suitable for Bullseye glass powders, setting the top temperature at 830°C (Table 2).

Table 2 First firing kiln program

Rate	temp.	Hold	Time going up
100	670°	30	7h
150	**830°**	30	1h
SKIP	482°	2h	-
30°	427°	-	2h
50°	371°	-	1,12h
70°	100	-	3,8h
END			

In a test firing utilizing calcium carbonate as a foaming agent, some parts of the pieces retained visible traces of calcium carbonate (Figure 5). This may have been due to inadequate mixing or insufficient foaming. Overall, the pieces remained flat, with only minor visible air bubbles on the surface.

Figure 5 Light Green Transparent test piece with calcium carbonate



5.1.2 2nd test sodium bicarbonate

Building on the findings from previous firings, I began to utilize sodium bicarbonate. I utilized same glass powders as in the previous test (Table 3).

Table 3 Test 2 glass powder, foaming agent, total weight

Test 2

Yellow Transparent 120g	3g (2,5%) sodium bicarbonate	123g
Light Plum Transparent 49g	1g (2%) sodium bicarbonate	50g
Light Green Transparent 98g	2g (2%) sodium bicarbonate	100g

To facilitate the firing process, I decided to try a metal mold, which offer efficient heat conduction and sustainability, allowing for repeated use across multiple firings (Figure 6).

Figure 6 Second firing test pieces in the kiln before firing

During the experimentation phase, it was observed that the glass effectively underwent foaming at a temperature of 760°C (Table 4).

Table 4 Second firing kiln program

Rate	temp.	Hold	Going up
100	670°	30	7h
150	**830°**	30	1h
SKIP	482°	2h	-
30°	427°	-	2h
50°	371°	-	1,12h
70°	100	-	3,8h
END			

However, subsequent observations revealed a decrease in expansion, leading to the formation of relatively flat forms with noticeable air bubbles (Figure 7).

Figure 7 Second firing test pieces after firing

Without the use of a separator for the mold, the glass stuck to the mold and hindered proper foaming. It was noted that the metal mold used tended to shrink more than the glass during the foaming process. To address this issue, it is recommended to utilize a separator or thick ceramic paper within the mold to allow sufficient room for glass expansion.

5.1.3 3rd test shapes

Based on the previous test, I decided to set the next firing temperature up to 760°C (Table 5), as it resulted in the highest foaming level in the kiln program during the previous test. However, despite foaming initially, the glass eventually deflated (Table 6).

Table 5 Third firing kiln program

Rate	temp.	Hold	Going up
100	670°	30	7h
150	**760°**	30	1h
SKIP	482°	2h	-
8°	427°	-	7h
16°	371°	-	3,5h
32°	100	-	8,5h
END			

Table 6 Test 3 glass powder, foaming agent, total weight

Test 3

Yellow Transparent 120g	3g (2,5%) sodium bicarbonate	123g
Light Plum Transparent 98g	2g (2%) sodium bicarbonate	100g
Light Green Transparent 49g	1g (2%) sodium bicarbonate	50g
Light Green Transparent 49g	1g (2%) sodium bicarbonate	50g

In terms of shapes, I aimed to observe the extent of glass expansion, particularly by creating small circles. Placing two pieces on top of molds to increase foaming by allowing more air from below didn't make a big change.

I monitored the kiln at 670° and observed no foaming yet. At 760°C, the foaming appeared less prominent than before. I maintained the top temperature and checked every 5 minutes but observed minimal change.

A glass artist I interviewed provided crucial advice on the process, suggesting terminating the kiln program once the foam glass appears satisfactory at the top temperature (personal communication 20.02.2024). However, due to the limitations of this kiln, it is not feasible to open the lid and accurately assess the process inside, primarily due to the absence of required safety equipment for such actions. As a workaround, I stopped the kiln program and created a new one to facilitate faster cooling, thereby preventing the glass from deflating.

In one green piece, I observed a distortion where there was insufficient glass powder applied to that spot. The optimal thickness of the glass powder layer is the maximum amount you can apply before the layer becomes unstable and begins to collapse or drop down. Overall, the test pieces were looking better with more foamy structure (Figure 8).

Figure 8 Third test after firing

5.1.4 4th test color mixtures

For this test, I experimented with new colors and mixed some of the old ones with clear glass powder to observe their interaction with the foaming agents. I selected different colors to see their differences in foaming. To maintain consistency and effectiveness in testing, I minimized alterations while contemplating the possibility of increasing the foaming agent and adjusting the top temperature again. I adjusted the temperature setting to be 20°C higher and extended the annealing time (Table 7) compared to the previous settings, with the intention of evaluating whether these factors would have a discernible impact on the outcome.

Table 7 Fourth firing kiln program

Rate	temp.	Hold	Going up
100	670°	30	7
150	**780°**	30	50min
SKIP	482°	2h	-
8°	427°	-	7h
16°	371°	-	3,5h
32°	100°	-	8,5h
END			

Additionally, I aimed to explore potential differences between colors and their mixtures with clear glass powder to assess their impact on foaming and achieve lighter shades (Table 8).

Table 8 Test 4 glass powder, foaming agent, total weight

Test 4

Yellow Transparent 25g + Clear Transparent 25g	1,75g (3,5%) calcium carbonate	51,75g
Yellow Transparent 25g + Clear Transparent 25g	1,75g (3,5%) sodium carbonate	51,75g
Light Green 50g + Clear Transparent 50g	3,5g (3,5%) calcium carbonate	103,5g
Sunset Coral 48,5g	1,5g (3%) sodium carbonate	50g
Neo Lavender Transparent 48,5g	1,5g (3%) sodium bicarbonate	50g
Light Pink 48g	2g (4%) sodium bicarbonate	50g
Light Aqua Blue 48g	2g (4%) sodium bicarbonate	50g
Light Amber 48g	2g (4%) sodium bicarbonate	50g
Light Green 25g + 6,25g Clear Transparent	1,5g (5%) sodium bicarbonate	32,75g
Neo Lavender Transparent 47,50g	2,5g (5%) calcium carbonate	50g
Neo Lavender Transparent 47,50g	2,5g (5%) sodium bicarbonate	50g
Clear Transparent 47,5g	2,5g (5%) sodium bicarbonate	50g

To facilitate better airflow, I started to use ceramic pillars underneath the kiln shelf. Despite the lack of visible improvement, the benefits of enhanced heat distribution and efficient combustion provided by using the ceramic pillars made it worthwhile to continue using them for more consistent and reliable processing. The pillars ensure that the air can circulate effectively, which enhances the quality of the foam glass (Figure 9).

Figure 9 Fourth test before firing

The test results using sodium bicarbonate were favorable, with minimal difference observed between the amounts of foaming agent used, except in the cases of Sunset Coral, Light Pink and Lavender Transparent (Figure 10).

Figure 10 Fourth test after firing

The lack of foaming in the Neo Lavender, Sunset Coral and Light Pink pieces could be attributed to the specific properties of these colors. Certain pigments or additives in colored glass powders may interact differently with the foaming agent or the firing process, affecting the foaming outcome. In this case, the chemical composition or behavior of these colors might have inhibited the foaming reaction, resulting in less foam production compared to other colors.

However, experiments with calcium carbonate were unsuccessful, as the pieces failed to foam and did not melt properly.

5.1.5 5th test without molds

The top temperature was at 830°C (Table 9) based on guidance from a glass artist I interviewed (personal communication 20.02.2024) who provided information on how to create test pieces without molds.

Table 9 Fifth firing kiln program

Rate	temp.	Hold	Going up
200	666°	15	
300	**830°**	1min	
SKIP	482°	1h	
30°	427°	-	
60°	371°	-	
32°	100°	-	
END			

The outcomes of this firing were successful in terms of color blending and foaming, particularly with circle shaped Neo Lavender, Light Amber, and Light Aqua Blue mixed with Clear glass powder (Table 10).

Table 10 Test 5 glass powder, foaming agent, total weight

Test 5		
Clear 85,5g (90%) + Light Aqua Blue 9,5g (10%)	5g (5%) sodium bicarbonate	100g
Clear 85,5g (90%) + Neo Lavender 9,5g (10%)	5g (5%) sodium bicarbonate	100g
Clear 47,5g (50%) + Light Amber 47,5g (50%)	5g (5%) sodium bicarbonate	100g
Sunset Coral 47,5g + 2,5g (5%)	2,5g (5%) sodium bicarbonate	50g
Light Aqua Blue 47,5g	2,5g (5%) sodium bicarbonate	50g
Neo Lavender 47,5g	2,5g (5%) sodium bicarbonate	50g
Light Pink 47,5g	2,5g (5%) sodium bicarbonate	50g

The round-shaped Light Aqua Blue and Light Amber turned out fine. However, the Neo Lavender and the Sunset Coral did not foam as expected nor did the Light Pink placed on the mold on the left side (Figure 11).

Figure 11 Fifth test pieces after firing

After observing the results of the test pieces, I was inspired to repurpose them into functional objects. One idea that emerged was to transform the test pieces into mirror frames. This decision came from the desire to not only explore the artistic potential of foam glass but also to create practical and functional items that could be used in everyday life.

By repurposing the test pieces into mirrors, I aimed to combine artistic experimentation with utility, turning the experimental process into tangible and useful objects (Figure 12). I cut the mirror and grinded the edges smooth. Then, I used glue to attach the foam glass frame to the mirror.

Figure 12 Collage of small foam glass test pieces (top row) and ready-made mirrors (below)

6 Production of the final piece

This section explores the inspiration and creative decisions shaping the final piece based on previous tests. It offers insights into the conceptualization of the theme and aesthetics. It further examines the process of translating these ideas into the finished piece.

Since there were no significant changes observed between the kiln programs, I opted to use the last program utilized for the final piece. The only alteration made was to extend the hold time at 482°C to ensure the durability of the piece (Table 11).

Table 11 Sixth firing kiln program

Rate	temp.	Hold	Going up
200	666°	15	
300	**830°**	1min	
SKIP	482°	2h	
30°	427°	-	
60°	371°	-	
32°	100°	-	
END			

The inspiration for the final piece was drawn from the beauty of sea foam found in the ocean. In terms of shape, I aimed to emulate the fluid and organic nature of sea foam.
After conducting extensive color tests, I decided using clear glass for the final piece because it closely resembles the color of sea foam (Table 12).

Table 12 Sixth firing glass powder, foaming agent, total weight

Final firing		
Clear 475g	25g (5%) sodium bicarbonate	500g
Clear 85,5g (90%) + Sunset Coral 9,5g (10%)	5g (5%) sodium bicarbonate	100g
- Clear 85,5g (90%) + Light Pink 9,5g (10%)	5g (5%) sodium bicarbonate	100g
Light Aqua Blue 95g	5g (5%) sodium bicarbonate	100g
Neo Lavender 47,5g	2,5g (5%) calcium carbonate	50g
Light Amber 47,5g	2,5g (5%) calcium carbonate	50g
Light Aqua Blue 47,5g	2,5g (5%) calcium carbonate	50g
Clear 71,25g	3,75g (5%) sodium bicarbonate	75g

Additionally, clear glass was a practical choice due to its affordability compared to colored glass options. To fill the kiln, I added some additional color test pieces (Figure 13).

Figure 13 Final piece and tests ready for firing

Despite my previous challenges with calcium carbonate, I decided to test again to understand why it wasn't effective. Unfortunately, the results were still unsatisfactory (Figure 14).

Figure 14 Final piece and tests after firing

It's possible that the type of calcium carbonate could be a factor influencing the results. Different sources or forms of calcium carbonate may have varying properties that affect the foaming process differently. Further experimentation with different types or sources of calcium carbonate could provide valuable insights into its effectiveness as a foaming agent for foam glass.

I’m satisfied of the texture and fluidity of the piece, which closely resembles sea foam (Figure 15). I decided to turn it into a mirror frame but I’m curious to explore further and elevate it into a more artistic creation. Certainly, using molds to shape this fused form could enhance the organic formation, adding more depth and complexity to the artwork.

Figure 15 Foam glass frame for the final piece

I decided to create a mirror because I envisioned using it for multiple purposes, such as showcasing it at a design fair (Figure 16).

Figure 16 Using a paper template of the foam glass frame for shaping the mirror for the final piece

This versatile piece could serve as both as a functional item and a work of art, making it suitable for various settings and events (Figure 17).

Figure 17 Final piece ready

7 Challenges

Each minor adjustment, such as altering the kiln program, experimenting with different foaming agents, adjusting the quantity of foaming agent, and incorporating molds, poses significant challenges. These changes require substantial investments of time, money, and energy for testing. To address these challenges effectively, it is needed to optimize kiln space usage to conduct multiple tests simultaneously, prioritizing essential experiments. To enhance resource efficiency, recommending the reuse of the test pieces for practical applications like mirrors is advisable. Implementing the most sustainable kiln program reduces electricity consumption and selecting durable molds to optimize longevity and effectiveness are also crucial steps in the process.

Despite these obstacles, the decision was made initially to abstain from using molds to fully explore the ideal kiln program and foaming agent for foam glass. This approach aimed to preserve flexibility and encourage creativity during the experimentation phase.

8 Sustainability

Based on the previous, foam glass demonstrates significant potential for sustainability in the field of glass art and design. Its unique properties, such as thermal insulation and durability, contribute to its sustainability by enabling the creation of functional objects that are both environmentally friendly and aesthetically pleasing.

Foam glass's thermal insulation properties make it ideal for creating objects like bowls and drinking glasses that can maintain temperature stability, reducing the need for additional energy consumption to keep beverages hot or cold. This aspect enhances its sustainability by promoting energy efficiency in everyday use.

Furthermore, foam glass's lightweight nature reduces transportation emissions and energy consumption during installation, especially in architectural applications and outdoor sculptures. Its durability ensures longevity, reducing the frequency of replacements and minimizing material waste over time.

The process of working with foam glass also presents opportunities for sustainable practices, such as optimizing kiln space and energy consumption to minimize environmental impact.

Implementing eco-friendly practices like recycling test pieces such as mirrors brings a concern. While foam glass and mirrors individually offer sustainability benefits in certain applications, their combination may present challenges in terms of recycling, reuse, and end-of-life management. Mirrors typically consist of multiple layers, including glass, reflective coatings, and backing materials, which makes it difficult for recycling. However, recycled mirrors can be reused with the foam glass frames. Careful consideration is needed when incorporating foam glass into mirror designs to ensure that sustainability goals are still met effectively.

9 Conclusions

The beauty of working with foam glass lies in its potential for experimentation and discovery. Foam glass offers unique visual effects that can add depth, texture, and dimension to glass pieces. Depending on the foaming agent used and the firing conditions, foam glass can create intricate patterns, bubbles, and variations with vibrant hues of range of colors. These visual effects open new avenues for artistic expression and experimentation, adding richness and complexity to the artwork.

The effects and potential applications of this unique material in the field of glass art and design are vast and yet to be fully explored. While the observations from test firings provide insights into the effectiveness of each combination of glass powders and foaming agents, they only scratch the surface of what is possible.

Beyond purely artistic endeavors, foam glass has practical applications in functional glass art. Its thermal insulation properties make it sustainable for creating objects such as bowls or drinking glasses that can maintain temperature stability. Additionally, its lightweight and durable nature make it ideal for architectural installations or outdoor sculptures.

However, the journey of working with foam glass also comes with its challenges. Optimizing kiln space and energy consumption is essential for sustainable production processes, especially as foam glass requires specific firing conditions for optimal results. Additionally, implementing eco-friendly practices, such as recycling test pieces and minimizing waste, is crucial for reducing environmental impact and promoting resource efficiency.

Despite these challenges, the process of experimentation with foam glass is incredibly rewarding. Each trial and error phase offers valuable insights into the material’s properties and behavior, allowing to expand the creative possibilities. By embracing flexibility in experimentation and integrating sustainable practices, the boundaries of foam glass can be pushed as a versatile and impactful material in the world of art and design.

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Appendix 1. Data Management Plan

Data collection and storage

The research data will be collected from written sources and personal experiments, supplemented by interviewing one individual via informal Zoom call and one through a message. The interviews were not recorded.

Handling of personal and sensitive data

The research data does not contain any sensitive or confidential information.

Ownership of the thesis data

The research data is owned by the researcher.

Future use of the thesis data after completion of the work

The researcher will only retain the material until the thesis is approved, after which it will be discarded.