The Riddle of the Mirror

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Color and Material Research on Expressive Possibilities of Silver Glass Colors in Glassblowing

Orcum Erdem Master's Thesis for Master of Arts 2019

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Abstract

The context of design is changing at a rapid pace. The impact of information technologies and digital creative tools continuously improving have revolutionized design practice. There has been a transition within the scope of a designer's role - from simply giving form to a material to designing digital services. These developments have distanced design from tactile materiality. The designer, whose practice began as a material-based and rooted in the arts and crafts, must now rethink and reposition their creative processes and role within the current context of design.

In this master thesis, I investigated this problem space by trying to answer the following research question: how does hands-on interaction with material influence the expressive and creative aspects of design practice? My method for investigating this research question is to engage in a practice-led research approach in which I explore the artistic potential of silver glass colors in glassblowing. I chose to research this topic in the field of glassblowing because of the intense physical interaction required between the artist and the material.

In glassmaking, silver glass colors are used to create specific aesthetics, ranging from iridescent to silver mirrored surfaces. However, silver glass colors have been very challenging for many practitioners due to their unpredictable nature. I have considered this unpredictable material nature as a research opportunity to explore a reliable method of achieving silver mirrored results and to have artistic control of the wide metallic and iridescent palette. I have then applied these insights from material research to my artistic process and, with the help of relevant theory, I have reflected on both of these processes to investigate their intersection as a whole. My aim has been to determine the influence of hands-on material exploration on my design practice.

The main findings are summarized in three points: 1) Hands-on interaction with the material has primarily influenced my early artistic vision and enhanced its expressive and creative aspects throughout my artistic production.2) Cyclical hands-on dialog with a material can support personal growth and help to develop an individual voice and creative expression; thus offering great potential for educational purposes. 3) The empirical data shows that silver glass colors provide a wide range of visual palette and can be preferred for local applications in particular, yet they require a long learning process to have control of them.

This work provides information for readers who wish to know more about the role of hands-on studio practice and developing an individual voice through a creative process. Moreover, it presents helpful insights and data for people who are particularly interested in conducting material-based research in glassblowing and utilizing silver glass colors as an artistic technique.

Keywords: *hands-on, color, material, exploration, expression, glass, glassblowing, metallic luster, silver glass colors, art, design, craft*

Chapter 1 Introduction

The Riddle of the Mirror: *Color and Material Research on Expressive Possibilities of Silver Glass Colors in Glassblowing.*

This thesis tells the story of my journey through glassblowing practices to investigate the impact of hands-on material-based artistic processes on the expressive and creative aspects of design practice. The impetus for this journey emerged due to feeling unsatisfied with the latest direction in product design and design education. My discontent started during the first year of my master' degree studies when I wrote a book review as an assignment for the Design Research Course. The book, "Design Research through Practice: From the Lab, Field, and Showroom", was mainly discussing constructive design methods and the chapter to be reviewed was focused on empathic and interpretive design. These methods primarily employ the idea that "the designers need to understand people before they start designing" (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2013, p. 149). As an example, the author mentions the case of "Luotain ", which is a smart product research group, based in Helsinki, and discusses the way they deal with traditional means of design. The chapter describes main pillars of design, such as the workshop culture and hands-on education as a " hard nut " to crack and highlights the conceptual side of the design, before "plywood and screws" (Koskinen et al., 2013, p. 150).

Even though these arguments may reflect a particular perspective on the design methods in question, I felt that they were actually describing a trend in the current direction of design scene - one which is hands off, digital and data oriented. Thus, this perspective concerned me as a designer who, for example, appreciates principles of the Bauhaus Movement that define design as a combination of art, craft, and industry. I was reminded that the "hard nut " workshop culture as well as " plywood and screws " are the reason I chose the design field in the first place. In consideration with this, Milton Glaser, a celebrated American graphic design legend, notes:

"Every once in a while, a work that is intended to be functional and has been made in response to a client's problem turns out to also be artistic – the feeling you derive from it is emotional rather than logical" (Dawood, 2018).

In this quote Glaser points out the relationship between functionality and clients' needs; he underlines that the best solution usually originates from emotion rather than a logical response.

I believe that constructive design methods that overemphasize user research, analytical models and data management tools for design development processes tend to overlook experimental and emotional aspects of the design process. I believe this creates a distance from its origin - design as a delicate balance of art, craft, and problem solving.

This transition from material-based art and craft roots of design to more systematized, analytic and abstract design approach left me feeling misrepresented as a design professional with an experimental, material-based practice. This urged me to rethink what are genuine values of art and design, origins of creativity, emotions, and self-expression. These latest developments have made me consider my own expectations and those who have received an artistic education in this field - do we still have a chance to contribute and feel fulfilled in the parameters of this new design scene?. Driven by these questions, I started a personal journey through the art and craft fields and histories to seek answers while questioning the origins of creative design practice. .

After initial research, I formulated my research question as: how does hands-on interaction with material influence the expressive and creative aspects of design practice? This question required me to focus on the physical and practical aspects of creative work. Thus to explore the practical sides of this question, I decided to specifically experiment with silver glass colors in glassblowing and examine my creative process with the help of associated literature. In this case, the glassblowing practice emerged as a unique research area due to its highly demanding workflow that requires timely and physical interaction of the practitioner with glass. Therefore, even though I had limited experience with glassblowing, I considered it as valuable research and a good learning opportunity. I have dedicated over a year to master the craft of glassblowing to the level that allows me to carry out my research in a reliable way.

In this research, I aimed to investigate and document my own material inspired artistic research. Therefore, this study acknowledges my reflection and gathered empirical data during the artistic process as the primary means of knowledge generation. In the field of craft, research such as Thinking through Making (Mäkelä, 2007), Thinking Through Material (Nimkulrat, 2009, 2010) and Making Sense through Hands (Groth, 2017) have addressed this topic from various points of view before this thesis project. I refer to them as previous literature and aim to contribute to this area of research by extending it to the field of glassblowing.

I discuss my main research question from the perspectives of theory and methodology, material exploration, and artistic production. The section on theory and methodology discusses the fundamental nature of dialog between the artist and creative medium for artistic production. This dialog plays a central role in the sense-making process for the analysis of the studio practice as well as tangible results. As concurrently progressing aspects, the material explorations incorporate my hands-on research of the visual and artistic potential of silver glass colors in glassblowing as a case study to explore the central theme of this thesis and presents the documentation of my studio practice. At last, the artistic production unifies theory and practice in application, throughout my exploratory artistic process.

Furthermore, this work incorporates two interconnected micro and macro perspectives, which are in constant interplay throughout the research. The macro perspective aims to identify the influence of hands-on practice on creative process from one's expressiveness. For this objective, I acted as an artist-researcher and analyzed my material inspired artistic process, in which I could consciously examine my rationales behind artistic decision-making processes. Meanwhile, insights and data from the material research provide a micro perspective encompassing the properties of silver glass colors, redox reactions, and glassblowing practices. Since this micro aspect primarily allowed me to explore the macro aspect of this research, they worked as integrated components.

Following this framework, in chapter one, Introduction, I define the theory and research methodology and the role of the literature review throughout the research process. Then, I introduce the main expression theories of art and discuss the material-based artistic process from the point of expressiveness and sense-making. Moreover, I present a historical perspective on the Arts and Crafts Movement, Studio Glass Movement, and reduction lusterware in glass and highlight the way they resonate in the contemporary craft field. Furthermore, I discuss the methods and research design with the various forms of data collection and the documentation processes used throughout the research.

After these, in chapter two, Material Research: Reduction Reactions in Glass, I present my hands-on experience with silver glass colors as a result of an intense experimental period in the Aalto University Glass Studio over a year. This part describes various methods to achieve clear, neutral mirroring coatings in glassblowing using silver glass colors. It presents insights and empirical data on key variables that affect silver color applications in terms of color, intensity, transparency, reflection, and consistency factors. Also presented are my material samples and early prototypes alongside the discussion. In addition to the technical data, I also provide basic guidelines for people who would like to do a color and material research in glassblowing.

In chapter three, Final Project, I combine the theory and the experiential knowledge I gathered throughout my studio practice into a conceptual artistic context, in which I explore the mirrored glass surfaces in various contexts including different color palettes and setups.

In chapter four, the Analysis and Discussion, I present my findings and reflections for the entire research process. I discuss my artistic material research experience and explore the way hands-on material research influenced my artistic practice throughout the project. Following that, I question whether this entire process contributes to developing individual expression and creativity and I discuss future directions and limitations of the research. Finally, in conclusion, I summarize my takeaways from this thesis work.

1.1- Research through Creative Work: Practice-Led Research

Since the macro perspective of this thesis project primarily aims to explore the value of an artist's conscious and physical interaction with a creative medium in artistic process, reviewing and understanding design research methods emerged as an essential aspect to be able to undertake proper research on such a subjective topic. My literature review on this subject shows that positivist and constructivist approaches arise as two major theoretical directions in the field of design and craft.

The studies of analytic methods for design practice begin with an American architect, futurist, and " a radical technologist " - Buckminster Fuller's call for a 'design science revolution' in the 1960s (Cross, 2006, p. 96). Fuller points out a need for a design method based on rationalism, technology, and science which can help to solve humanity's major challenges that cannot be solved by politics or economics (Cross, 2006, p. 96). This rational and systematic approach primarily aims to address two main issues: identifying and classifying all recurring parts of a system or a design process and extracting the essential knowledge from natural sciences which can be helpful for the design process (Cross, 2006). Furthermore, Herbert A. Simon (1969), an American political scientist who is especially focused on decision-making and problem-solving processes, defines the science of design as " a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process" (as cited in Cross, 2006, p. 96). Later on, this approach was further developed and defined to be known as "Designerly Ways of Knowing" by design research and theoretician, Nigel Cross, whose contribution includes cognitive activities of designers at work from 1970 to 1990 (Groth, 2017, p. 15)

However, this analytical method of reasoning had been criticized by some other researchers who were distant to such a pragmatic approach in design (Groth, 2017, p. 15). For instance, architect and design theoretician Gabriela Goldschmidt (2001) argued that The Design Method resulted in neglecting traditional, intuition-based design strategies in exchange of an analytical approach. which has eventually failed to provide a well-defined formula that was capable of delivering the anticipated improvement in the design process. As she further underlines, many design practitioners refused to give up their craft-oriented traditions anyways. Similar to Goldschmidt, Donald Schön (1983), design theoretician and philosopher, opposed The Design Methods Movement as well, and he coined the term reflection-in-action which suggests a more humane and constructive approach (Schön, 1983).

Schön (1983) remarked the uncertain nature of everyday circumstances which cannot be pre-formulated ahead and pointed out the practical knowledge neglected thus far, stating that " In the light of such Positivist doctrines as these, practice appeared as puzzling anomaly. Practical knowledge exists, but it does not fit neatly into Positivist categories" (Schön, 1983, p. 33). Schön (1983) argued that in the case of novel situations, practitioners often need to deal with brand new, unexpected conditions and each novel experience inevitably alters practitioners' vision about the main problem as well as its solution. In such cases, practitioners must test their new vision in practice and, following that, reflect on their personal experience analyzing its outcomes, which possibly leads to further inspiration for upcoming tryouts (Schön, 1983). This creates a circle between practice and reflection, which eventually opens a new door to knowledge acquisition (Schön, 1983). Schön (1983) defines this continuous dialog as reflection-in-action and notes that:

"Much reflection-in-action hinges on the experience of surprise. When intuitive, spontaneous performance yields nothing more than the results expected for it, then we tend not to think about it. But when intuitive performance leads to surprises, pleasing and promising or unwanted, we may respond by reflecting in action" (Schön, 1983, p. 56).

As this statement suggests, Schön considers the experience gained by practice as the core of the problem-solving mechanism, especially for cases requiring impulsive decision-making processes based on intuition and unpredictable circumstances. Schön states that "It is this entire process of reflection-in-action which is central to the "art" by which practitioners sometimes deal well with situations of uncertainty, instability, uniqueness, and value conflict" (Schön, 1983, p. 50). Schön's note on art showed me that the idea of the reflective practitioner has a critical role in artistic processes aimed at exploring subjective topics, such as aesthetics or expression. Since the iterative process between creative medium and the artist can fundamentally influence the way the artist perceives and interprets the material, it shapes the process differently than for those artists who envision a work in advance. In most cases, physical engagement with the medium might be unexpected and inspiring for the maker. This active reflection and the documentation of the artistic work helps artists to know more about their creative medium as well as themselves throughout the creative process.

This literature review showed that problem-oriented scientific design methods provide useful frameworks and analytical tools to overcome challenges believed to be possible to solve through design. These challenges may include an engineering problem, environmental issues, or specific areas of industrial design, in which the context of research focuses on an objective, quantitative data, such as statistical information about certain user behavior, or product efficiency. However, since this study aims to undertake subjective and artistic research examining my own artistic production, it primarily employs hands-on practices, empirical experiments and embodied experience for knowledge generation and sense-making process rather than accountable data. Therefore, Schön's reflective practitioner method emerges as a more appro- priate approach for this research. Based on this central role of practice and reflection in action, I considered practice-led design research as the most appropriate design research methodology for this thesis project.

Accordingly, Mäkelä (2006), associate professor of practice-led design research at Aalto University, states that practice-led research approach mainly relies on the reflections of artists on their own artistic production and reveals their subjective point of view on the research question. By this experiential method, practitioners become aware of the decisions they made and analyze their motivations throughout the creative process. She defines practice-led research as an approach that artist and designers use to contribute to the field of research with their artistic practices and artifact production (Mäkelä, 2007). This approach elevates the studio practice as the backbone of artistic research and suggests that artifact production embodies knowledge and insights within. However, Mäkelä (2007) argues that artifacts cannot speak for themselves, and therefore interpreting artifacts to reveal the knowledge embodied within appears as an essential task for artist-researchers.

As a research method, practice-led design research exhibits certain characteristics. First, in practice-led design research, self-reflection plays a significant role. Artist-researchers analyze their own interaction with the material to become conscious of their own actions and document significant moments. These processes of documentation, interpretation, and reflection continue in an iterative fashion along with the research. Second, the research questions in practice-led design research tend to be formulated differently compared to other approaches. Mäkelä (2006) notes that the intuitive essence of practice-led design research frequently requires a set of research questions instead of a single inquiry. She argues that "practice-led research does not aim at one singular and objective truth, but rather as an analysis of the process of meaning construction" (Mäkelä 2006, p.120).Practice-led research emerges as a significant approach for contextualizing a craft-art creation. However, practice-led design research has been receiving international recognition and has been discussed only recently across a wide range of artistic practices, such as dance, theatre, music, architecture, fine arts and design (Mäkelä & Routarinne, 2006). As a relatively young approach, practice-led research has been utilized by noteworthy artist-researchers during the last several decades. This study intends to conduct practice-led research and expand its boundaries to intersection of technical and artistic material exploration in glassblowing.

In conclusion, this practice-led research primarily aims to explore the influence of hands-on interaction with material and analyzing my iterative artistic process with glass and glassblowing practices. The constant dialog between practitioner and medium usually shapes the process differently than artists envisioned in advance and the physical engagement with the medium might result in unexpected and inspiring outcomes for the maker. Regarding this phenomenon, the present study mainly focuses on material specific creative work flows through which practitioners begin their artistic journey by choosing a specific material and investigates the effect of the intrinsic character of the medium throughout the process.

1.2 The Role of Literature Review

Along with the practical aspects of this research and the iterative reflection-in-action practices, the literature review widely contributed to the sense-making processes in two ways. First, the initial literature review helped me to construct a theoretical background which functions as a general guideline and enables knowledge accumulation through the following stages. Second, the knowledge gained from literature review became more infused in the process as an integral component of each circle of practice-reflection.

Regarding the cyclical nature of practice-led research, Mäkelä (2006) highlights that the literature review finds itself in an iterative role between the artist and the material; each cyclical period makes the artist aware of different aspects of their artistic production, and it widens their vision. This new vision often introduces new issues to address along with new topics to explore in the literature. Moreover, each literature review, in a similar manner with reflection over the practical work, provides a new vision with artist-researchers. This vision triggers new ideas to be tested in practice and each cycle influences the artist-researcher's perspective, keeping the whole practice in progress in terms of the meaning-construction and sense-making processes. In this process, literature review functioned as a roadmap in which I frequently checked my position and decide the next possible action.

In the present research, literature review primarily focuses on the topics of embodied knowledge, hands-on material exploration, expressiveness in art, thinking through making, material-specific creative workflows and, from an historical point of view, a review on principles of Arts and Craft, and The Studio Glass Movement.

1.3 Historical Background and Context of the Research

This historical review discusses critical events that have paved the way for a contemporary understanding of glass as a creative medium today. However, instead of presenting a chronological order, I will focus on the intellectual aspects of events and follow their echoes to identify how they resonate with current art and craft practices. Therefore, the first section explores the core of The Arts and Crafts Movement back to its origins. The following section analyzes its influence on the development of The Studio Glass Movement in the following decades.

1.3.1 Arts and Crafts Movement

The Arts and Crafts Movement was born, in late nineteenth-century in Victorian Britain as a response to the ethos of industrialism that favored high profits in exchange for aesthetic appeal, individual creativity, social well-being and decreased qualities of life compared to pre-industrialized era, which was idealized as having infinitely better moral values and wholesome production methods (Adams, 1996, p. 9). In this period, the theorists and the creatives of Britain began to consider art as an antidote for dealing with these socially downgrading consequences, because of its redeeming power and potential for social improvement. Regarding this, a wide variety of artisans and craftsmen involved in the movement, such as architects, potters, jewelers, cabinetmakers, as well as designers emerged.

The Arts and Crafts Movement began with John Ruskin and William Morris's writings before the 1860s and Morris's apprenticeship program, in which he offered industrial arts (Triggs, 2014). Ruskin, leading English art critic and economist of the Victorian era, proposed a different direction than the established teachings of his time, concerning three topics: theory of beauty, the doctrine of work, and the general economy. "Aesthetic" as a term was coined by Baumgarten in the eighteenth century; he defined the word as the science of beauty and argued that it proposed an appealing sensation. However, this focus on sense effects eventually led to the notion of "art for art's sake" and limited art as a mere amusement for aristocracy (Triggs, 2014). Opposing that, Ruskin argued that art is not a notion that can be defined by its quality of beauty, rather it is an expression which essentially refers to social and moral issues, and its value should be measured by its inclusiveness, universality, serviceability, and usefulness for society (Triggs, 2014). By this definition of art, Ruskin stresses on withdrawal of art from daily life and argues that it must actively be incorporated as a part of life as well as production. Besides Ruskin's opinions on art, he strongly criticized mechanized mass-production models and discussed that as long as machines were in service of humanity liberating them from hard labor, there would be almost nothing to criticize about it, especially if they were not used to enslave workmen and confine them to exercise a single job repetitively (Triggs, 2014). Regarding this segmented way of production, Ruskin opposes the division of labor and argues that it separates people from the knowledge of the final product which eventually gives the rationale for their labor (Triggs, 2014). He suggests that the problem of labor was not about working conditions but the character of the work which lacks satisfaction, " it is not the labor that is divided, but the men – divided into mere segments and crumbs of life." Ruskin states (Triggs, 2014, p. 26).

Following that, Ruskin strongly advocated for the moral value of individual work and praised the reunification of labor in a similar form which medieval painters performed as they prepared their handmade paints and artisans who had the freedom of design and production as well as the self-expression of their creations (Cumming, E. & Kaplan, 1991). Ruskin believed that those artists and artisans of the late medieval era had the absolute freedom of expression and it was the central theme of his proposition (Cumming, E. & Kaplan, 1991). In addition to these ideas, The Arts and Crafts movement suggested not only a new paradigm against the downgrading influence of industrialism on handwork and craftsmen but also implied a particular lifestyle. For instance, Ruskin and Morris both moved out of London to the countryside and attempted to facilitate a self-sufficient, craft-oriented community.

Along with Ruskin's thoughts about the division of labor, an English designer and architect Charles Robert Ashbee (17 May 1863 – 23 May 1942) played a prominent role in the Arts and Crafts Movement (Cumming, E. & Kaplan, 1991). Ashbee followed Ruskin's teachings and founded the Guild and School of Handicraft in 1880 (Triggs, 2014). In 1888, Ashbee famously dedicated his translation of Cellini's Renaissance Treatise to people who find the meaning of their life in handwork. By doing so, his primary aspiration was to reveal the dissatisfaction of laborers caused by a mass-production business model that promoted the division of labor, rapid manufacturing, and high profit. In contrasts to these grounds, Ashbee argued that an artist and producer should share the same ethics; the production must exhibit its own character similar to an individual mark of an artist, yet the core values of current mechanical systems detach individuality from the production (Triggs, 2014). " The system has destroyed the things created and destroying the productions we destroy producers. Lower the standard of the work; you lower the standard of the man. " Ashbee states (Triggs, 2014, p. 87). Besides individuality, Ashbee pointed out the satisfaction of control over every sensory aspect of an object in a production process - which is possibly the notion that attracts people from every part of the society and drives craft-based activities to flourish all around the world until today (Cummings, 2002).

As this review shows, The Arts and Crafts Movement emerged as a philosophical, artistic and social movement in the late nineteenth century as a counter-reaction to adversities of the automated methods of mass production which compelled people to have a limited as well as a repetitive, daily work-routine. Regarding this degradation of society, the movement primarily advocated four principles: individualism, the joy of labor, the unity of design, and regionalism (Cumming, E. & Kaplan, 1991). Pioneers of the movement profoundly aimed at these adversities of industrialism, and in contrary, they promoted handwork and the joy of making as a way of restoring social and spiritual harmony in society. In addition, there was also a strong emphasis on reconsidering the relationship between society and production, unification of artistic fields as well as their integration into daily life, and reimagining aesthetics of traditional and natural materials (Cumming, E. & Kaplan, 1991).

Regarding the objectives of this MA thesis, the most significant aspect of the movement emerges as its emphasis on self-expression, which could only be possible with complete authority over a creative production accompanied by notions of Individualism, the joy of handwork, and freedom in aesthetic and creativity. These notions perhaps have been the main attraction points that have sustained a growing interest all around the world and kept fostering new craft-based movements throughout the decades. As one of them, The Studio Glass Movement, as the next chapter discusses, could be the most remarkable and profound influence on the contemporary glass as well as this research.

1.3.2 The Studio Glass Movement

As the previous section discussed, central themes of The Arts and Crafts Movement inspired various craft movements in following decades and The Studio Glass Movement was one of the most revolutionary one considering its mark on the history of glass as well as contemporary art practices. This section discusses the emergence of the movement in the early 1960s because of a group of prominent artists/practitioners who sparked a profound paradigm shift in glass art. Besides its historical value, the philosophical propositions of this movement provide an intellectual background for central inquiries of this MA thesis.

The first step of The Studio Glass Movement dates back to the 1870s when French designer Emile Galle signed his glass artworks for the first time, as other traditional artists like painters or sculptors do, which signaled the impending radical shift in the course of glass as a creative medium (Carboni, 2001). This was an exceptional attitude for this period because people were used to viewing glass entirely as an industrial material which belonged to factories rather than artist studios. Thus, for a long time, except for some individual attempts, glass remained to be produced in factories around the world, such as Lalique in France, Tiffany in the United States and Orrefors in Sweden (Carboni, 2001).

Following this individual yet revolutionary attempt, Maurice Marinot, a renowned French painter, emerged as the most significant artist who could foresee the future of glass practices, clearer than anyone, as Harvey K. Littleton states, an American ceramist, educator and leading figure of the movement (Littleton, 1971, p. 29). Marinot's journey began with his visit to Viard Brothers' hot glass workshop, in which he discovered the potential of glassblowing for artistic form exploration, similar to what sculpture and painting could do (Littleton, 1971). Appreciating Marinot's enthusiasm, the Viard brothers offered him a corner in their factory where he could work on his designs and access factory facilities (Littleton, 1971). Marinot's first designs exhibited a painterly character that were achieved by using acid and enamel decoration techniques on ready-blown glass pieces created by craftsmen in the factory (Cummings, 2002). Yet, being confined to factory-blown standard shapes became unsatisfying for Marinot after a while, and he came to the conclusion that: "for genuinely expressive artistic explorations one must acquire the mastery of shaping hot glass" (Cummings, 2002, p. 177). At this point, a critical difference between practices of Marinot and his contemporaries appears: even though artists like Cros and Decorchement had a similar journey as Marinot, they used kiln-casting techniques rather than glassblowing (Cummings, 2002). Prof. Keith Cummings (2002), a glass artist, educationalist, and author, underlines the fact that the two techniques inherently differ because, unlike kiln-casting, glassblowing requires a practitioner's constant attention, physical interaction and embodied knowledge to be able to shape hot glass. These attributes take a long time and a serious commitment to develop. Fortunately, Marinot was enthusiastic enough to invest years of effort to acquire the technique and achieved a level of mastery enabling him to express himself in glass freely (Cummings (2002). Marinot's journey was articulated by Littleton stressing the privilege he acquired:

"By 1920 he was able to control his pieces, giving them the full range of expression under the guidance and inspiration of his own hands and breath"(Littleton, 1971, p. 29).

Despite individual efforts like Marinot's, the glass industry was still dominated by renowned designers, such as Carder, Galle, Tiffany, Aalto, Toikka, and Sarpaneva in the 19th and 20th century (Cummings, 2002). Even though all these highly appreciated names had a specific style, they shared one aspect in common in their practices: instead of translating their ideas through direct physical engagement with the glass, they preferred to use representational ways such as prototypes or sketches to communicate their ideas with craftsmen who were responsible for the execution of their designs (Cummings, 2002). However, this method created an inevitable interruption in artistic production, which should stay more integrated and fluent, as Cummings (2002) highlighted. Regarding this method, it can be argued that this way of production was distant from the ideals of The Arts and Crafts Movement which promotes the integration of art fields and unification of labor with a full range of control over every detail of the production. Nonetheless, besides these renowned names, there were still glass artists who were experimenting with establishing hot-glass within their studios in Europe.

Meanwhile in the 1950s in the United States of America, craft mediums and studio activities were becoming popular; American artists were striving for innovative ideas on craft media. Specifically, Littleton was inspired by American artist and Californian potter Peter Voulkos' abstract expressionist ceramic works and decided to take a similar approach with glass (Corning, 2008). After his personal experiments in 1958 and visits to small-scale hot glass workshops established in various places in Europe, Littleton was convinced that glass-making in a studio scale was possible. Following that, he organized two glassblowing workshops that mark the beginning of the Studio Glass Movement in the Toledo Museum of Art (Corning, 2008). Besides Littleton's efforts, a liberal and social atmosphere in Western politics in the 1970s provided a perfect breeding ground for novel approaches in artistic expression (Adlin, 1996). In this Libertarian climate, individual creativity was highly valued within The Studio Glass Movement and artists could enjoy the freedom for personal exploration as well as with their medium. In this regard, Cumming (2002) defines Littleton's model as an open, ongoing process, involving artistic interaction – as a 'conversation' between artist and medium. However, the movement was inhibited by unavailable technology and knowledge, specifically proper glass formulas and equipment that would enable artists to experiment freely in a small studio setting.

Progress in glass-making usually follows technical advancements; these are attributed as supporting materials, such as metal and ceramics that are indispensable elements for constructing high-temperature heat sources and essential tools for shaping hot glass (Cummings, 2002). Regarding that, The

Studio Glass Movement required a leap forward in glass technology to take the glass process from its conventional industrial use to be adapted to small-scale artist studios considering the demand on cost efficiency. This problem was addressed thanks to the early experiments of Littleton and contributions of artists Dominick Labino and Erwin Eisch that invented low-cost glass melting furnaces and a new glass formula which made possible a lower melting temperature than its industrial counterparts with proper viscosity for free shaping in small-scale glass studios (Cummings, 2002). These developments enabled artists and designers to independently develop their experimental methods and become both designers and craftsmen - bringing thinking and making together once again. Since this unity and full authority on the medium emerged as a considerably exceptional experience in the Post-Industrial Age, The Studio Glass Movement has managed to evoke such excitement and remarkable attention from all over the world (Cummings, 2002). Following the field's technical progress, Littleton introduced a glass program to the ceramics department at the University of Wisconsin. His first students, such as Dale Chihuly, Marvin Lipofsky, and Frits Dreisbach, became prominent names in The Studio Glass Movement (Corning, 2008).

In conclusion, The Studio Glass Movement perpetuated vital principles of the Arts and Crafts Movement in the context of glass-making by allowing experimentation and artistic expression with advances in material technology. The movement positioned the act of making as its central theme and integrated thinking and making to achieve an uninterrupted fluency in artistic expression, thus allowing glass artists to be both designers and makers within their artistic process. This way, it succeeded to provide a new stage for self-expression and, most significantly, offered an opportunity to experience the joy of a full-scale artistic production in the glass field for individual creatives.

1.3.3 A Historical Perspective on Reduction Lusterware

It is a common belief that the first examples of metallic luster were found on ancient earthenware, however as historians have shown, the first luster decoration known today is actually on a glass goblet found in Cairo dated to AD 773, which precedes the first luster decorated pottery by approximately a hundred years (Clinton, 1991, p. 10). Nonetheless, early examples of metallic luster more commonly appear on earthenware elements, their first appearance originating from Mesopotamia in the ninth century (Clinton, 1991, p. 10). The first examples of reduction luster were applied to tiles reserved for exceptionally religious purposes, such as on the most holy areas of mosques and tombs (Clinton, 1991, p. 10). Afterward, the luster technique spread to Egypt in the twelfth century and further reached its apex in Persia around the thirteenth-century (Clinton, 1991). However, the arrival of metallic luster to Europe dates back to the eighth century; the Islamic potters brought their skills with them to Spain, conquered by Moors. In the sixteenth century, two potteries in Italy, Deruta and Gubbio, became famous for their lusterware of a pale gold wash luster on blue-white decorations (Clinton, 1991).

The use of metal salts in glass boomed in the Art Nouveau period that witnessed significant advancements in glass art and design. Metallic luster was undoubtedly developed by Louis Comfort Tiffany (1848-1933), an American glass designer, inventor, and adventurous experimenter in glass (Klein & Lloyd, 1989). Tiffany's designs were exhibited for the first time in the late nineteenth century and later imitated by designers and artists in Europe and America (Klein & Lloyd, 1989). As the son of a New York jeweler, Tiffany had a passion for art studies and began to study landscape painting, mainly focusing on themes of exotic eastern landscapes (Klein & Lloyd, 1989). After a moderately successful painting career, Tiffany's interest shifted towards decorative arts, and in 1879 he founded his decoration company in which Tiffany and his fellow artists designed colorful exotic landscapes with geometric designs for interior decorations (Klein & Lloyd, 1989). Their most prestigious commission was the decoration for the White House in 1883 (See Fig.1) (Klein & Lloyd, 1989). However, the poor quality of the stained glass did not satisfy Tiffany, and he started to undertake ceaseless experiments using different compositions of metal oxides in order to achieve more brilliant and deeper color effects than the medieval stained glass (Klein & Lloyd, 1989). Tiffany experimented with wrinkled glass, light, and color gradations using metal salts. The infusions of metallic salts into the hot glass resulted in unique iridescent effects which came to be known as ''favrile" later on as his trademark (See Fig.2) (Klein & Lloyd, 1989). Tiffany had already been captivated by metallic luster around the early 1880s and, as a visitor in his studio once stated, he had a collection of 5000 colors and variations stocked in his studio in the 1890's (Klein & Lloyd, 1989). The metallic luster was not entirely new to Europe; the exception of Tiffany's success was in his application methods which turned the hot application of metal salts into an artistic technique that had never been done before (Klein & Lloyd, 1989).

Fig. 1.

(Tiffany, 1882) Stained glass screen installed in the White House Entrance Hall Artist: Peter Waddell, The Grand Illumination, oil on canvas, 55 x 73

Fig. 2.

(Tiffany, 1897) Vase, blown and iridized glass with applied and tooled decoration, New York

Another influential use of iridescent glass appears in Finnish glass designer Oiva Toikka's richly colored, individually shaped, hand-blown glass birds (See Fig.3) (Toikka, Jantunen, & Aalto-Setälä, 2008). Besides their international fame, they have played a prominent role as a driving source for developing skill and expertise in Finland's oldest glassworks, Nuutajärvi Glass factory founded in 1763 (Toikka et al., 2008). In 1963, Oiva Toikka was employed as a designer at the Nuutajärvi Glass factory and alongside his successful glassware collections, like Kastehelmi, Flora, Fauna, he started to experiment with "one-off" glass art pieces, which had been a tradition as a leisure activity after work in Nuutajärvi for a long time (Toikka et al., 2008).

The artisans of Nuutajärvi glassworks had exceptional progress in working with colored glass due to Kaj Franck's designs in the 1950s. As their expertise combined with Toikka's artistic vision and close interaction with the artisans during the blowing process, the 'birds' theme was born. (Toikka et al., 2008). Early experiments of the theme started spontaneously without any initial plan and while Oiva Toikka used only the colored glass available at the time, he enjoyed this spontaneous way of artistic development and gladly let it guide his creations (Toikka et al., 2008). His first variations of the birds started to be produced in 1972, as a part of his Sieppo theme and received their name 'birds' afterward (Toikka et al., 2008). In the following years, Toikka's collection captured international success and became a key product of Iittala's product range (Toikka et al., 2008) As the examples presented here reveal, the metallic luster has been a significant part of his collection and is mostly used as decoration on the beaks of birds or as full-body pattern applications.

Fig. 3. (Toikka, Jantunen, & Aalto-Setälä, 2008, p. 18)

1.4 Material Inspired Expression and the Creative Process

1.4.1 Expression Theories in Art and Material

The role of materials in artistic expression is discussed by many thinkers, including philosophers, anthropologists, sociologists, artists and craftspeople since the eighteenth century. This diversity explicitly reveals the multifaceted nature of the topic and that it requires a wide scope of investigation from various perspectives. In material-inspired hands-on artistic practices, the intrinsic characteristics of materials and their expressive aspects play a major role. Therefore, regarding the main research question of this thesis, the chosen literature in this review and the following sections particularly discuss theories that deal with expression in art relating to physically creative media and materiality.

The theories of expression in art represent a relatively recent approach compared to the representational sense of art that encompasses imitation of surroundings during antiquity and the medieval era. The imitation theories of art precede Plato (ca. 428-347 BCE) and his characterization of art as mimetic (Kelly, 1999). Plato argues that art can only be valuable if it imitates the world of forms in the process of approximation to absolute 'truth'; otherwise, the involvement of emotions subverts art to be an unreliable, misleading endeavor (Kelly, 1999). Plato's doctrine continues to echo into the Renaissance Era as well; for instance, Giorgio Vasari, an Italian painter from this period, famously states that painting only mimics colors and arrangement of elements in nature as they are (Bondanella, 1995). However, by the beginning of the Romantic Movement, around the late eighteenth century, the dominance of Plato's doctrine became less relevant (Kelly, 1999). In 1898 novelist Leo Tolstoy, in his essay" What is art?", suggested to shift the focus of art from its subject to its interpretation as communication of emotions and marked the beginning of expression theories in art (Kelly, 1999).

The classic philosophical approach in expression theories of art includes two prominent names: Benedetto Croce, an Italian idealist, philosopher, historian, and politician, and R.G Collingwood, English philosopher, historian, and archaeologist (Kelly, 1999). Michael Kelly (1999), the author of the Encyclopedia of Aesthetics, summarizes Croce's Aesthetics and Collingwood's Principles of Art, as follows: the process of expression is an artistic act for an artist to clarify and better understand their emotions and thoughts; thus, the mode of knowledge conveyed by art includes intuition, besides the expression. Croce strongly associates intuition with expression and claims that intuition and expression are in fact indistinguishable pairs and cannot be examined separately in a cognitive process. He argues: "The one is produced with the other at the same instant because they are not two, but one" (Croce, 1995, p. 12).

Referring to Croce's account, Kelly (1999) further explains that Croce's view suggests that expression is the forming of the intuition, based on the artist's current emotional status. Moreover, Croce (1995) suggests that the word expression should not be limited to verbal constraints. For instance, expression may be derived through words by poets, whereas it takes a pictorial form in the account of artists. However, Croce (1995) argues that this communication cannot reach its full potential in the externalization of the artwork; he believes that a genuine work of art can only be entirely experienced in the artist's mind as a conceptual activity, and due to moral and practical limitations, it can never truly be externalized. Opposing Croce's idealistic view, John Dewey, an American philosopher, and psychologist suggests a rather naturalistic view on externalization of artworks (Dewey, 2005). Dewey shares Croce and Collingwood's thoughts on the act of expression and considers it as the self-exploration of the artist. However, distinctively, Dewey stresses the externalization of artistic work and defines its function as an instrument of communication (Dewey, 2005). Furthermore, He highlights the similarities between an artistic process and language and Dewey claims:

"Each medium says something that cannot be uttered as well or as completely in any other tongue" (Dewey, 2005, p. 111).

As this quote suggests, Dewey defines externalization of artworks as a means of communication and the expression of the artwork similarly functions as a language that communicates its context with the audience. In this sense, the expressive characteristics of materials, which are displayed by the physical properties of them, may hold the key to an explicit conversation between the artwork and the audience.

Furthermore, if an artwork functions as a mediator and communicator, it should use a certain language constituted by certain symbols which refer to broader meanings and metaphors. Nelson Goodman (1906-1998), American philosopher known for his studies on the philosophy of language and aesthetics, widely elaborates this idea and states: " what is expressed is metaphorically exemplified." (Goodman, 1979, p. 85). Goodman (1979) suggests that a concept, metaphorically represented in artwork, does not necessarily possess the concept itself. For instance, the impression of sadness could be associated with a picture even though it does not include anything 'sad' literally, and therefore the metaphorical meaning of the work transcends the physical boundaries of the artwork. Goodman emphasizes:

"From the nature of metaphor derives some of the characteristic capacity of expression for suggestive allusion, elusive suggestion and intrepid transcendence of basic boundaries." (Goodman, 1979, p. 93).

Regarding this relationship between symbols and the metaphorical subject, Goodman clearly distinguishes between literal and metaphorical references (Goodman, 1979, p. 85). Referring to architecture, he argues that, if a glue-factory expresses the process of glue-making, this would be a literal exemplification rather than metaphorical (Goodman, 1979, p. 85). In this example, he highlights that values expressed by these symbols belong to them, and they are just metaphorically associated, imported properties; therefore, symbols themselves do not necessarily include that meaning literally. For instance, again with Goodman's example: " The subject inanimate does not determine whether the face or picture is sad or not. The cheering face of the hypocrite expresses solicitude…" (Goodman, 1979, p. 86). As his quote states, metaphorical exemplification in artwork does not necessarily rely on a visual or physical element in an artwork, yet it exceeds with a broader meaning allegorically implied, sometimes in an ambiguous and subtle way.

In this literature review, considering immensely broad literature of expression theories, I intended to review philosophical approaches on expression that correspond to the objectives of this research. Classic philosophical views on expression remark on the role of the artist's emotional status, intuition and, the instrumental function of art as a communicator between artist and the audience. Following that, Goodman's thoughts elaborate on this communication function through symbolic meanings and metaphorical exemplification that exceed the physical boundaries of artwork to share metaphors with the audience.

From a practical perspective, this review provided me with a theoretical basis to understand the intersection of expression and intuition for material exploration and artistic production stages. During material exploration, numerous details and possibilities compete for attention throughout the process. In such complexity, the ideation process and finding the right expression required a long period of trial and error because, as a material-inspired process, I did not know exactly what I was seeking in the beginning. However, the theory provided me with some perspective of what I could possibly be looking for. Therefore, it facilitated the decision-making process and helped me to distinguish elements that I wish to highlight for my artistic process.

1.4.2 Expression and Material Inspired Creative Process

The literature review for this section has argued that terms of material and medium can be used interchangeably in many cases. However, especially in certain contexts, they might imply different meanings. The Concise Oxford English Dictionary defines material, in its first definition as: "the matter from which a thing is made" (Allen, R. E., Fowler, H. W. & Fowler, F. G., 1990). David Davies, Professor of Philosophy at McGill University, known for his work on metaphysical and epistemological issues in the Philosophy of Art, suggests that art media should be an agent that conveys the content of the artwork to the reception (Levinson, 2005, p. 181). Following this, Davies suggests various interpretations for the medium: as physical matter such as stone, bronze; as sensible marks on a material such as color, pattern or tone; as methods of creating these marks such as brushstrokes/gestures; and, finally as the coordination of these marks, values, or symbols, similar to language systems (Levinson, 2005, p.181).

Undeniably, physical properties of materials play a significant role in creative processes, which incorporate tangible results. These properties exhibit visual and tangible cues, which together establish the overall mood of the artwork. Relating to that, Davies concludes his essay " Medium in Art " with three pieces of advice about the role of art media (Levinson, pp. 181-191). First, the material may function merely as a platform in the realization of artwork; in this case, material only serves to materialize the artist's statement. Second, artwork might imply a high level of fine work, skill or technique employed for its materialization, which affects the way the audience appreciates it because of the technical achievement behind its execution. Third, an artist may begin with an initial idea and purposefully employ the intrinsic character of the medium in order to improve its communication with the audience (Levinson, 2005, p. 189). Regarding that, Davies refers to Richard Wollheim (1968), British philosopher known for his studies on visual arts, and discusses Wollheim's account on the appreciation of an artwork. According to Davies, Wollheim (as cited in Levinson, 2005, p. 187) claims that appreciation of an artwork depends on two key points: the context and its interpretation. These theories suggest that the value of an artwork depends on an artist's ability to be aware and benefit from the expressive potential of the creative medium. This awareness improves the communication between artwork and the audience when used properly.

Regarding these thoughts, it can be argued that even though the intrinsic character of the material plays a significant role in the appreciation of an artwork, its full effect cannot be grasped only by analyzing the final work. In fact, the major effect of the chosen media occurs, in the broadest sense, during the creative process. As it was discussed above, appreciation of an artwork is dependent on the artist's awareness of the intrinsic character of the art medium. Thereby, artists can design a coherent composition utilizing the expressive potential of their media. Hence, expressiveness requires an artist's informed, purposeful action during their creative process. Concerning this, Nithikul Nimkulrat, professor of textile design in the Estonian Academy of Arts, underlines that: " An act of expression comes into being when an artist becomes conscious of the meaning of his action." (Nimkulrat, 2009, p. 94). As she suggests, if artists employ the act of self-reflection throughout their creative process, observing and evaluating their acts after each step, they eventually become more aware of their material, the process, and finally themselves (Nimkulrat, 2009). Eventually, this state of awareness extends to multiple dimensions constituting a unique expressive statement. On the act of expression, Nimkulrat (2009) refers to John Dewey's thoughts; according to her, Dewey argues that expression related to experience includes both action and result, product and process (Nimkulrat, 2009, p. 94). Therefore, artwork cannot be entirely apprehended and created in the artist's mind in the first place, yet rather as a process, it keeps developing whilst the artist engages with the medium.

These statements clearly stress the substantial connection between the reflection of studio practice and material inspired creative process. A material-inspired artistic process needs a broad comprehension of tangible features of a medium and its reinterpretation as an instrument to communicate a particular theme through tangible artifacts. Nimkulrat describes this notion as "materialness" and states that materialness of a medium implies its inherent potential to express certain meanings through its physical features (Nimkulrat, 2009, p. 229). However, since the perception of these features and their meanings are subjective, they usually differ from person to person according to the personal aspects such as cultural background and previous experiences (Nimkulrat, 2009, p. 207). Therefore, communication of a certain expression inherently depends on the artists' own perception of the creative medium, and this perception gradually emerges as the artist interacts with the material (Nimkulrat, 2009). Nimkulrat notes that materialness initially begins with the artist's special affection on a specific material and it continues to develop through their bodily interaction (Nimkulrat, 2009, p. 229). This interaction becomes a dialog throughout the process and finally arises a particular expression (Nimkulrat, 2009).

Regarding these thoughts, I believe that Stephen De Staebler, an internationally celebrated American sculptor who worked in clay and bronze, constitutes an illuminating example for my material research and artistic process (See Fig.4&5). De Staebler rejected the abstract expressionist approach of the Otis group, where he was a student in Peter Voulkos' Berkley Studio since the early period of his career (Adamson, 2007, p. 49). He rejected dramatically gestured forms attempting to defy gravity or bright glazes and considered them as artificial add-ons, which disrespect intrinsic character and the integrity of the material (Adamson, 2007, p.49). Instead, De Staebler mixed colorants with the clay itself, employing them not as artificial add-ons, but integral parts of the raw material (Adamson, 2007, p. 49). Similarly, considering a slab of clay and its natural reception to gravity, his artworks were constructed by letting the natural pull of gravity form the material (Adamson, 2007, p. 49). Harvey Jones comments on De Staebler's work in a 1974 Oakland Museum catalog:

"De Staebler can point to the sculpture he made as a student, and to the particular slab of clay that opened the door for him. What happened, he recalls, is that this slab did not do what he wanted it to do, but what it did do as he laid it on the sculpture was better... He has learned by long experience to recognize the intrinsic character and beauty of the medium, and more importantly to respect its natural limitations. De Staebler responds to the peculiar qualities which clay possess: its plasticity when wet, its fragility when dry, its tendency to wrap, crack and slump during the drying and firing process" (Adamson, 2007, pp. 49-50).

In addition to Jones' comments on De Staebler's approach, De Staebler describes his process as an exploration of the inner instinct of the material and defines his long relationship with the material as an attempt to study the will of the material (Adamson, 2007, p. 50).

In conclusion, this review shows that the expressive character of a material is a many-sided topic that includes three main points: the physical attributes of the material, the artist's dialog with the material, and finally the way it is interpreted by the audience. These insights helped me to widen my focus from being stuck on the physicality of glass/silver colors to stretch it to the abstract dimension of expression. In response to this refocusing, I first directed my material exploration processes to comprehend what is the inner voice of the material, as similar to what De Staebler did. Then, I conducted my ideation process for the artistic production aiming to use this inner voice of glass as an instrument to amplify the communication of my artworks and their expressive aspects to the audience.

Fig. 4. *(De Staebler , 2008). Figure with Lost Torso'76 x 18.5 x 21*

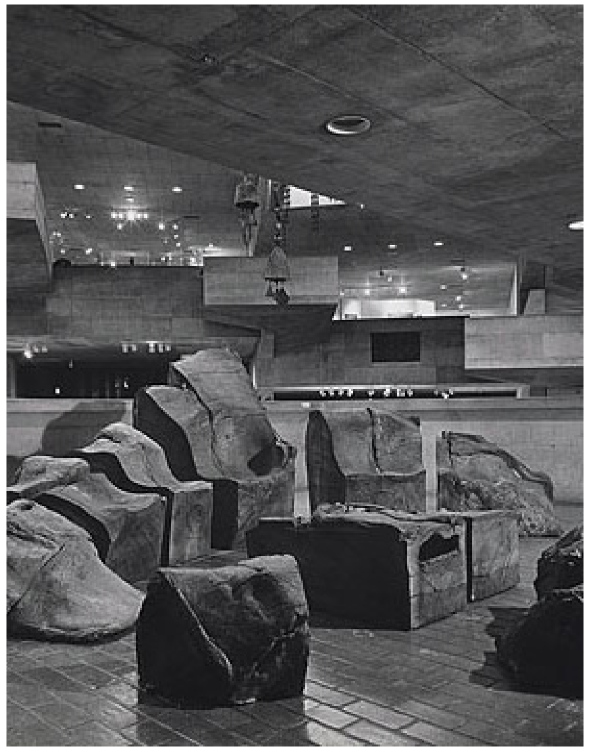


Fig. 5. *(De Staebler , 1970). Landform sculptures, seating Environment at UC Berkeley Art Museum,Thirty-Two Pieces-63 x 240 x 180*

1.5 Methods and Research Design

Due to its subjective nature, practice-led research usually produces experiential knowledge and can generate information if readers can easily follow rationales behind the decision-making process of the practice in question (Mäkelä & Routarinne, 2006). Therefore practice-led research should be a transparent process and this transparency can only be achieved by clear documentation of the process (Mäkelä & Routarinne, 2006, p. 124). Thus, documentation of the process is conducted as a fundamental part of the research. Otherwise, an artistic production alone cannot function as research unless the artist-researcher interprets the artwork as well as the process that leads to it.

First, since the material research of this thesis emphasizes communication of the embodied knowledge and practical details of the glassblowing practice, I prioritized the personal notes based on reflection in action via digital devices and numerical data as documentation. I preferred the most basic and flexible tools for active note taking instead, such as pen and paper. In addition, I realized that any form of 2D representation would not be adequate for the objectives of this thesis. As a material-inspired artistic research, this thesis aims to explore the material as a whole and does not exclude any feature, such as tactility, transparency, visual quality, their reaction to artificial and natural light, sense of volume, and so on. It is not possible to represent these tangible features with 2D media or any written form. Therefore, I began my research process in the studio by making samples straight in the glass material and prioritized archiving and selecting key samples for various possible directions of artistic expression from the very beginning of the process (See Fig.6). The collection of samples profoundly supported me as references to develop my final artworks throughout the process.

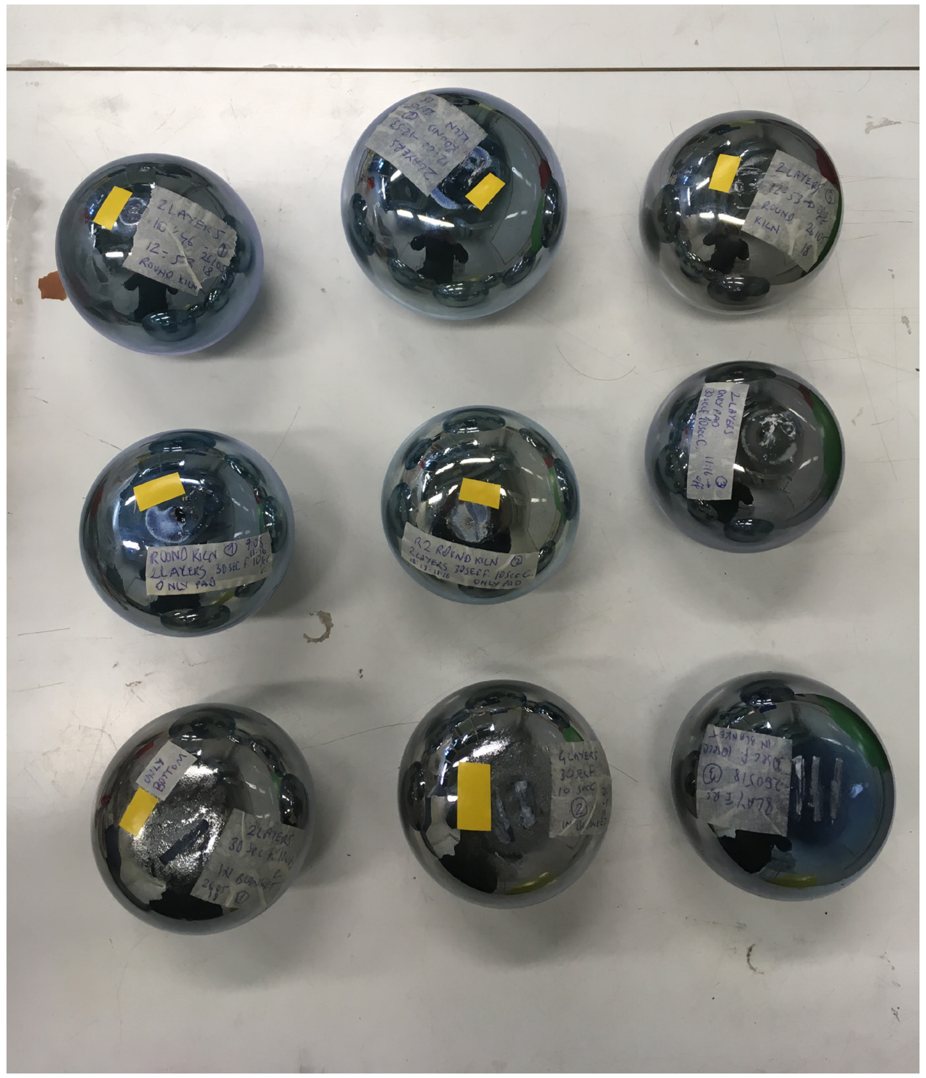


Fig. 6. *Labeled test samples for further evaluation*

1.6 Data Recording Process

Glassblowing demands practitioners to keep pace with the rapidly cooling molten glass, and this time-sensitive practice dominates the process. This fast and ever-changing nature of the glass-making process required specific methods of data recording, especially during the blowing process. Therefore, I mainly used three types of notebooks for different purposes.

First, due to the rapid pace of the glassblowing process, I preferred a pocket-sized notebook (See Fig.8) where I took only short notes or used abbreviations. Since my hands were usually busy with the blowing tools, taking detailed notes during the process was not possible. Therefore, I preferred to record only icons or small sketches; these remind me of the actual content of each making session. Afterwards, I compiled my notes into more detailed texts, adding my insights about critical situations that I experienced during glassblowing sessions. Following that, I compiled all the data into evaluation papers that I prepared in advance. These ready-prepared papers included a set of questions that helped me to organize my thoughts and keep track of the progress on a nearly daily basis. Eventually, my sketchbooks and evaluation papers all together constituted my studio diaries. These diaries served as a central source of information, especially considering the practical side of the material research. In addition to this method, I used another sketchbook mainly for artistic development and notes for the relevant literature review. In this one, I sketched my conceptual ideas, developed my thoughts, and recorded essential quotes from literature readings. This sketchbook played a significant role in the written part of the thesis as well.

Along with my studio diary, I used digital equipment for two specific purposes. First, in order to determine the specific time and temperature limits for the process, I used an infrared thermometer with a laser pointer (See Fig.7) and chronometer. These devices allowed me to determine the maximum and minimum limits of the process by numerical data. Additionally, I recorded my actions by a video camera in the studio and watched them later for error correction, especially for the glassblowing techniques that I had to perform with a certain precision.

For specific technical advice, I conducted interviews via email with specialists on particular cases in my material research. I prepared a series of questions to ask and had a conversation through emails about the puzzling situations I encountered during my experiments. I chose to use these specialists as a resource to seek additional relevant literature, clarify information I found in my own literature review, and to better understand the scientific reasons behind my research. I do not have a background in science and did not want to risk misinterpreting scientific information.

Research Diary Questions

1-What was the main inquiry tested today?

2-What were the critical points? What facilitated / hindered the process?

3-Who were the participants?

4-How do you feel now? Did your plans change? Why?

Fig. 8. *My pocket-sized sketchbook for hot work sessions*

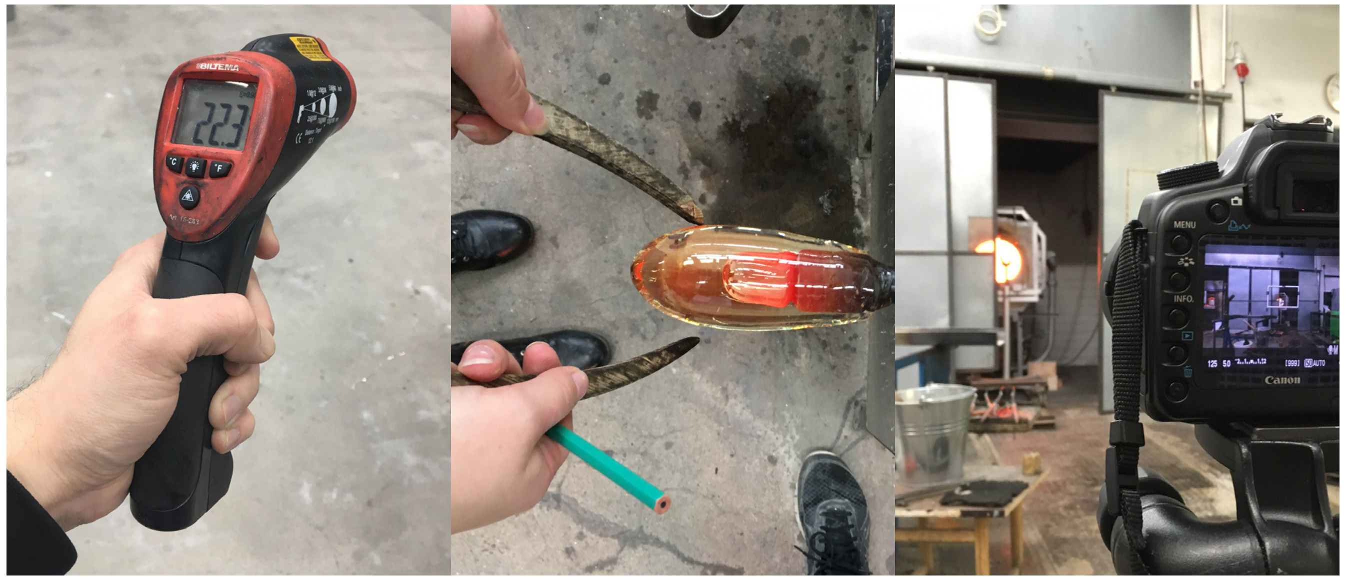


Fig. 7. *Tools for research and documentation / Infrared thermometer, Compass, and Camera*

Chapter 2 Material Research: Reduction Reactions in Glass

This material research aims to explore the aesthetic and visual potential of silver glass colors and to search for a reliable method for producing neutral, silver-mirrored surfaces in glassblowing. Furthermore, the research aims to provide a set of guidelines for other creatives, which will enable them to utilize the potential of silver glass colors as a part of their artistic repertoire.

The content of this section consists of two elements. The text presents technical and practical data on the topic. At the same time, visual elements display samples or early prototypes, which are inspired by the content in question and shaped by my early artistic vision in the process. I aimed to reveal the correlation between my technical knowledge and artistic vision along with their progress throughout the research.

Metal salts found in ceramic glazes and glass colors have been used to produce various types of metallic luster, resulting in a wide range of visual effects varying from iridescent effects known as " Newton Rings" or " Rainbows" (see Fig.9), to aesthetic qualities similar to solid metals including gold, copper, silver, and sometimes even pink mirrored surfaces. The mysterious transformation of metal salts into glittering, shiny surfaces has been an intriguing phenomenon for artisans,and perhaps early accidentally successful firings allowed artisans to believe that they could transform their ceramics into gold pots and discover the secrets of the art of alchemy (Clinton, 1991). However, even golden luster does not contain any actual gold particles and this effect is achieved by reducing metal salts, such as silver and copper oxides in colorants, by exposing them to an oxygen-hungry firing atmosphere (Clinton, 1991).

Metallic luster has been widely used for decorations as rim borders, motifs or solid areas on ceramic and glassware for ages (Clinton, 1991). However, even though the luster effects from metallic salts have been appreciated throughout the ages, the reduction process has been considered a challenging and hazardous process due to its unpredictable and challenging nature. A record from a sixteenth-century Italian workshop by Cipriano Piccolpasso clearly illustrates this struggle of unpredictability, as he states: " the art is so uncertain that often out of one hundred pieces of ware hardly six are good. " (Clinton, 1991, p. 10). Similar as to pottery, the use of metal salts in glass has continued to be a puzzling subject for many practitioners throughout the ages, partially due to the lack of organized information on the subject. For instance, one of the most detailed studies on depositing metal salts on glass and glazes predates to a published book from a French chemist, M.L Francher in 1906 (Clinton, 1991). Even though his research has been widely circulated ever since, it was not translated into English; hence the reduction process remained to be a confusing subject for many (Clinton, 1991).

This confusion and unpredictability primarily occur because of the sensitive electrochemical processes behind the reduction of metal salts. These processes continue to keep many practitioners puzzled with clearly unintended results, even today. This situation has led most practitioners, especially novice ones, to gradually abandon the usage of these glass colors. This is not surprising, because with the challenging and rather expensive nature of hot glass practices, any undesirable outcome can cause a critical loss of time and a waste of valuable resources. In effect, attempting unreliable techniques can threaten the longevity of studio production as well as mass-production. This seemingly unpredictable alchemy of reduction intrigued me to undertake as material research. I was interested to explore new reliable ways of achieving greater control in the process and to share technical information, practical guidelines, and an archive of visual references with the glass-making community.

In addition, another motivation for this material research emerged due to the limited academic literature on glassblowing practices, possibly due to its unique aspects compared to other craft materials. At first, hot glass inherently behaves similarly to a honey-like viscous liquid; it is sensitive and even reacts to the slightest inputs, such as bodily gestures, gravity, and heat. These physical variables interdependently change in constant interaction. Thus, the blowing process demands the continuous focus of the practitioner on the medium and requires years of practice with a steep learning curve requiring commitment, patience and preferably a mentor. Regarding this interaction, Polanyi (1966) highlights that masters pass their skills, experience, and techniques to their apprentices in the form of tacit knowledge - a form of information which can only be gained through physical interaction and experience. Due to these reasons, transfer of theoretical knowledge to practice takes a long time and decreases the accessibility of this craft. Another reason for the lack of academic research on this topic is that an experimental academic research project might become costly due to the running expenses of a glass studio and limited due to physical constraints of available workbenches and equipment. In addition, the apprenticeship tradition in glassblowing often narrows the sharing of knowledge with academia. These reasons inevitably lead to less technical information and academic research available on the topic. Considering these problems, I regarded Aalto University's well-equipped glass studio as an exceptional opportunity to expand the academic information on this specific topic and decided to undertake this material research.

Therefore, this material research serves several purposes. First, this thesis contributes to knowledge in glassblowing and craft practices by providing experiential knowledge gathered by empirical hands-on experiments in a glass studio. Since the complex electrochemical nature of silver colors requires many blowing sessions for analyzing each variable, my research required me to repeat the same sample-bubble blowing process

Fig. 9. *Iridized Blue Vase, 2018, from the Collection of Material Research Experiments*

many times while only changing small nuances. In fact, Dormer (1994), author and critic focused on 20th-century design and applied art, considers such repetitious actions as an essential part of a basic learning process of any craft, and being aligned with his thought, this repeated course of action eventually equipped me with enough knowledge and experience improving my glassblowing skills to an adequate level, which allowed me to conduct this material research in a reliable and measurable way. Furthermore, besides the technical findings, I wished to give some insights about different phases of my journey of material exploration in glassblowing and to signify the different nature of each phase, I assigned one narrative for each: the Explorer, the Inventor, and the Magician. These phases were not preconditioned concepts in advance. Instead, they naturally appeared as significant reflections throughout my interaction with the material. However, they were not clearly distinguishable in action. Hence, it was only possible to identify them once I analyzed the entire journey in the end. Therefore, these narratives will be discussed in detail in the analysis and discussion chapter.

As a result, this material research combines practical knowledge and the supporting scientific explanations to explore the proper application methods for reducing silver glass colors within a small scale artist's studio. In doing so, the inherent character of the material unfolds as my creative persona is revealed throughout the research process while the results are recorded as visual references - the artefacts. Therefore, to touch on this personal aspect of the process, the next chapter develops this discussion from another angle and examines the process and results from the viewpoint of expression.

2.1 The Nature of Glass

The term glass refers to a unique state of matter, rather than a specific material or mix of compounds. In fact, a glass material can be made of a surprisingly wide range of substances, such as compounds of oxygen, sulfur and selenium, various organic compounds, polymers, and even some alloys of metal (Falk et al., 2011, p. 16). This section primarily focuses on the soda-lime-silica glass as the most used type of glass for free-blowing studio practices and articulates their physical and chemical properties concerning artistic processes.

In its essence, all glass mixtures incorporate three main components: the former, the flux and the stabilizer. According to this classification, soda/lime silica glass utilizes silica as the glass former, soda as the flux, and lime, i.e., calcium, as the stabilizer (Kulasiewicz, 1974, p. 89). In this combination, each compound induces a specific effect on the behavior of glass material and is combined to accord glass feasibility for different purposes. Fundamentally, silica establishes the basis of a glass mixture as the main melted material, yet due to its high melting point, it remains impractical to use it alone. In order to decrease this unpredictability, a flux, (sodium oxide) is added to the mixture. However, it becomes water-soluble once the sodium is added and requires the lime/calcium to stabilize the sodium oxide mixture. If the amount of calcium increases, the glass becomes more resistant in the melting process, and the working range of the glass becomes shorter. These trade-offs determine the workability of the glass and significant drawbacks for studio glass can mean advantages for mass-production objectives (Kulasiewicz, 1974, p. 89).

Along with the compounds of the mix, viscosity and heat emerge as main determinants regarding production and forming of the glass (Cummings, 2002, p. 11). The term viscosity in principle refers to the resistance to flow; this is caused by intermolecular forces of attraction changing because of the molecular kinetic energies of the particles (Petrucci, Herring, Madura, & Bissonnette, 2011, p. 509). In glass, oxide composition determines its crystalline structure and therefore profoundly affects its viscosity, and the way it is formed and melted (Falk et al., 2011). This crystalline structure closely relates to the state of matter and changes in accordance; for instance, in solid materials, such as stone, metal, or sugar, molecules form a stable crystalline structure in an ordered arrangement (Falk et al., 2011, p. 13). Yet, liquid and gas particles do not become bonded in a specific pattern; rather they move continuously relocating themselves (Falk et al., 2011, p. 13). However, neither of these states can truly reflect the characteristics of glass; therefore, a specific status is granted for its unique state known as a super cooled liquid, in other words, a "very cold liquid" (Kulasiewicz, 1974, p.85). This unique state occurs due to the combination of different inorganic components in the glass which do not form regular crystalline structures as they shift from molten state to a solid (ibid.). Instead, these components gradually slow down until they become trapped in a randomized pattern and their movement is continuous even when the glass completely cools down (ibid.). This gradually decreasing movement means that specific freezing or melting points do not exist for glass, but instead, these transformations occur over a period of time, instead of specific points, and glass remains workable within that range. (Falk et al., 2011, p. 15). Glassblowing practices mainly occur within a specific range, and this research especially focuses on artistic activities that take place within this short time period.

During this cooling process, the viscosity of glass gradually changes according to the temperature of the glass and becomes less responsive to an external force as it cools. Eventually, it completely hardens and sets as a solid. This transition reveals that heat directly affects the viscosity of glass; the higher the temperature, the softer the glass becomes, allowing the artist to manage even significantly detailed sculpting processes. The regulation of viscosity is one of the main factors that practitioners must master in order to control the material for their objectives. Following the same logic, when molten glass comes into contact with the colder air molecules, its outermost layer starts to form a rubberlike elastic skin which encapsulates the liquid molten core inside. All hot glass procedures utilize this interplay between cold outer skin and hot inner mass as the most basic rule (Cummings, 2002). In a similar vein, if any other material other than air contacts the glass surface, it instantly cools the contact area and remarkably changes the heat configuration of the entire body of glass. This principle outcome is also affected by hand tools made from different materials – these require practitioners to preplan tool order, workflow, and type of equipment to be used in advance.

2.2 Redox Reactions and Reduction Colors in Glass

The History of Redox reactions in metal processing goes back to the invention of the first metal tools in prehistoric times (Petrucci, Herring, Madura, & Bissonnette, 2011, p. 165). Since iron can be found only as iron oxide (Fe_2O_3) in nature, in order to be able to utilize it, it is necessary to set iron atoms free from their oxygen by heating them in a carbon-rich environment until carbon atoms catch oxygen (Petrucci et al., 2011, p. 166). This process eventually produces CO_2 and deposits elementary iron as the final product of the process (Petrucci et al., 2011, p.166). Redox reactions occur due to oxygen exchange between substances and always consist of two elements: one oxidized substance that receives oxygen, and its reduced counterpart that loses oxygen; these reactions always follow each other, and therefore takes its name from the abbreviation of reduction-oxidation reactions, as redox reactions (Petrucci et al., 2011, p. 166). Due to this exchange, they are also known as electron transfer reactions and take place not only in metal processing, but also in various modern marvels of technology such as batteries, photography, corrosion protection, electroplating, and combustion reactions (McQuarrie et al., 2011, p. 899). Besides in industrial applications, they also occur in critical biological reactions such as photosynthesis, respiration, the transport of energy within the body, the prevention of food spoilage, and even aging of wine (McQuarrie et al., 2011, p. 899). Regarding this variety, this study focuses on high-temperature redox reactions that occur in the reduction of silver glass colors by using carbon-rich combustion flame during glassblowing practices.

To have more specific information on this subject, I consulted with Jane Cook, chief scientist of Corning Museum of Glass to ask her about high-temperature silver reduction processes in glassblowing. Cook (personal communication, January 22, 2018) explains that silver glass color contains silver ions in the form of silver oxide (Ag_2O); thus, how they could dissolve in the glass color matrix in the first place. Subsequently, when a carbon-rich reducing flame is applied by a hand torch or glory hole (open oven used for heating the glass temporarily) onto the color surface, oxygen of silver oxide combines with carbon in the flame, deposits elementary silver on the surface (See Fig.10), and leaves a thin layer of silver coating on the glass surface (J. Cook, personal communication, January 22, 2018). This information suggests that redox reactions in glassblowing rely on two key elements: excess carbon presence and a hot flame to provide enough energy to trigger the reaction. Moreover, Cook further states that since silver is an active transition metal, this reduction process easily occurs in proper conditions; however, this feature of silver turns against us when the reduction is completed. Because oxidation and reduction processes follow each other and at the first chance silver starts to recover its oxygen back. This cyclic process causes certain difficulties of application of silver glass colors in glassblowing, due to its tendency to reversing effects. Therefore, the following sections will review this issue in detail.

In conclusion, redox reactions constitute an essential part of electrochemistry and refer to oxygen exchange from one substance to another. They generate new compounds and change the electron configuration in the reaction. Even though this exchange may sound like a minor process in atomic level, this invisible process miraculously manifests itself through striking changes in the visual appearance of compounds. Therefore, outside of the scientific field, it has also long been an intriguing subject for ceramists and glass artists who wish to utilize the visual potential of redox reactions for finishing and decoration purposes.

2.3 Application of Silver Glass Colors

The previous section discussed redox reactions, focusing on the chemical mechanisms behind it, and concluded that it highly depends on the proper atmosphere and heat. Besides these external factors the success of the process, without doubt, depends on the properties of the color layer as well.

This section aims to discuss forms of glass color and their proper application, for a successful silver mirroring luster. The information presented here includes my own studio experiments, observations as well as expert opinions from the glass color producer.

2.3.1 Application of Color for Reduction Process

From an artistic viewpoint, each glass coloring technique provides artists with a generous visual repertoire that is only limited by their artistic vision. However, as discussed in the previous section, the silver glass colors require specific conditions for successful color applications which can be limiting for certain cases. This section provides an overview of the main principles of traditional coloring methods in glassblowing and then discusses the specific requirements of the silver colors compared to them.

Traditional colorization techniques are primarily divided into two groups: underlying and overlying methods. Using the underlying technique, practitioners begin by melting a piece of colored glass rod and forming a parison (initial bubble). Subsequently, new glass gatherings are added onto the parison and the color layer inside expands together with the glass body, following the direction of heat and air. However, since the color layer resides inside of the glass bubble, the reducing flame cannot directly touch the color to deposit elementary silver on the surface, as discussed in the previous sections. Therefore, underlying technique cannot be used for the reduction colors, unless the color bubble will be reversed (inside-out) later. Another method encompasses the overlay technique - the practitioner gathers a chunk of clear glass and sets the bubble size with subsequent gatherings according to their need. Then, they apply the color layer directly on top of the glass body by using glass frits or other overlay techniques. In the next stage, both with underlying and over-laying techniques, a thin layer of glass is usually applied to cover the colored layer to encapsulate the colored layer in between two layers of clear glass.

Fig. 10. *Reduction process of a test sample*

This process varies significantly depending on the type of work; however, even though workflow may change, this layered structure plays a prominent role in most of the conventional practices due to several reasons. First, a new gathering on top of the color layer drastically increases the temperature of the glass bubble from its neck to the bottom. The increased temperature provides a smoother workflow and easier control. Secondly, a thin layer of clear glass helps to protect the layer of color against external factors such as scratches in cold-work finishing or from the atmosphere in the reheating furnace. And lastly, this outer layer significantly supports the annealing (final cooling down) process. During a creative process, an artist may prefer to mix different colors to explore complex color compositions for their artwork; however, the different thermal expansion rates of the colors in combination can cause stress leading to cracks during the annealing process. A thin layer of fresh gathering glass can considerably decreases this risk.

However, reducing glass colors demands a different workflow which does not allow any subsequent gathering layer on top of them. This is necessary due to the very nature of reduction reactions, which was discussed in the previous chapter. These reactions require an electron exchange with a reducing agent to become a mirrored surface. Therefore, the reaction cannot occur when the color coated surface is enclosed with another layer of clear glass or anything which can prevent the flame from touching the surface. Thus, reducing colors must always be applied as the last layer, without any other application onto them. This necessity brings two major difficulties: the absence of a protective layer leaves the color layer vulnerable to various physical and chemical external factors and it requires that the volume of the glass piece should already be set before the color application because the process does not allow additional gatherings later. Regarding these technical necessities, I will in the next sections discuss different forms of overlay methods and review these problems in particular for each technique.

2.3.2 Form of Glass Colors

Principally glass colors can be formed in any shape by practitioners. However, there are generic forms of glass colors available in the market such as: below 0,2mm particle sized powder, below 0,5mm sized grain, 0,5mm- 8mm frits, overlay rods, and ready-made cups for the overlay. In order to simplify it, I grouped these forms into two categories: powder/frits overlay colors and overlay rods. Each form of color produces a different visual effect on the glass and requires a distinctive application process.

A. Powder/Frits Overlay Method

Among other glass coloring techniques, the frits overlay technique emerges as the most practical and straightforward method. This technique generously allows artists and artisans to explore unlimited visual possibilities, such as patterns, textures, and color combinations because of its ease of layering in glassblowing. Moreover, it provides both novice practitioners as well as professionals the ability to prototype and test their color themes in the quickest way.

This method involves the use of colored glass particles available in various sizes changing from 0,2mm to 11,5 mm in diameter (See Fig.13). In principle, the coloring occurs as the colored glass particles are gathered on top of the glowing hot glass surface and then melted in the glory hole (See Fig.12). The glass bits merge into each other creating a thin film of colored glass surface on top of the clear glass. Fine-sized particles do not require preheating before gathering and can be applied directly on top of the hot glass surface. I employed this method primarily for initial tests and prototyping purposes throughout the research. Its ease of use and flexible manner of application, in almost any stage of the blowing session, gave me an opportunity to facilitate numbers of experiments in which each factor could be separately tested and analyzed in a short time. Therefore, this method served as the primary research tool for my material research.

Although these advantages supported the exploration phase in my research, my subsequent experiments revealed that the frits overlay technique might not be suitable for final production quality if smooth and consistent reflective glass surfaces are the target because of three main reasons. First, this technique may become an excessive and laborious process in later stages of the glass blowing process; due to its particle-based format, creating a consistent color layer for silver coating requires a manifold of layers. Second, the color must remain on the outer surface of the glass for the reduction process; therefore, it is not possible to apply additional layers of clear glass on top of the color layer. Because of this, an adequate amount of glass must be gathered before the color application. This situation suggests that the practitioner may need to carry a heavy glass bubble for multiple layering for a longer time. The weight and volume of the bubble reduces the practitioner's control and usually creates complications; the bubble requires a greater surface area to be covered which may unfavorably affect the uniform layering. Since a larger mass of glass takes a longer time to reheat, it becomes difficult to reach high temperatures required for completely melting the color particles to produce a smooth layer. Numbers of reheating and melting layers of color on the surface may also be limiting complex geometric forms. Third, the results of experiments show that the expansion of the glass bubble considerably decreases the smoothness of the silver color layers. The inflation of the bubble expands the surface area, and the distance between color particles becomes larger. This situation breaks the consistency of the mirror effect since the color layer loses its uniformity. As a result, particles become visible and leave a texture including dents and bumps on the surface (see Fig.11). This problem prevents practitioners from applying the color layer in the beginning and then blowing the bubble to the targeted size. These concerns revealed a need for a different color application method for the production of the thesis artifacts.

In conclusion, the frits overlay technique appears to be a highly strategic tool for quick tests and prototyping artistic ideas for color and material researches in glassblowing. Its direct application and practical use, without the necessity of preheating, significantly helps artist-researchers to be able to work alone and freely continue their research. However, if an artistic project requires smoother and sharper results, the Swedish overlay technique seems to outperform the frits overlay technique, as the next section discusses in detail.

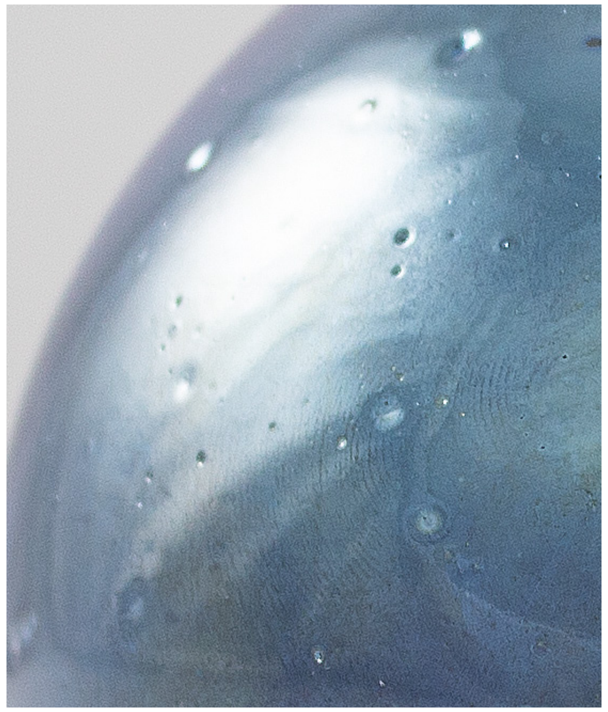


Fig. 11. *An example for dents on surface*

Fig. 12. *Alternative application methods for frits overlay*

Fig. 13. *144RW Dark Blue 0,2mm Powder*

B. Swedish Overlay Method

The frits overlay method involves critical advantages as a research tool, however it also consists of various drawbacks to producing a consistent layer of color required for a sharp-mirrored finish. As my early experiments revealed, instead of infusing frits of glass colors to produce a consistent layer of silver color, it could be more convenient to use a piece of glass color rod, which is already consistent and intense, to shape it as a thin layer of color during hot work, which can then be wrapped on top of a clear glass later. In this regard, the method which is known as "Swedish Overlay" came forth as a more appropriate alternative to the frits overlay technique.

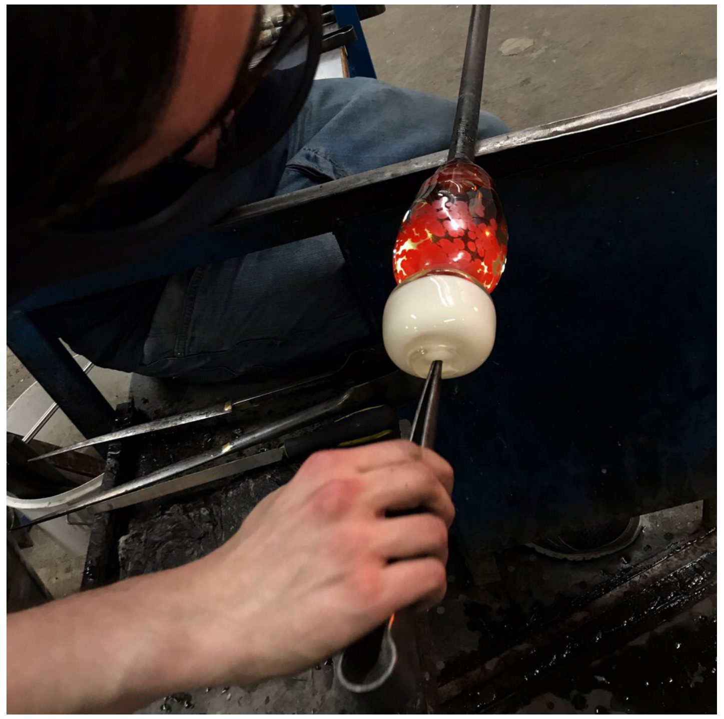
Swedish Overlay technique primarily requires two components: a color overlay bubble and a base bubble to be merged at the end. To begin with, the glassblower melts a color rod slice and blows the first bubble. Then, they gather a new layer of clear glass on top and continue to blow; instantly the color bar infuses with the clear glass inside and evenly expands together following the direction of air and heat. This way, the artist achieves a consistent color layer inside the overlay bubble. As the overlay color bubble becomes ready, it must be kept hot with the help of an assistant or in a kiln around 500-515°C until the second bubble is prepared. After that, the glassblower blows a clear glass bubble, which will be covered by the overlay color bubble. As both bubbles are ready, the assistant attaches the hot overlay color bubble on the bottom of the base bubble and they merge (See Fig.15). Next, the blower opens and flattens the overlay bubble similar to a plate shape by using an overlay jack tool. The overlay jack has a pair of wooden arms instead of typical metal blades (See Fig.14). After flattening, the artisan pushes and stretches the plate along the base bubble and simply overlays it on top of it. As a result, the overlay bubble becomes turned inside out, and the inner colored layer is reversed to be the outer layer.

In this technique, the practitioner creates a thin sheet from the color bar. Unlike the particles in the frits overlay, this method allows the practitioner to start with a smaller bubble and expand it later. Using this foil-like piece of color, even if the base bubble is blown to its extreme size, the color layer expands and remains consistent. Therefore, it does not produce dents or inconsistencies, such as when using frit particles for color, as shown before (see Fig.11). Using powdered frits instead of color bar also risks contamination of impurities in the colored powder and the larger and thinner the bubble becomes, the higher the likelihood of imperfections. The advantage of using color bar as thin foil eliminates any limitation in size, provides a uniform tint on the glass, and facilitates artistic processes that require consistent and sharp visual results. However, in return, since the Swedish Overlay technique involves complex transferring and reversing procedures, it requires a higher degree of experience and skill compared to the frits overlay technique, but is the best method for creating concentrated integrity of a glass color.

To be able to utilize this technique in my research, I spent nearly two months to learn how to perform this technique properly and gradually developed it throughout the process. During this learning period, my intensive trial and error process helped me to understand the basics of the technique. In addition, advice from glass artist Kazushi Nakada from the Aalto University Glass Studio and Alma Jantunen from the Nuutajärvi glass village helped me to see my mistakes and master the technique. I kept practicing the technique until I had enough confidence to proceed with the next steps.

Fig. 14.

My hand-made wood jack before its first use, february 2018



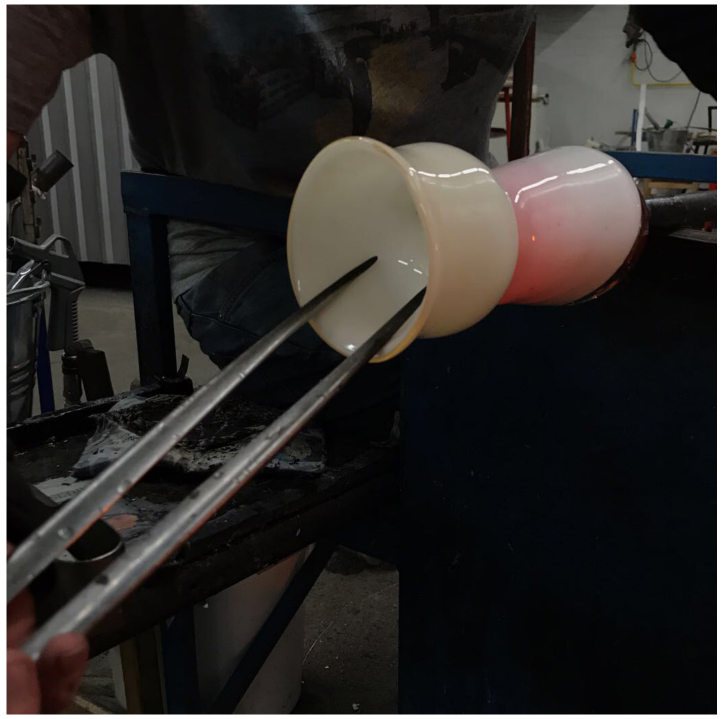


Fig. 15. *Different stages of the Swedish overlay method*

2.3.3 Other Silver Mirroring Methods

This section will introduce another two common metallic luster techniques in glass making. These methods do not include the hot reduction process in glassblowing and primarily takes place in cold working; therefore, I included them neither in the practical part of this material research nor the production of my artworks. However, I conducted this review to clarify and compare the advantages and disadvantages of the hot reduction processes with silver glass colors compared to other metallic luster techniques. Later, the findings of this comparison guided me in my artistic thinking process and helped me to comprehend the intrinsic character of this technique. This way, I could incorporate it into my artistic process while looking for the right expression for my artworks.

A. Fired-on Technique

Fired-on technique involves the use of color mediums that primarily consist of metallic salts dissolved in a liquid. For example, lavender oil is used to dissolve metallic salts; the liquid provides metallic salts with proper viscosity enabling them to be applied by various methods, such as brushing, spraying, and dipping, similar to oil painting (Kulasiewicz, 1974). Besides silver, other bright metals can be applied such as gold, platinum, palladium and luster colors (Kulasiewicz, 1974). After the application of the paint, the glass piece is re-fired to fuse the metal salts onto the glass sufficiently. During the firing process, the oil burns away leaving a thin layer of coating and electric kilns are recommended to avoid the reducing or oxidizing effects of flame. In general, this application produces a thin layer of metallic coating on glass surfaces that can be easily scratched (Kulasiewicz, 1974).

The fired-on technique emerges as the most common method to apply metallic luster paints on any glass surface and the application entirely takes place after the glass piece has been formed, blown and annealed. Since the practitioner works on a cooled glass piece, it enables them to imprint fine details, including elaborate decoration and ornaments on the glass surface. Therefore, this process differs from the high-temperature reduction processes in which practitioners must act in precise time and temperature limits. Besides, the control of the effect of high-temperature reduction requires more experience and practice compared to the fired-on technique. On the other hand, the fired-on techniques require an additional re-firing step, and the process lasts longer than the mirroring process during hot work.

As a result, the fired-on technique provides artists with a reliable workflow and greater precision for detailed works. In contrast, the high-temperature reduction process provides more room for improvisation with natural color flow and does not require additional cold work or re-firing.

B. Mirroring Glass with Silver Solution

This method can be applied on top of any material including leather and wood and can be used as the primary procedure in the common flat mirror manufacturing process; this procedure requires an ammoniacal metallic silver solution and a reducing agent, such as Rochelle salt (Kulasiewicz, 1974). In the beginning, both compounds appear to be clear liquids; however, when they are mixed and poured into the glass piece, they deposit elementary metal on top of the glass surface becoming visible in several minutes (Kulasiewicz, 1974). After formation of the mirrored surface, a layer of lacquer or paint can be applied to seal and protect the silver deposit.

The silver solution method can provide a perfect mirroring coating, and it can be easily applied to the inside of any vessel or on top of a surface. In contrast, it may not be as convenient as other luster techniques for detailed and local applications. Moreover, since the compounds used in the process are highly poisonous and caustic, it may cause serious health issues unless appropriately applied. Besides, in order to increase the metal deposit, it requires expensive equipment (Kulasiewicz, 1974). Similar to the fired-on technique this method does not require experience with hot glass and is mostly applied in a laboratory to prevent health risks.

2.4 Material Exploration

2.4.1 Preliminaries

For the Initial stages of the research, I started my ideation process by choosing a set of colors that could be suitable for my artistic process. I selected five different reduction colors labeled as IRIS colors in the German glass color manufacturer Reichenbach's color catalog as follow: IRIS violet (128RW), IRIS Aqua Blue (719RW), IRIS Dark Blue (144RW), Silver Smoke (770RW) and IRIS Black (146RW). It could be argued that it would be ideal for selecting only one constant color throughout the research. However, even though these colors are supposed to produce similar neutral, silver, mirroring effects, in fact, their metal oxide composition widely varies. This compositional difference significantly affects their compatibility with the variable components of the glass studio, such as the equipment, the gas in use, and the type of glass melt. According to their compounds as well as their rate of compatibility, some colors tend to react much easier than others do. Therefore, starting with a group of colors helped me to specify the most suitable selection of glass colors for the premises of Aalto University's Glass Studio.

Later I realized that the issue of compatibility was just one of many other factors of which I was unaware. My initial curiosity and optimism inspired me to start working on my artistic ideation process with a series of different colors. However, it did not take me long to realize that such a material exploration in glassblowing could have a much broader complexity than I initially thought. This awareness enabled me to realize that I had to overcome a series of technical problems, such as glass-blowing mechanics and chemistry of silver glass colors before I could gain artistic freedom to guide this process to create a particular expression.

2.4.2 Early Experiments

To begin with, I blew a series of random test bubbles without any preset guidelines for each silver glass color mentioned above. All the bubbles surprisingly became a milky, greenish-brownish tinted, opaque composition of colors without any trace of silver mirroring (see Fig. 16&17). After these first failed tests, I set my first goal to overcome this milky greenish/brownish tint and focused on achieving a certain level of mirroring effect on small-scale sample bubbles, approximately 70-80 mm in diameter. Fol-

Fig. 16. *Various test samples from the first experiments*

lowing this objective, I decided to take a systematic approach and designed a simple workflow to provide the maximum amount of identical test bubbles for each hot working session.

First, the workflow starts with a small amount of glass gathered on a heated tip of a blowing pipe. Second, I blow a parison which holds a considerable amount of wall thickness, ensuring a sturdy base for the next gathering. After a second gathering, I overlay silver glass powder and give the final form by using the jacks and paper. As the bubble takes form, I finish the process with the reduction process using a hand torch until it triggers the mirroring reaction. I repeated this process for each type of color powder and tried to keep all variables constant, such as temperature and atmosphere of the reheating furnace, heat, timing, and tools.

My studio notes show that even though I intended to keep detailed records about the blowing of each test bubble, I soon realized that keeping such a detailed log for each sample was neither an effective nor a precise method to proceed. Therefore, I then decided to focus on recording only major changes between each test and compare them to see if there was a significant correlation or inversion between them. In addition, as my studio diaries reveal, the first experiments mostly question the blowing process itself and focus on the amount of color, the appropriate color application, the duration of the process, the number of reheats, and the sequence of procedures. Although they remained as critical issues to be addressed in later research, the following experiments have shown that these early concerns had only a limited effect on the final results of the reduction processes.

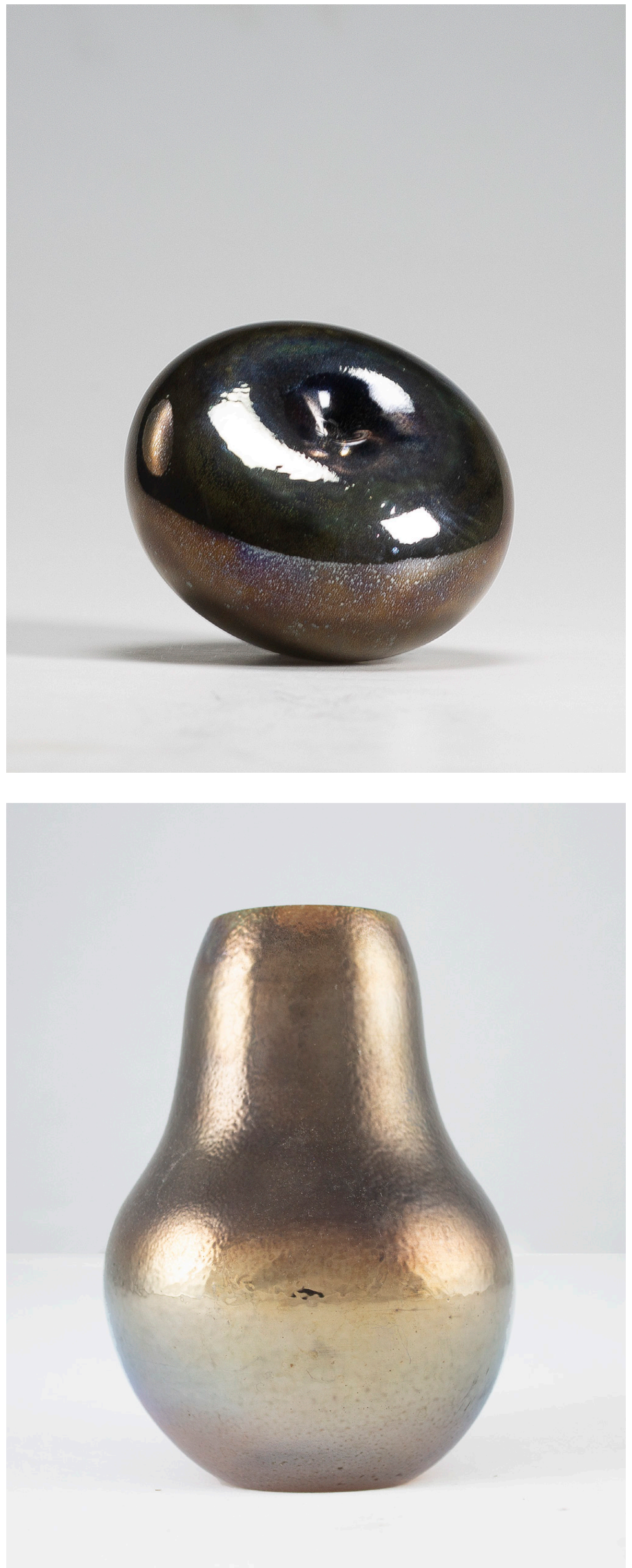


Fig. 17. *Various test samples from the first experiments*

Fig. 18. *Bullet, 2018, one of the first samples that I started to understand the redox mechanisms, from the Collection of Early Samples*

2.4.3 Evaluation Method

The early stages revealed that there were a number of difficulties preventing reliable and accurate data extraction in this research. Redox reactions as a complex electrochemical process depend on many different variables, which have an impact on the process due to their interrelationship. Therefore, investigating each variable means focusing on one aspect at a time, without stopping to consider other variables affecting the process. This process requires precise and reliable glassblowing performance to produce dozens of identical test samples that can measure each variable and their correlation with other variables. However, glassblowing practice hardly allows such a precise experiment process due to its ever-changing elements, low observability of critical variables, and its fast pace of working rhythm. These factors significantly hinder making measurements with considerable precision, even with the assistance of digital devices or other helpers. Therefore, I realized that trying to produce identical test bubbles and measure their specific data might not be a convenient way to undertake material research in glassblowing for the early stages.

This situation revealed a need for an evaluation method to carry out this research. Especially at the beginning of the process, the reliability of early results was low, and it was not possible to perform a linear test process that focused on one constant at a time. Therefore, I decided to follow an intuitive approach. I started with testing different ideas that I believed to be the best solution each time instead of blowing a series of samples measuring one variable. I preferred to focus on the most significant changes between blowing sessions without any numerical record or a detailed log and took only short notes and sketches in my studio diary. Eventually, this method resulted in boxes of random test samples without any specific data. After this point, I frequently opened these boxes and spread test samples like a display (see Fig.19), without any specific order. These occasional displays provided me an overall view of the process, and I noticed that I could clearly read the whole glassblowing process just by interpreting the visual cues on the sample articles. This bird-eye view enabled me to quickly compare one sample to another and identify the most remarkable similarities and differences between them. For instance, as one of my studio entries reads:

" First of all, if there is a loss of effect in both overlay and powdered bubbles than it cannot be related to the thickness (of color). If there is a loss (in mirrored effect) in both kilns, then it cannot be related to kilns either." (Personal diary, 23.01.18).

As this entry points out, I could quickly distinguish the most critical elements of the process without being stuck in individual samples, numerical data or repetitive experimental procedures. This flexibility allowed me to gather more data in a shorter period of time than with a linear line of experiments and enabled me to eliminate insignificant variables quickly. This way, I could focus on fewer variables with greater precision in later experiments and could conduct well-structured experiments by utilizing digital equipment for more precise results.

The evaluation process did not remain restricted to only technical issues and grew to be a multilayered process including my artistic concerns. As the research advanced, the evaluation process started to involve prospective artistic concerns about the applicability and scalability of test results for my artworks regarding their visual and expressive potential. Following that, I became concerned with the convenience of the application methods of different visual elements regarding the capacity of equipment, the number of helpers required, and the level of skill needed for the production of my artworks. Consequently, the evaluation process fusioned these artistic and technical decision-making processes and constituted most of the ideation process.

Fig. 19. *A photo from an evaluation session*

2.5 Silver Mirroring: Experiments with Variables

After the puzzling results during my early experiments, I decided to take a more systematic approach for my experiments and first started with determining all of the factors involved. This way, I intended to acquire a certain reliable consistency with which to conduct my artistic process and explore all possibilities. Thereby, I could start focusing on my artistic process without concerning the technical side of the project. Hence, this section first defines major inputs in the process and dives into the inner dynamics of high-temperature reduction reactions in detail.

As a basic principle, the temperature refers to the kinetic energy per molecule of a substance and heat refers to thermal energy difference variation between two temperatures. This is the general formula for heat:

$$q = m \times C \times \Delta T$$

As this formula suggests, heat (q) is dependent on mass, (m), the specific heat capacity of the substance, (C), and the change in temperature (ΔT). Since this research always uses the same type of soda glass, the heat capacity of the glass remains constant. Therefore, it suffices to say that the change in temperature depends on two factors: the mass of the glass and the thermal energy it holds. As a numerically measurable variable, the following sections will use temperature as the central term.

This part divides silver reduction in glassblowing into several subheadings, and each heading will add one more layer to the level of complexity. In this way, I aim to provide a detailed overview of the subject and share my experimental process throughout the project by presenting the progress of my glass works in parallel.

500-550 C°
No flaming
Original color

500-550 C°
30 sec Flaming
Reduction is not completed: blueish mirroring with a hint of reflection.

550-600 C°
30 sec Flaming
Reduced adequately: Neutral Grey silver mirror.

600-650 C°
30 sec
Flaming
Beginning of over-reduction: Yellowish-goldish still reflective surface.

650-700 C°
30 sec Flaming
Over-reduction continues: Yellowish- Brownish opaque surface with slightly reflective character.

Above 700 C°
30 sec Flaming
Complete over-reduction in neutral atmosphere: brown, green, yellow and red tones are dominant. Newton's rainbow rings are visible with poor reflective character.

Above 700 C°
30 sec Flaming
Complete over-reduction in gas-rich atmosphere: shades of green are dominant with almost no reflective character.

Fig. 20.

2.5.1 Temperature and Color: Phases of Silver Reduction in Glassblowing

Timing and temperature emerged as the most vital factors and require delicacy in any glassblowing process. Likewise, these key elements demanded even more attention with the redox reactions. Previously mentioned, the redox reactions can only take place in proper atmospheric conditions to receive the right amount of carbon and thermal energy accompanied with perfect timing.

Figure.20 presents results of an experiment that I conducted to investigate the relationship between temperature and the color of the silver coating. The experiment incorporates six identical test articles - glass bubbles 8-10cm in diameter with approximately 3mm wall thickness. Each article has two layers of (144RW) silver dark blue color powder applied in hot work and thirty seconds of applied reducing flame. Ranges of temperature showed in table 1 present the average temperature of each article right before the reduction process. For the measurement of temperature, I used a digital infrared thermometer with a laser pointer. However, since the temperature widely varies among the different spots of the same article, I found it more appropriate to present temperature ranges rather than exact points.

These results show that the reduction of silver colors occurs in different rates according to the temperature before the flaming process. The right-hand side of the chart shows the correlation between the degree of temperature and the appearance of the silver coating. As the pre-flaming temperature increases, the reduction process yields different results. For instance, degrees above 650C° dramatically accelerate the rate of the reaction and the surface becomes over-reduced instantly, resulting in a brownish-yellowish opaque surface. Regarding this color change, I interviewed Jens Teuchert, a technician responsible for glass color chemistry from Reichenbach GmbH, to ask about the reasons for the color change. Teuchert (personal communication, December 07, 2017) stated that, if the bubble is flamed too hot, elementary silver wears out and reveals a yellowish-brownish tint. Moreover, especially in the case of exceptionally high temperatures, other metal salts included in the color matrix may become reduced and cause a significant decolorization (j. Teuchert, personal communication, December 07, 2017). This information showed me that If this decolorization gradually occurs during the flaming process, it indicates that the thermal energy input of the reducing flame is capable of increasing the surface temperature of the bubble to the range of over-reduction. Otherwise, the duration of the flaming process alone does not cause an over reduction if the flame cannot raise the temperature of the glass piece.

On the contrary, around 500-550 C°, the same volume of reducing flame yields a greenish blue tint with a slightly reflective result. This result indicates a weak reduction process, which could be a result of inadequate pre-flaming temperature or a weak reducing flame. These findings indicate that a balance between the pre-flaming temperature of the glass piece and the capacity of the reducing flame plays a critical role in catching the right color and effect.

In glassblowing practices, the reduction process usually receives the required thermal energy from two main sources: the initially stored energy on the glass body and the amount of energy received from the hand burner during the flaming process. Along with these sources, the glass piece gradually loses its thermal energy due to its contact with the atmospheric air around it, because heat always moves from hot to cold. Therefore, I realized that I had to catch the right pre-flaming temperature with the help of the reheating furnace and then manage to maintain the same temperature by using the hand burner in order to compensate for the heat loss and maintain the reduction process. Otherwise, the reduction process either would stop or proceed too fast and reach to the over-reduction in the blink of an eye.

Regarding that, I used two methods to catch the right temperature and balance the process: pre-heating and post-cooling. Both methods can be preferred according to the type of artwork and inevitably require a trial-and-error period to acquire a specific sense of timing concerning the right duration for heating and cooling processes for each project. Table-1 presents my own study to figure out the right timing and temperature ranges for identically blown test articles, which are similar in size and shape as with the previous experiment. I conducted this experiment to improve my understanding on the redox mechanism, hoping to find the right balance for these small-scale test articles. I thought if I could capture the right timing for the cooling and flaming processes for these samples, it would be easier to adjust the scale for the final production of my artworks. The results of this experiment showed me that the cooling process before flaming plays a significant role on the color tone of silver mirroring. As it can be seen, samples with longer cooling time have a darker tone than others.

Table-1 Flaming duration experiment, *30 April 2018*

Tools: Metal jacks and carbon pad, no paper

Test Bubbles	Layers of Color	Cooling Before the Flaming Treatment	Flaming Duration	Detaching the Bubble (Filling)	Cooling	Annealing
F01	2 layers of 144RW	60 Sec Air Gun	No Flaming	25sec	5sec (Knock-Off)	In thermal blanket
F02	2 layers of 144RW	60 Sec Air Gun	30sec+ (Still Blue) 30sec (Neutral silver)	45sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket
F03	2 layers of 144RW	80 Sec Air Gun	60sec (It seems it needs longer flaming)	30sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket
F04	2 layers of 144RW	100 Sec Air Gun	60sec	30sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket
F05	2 layers of 144RW	30 Sec Air Gun	60sec (Flaming was too long)	30sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket
F06	2 layers of 144RW	30 Sec Air Gun	30sec (Flaming was not enough some parts left blue)	30-45 sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket
F07	2 layers of 144RW	30 Sec Air Gun	45sec (Only the middle part got silver, bottom and neck left blueish)	30-45 sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket
F08	2 layers of 144RW	30 Sec Air Gun	55sec	30-45 sec	5sec Air Gun + 5sec (Knock-Off)	In thermal blanket

2.5.2 Depth of Color and Opacity

After addressing the relationship between color and temperature, this section focuses on the proper amount of color for a perfect mirroring effect. Due to the wide range of variables and their complex web of interactions in the process, it could not have been possible to draw a clear conclusion before addressing the other variables of the process. Therefore, I could only undertake reliable tests on the different amounts of color during the later stages of the research process.

In the early stages, I assumed that the overall quality of the mirrored surface is strongly associated with the thickness of the color layer and undesired outcomes could be solved by adding more layers of color. In order to examine this initial idea, I decided to undertake a review about the scientific background of the silver deposition in glassblowing; however, due to the lack of specific sources on the topic, the review shifted towards a neighboring field: electroplating. This review showed that, even in such an industrial process like electroplating, the thickness of the silver deposition changes between 1 micron to 10 microns – 1 micron is equal to one-thousandth of a millimeter ("Silver Plating Process | Applications and Technologies"). This information suggests that the number of color layers might not critically affect the quality of the mirrored coating, as long as it can deposit 1-10 microns thick of elementary metal on the surface. To test this theory, I conducted the following experiment C1 to examine the correlation between the amount of color and the quality of the silver mirror coating.

Experiment C1: Depth of Color

26 April 2018

This experiment involves three identically blown test articles which were coated by the silver color (144RW Dark blue) powder respectively using two layers, four layers, and eight layers of color (see Table-2). Following that, thirty seconds of reducing flame were applied to each bubble at the end. Then, each article was placed into a piece of thermal blanket at room temperature and cooled down without using any annealing equipment in order to eliminate the possible effects of the kiln annealing. Thanks to their thin wall thickness and small size, the articles could maintain their integrity after such a fast cooling process. The results of the experiment revealed no significant difference regarding the quality of mirroring and the color tone.

This experiment revealed that, for the color in use (144RW Dark Blue), even though the number of color layers increased; color tone and reflective quality of the test pieces showed no significant difference. However, as the count of layers increased, the consistency of the color layer became smoother. Color consistency emerges as a critical step for a smooth, mirrored coating, especially for the frit overlay method. It may require several layers of overlapping color bits to be able to create a consistent color layer and the suitable particle size of the color powder for layering changes between 0,2 mm-0,5mm in diameter (see Fig. 21). For the Swedish Overlay method, since the color layer stretches as a one-piece foil across the surface beforehand, it does not require additional layering.

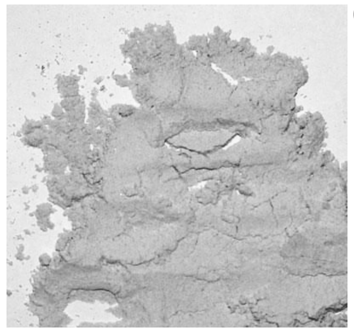
Table- 2 Experiment C1: Depth of Color and Opacity, *26 April 2018*

Test Bubbles	Layers of Color	Cooling Before the Flaming Treatment	Flaming Duration	Detaching the Bubble (Filling)	Cooling	Annealing
C01	Two layers of 144RW Dark Blue	Waited until it is purple	30sec	Not specified	10sec	In thermal blanket
C02	Four layers of 144RW Dark Blue	Waited until it is purple	30sec	Not specified	10sec	In thermal blanket
C03	Eight layers of 144RW Dark Blue	Waited until it is purple	30sec	Not specified	10sec	In thermal blanket

My observations reveal that the most critical point may not be the amount of color used, but the amount of expansion that will be applied to the color layer. For instance, if a surface will not be blown later, even a single layer of silver color powder may be adequate to have a neutral silver mirror. However, if this surface will be expanded in later stages, then practitioners may need to use an excessive amount of color in order to compensate for the amount of expansion. Otherwise, the color layer may lose its integrity and can no longer perform consistently. This example shows that the amount of expansion primarily determines the amount of color to be used. If the color layer is used thick, even though it may help to decrease over-reduction risks and provide a greater color consistency, the results will be similar with its thinner counterpart in terms of intensity of the mirroring effect under the same circumstances.

The color depth did not significantly affect the opacity of the coating in this experiment. However, the relationship between color depth and opacity of the mirrored coating significantly varies among the different types of silver colors. Therefore, this result cannot be generalized. For instance, if the silver glass color has a light hue, such as light blue, yellow, or violet, or has a highly transparent character, then the mirroring process may yield semi-transparent reflective surfaces, whereas the same amount of color could produce an opaque mirrored surface with another silver color. In such cases, practitioners may prefer to use thick transparent silver colors or use an opaque underlay color underneath. An opaque underlay color can visually support the mirrored coating, yet, if the quality of reflection seems inadequate, then practitioners may need to check their working temperature, flaming process, and annealing schedule instead of variables about color.

Regarding these findings, this study suggests that as long as the amount of color can deposit a couple of microns thick of ele-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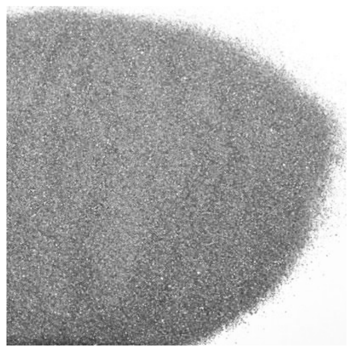

0.5mm

Fig. 21.

mentary silver on the glass surface, and maintains its consistency across the application area, the increase in the amount of color does not necessarily increase the reflective quality. As the previous sections discussed, the color tone and the reflective quality of the coating mainly depend on the working temperature and flaming process, which substantially affect the chemical composition of the colorants. If practitioners come across inadequate results, they may try to cut a cross-section of their glass piece and check the actual depth of color beneath the surface. If the depth of the color is reasonably thick, for instance, 1-3mm, presumably the inadequate results do not occur due to the amount of color in use; even if the amount of color increases, results may not change.

2.5.3 Reducing Flame and The Quality of Silver Coating

The reduction of silver glass colors in glassblowing relies on the interaction of two key-points: an adequate amount of thermal energy and a proper reducing flame. The following two sections discuss in detail the reducing flame and its application during the process.

A. Characteristics of a Reducing Flame

The flaming process arises as one of the most critical elements of this material research because of its vital role in redox reactions. Essentially, the flaming process provides the necessary thermal energy and the reducing atmosphere to initiate reduction of the metal salts on the exposed surface. However, the success of the flaming process depends on several factors including the length and pressure of the flame, the ratio of oxygen and gas used for the flame, the direction of the flame, and the temperature and duration of the flame. In addition to these, the placement of the glass piece in the flame remarkably affects the outcome. Even subtle changes in these sets of variables tend to produce notably different results which should be carefully observed to avoid over-reduction or oxidation. This section starts with shortly discussing the working principle of a hand-torch, and based on this knowledge, it describes each variable and their possible effects on the outcome.

A hand torch is a commonly used handheld device for glassblowing applications to provide heat on a specific spot as well as the whole glass body. Hand torches use a flammable gas ignited with an oxidant to generate heat and light. The hand torch used for this research uses a continuous fuel stream of natural gas and burns the fuel with the oxygen diffusion from the surrounding atmosphere. It is equipped with a single gas line, a pressure valve to adjust the fuel stream, and a nozzle with four air holes which allows oxygen diffusion into the gas stream. Once the gas arrives at the nozzle, due to the lower pressure than the atmospheric pressure in the narrowed pipe, called the Venturi Effect, it vacuums the atmospheric air inside and infuses into the fuel ("Venturi effect", 2019). With an initial ignition, the gas torch begins to blow hot flame.

Different types of flames, according to their oxidant supply, can be divided into three categories: oxygen-rich oxidizing flame (see Fig. 22), neutral flame, and gas-rich reducing flame (see Fig. 23) (Jones, 1989, p. 2). The reduction process specifically requires gas-rich flames; an excess amount of fuel is fed but not entirely burnt by the oxygen intake. They typically involve a short blue combustion zone and a low pressurized, long yellow tail that contains combustion byproducts, such as water steam, carbon monoxide, and excess unburnt gas (Jones, 1989, p. 3).They mildly wave and do not clatter, compared to noisy and pressurized oxygen-rich, oxidizing flames. A reducing flame does not exhibit a well-defined outline or a structure due to ongoing chemical reactions (Jones, 1989, p. 3).

For the reduction reactions, combustion byproducts in the long yellow tail of the flame create a suitable environment for the reducing silver oxides and the glass piece must be held in this part of the flame. According to my observations, if the blue reaction zone of the flame touches the silver coating, it may cause oxidation and create a blue-green or brown rust color effect. Therefore, the gas torch should be held from a certain distance from the glass piece.

Fig. 22. *Oxygen-rich flame*

Fig. 23. *Gas-rich flame*

Fig. 24. *Modification on hand burner head*

B. Experiments with Reducing Flame

As the previous sections discussed, reduction of silver glass colors requires a delicate balance of sufficient thermal energy to maintain the process and a proper amount of reducing agent for depositing elementary silver on the surface. In this section, I conducted a series of experiments such as different oxygen-gas ratios for the flame, the direction of the reduction flame and the flaming frequency to find the most appropriate flaming recipe for silver mirrored results.

To begin with, to improve the reducing ability of the flame, I tried to reduce the oxygen intake to the minimum and plugged the air-intake holes of the blowing head, using one bolt for each hole (see Fig. 24). The initial idea was to decrease the oxygen intake to improve the carbon-rich atmosphere at the end of the flame tail. However, the lack of oxygen drastically reduced the pressure and heat of the flame to the degree that it could no longer maintain the reduction process. For such cases, the reduction process may start by the initial temperature of the glass bubble. However, since its temperature rapidly drops while in the room temperature, without receiving additional energy from the hand torch, the reduction process occurs inadequately. This yields unsatisfactory visual outcomes, such as a green-blue tint, weak reflective quality, uneven mirroring, and visible flame marks (see Fig. 25). Results of weak reduction processes also may fade away during the annealing process. Therefore, I began to remove the bolts one by one and to gradually loosen the isolation to find an excellent balance of oxygen intake. This modification entirely depends on the type of gas and equipment used in the studio and requires each practitioner to test and adapt their equipment if necessary. Nonetheless, the logic is to find a fine ratio between the minimum oxygen intake, maximum free carbon particles, and an adequate amount of heat in the flame.

In addition to the chemical properties of the flame, the experiments revealed that the direction of the flame is another critical element. According to the test results, the tail of the flame must touch the targeted surface with approximately 90° angle. For example, if the reducing flame is pointed at a perfect glass cube and focused on one of its faces at 90°, the face in focus becomes the most reduced, while a mild mirroring effect can be seen on the neighboring surfaces. On the contrary, the opposing side displays no significant transformation, even though the whole glass cube stays within the flame. This becomes critical in glass pieces which have complex geometries, which could be ideal situations for handling the flaming process with assistance. As the assistant holds and rotates the glass piece, another practitioner can move around the piece with a hand torch and ensure that the tail of the flame evenly touches each surface at the correct angle.

Lastly, the flaming frequency appears to be a genuinely critical point. My experiments show that if a target surface continuously receives the reduction flame, it may not produce satisfactory results because the oxidation and reduction reactions follow each other in cycles and each time amplify the effect of each other. Therefore, more oxidation means stronger reduction as well. If the target surface contacts oxygen every once in a while, rather than continuously being choked by the flame, the next reduction cycle occurs stronger than its previous cycle.

2.5.4 The Balance of Volume, Wall-thickness, and Surface

Since the previous experiments include only identically blown articles, they could be used to analyze the temperature independent of other variables, such as wall-thickness, volume, and form. However, the relationship between these variables may significantly affect the process in many cases.

In principle, since the reduction process occurs only on the outermost layer of the glass, it can be claimed that as long as the surface temperature remains within the proper range for reduction processes, wall-thickness does not seem to have a significant effect on the process. However, in exceptionally thick or thin cases, it might affect the process. For example, a thick under-layer of the glass piece increases the glass mass; more energy is required to increase its temperature and thus also more heat and a longer flaming process. On the other hand, If the wall-thickness is exceedingly thin, the hand burner can rapidly increase the temperature of such a low mass, which may instantly result in over-reduction.

If the mass remains the same but the volume of the glass piece increases due to inflation, it may cause two consequences. First, the volume and surface of the glass piece increase, creating a much larger surface to process. In this case, the reduction flame can be imagined as an airbrush and the glass piece as a canvas. As the surface area enlarges, it inevitably prolongs the reduction process to cover the entire canvas. Second, larger surfaces increase the contact area with the surrounding air and significantly accelerate heat loss. This means the increase in volume has its natural limits which should be considered and tested by practitioners for each project. Reducing a rapidly cooling large surface using a hand burner may become truly challenging for many cases. As the burner heats a certain area, the rest of the glass body keeps cooling and it

Fig. 25. *Flame Marks, 2018, from the Collection of Material Research Experiments*

becomes challenging to maintain a certain temperature all over the glass body.

In general, one should remember that since the reduction process is an electrochemical reaction - if the proper conditions exist, it occurs in an instant. Therefore, if the process lasts for a long time, this may imply flaws in the design or some missing elements for the reaction. Besides the balance between wall-thickness and the volume, the form of the glass piece also plays a critical role due to its effect on the heat exchange. Therefore, the next section discusses the interrelationship between temperature and form.

2.5.5 The Temperature and the Heat Composition

Previous experiments showed that the reduction reactions require approximately a 550-600 C° temperature for neutral silver mirroring, preferably provided before the reduction process. Practitioners must be aware if the glass piece has enough energy to facilitate a proper reduction process by the help of additional heat from the reducing flame. If the glass piece is not hot enough, no matter how long it interacts with the reducing flame, the hand burner may not be enough to complete the reaction in some cases. Therefore, the final reheating process in the furnace before the reduction flame plays a critical role in this process.

However, the final reheating process may not increase the temperature of the glass piece equally due to its form and the inner construction of the reheating furnace. For instance, the reheating process usually increases the temperature of the bottom areas of a glass bubble faster than its neck near the blowing pipe. Furthermore, if the glass piece involves complex geometries, the heat flow may change according to the surface curvature. If the glass object has some extensions moving away from the main body, they reach higher temperatures before the main body (See Fig.27). These factors finally create a pattern, which is referred to as heat composition on the glass body. Following this composition, the reduction process may yield different results for each spot due to the difference in temperature. Therefore, if practitioners aim for an even metallic luster, the reduction process requires a balanced heat distribution before the reduction process.

Considering that, practitioners should ensure an equal heat distribution possibly by changing the placement of the glass object in the reheating furnace, reconsidering the duration of the reheating process, additionally heating the relatively cold parts, or cooling off the hot parts such as extended elements before-hand. Otherwise, the hottest parts of the glass might have a risk of over-reduction or the coldest parts of the piece may not become reduced, chip off, and crack during the flaming process. After this rebalancing process, the glass piece should be shortly “flashed” into the glory hole for the last time to be able to avoid tool or mold marks (see Fig. 26). This final flash acts as a polisher for the surface and prepares the glass piece for a smooth and mirrored finish. According to my experience, if the glass piece mildly glows red, it presumably has enough heat to proceed with the flaming process

This principle can be used for artistic purposes. For instance, artists may create intentional temperature differences to achieve compositions that have different visual hues on the body of artwork. Following the same method, molds can be designed to create patterns on the body of glass; this pattern may not be visible after completing mold blowing, yet it becomes visible as a composition of hue variations because of temperature difference during the flaming process.

Fig. 26.

Tool Marks, 2018, from the Collection of Material Research Experiments

Fig. 27.

Spin, 2018, full metallic lustered glass body, from the Collection of Material Research Experiments

2.5.6 Hand Tools and Their Order

Previous sections have underlined that the temperature plays a key role in the redox reactions and an equal reduction process requires a balanced heat composition across the target surface. However, the tool selection and their order of use may notably affect the heat composition and therefore they must be discussed in detail considering the temperature sensitivity of redox reactions.

Hand tools primarily affect the heat composition according to the type of material they are made of. Metal, wood, graphite, and paper are the most commonly used materials in glassblowing and their effect on the heat composition can widely vary. In this group of materials, metal cools down the molten glass at the fastest rate, andwood, graphite, and paper follow respectively. This fact implies that it could be preferable to use metal tools in the earlier stages of the sculpting process. Otherwise, it could be challenging to rebalance the heat composition, without risking the fine details of the artwork, since metal hand-tools can dramatically decrease the temperature of the contact area compared to the rest of the body. As the coldest areas are still reaching the correct temperature, the hottest areas might start to melt and already become misshapen. Therefore, if practitioners are aiming for a perfect silver-mirroring surface on complex shapes, I found that it could be ideal to reserve metal tools for the early stages of the blowing session.

On the other hand, graphite, wood, and paper tools can be more flexible in use thanks to their low rate of heat exchange with molten glass. Therefore, they can remain convenient until the last stages of the blowing process. However, the use of wood and paper involves two critical problems. First, since they are flammable materials unless wet, they might easily catch fire and cause local reductions in the contact area during the shaping process. These local reductions might change the chemical composition of the area and cause decolorization at the end of the process. Second, the silver glass colors seem to have a "stickier" quality than clear glass and other glass colors; therefore if wood and paper tools are used in dry conditions, material residues may easily adhere to the glass surface. Most types of papers contain kaolinite. Kaolinite is a substance exceptionally durable to high temperatures even above 1200C°. Therefore, if some burned bits of paper stick to the glass surface, neither a reheating furnace nor hand-torch can help to remove them. Since these paper bits interrupt the flame, it cannot touch those areas. As a result, the reduction process does not occur. Therefore, I had to be particularly careful about whether the wood and paper tools were wet enough during the glassblowing process.

According to my experience, non-flammable apparatuses, such as graphite tools and carbon glassblowing pads, appear to be the safest tools for glassblowing processes including the use of silver glass colors. I found that replacing traditional newspaper with a carbon pad could eliminate the risk of paper bits and local reduction problems. Besides the carbon pad, replacing tools with their graphite counterpart helped me to balance the heat composition across glass pieces and provided more freedom for creativity, without being too concerned about tool marks and temperature fluctuations.

In conclusion, I found that it is important to consider the hand-tools and their order of use with the utmost delicacy for the processes involving silver glass colors. Even though metal tools, such as the jack and pincher are suitable for early stages, as the process advances it is ideal to prefer graphite tools and carbon pads for the best quality results in neutral silver mirrored finishes.

Fig. 28. *A view on a collection of different jacks used for my process*

2.5.7 Annealing

If a chunk of molten glass cools down without any interference, outer layers of the glass cool faster than the inside due to the poor heat conductivity of glass. The temperature gap between these parts of the object widens and eventually leads to inner stress due to the difference in heat expansion. However, this is prevented by the slow kiln-cooling process known as annealing (Falk et al., 2011, p. 59). As discussed before, temperature and atmosphere remarkably affect redox reactions as an electrochemical process. Therefore, the annealing program, its duration, and annealing atmosphere are critical parameters for the annealing process of silver coated glass surfaces.

Once a glass piece is completed, the practitioner applies reducing flame on the target surface until the reduction reaction reaches its peak point. Once this occurs, the silver oxide on the surface releases its oxygen and becomes reduced to elementary silver. However, as mentioned earlier in the section of redox reactions, the oxidation instantly follows the reduction when suitable conditions exist. As soon as the high-temperature silver coated surface is in contact with oxidative air, elementary silver begins to recapture the oxygen. Findings of this study show that a kiln set to an annealing temperature, approximately 500C°, with an oxidative atmosphere, appears to accelerate the oxidation reactions. Thus, if the glass piece is stored in such conditions for an extended period, the oxidation eventually can reverse the silver coating, returning the piece to its original color.

A completely reliable and accurate test on the variables of the annealing process can be challenging in a studio glass workshop. A researcher can blow two identical bubbles one after another, but there will always be a time interval in between them since the first blown bubble will be exposed to the atmosphere of an annealing kiln longer than the subsequent one. This difference in their annealing time makes them no longer comparable. It can be argued that two bubbles could be blown one after another but stored in different kilns so that their annealing duration is the same. However, this option is not possible either, since each kiln can have a different effect on the silver coating, again making the bubbles different. Therefore, I found that it was crucial to choose only one kiln and to analyze its specific characteristics with a series of experiments before proceeding with the research.

Regarding that, as a first step, I had to evaluate all available annealing equipment in the studio and decided to undertake all of my experiments using the same equipment throughout the research. I noticed that even different kilns of the same product might cause different reactions due to the micro atmospheric changes or various concealed problems, such as an air leak. Therefore, changing between different kilns could lead to severe confusions and disruptions within material research and the production of artworks. Besides, my experiments also revealed that opening the kiln door several times during a hot work session affects the atmosphere inside the kiln and may cause damage to the silver coating on previously stored pieces.

Under these circumstances, I realized that if only one kiln could be used for every hot work session, only one sample bubble could be tested per day to avoid a time interval problem. I thought that this could extremely slow down the research, therefore, I aimed to address this problem in two ways. First, I tried to eliminate the effect of the annealing process by using a thermal blanket to anneal the test bubbles. (see Fig. 30). If the bubbles have a wall thickness less than 3-4 mm, they usually keep their integrity without cracking. Another solution could be cross-testing. In this technique, if a determinant requires a set of sample bubbles to test it, this experiment must be divided into two sessions. In the second session, the same set of sample bubbles must be blown in the opposite order. The last test bubble of the first day comes into the annealer as the first bubble of the second day. This way, if the duration in annealer affects the results, it can be readily detected in the early stages. These solutions might help researchers not only for this specific subject but also for other color and material explorations in glass as well.

Fig. 29. *Annealing process in kilns*

Fig. 30. *Annealing in thermal blanket*

In this research, I have conducted two experiments to analyze the characteristics of different kilns available in the studio; these experiments were crucial to conduct the material research reliably and to successfully anneal my final glass pieces at the end of the project. Even though the results are specific to the studio equipment in Aalto University glass workshop, I present the details of the experiments in Table-3 as well as the technical specifications of each kiln in the appendix section, so other researchers can check and adapt these results for their own needs.

Experiment 1: Determining Behavioral Properties of Annealing Equipment

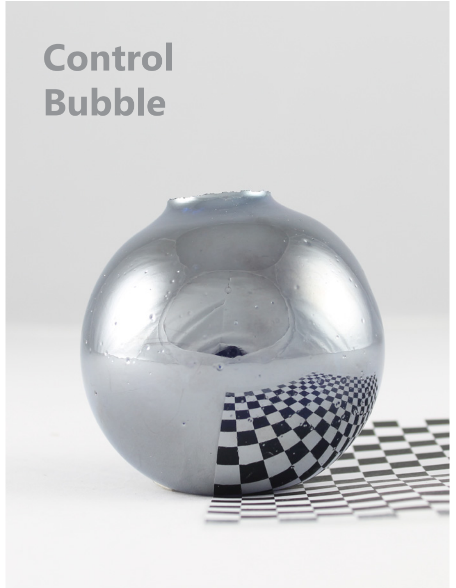
7 May 2018

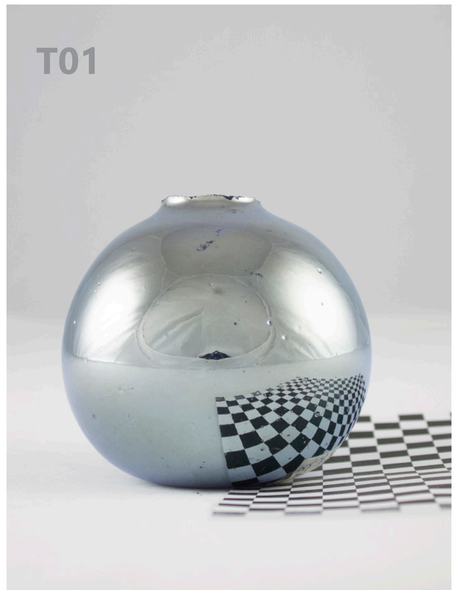
The purpose of this experiment was to investigate the behavior of different kilns available in the Aalto University's glass studio in regard to their effect on the silver mirrored surfaces. This step was also elemental for my artistic process to give me the freedom of being able to manipulate and control the material in the intended direction. For the experiment, I blew a series of identical test bubbles and stored each of them in different kilns programmed to run the precisely same cooling program. My intention was to expose identical glass bubbles to different kiln atmospheres for the same amount of time to measure their effect on silver coating. The results of the experiment revealed that kilns equipped with tight insulation and heavy horizontal doors tend to retain the mirrored effect more successfully than their counterpart, possibly due to their greater seal from oxygen intake during the annealing process.

I evaluated test results according to the visible bluish-greenish tint, which I interpreted as the indicator of high-temperature oxidation and loss of silver reduction. According to this assumption, kiln 3 outperformed other kilns and yielded the results with least blue-green tint in the mirrored surface. Therefore, for the following experiments, I focused only on kiln 3.

Table-3 Experiment 1: Determining Behavioral Properties of Annealing Equipment, 7 *May 2018*

Test Bubbles	Layers of Color	Cooling Before the Flaming Treatment	Flaming	Detaching the Bubble (Filling)	Cooling	Annealing Program: *496 C° 39 Min Soak* *496 C°- 386 C° 40min* *386 C°- 336 C° 15 min* *336 C°- 30 C° 10h*
Ideal Bubble Example	2 layers of 144RW	30 Sec Air Gun	60sec	30sec	5sec	I aimed to follow this order for all bubbles. However, I had to adjust it for each of them according to my real-time observations.
Control Bubble	2 layers of 144RW	30sec	90sec	30sec	5sec	Thermal blanket
G01	2 layers of 144RW	30sec Air Gun	108sec	30sec	5sec	Green Kiln Cooling program runs immediately.
R01	2 layers of 144RW	30sec Air Gun	104sec	30sec	5sec.	Round Kiln Cooling program runs immediately.
T01	2 layers of 144RW	30sec Air Gun	110sec	30sec	3-5sec.	Kiln3 Cooling program runs immediately.
CA01	2 layers of 144RW	30sec Air Gun	110sec	30sec	3-5sec.	Casting Kiln + 5min programming time. Cooling program runs immediately. (Same product with kiln3 but different equipment)





Experiment 2: The Oxidation Level in Kiln 3

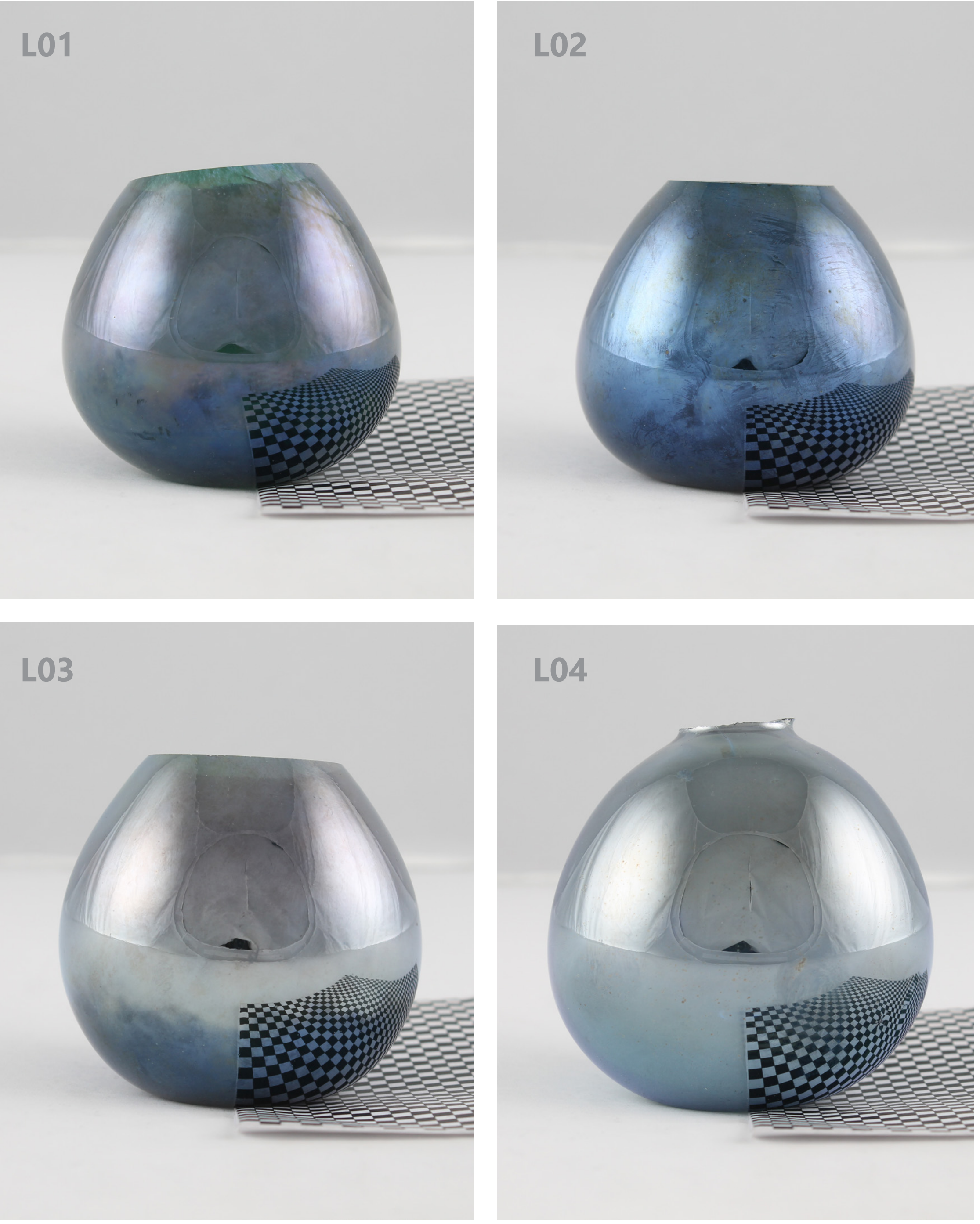
8 May 2018

The first experiment was conducted to find the most suitable equipment available in the studio – kiln 3. The next experiment focuses explicitly on its performance in maintaining the silver coatings during the annealing process. In experiment 2, to check the correlation between loss of reflective effect and time of annealing, I placed every test bubble approximately an hour apart inside the kiln, so I could compare them according to their different durations in the kiln. I intended to have the bubbles blown identically, yet the cooling and flaming timings were determined by real-time observations and continued until each glass bubble was coated with a neutral silver mirror. Table-4 below presents blowing steps of each test bubble.

Experiment 2 revealed that the annealing time and the quality of the silver coating has an inverse correlation in kiln 3 as well. Initially, neutral silver mirrored surfaces gradually became green and eventually turned into their original color, as the duration in the kiln prolonged. These results suggest that duration in an annealing kiln adversely affects the quality of silver coating and it should be minimized to achieve results without loss in the reflective quality. Accordingly, the annealing program can be initiated right after the glass piece is delivered to the kiln, annealing can be programmed to its minimum, and glass pieces can be designed in advance in a way which does not require a long annealing process. From an artistic point of view, this could be notably restricting for particular projects.Therefore, the artist or designer might need to compromise their artistic production to consider this aspect in advance. Nonetheless, at least being aware of this issue might help them to avoid considerable loss of time for some cases.

Table-4 **Experiment 2**: The Oxidation Level in Kiln3, *8 May 2018*

Test Bubbles	Layers of Color	Cooling Before the Flaming Treatment	Flaming	Detaching the bubble (Filling)	Cooling	Annealing *(I turned off the kiln after the last bubble placed and let it cool to 30C°)*	Tools Date: 8 May 2018
L01	2 layers of 144RW	30 Sec Air Gun	104sec Flame	44sec	5sec	Kiln3 08:34 loaded	Only Pad
L02	2 layers of 144RW	30 Sec Air Gun	104sec (I needed this time to get full mirror otherwise it was partially blue)	44sec	5sec	Kiln3 09:10 loaded	Only Pad
L03	2 layers of 144RW	30 Sec Air Gun	60sec	42sec	5sec	Kiln3 10:15 loaded	Only Pad
L04	2 layers of 144RW	No air	60sec	30sec	5sec Air Gun + 5sec (Knock-Off)	Kiln3 11:18 loaded	Only Pad



Besides these solutions, another option could be reconditioning the kiln atmosphere to not allow or inhibit any oxidation until the glass piece cools down to lower temperatures. I assume that a reductive or neutral atmosphere inside the kiln can be generated by the aid of a chunk of active carbon, or a candle flame, which can consume the excess oxygen inside. Within the limited time of the research, I could roughly conduct three experiments as follow:

Conditioning Experiment 1: *Test for the graphite powder, kiln 3, 09.01.18*

In kiln 3, I placed a metal container that had a couple of spoonfuls of graphite powder inside at 30 C°, heated it up to 490 C°, placed the silver coated test bubble, and shut off the kiln to cool it down.

Conditioning Experiment 2: *Test for wood chips, kiln 3, 13.01.18*

I placed the silver coated test bubble in the kiln 3 at 490 C° together with wood chips in a ceramic bowl, without the metal cylinder.

Conditioning Experiment 3: *Test for the active carbon, the round kiln, 09.01.18*

I placed the silver coated test bubble together with some active carbon in the round kiln, around 490 C°, and shut off the kiln to cool it down.

Experiment 1 and 3 did not reveal any improvement in the quality of the silver coating. On the other hand, experiment 2 resulted in an over reduction from the excessive carbon released by the wooden chips. This idea requires further research that must include a series of tests to explore a balance between the type of conditioning agent, amount, timing and temperature. Otherwise, over-reduction or over-oxidation might occur. These issues require a precise analysis of the atmosphere in the kiln and could be a potential topic for another research.

In conclusion, annealing constitutes an inseparable part of the glassblowing process, and it must be carefully managed, especially for chemically sensitive applications, such as silver colors. Experiments in this section showed that the annealing process can adversely affect the silver mirrored coatings unless several factors are not considered. These include decreasing the annealing temperature to its minimum, minimizing overall annealing duration, and preferring well-insulated kilns with a minimum air leak. Besides, if a neutral atmosphere can be provided in the kiln, annealing duration and temperature may not be as vital as before. However, further methods of controlling the atmosphere in the kiln require more in-depth research.

2.6 Selected Samples and Prototypes from Material Research Experiments

Fig. 31. *Blue Stripes, 2018, blueish iridized stripes on mold-blown clear glass, from the Collection of Iris Bottles*

Fig. 32. *Purple Shade, 2018, iridized patches on mold-blown clear glass, from the Collection of Iris Bottles*

Fig. 33. *Rainbow Tubes, 2018, from the Collection of Material Research Experiments*

Fig. 34. *Various examples from the Collection of Material Research Experiments*

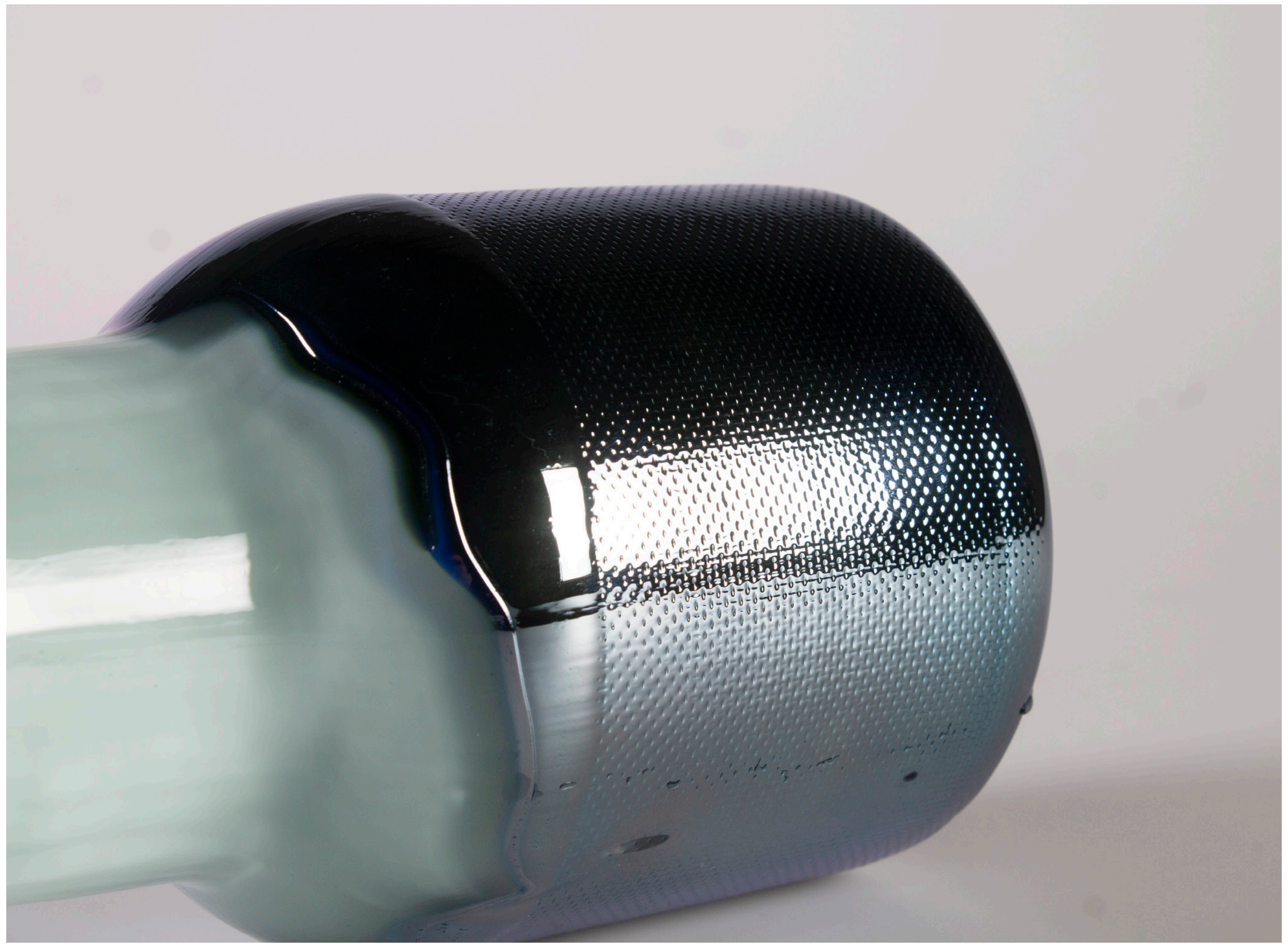


Fig. 35. *Detail of a texture study on a mold blown piece, 2019, from the Collection of Material Research Experiments*

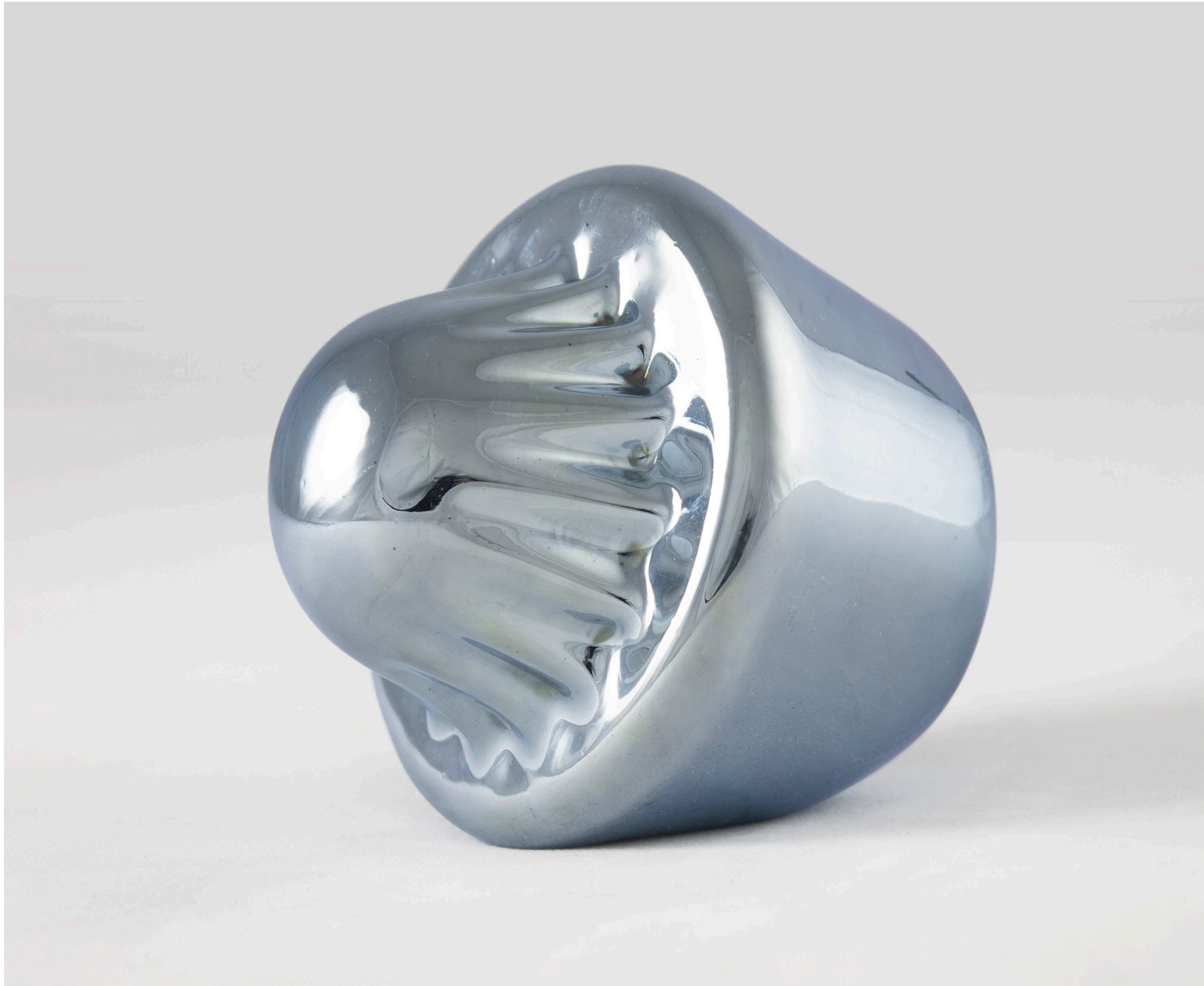


Fig. 36. *Lemon Squeezer, 2018, silver coating on solid clear glass, from Material Research Experiments*

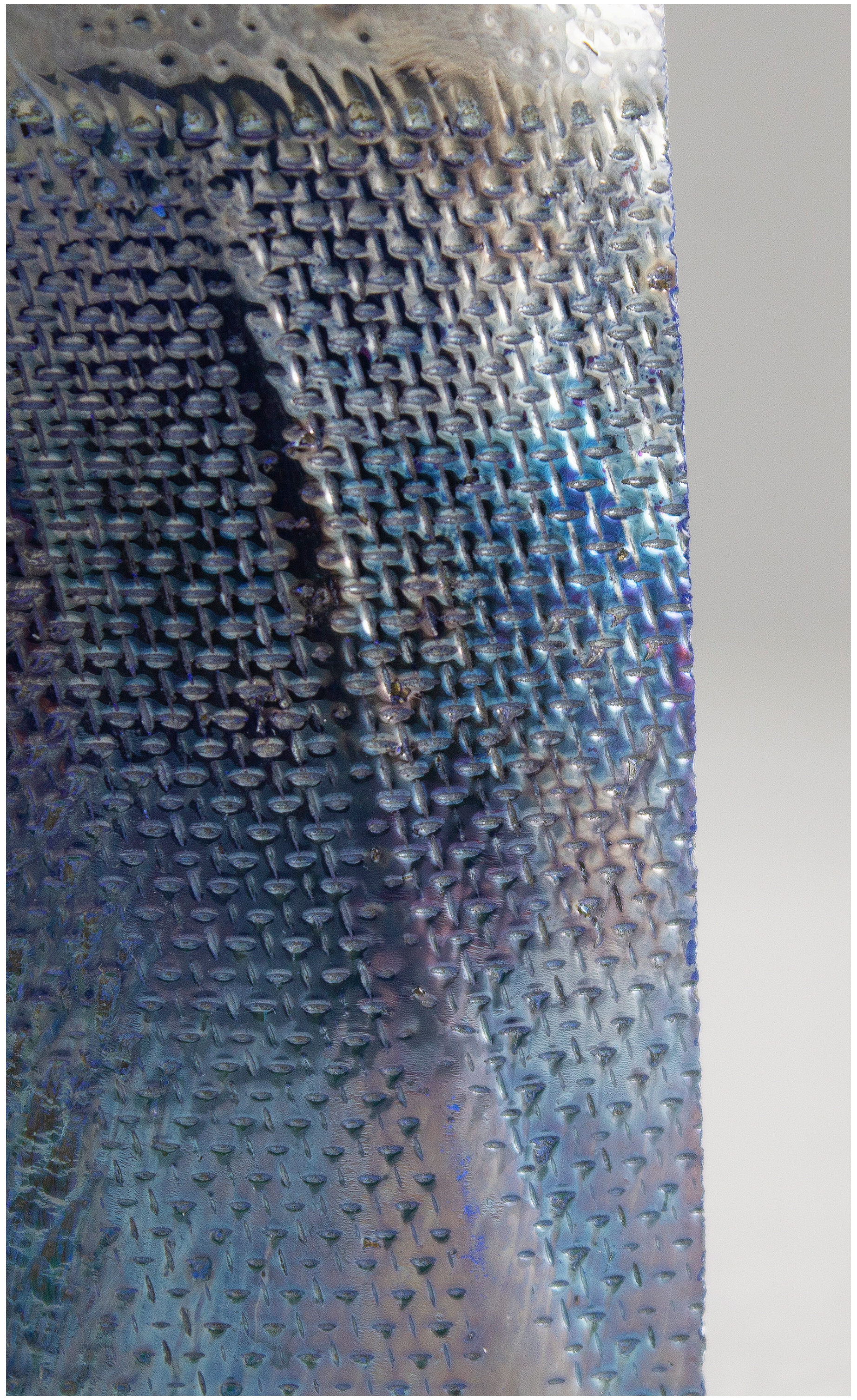


Fig. 37. *Rainbow Texture, 2018, silver coated on clear glass and blown against a textured mold, from Material Research Experiments*

Fig. 38. *Chain, 2018, silver coating on clear glass blown and twisted, from Material Research Experiments*

Fig. 39. *Ocean Blue Dots, 2018, mold blown, iridized large blue patches on clearglass, from the Collection of Iris Bottles*

Fig. 40. *Ocean Blue, 2018, mold blown, fully bluish silver lustered glass body, from the Collection of Iris Bottles*

Chapter 3 Final Project

3.1 Artistic Development Process

The materiality of glass including its exceptional formability, uniquely bright colors and naturally occurring round geometries constituted the major sources of inspiration for this project. In addition, my personal perception of the medium and dynamics of glassblowing practices have been an essential part of the artistic development process from the very beginning of this color and material research.

The artistic development process concurrently began with a phase of material research and rough, intuitive sketching. However, in early stages, I separated these two processes as much as I could and aimed to keep the initial sketching phase as intuitive as possible without the interference or limitations concerning physical constraints of the studio practices (See Fig.41). Thereby, I aimed to compare my intuitive initial sketches with final artifacts at the end of the process and precisely define the influence of the material exploration on my creative process. In subsequent stages, I gradually allowed the influence of glass to become more blended into the artistic development process.

In the beginning, I assumed that the glassblowing and the material exploration process could be significantly influential on the form related decisions, due to physical limitations, such as the capacity of the reheating furnace, the number of helpers and challenging nature of hot glass. However, except for some adjustments, the most considerable influence of the material exploration process did not occur via form, but by influencing the mood of the conceptual development instead. Even though my initial forms remained similar, the mood and color palette of the project underwent a dramatic change throughout the process.

Another artistic decision was to compose my artworks as a collection to illustrate a conceptual world with them at the center. In relation to this approach, Nimkulrat refers to Merleau-Ponty, a French phenomenological philosopher, and summarizes his thoughts about the relationship of an object and its spatial-temporal context stating that:

“ According to Merleau-Ponty, one experiences an object or an event within a spatial-temporal context, and knows it from an embodied perspective, with one’s body, one sees an object hears it and touches it at one time and in one place. To experience an object is to be in its world where it shows itself.” (Nimkulrat, 2009, p. 131)

This idea suggests that objects are interpreted as a part of the spatial context around them and this enables us to enrich our experience of them with our embodied perspective. These thoughts inspired me during my creative process. However, I explored this logic in the opposite direction. I did not use a spatial element to improve the expression of my artworks. Instead, I intended to express an imaginary world through them. Therefore, I outlined each piece as a part of this world which they belong. Doing so, I decided to explore, similar yet different, reflections of familiar objects with a “twist” that is genuinely inspired by my interaction with glass. By choosing familiar references, I aimed to inspire the audience to complete the story themselves and empower their connection with the work. Therefore, I did not involve any physical representation of this abstract dimension, except the artworks themselves, and left the rest to the imagination of the audience.

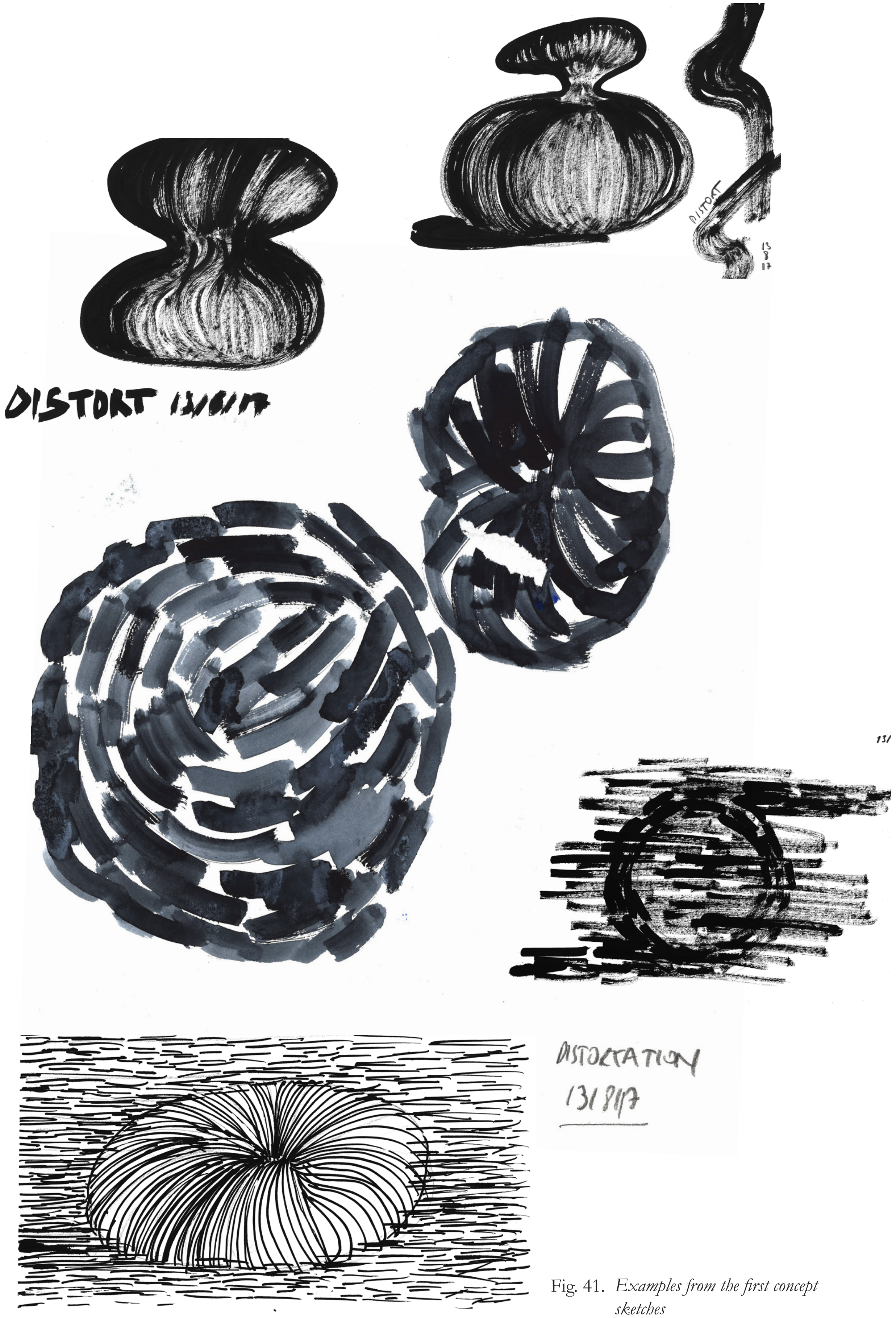


Fig. 41. *Examples from the first concept sketches*

3.2 Mood and Color Palette

For the development of mood and color palette within the glass artifacts, I used a sampling method throughout the process. First, I gathered various pieces of glass samples that could be inspiring for the process. Next, I organized them as a visual archive exclusively for this project. Later, similar as to Lego pieces, I tested different combinations and visual compositions by only pairing different pieces from my sample archive before actually prototyping them in hot work. Thanks to this sampling method, I could test numbers of combinations without using the hot studio and could envision every possible direction for my final artworks. I continued by developing mood boards and various options for possible color palettes. During these initial experiments, I primarily focused on the interactions between different color palettes and silver colors accompanied by textural experiments in which I explored the dispersion of mirrored patterns.Through this experimental trial and error sampling period, I gradually refined my palette of color, pattern and texture experiments to its final version.

My initial idea was to use a color palette with diluted, moody, pastel tones, to be reminiscent of the Scandinavian environment, such as water, mist, ice, and various textural landscape references. However, my early prototypes and color tests revealed that the combination of the silver mirror with dark, moody colors tends to create a sharp, cold feeling in the artifacts instead of a previously presumed mystifying atmosphere. This early prototyping process helped me to realize that I actually aspired to explore a festive and joyous mood in this project, which celebrates my joy of making. Therefore, I decided to change the artistic direction of the project.

After this point, the mood and the color palette of the project faced a dramatic change. The landscape-oriented and subtle pastel tones were replaced by a world of bright, warm, vivid, and even neon tones that shifted the color palette to the other side of the tonal spectrum (see Fig.42). This decision was particularly exciting for personal reasons because this vibrant side of the color palette had been uncharted territory for me during my design career. The silver color and pattern experiments followed this progress through trials on the size and dispersion of patterns in accordance with the new color palette and the overall development of the artistic vision. This radical shift in color palette essentially shifted my theme and motivated the overall process. In my search for the right expression, these warm and vibrant colors inspired me to explore a more cartoonish aesthetic in my artworks, in which different color and pattern combinations conjoin with the chromium effect of the silver mirror. Furthermore, this conjunction of vibrant colors and chromium effect was intriguing to me because it reminded me of the aesthetics of Synthwave music culture.

Synthwave is a genre of retro 80's electronic music largely inspired by 80's class B sci-fi and action movies (Hunt, 2016). In this genre lasers, grids, chromium effects, shiny neon lights, and highly saturated contrasting colors emerge as the most significant aesthetic elements. Besides that, the genre exposes strong associations with certain counter-cultures such as with movie-buffs, music, and video game enthusiasts, and perhaps the DIY culture (Hunt, 2016). However, in contrast with its sharp and bright aesthetics that employ a bright palette, such as bright pink and light blue tones, oddly enough, Synthwave hides a darker undertone referring to a dystopian sci-fi future vision too (Robert, 2016). This contrast between Synthwave color palette and dystopian take on the future also attracted me to explore its aesthetics more comprehensively. This association of the color palette notably intrigued me, and I decided to include it as an additional dimension, which stays hidden behind the bright colorful look. However, this tone of the concept gradually became diluted in later stages, even though it was a remarkable inspiration during the sketching phase.

In addition to Synthwave, the astonishingly colorful and vibrant world of doughnuts, cupcakes, and ice-cream widely influenced visual concepts of my artworks. The primary reason for my interest was the metaphorical status of these sweets that indicate a joyous, appetizing, 'festive' ambiance. I analyzed the visual essence of this world and formulated its visual code as rich combinations of warm and bright colored layers of various pastry-like elements piled on each other. These curvy, slumps of colorful layers constituted the main form language, accompanied by detailed surface decorations. Besides artistic purposes, I designed this formula to use it as a stage to display various uses of silver colors in conjunction with different pattern and color combinations.

All in all, the general mood and artistic theme of this project has drawn inspiration from various sources. Without a doubt, the intrinsic character of glass and my expressive interpretation constituted the main framework. The aesthetics of Synthwave culture and the appealing and festive aesthetics of pastries inspired me and helped to find the final expressive vision for my artefacts.

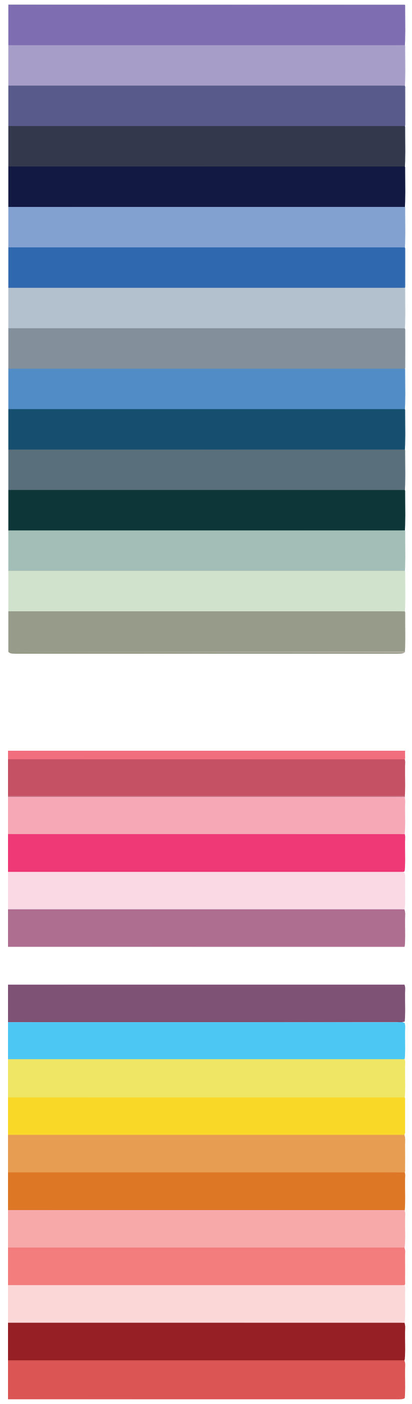


Fig. 42. *Before and after color palettes*

3.3 Art Direction

During the ideation process, I decided to adopt a painterly approach and aimed to shape my artifacts as three-dimensional glass paintings which would reflect a cartoonish quality. Thereby, during the creative process, I considered my pieces as glass canvases that allowed me the freedom to explore new aesthetic and expressive directions. Following this notion, even though the focal point of the project was to create an artistic expression inspired by the materiality of glass, the transparency of glass surprisingly did not find its place in this project. Neglecting one of the most prominent features of glass can arguably be regarded as a major contradiction. However, I chose not to involve its most obvious feature to decrease the effect of depth and to achieve a pictorial effect. This particular example reveals that even though the materiality of the creative medium affects the ideation of the artist, conscious decision-making on the coordination of visual elements still plays a vital role during the artistic development process to be able to communicate the aimed theme or expression.

From the beginning of this project, I had no intention of following any specific art movement. However, my literature survey on associated subjects revealed some artists and movements which could be helpful to discuss the artistic direction of my collection of artifacts. For instance, American Abstract Expressionist Peter Voulkos' ceramic works (See Fig.43&44) and his connection to the ideas behind the movement appears to be an enlightening example for this project, due to his painterly approach on ceramics and other equally significant controversies in the intellectual background of his work. Voulkos' ceramic sculptures consist of roughly shaped, piled up slumps of clay and thickly thrown cylinders decorated by slips of colored clay and glazes based on a technicolor palette (Adamson, 2007). Art critic Rose Slivka first linked his exceptional working methods to abstract expressionism in 1961. Slivka analyzed Voulkos' works in the article "New Ceramic Presence" in Craft Horizons magazine with high precision (Adamson, 2007, p. 43) stating that:

Fig. 43. *(Voulkos, 1959), Cross, glazed stoneware, thrown and slab constructed*

Fig. 44. *(Voulkos, 1960), USA 41, glazed stoneware and epoxy paint, thrown and slab constructed, seamed.*

"Today the classical form has been… discarded in the interests of surface – an energetic, baroque clay surface with itself the formal 'canvas.' The paint, the 'canvas' and the structure of the 'canvas 'are a unity of clay." (Adamson, 2007, p. 44)

According to this, Slivka proposes three methods within contemporary pottery that clay can be used as a painterly medium. First, the vessel itself is used as a canvas. Second, painting three-dimensionally with clay focusing on sensory elements, such as tactility and color. Third, physical interference of color on the form, by shaping and defining it (Adamson, 2007, p. 44). Slivka's proposal and Voulkos' painterly approach to ceramics seems to be in line with my direction in this project. However, besides using clay as paint, Voulkos' approach to the medium exhibits an opposite direction. Adamson (2007) summarizes Voulkos' fashion of using clay as 'how not to' approach. In fact, he intended to neglect intrinsic characteristics of the medium entirely including its advantages, physical qualities, and working logic; this way he aimed to destroy ceramic principles from its foundations. As it is clear, this approach notably contradicts my approach in which I aimed to design my artifacts inspired by the intrinsic and expressive character of glass. However, steps of my own artistic process surprisingly, and perhaps coincidentally, show similarities with the three directions of the painterly approach that Slivka (1961) coined in her critique of Voulkos' works. Regarding this, my artifacts can be divided into two distinctive but complementary collections, presented in the following sections.

3.4 Candy Bottles

To experiment with my painterly approach, I began by designing a generic glass bottle intended to display an ordinary, yet iconic geometry. During the ideation phase, I only studied the outline of the bottle and divided it into two morphological areas with a narrowing shoulder line. Thereby, I aimed to create a compositional diversity and an easily recognizable, characteristic outline, instead of a straight cylindrical geometry.

In this stage, to focus on my pictorial exploration, I preferred to use the mold-blowing technique in order to standardize the form of the bottles. For each session, I first prepared a glass bubble and I then experimented with different color combinations and palettes on top of it. My intention was to explore the expressive potential when the bubbles were combined with silver mirrored patterns. Then I applied silver colors using different forms of coloring techniques such as frits overlay or Swedish Overlay technique to experiment with patterns ranging from dots to large patches. Finally, I blew each piece into the mold, specially designed and modified for silver colors, to give their final shape.

In the end, I concluded this part with a collection of candy bottles with silver mirrored patterns on top. As mentioned in the previous section, the radical transition of the color palette from dimmed colors to a vibrant palette became apparent in this stage and it continued to inspire the artistic direction throughout the project. Even though I conducted this project in an explorative mode without any significant inclination until this moment, the outcomes of this phase helped me to establish the overall mood and character of the project. After this point, the sugar-coated, candy-flavored theme of the final project started to appear slowly. For the next phase, I decided to adopt a more comprehensive approach and extended this artistic exploration to include the form.

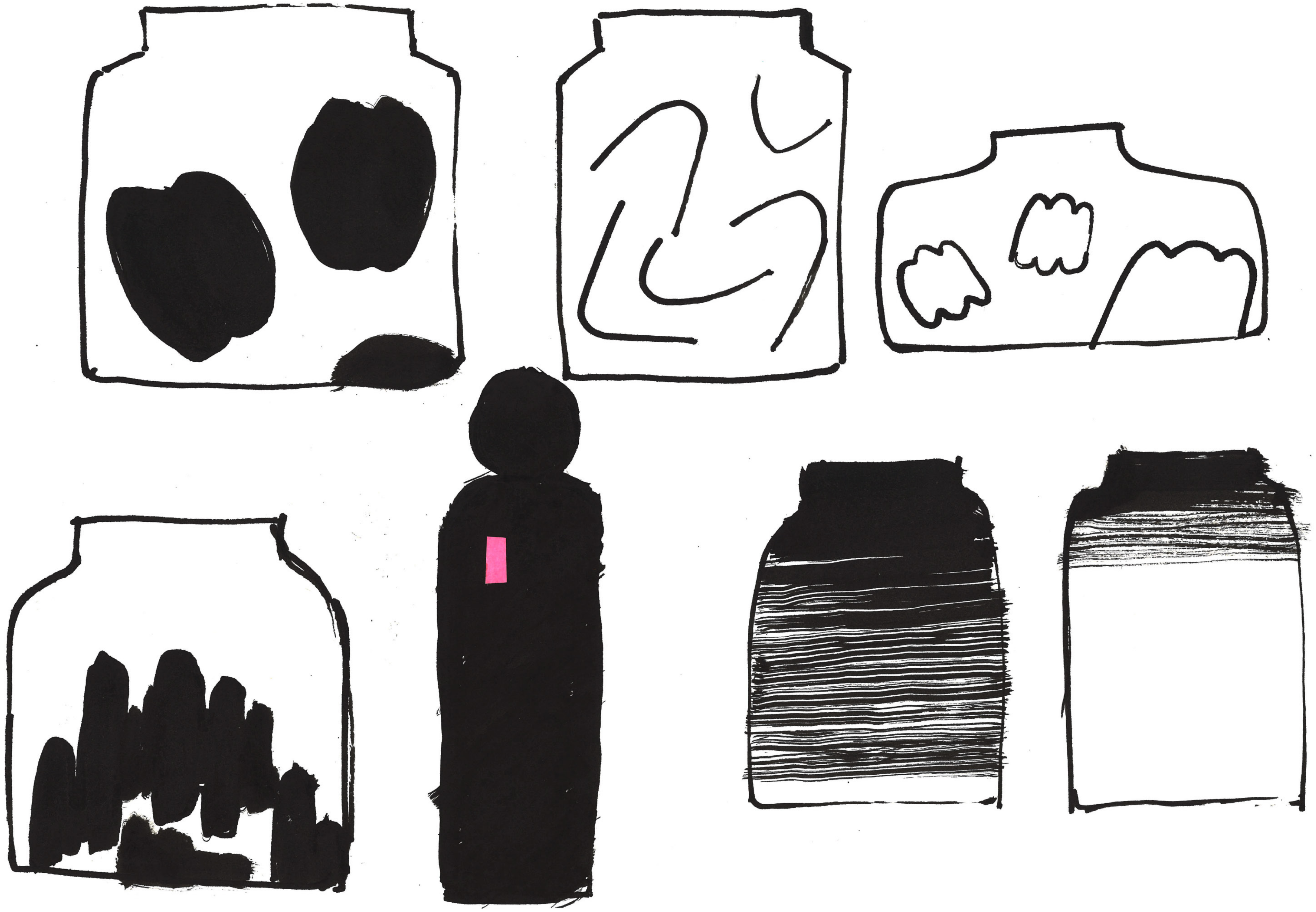


Fig. 45. *Early concept sketches for Candy Bottles*

Fig. 46.

Some selected pieces form the Collection of Candy Bottles

Fig. 47.

Milky, 2018, mold blown pink glass bottle with metallic lustered thick stripes, from the Collection of Candy Bottles

Fig. 48.

Electric Blue, 2019, mold blown blue glass bottle with metallic lustered dashes, from the Collection of Candy Bottles

Fig. 49.

Silver Dots on Pink, 2019, mold blown pink glass bottle with metallic lustered dots, from the Collection of Candy Bottles

Fig. 50. *Reddots, 2019, mold blown blue glass bottle with metallic lustered layer on top, from the Collection of Candy Bottles*

Fig. 51. *Bunny Canopic Bottle, 2018, full metallic lustered mold blown glass bottle with stylized bunny figure as the lid, from the Collection of Candy Bottles*

Fig. 52. *Breakfast before School, 2019, photo installation for the Collection of Candy Bottles*

Fig. 53. *Transformation Trio, 2019, from the Collection of Candy Bottles*

3.5 Plastic Crush

In this final stage, I intended to incorporate all practical and theoretical knowledge I had gathered throughout the research. This includes my experiential and embodied knowledge in glass blowing, the technical insights from the material exploration, and the literature review on expressiveness. Until this step, I had not been primarily concerned with the form. In this stage, finally, I started to feel confident enough to include the aspect of form and decided to employ it as another artistic component in the visual composition, enriching the intended expression.

The notions of distortion and reconstruction of reality came forth as key elements of this part of the process and they constituted the main inspiration behind the ideation process. Following these keywords, I became interested in experimenting with forms which are reminiscent of casual objects and intended to establish a connection with daily life through them. This way, I intended to enhance the connection with the audience and the artworks by the metaphorical dimensions of objects. I explored this approach with various visual styles to find the right expression and experimented with different references from pop culture, which I could reconstruct and reimagine as a part of the overall theme.

During the process, I became fascinated by forms that are reminiscent of sweets with references to various delicacies such as doughnuts, ice cream towers, and candies. However, I did not intend to make glass sculptures of sweets; instead, I wished to make "sweet sculptures" using iconic visual elements and form language of this theme to be able to transfer their symbolic associations to my work. Following these thoughts, I continued to create oversized and unusually decorated versions of the various forms of sweets. In doing so, I attempted to construct a sugar-coated theme to expresses a joyous and celebratory emotional state communicated by the tangible qualities of these artifacts. In the following stages, I gradually developed the elements of the theme in terms of the visual language with new prototypes. In doing so, this time I involved form as an integral part of the process and shaped my artworks as sculptural pieces in a childlike manner.

Along with its conceptual side, another objective was to demonstrate the experiential and technical knowledge I gathered during the material exploration of silver colors. Considering that, I preferred to work with peculiar forms, which are easily customizable and allow freedom for color and material experiments. Thus, the doughnut served as a template and constituted one of the primary forms for helping me to freely explore different visual compositions and technical insights from my material research in tandem. This way, I could continue my color and material research by evaluating their relation to each other in terms of their overall aesthetic and expressive value as well.

Fig. 54. *Concept development sketches of Plastic Crush*

Fig. 55. *Friday Afternoon, 2019, photo installation for the Collection of Plastic Crush*

Fig. 56. *Fried Space Egg and Jelly, 2019, photo installation for the Collection of Plastic Crush*

Fig. 57. *Selected works from the Collection of Plastic Crush*

Fig. 58. *Saturday Night Fever, 2019, photo installation for the Collection of Plastic Crush*

Fig. 59. *Biggie on Pink, 2019, photo installation for the Collection of Plastic Crush*

Fig. 60*Grandma's Tea Party, 2019, photo installation for the Collection of Plastic Crush*

Fig. 61. *Carnival Day, 2019, photo installation for the Collection of Plastic Crush*

Chapter 4 Analysis and Discussion

Fig. 62. *Ice-cream and the Flying Saucer, 2019, the Collection of Plastic Crush*

The main objective of this thesis was to investigate the influence of hands-on material explorations on expressive and creative aspects of design practices. To do this, I examined my artistic process and analyzed the topic through three interconnected aspects: theory, experiential studio practices, and their application in my artistic production.

In this research, the literature review and my experience throughout the process has shown me that an artist's interaction with material followed by self-reflection can help to gain a greater awareness of their thoughts, rationales, and decision-making processes. This awareness progressively affects artists' perception as well as their expression, which arises through the art object shaped by them. In a hands-on material exploration, artists' dialogue with the medium enables them to develop a unique expression involving both the artists' will and intrinsic character of the material. The intrinsic character of the material usually presents a range of restrictions, possibilities, and unexpected inspirations that the artist needs to evaluate and negotiate. Decisions from this making stage result in an individual tone that grants an expressive dimension to the outcomes of the process. In my practice, the effect of the material manifested itself on my artistic work and substantially influenced the final theme and color palette. Regarding this potential, the following chapter, Representational and Non-Representational Modes of a Creative Process, will compare hands-on practices with other design methods such as sketching and brainstorming and highlight their different attributes in detail.

The literature review further questioned the division of work between the execution and intellectual parts of a creative process in glassblowing. Unlike any other craft material, partially due to the apprenticeship culture and its demanding learning process, the production of glass has traditionally been handled by skilled artisans. However, with the Studio Glass culture and the invention of low-energy consuming glassblowing equipment, the gap between design and execution has diminished and led to Studio Glass Movement in the United States of America. However, one question remained unanswered: whether it would be beneficial for glass artists to blow their pieces or if the execution should be left to professional glassblowers. According to my experience and findings of the research, the answer to this question varies according to the context of artistic production. If the context is going to be developed as an explorative, material-inspired artistic process in glass, an artist's first-hand experience with the medium may increase the fluidity of the creative development and enhances expressive aspects of the final work. Notably, during the prototyping process, first-hand interaction with material provides an artist with a level of privacy, the courage to take instant decisions, and the freedom to try even most extraordinary ideas without being dependent on others' schedule, vision, and initiative. In line with ideals of the Arts and Crafts Movement, it contributes to the self-fulfillment of the artist. After this conceptual development stage, professional practitioners can be involved in the final production process, depending on the complexity of the final work. On the other hand, if the glass object is the realization of a thought process separately developed in another context, then the participation of the artist in the production process may remain limited to the role of a supervisor.

According to my experience, employing making as a fundamental part of the thinking process and coupled with reflection in action in a circular manner constitute a coherent and unique creative workflow. This process can be a critical tool to unlock unexpected and innovative outcomes, which could be hidden or unknown prior to the practice, and the versatility of the method implies that it can be extended to any context. For instance, in this thesis as well as previous research, the discussion was mostly undertaken around tangible mediums; however, I believe this creative method can be highly beneficial for even digital means of creativity as well as their fusion with traditional techniques. The practice of making and self-reflection can also be beneficial for self-development and personal growth. It could be utilized as an educational tool for all those who wish to take advantage of craft thinking in their field to develop an individual style and self-awareness. For further studies, the ideas mentioned in this study can be examined, including cognitive science perspectives, and can be developed as an alternative creative thinking method for other fields as well.

This research investigated artistic aspects of conducting hands-on material research in glassblowing and also questioned that if the practice itself could function as an educational tool for creative studies. A material-inspired artistic research in glassblowing requires consideration of both instant actions during the blowing process and their echo for the entire project. This demands a fast-paced, flexible and delicate decision-making process and requires the artist to evaluate each step in a complex web of possibilities, including artistic opportunities as well as technical difficulties. For example, during my research, when I encountered an obstacle, I had three major options: practicing more to master a technique, making an additional tool, or changing the design. Sometimes the solution was one or a combination of these options. Therefore, finding the best possible option out of this entanglement requires a careful decision-making process based on design sensibilities. Schön (1983) argues that to deal with such complexities that involve unknown and unique situations demands an artistic performance. He states that artistic performance requires the ability to switch in between micro and macro perspectives with careful management of information to foresee possible problems or opportunities in a process - without missing the primary objective. Therefore, I think that artistic research in glassblowing not only reflects Schön's definition but also requires the same processes to be applied in a more comprehensive and versatile way, due to the challenging nature of glass and the personal performance factor in hot work. Thus, I believe that practicing a hands-on artistic exploration in hot glass can be an exercise in practicing art and design sensibilities, regardless of profession.

My experience has shown that glassblowing offers practitioners a dynamic, intuitive and performative creation process full of surprises; it provides the unique form language of blown glass and great potential to prototype new ideas in an incredibly rapid pace. Besides that, as mentioned before, the glassblowing process requires specific tools made from other materials, such as metal, graphite, wood, and ceramics, for safely and efficiently processing hot glass. This required me to learn more about other materials and their reaction with hot glass to be able to achieve my own specifically desired results in blowing sessions. This enabled me to develop a holistic view of other craft materials as well and expanded my vision of this material ecosystem. This awareness eventually helped me to improve my sensitivity towards the notion of materiality and intrinsic characteristics of materials.

In this research, I also aimed to contribute to the knowledge in the use of silver glass colors. My experience shows that they produce a satisfying metallic or iridescent coating when the color variation on the surface is targeted or acceptable. Besides, they perform best when they are applied locally or used to create metallic lustered, fluid patterns during glassblowing practices. Otherwise, using silver glass colors to have a uniformly colored, neutral metallic coating on large surfaces appears to be a challenging goal. Achieving this goal may require a long period of trial and error in which a practitioner needs to test the right timing and temperature. My experiments reveal that if the goal is to have a neutral silver mirroring surface, it could be ideal to limit their use on certain parts of the glass body. This way, artisans can focus on a particular area to fulfill its requirements for a successful mirroring process and, compromising the size, they can increase the chance for successful results at least for a certain area on the glass body. Moreover, due to the sticky character of these colors, a full body application may introduce additional problems during their transfer to the kiln and the annealing process. This problem may require designing additional tools or extensions that a practitioner could use to protect and handle the artwork while keeping the metallic surface intact. Otherwise, thermal protection gloves or the kiln wash may leave marks on the metallic coating. Therefore, I suggest that an artist may need to find a compromise between the surface area and the evenness of the effect. The risk of not achieving an evenly mirrored surface increases as the application surface grows. If the entire glass body has to be equally silver mirrored, even though it is possible with silver glass colors, other silver mirroring methods may be more successful.

Furthermore, besides the technical data, I aimed to give insights about the general mood and mental phases of material research in glassblowing. Therefore, I utilized my studio diaries, organized them into a narrative format compiling my key findings, and made them easier to picture using different metaphors for each stage as: the explorer, the inventor, and the magician. These sections only reflect my personal experience on this subject, and the generalization of this experience might be limited to other contexts. Yet, I believe that people who will do similar research may relate and adapt this information to their own process. The following section will discuss them in detail.

This research also revealed that conducting material-inspired artistic research in glassblowing has particular difficulties. First of all, since it requires long hours of studio time, it may easily become an expensive process due to the cost of gas, raw material, glass colors, and other studio resources. Second, even though this research acknowledges the material exploration as an extension of an artist's sketchbook, naturally it cannot occur as fast as sketching an idea on the paper and may grow into a time-consuming practice due to long annealing hours, time-consuming mistakes while learning, and even maintenance of the working environment. Above all, it requires novice practitioners to commit themselves to the craft for a considerable amount of time to gain enough experience to undertake reliable research.

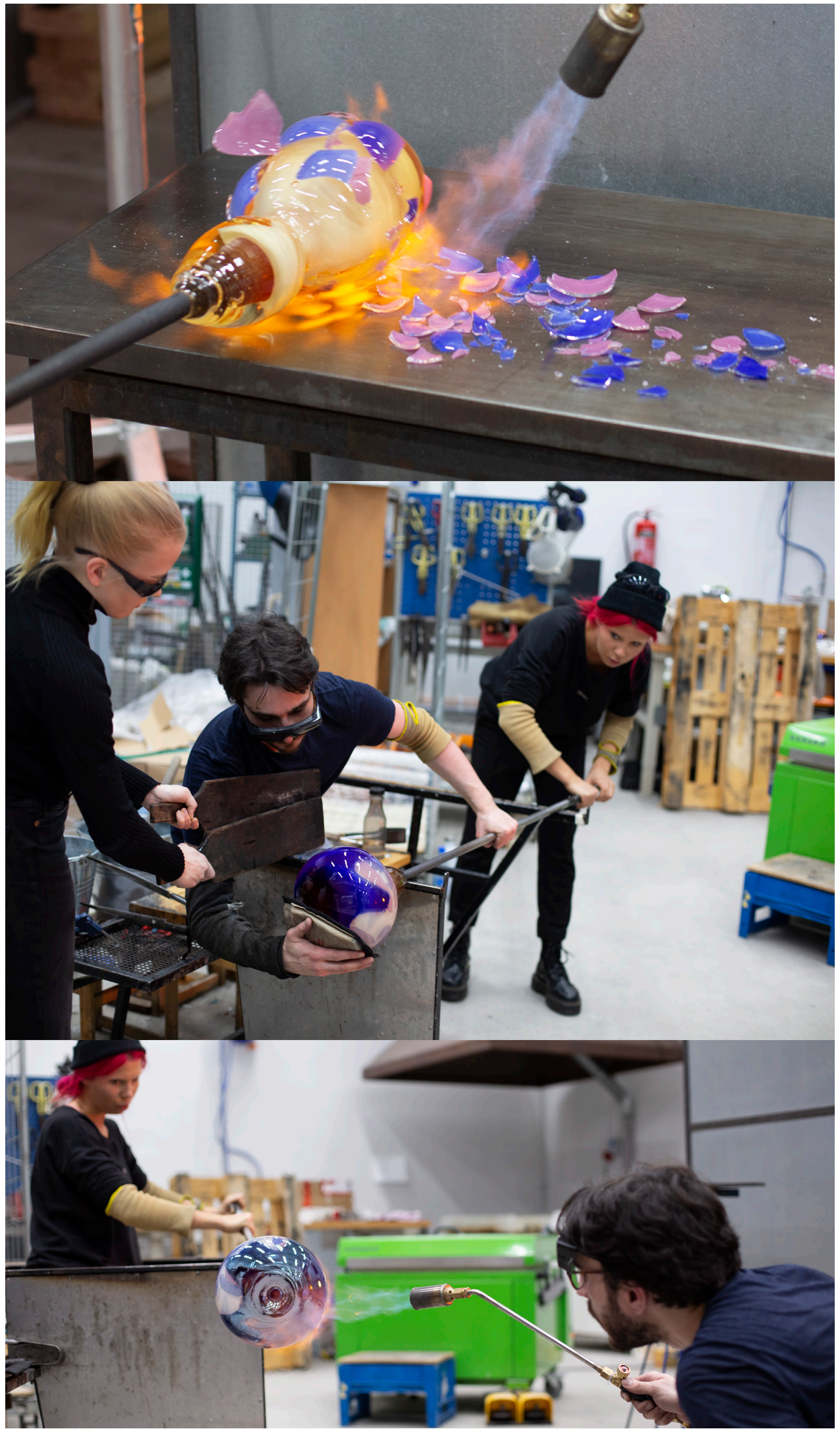
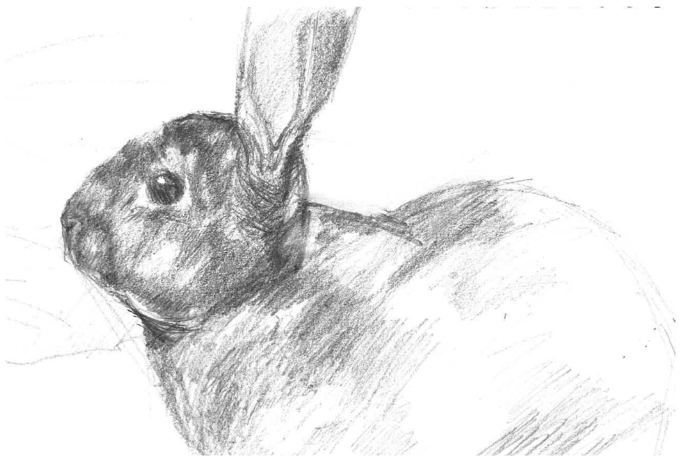
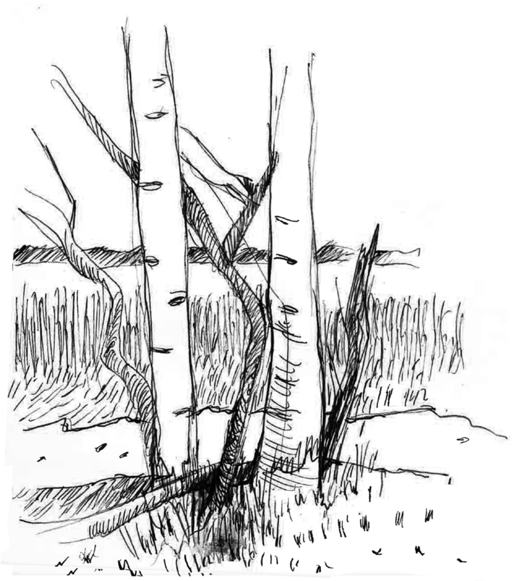


Fig. 63.

Making of a piece, 12 February 2019



4.1 Three Mental Stages of Color and Material Exploration



4.1.1 The Explorer

My experience in the first stages of my process made me feel like an explorer stepping onto uncharted land. I set off with curiosity, yet I was inevitably limited to my short eyesight without knowing what to expect. Each step forward gradually kept revealing new points until I reach to an overview of the land.

I used this metaphor to define the process of discovering and determining all critical parameters in the material exploration process. This stage involved a challenging trial and error period, which required patience and readiness for unexpected, puzzling, and unreliable results. This vague situation emerged due to the lack of knowledge and narrow vision of early phases, in which I was not capable of recognizing and recording all the key elements in the process. Therefore, these early experiments could help only to develop a wider vision of the process for further stages rather than providing reliable data. I believe this situation occurred due to still missing pieces of the process puzzle and relying on tacit knowledge, which I could not identify and define even for myself yet.

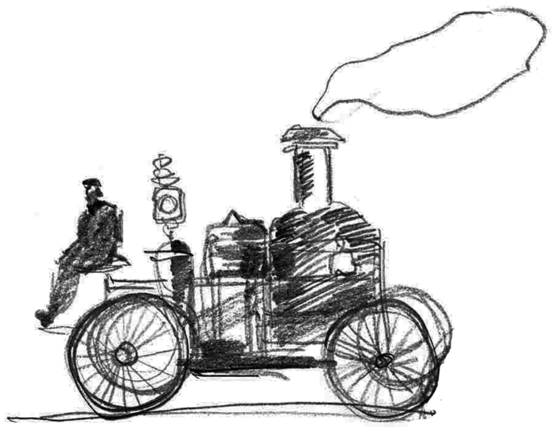
On the other hand, regarding the variety of outcomes, this period might be the most fruitful and playful one. Outcomes from this period exhibited a rich variation in terms of visual composition, color, texture, and finishing. I believe this richness mainly originated from my uninformed steps. Therefore, the majority of results may not be repeatable later due to spontaneity, lack of record, and possibly missing information. Outcomes of this period mostly emerged as mini glass bubbles as adventurous, one-off, unique objects, which gave hints about the ideation process for the following stages. At this point, inspired by some exciting results, I found the courage to try them on a larger scale with complex geometries. However, after a few failed attempts, I realized that the early application of research results on a complex form could introduce indistinguishable new challenges at the beginning of the material research with my initial limited understanding. Therefore, in the beginning, I decided to concentrate my efforts on the evaluation of surface features, to make reliable measurements, and to search for scientific reasons behind them. Hence, I simplified the form elements as much as I could and postponed the form exploration phase until I felt I had gained adequate experiential knowledge to be able to handle its additional complexity.

To conclude, this stage can primarily be remarked by the element of surprise, in which each attempt yielded unexpected, accidental results and served as an eye-opener for upcoming chapters of the process. It can also be pictured as a puzzle, in which each piece placed on the board brought joy and wonder to for upcoming stages.

4.1.2 The Inventor

In this stage, I felt an urge to design various devices, varying from simple hand tools to complex fire chamber setups. I believed these could help me to produce improved and more critically reliable results. I intentionally preferred to use the word invention here to wink at 18th-century inventors, referring to their bulky, mechanical, clockwork inventions, such as steam engines. I followed a similar path in this stage and attempted to solve all the problems in the process by designing physical and mechanical solutions, hoping to standardize the whole process and eliminate my errors.

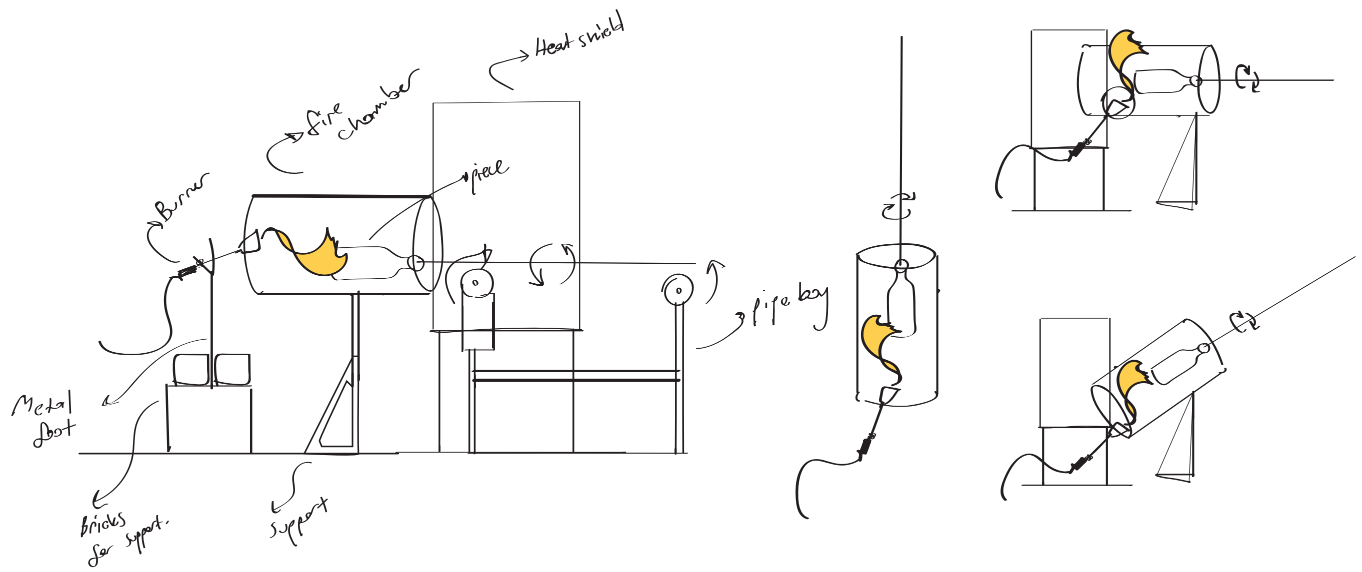
Based on my studio diaries, I believe this phase emerged due to my unconscious effort to compensate for my lack of experience and embodied knowledge in the use of silver glass colors in glassblowing, in a short period. Although I had some previous understanding of the general principles of the redox reactions, due to the complex relationships of volume, geometry, temperature, flame, and timing, I was unable to consider these variables at the same time and execute the process with the right order and timing. Since the procedure was not internalized yet, it required a different path of cognitive process that is probably slower than reflexes based on embodied knowledge.



In this stage, I was convinced that the imprecise flaming process was the reason behind the unsatisfying results. Therefore, I started to build my own equipment and tools in order to maintain a reliable, proper and comfortable flaming process. These efforts began with simple modifications on the blowing head of the hand torch in the beginning. I tried to adjust the gas-oxygen ratio in the flame by modifying the air holes on the torch. Later, I intended to automate the entire process and decided to employ the studio pipe boy – a machine which can rotate blowing pipes automatically at the same rate. With this machine, I aimed to take advantage of the exact same rotation speed. Afterward, I built a stand for the hand torch and attached it to the end of the pipe boy, hoping to apply a steady flame to an evenly rotating glass piece from a fixed distance. The weakest aspect of this setup was that the flame was in contact with the glass piece in one direction. Therefore, I decided to extend my setup and build a flaming chamber around the hand torch (see Fig.64) to distribute the flame evenly around the glass piece. In this stage, the reheating furnace could be used as well, but it would be far too powerful for such a delicate process, and the piece would become over-reduced in seconds. I designed my flaming chamber as a much gentler version of a reheating furnace using a metal tube, 32 cm wide and 100 cm long. Later, I attached the hand torch to the tube and then placed the whole structure at the end of the pipe boy. My intention was to maximize the automation to standardize results. This process continued with various modifications and combinations on the setup concerning the direction of the flame, the position of the chamber and modifications on the hand torch.

These efforts revealed that for such a dynamic process, fixed setups or mechanical inventions remain too slow and limited to function for every situation appropriately. Many cases require instant decision making and flawless timing, which could be challenging to perform in a fixed installation. Lastly, I believe this stage describes an essential step in the cognitive progress because even though my intention was different, I could set myself free of laborious actions by the aid of machinery and had a moment to observe and analyze the process as a third party freely. This observational perspective helped me to notice some nuances and to gather enough substantial experience for the final stage: “ The Magician”.

Fig. 64. *My flaming chamber design for the reduction process and its variations*

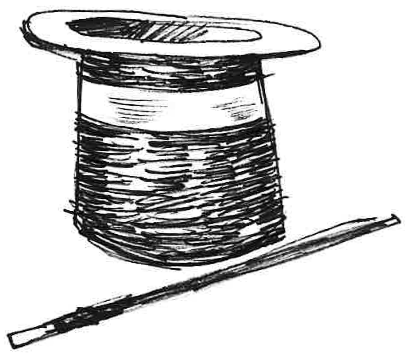


4.1.3 The Magician

For this stage, I needed a poetic tone to express my insights and amazement at the dramatic changes that occurred in the process. One quote by Arthur C. Clarke, a British author, inventor, and futurist, acted as the source of inspiration for the name of this phase. As I was reviewing my studio notes from this part of the research, I decided to name this phase after his third law; as he famously noted: " Any sufficiently advanced technology is indistinguishable from magic" (Clarke, 1973, p. 14, 21, 36).

Surely, Clarke describes his future projections about the progress of technology. However, I wish to emphasize the 'indistinguishable from magic' part in this quote. Reviews of my studio diaries show that a similar transition from complex physical tools to 'knowledge' occurred as the whole process took a leap towards simplification while compressing the layers of information. After this point, the complex details of the process become no longer traceable for outside observers.

As noted before, the most critical variables of glassblowing - temperature and timing - are invisible elements that must be mastered and delicately controlled. Moreover, as an electrochemical reaction, redox reactions added atmospheric effect as an additional invisible layer in this particular case. In that sense, the exploration stage was about discovering and defining relevant variables, and the inventor stage explored various solutions for management of this complex web of variables by employing auxiliary tools and setups as an attempt to take control of the process. However, in the magician stage, the process reaches a point that all the gadgets and experiential knowledge from previous efforts become distilled into embodied knowledge. All additional equipment, tools, and steps in the process were gradually simplified and eventually vanished, re-emerging as the intuitive knowledge of time sensitive actions, choosing the right action and amount for each interaction.



Eventually, I discovered that a proper redox process does not depend on any means of complex tools or techniques; it only requires the correct rhythm of timely actions. Polanyi (1966) describes this 'sense' as tacit knowledge, which is codified in the practitioner's mind and difficult to decode by means of verbalizing or writing. Therefore, it becomes challenging to define and translate this information. According to my experience, tacit knowledge involves a manifold of information layers consisting of varieties of data gathered from all sensory experiences of the practitioner. This data accumulates until it reaches a certain level of refinement. After this point, artisans can focus on in-depth creativity and self-expression, without consciously thinking of technical aspects.

In conclusion, the findings of this part strongly relate to the reasons behind the frustrating learning process of glassblowing as well. As a performance-based craft, it primarily operates on a tacit dimension, which can be difficult to be taught or to be transferred by verbal or written means only. Therefore, the presence of a master appears to be compulsory to gain a grasp of the craft. I believe it could be favorable to undertake further research about alternative means of transferring tacit knowledge in glassblowing, as well as in other areas of craft.

4.2 Representational and Non-Representational Modes of a Creative Process

As it was discussed in the theoretical background of practice-led research, design science studies and embodied cognition represent two approaches in design reasoning. Therefore, as these viewpoints vary in the process of reasoning and knowledge production, their methods for the development of creative processes differ as well. This section compares these differences and articulates how they relate to the discussions in this research.

Regarding these two design orientations, most fundamental contrasts arise with the process modes of reasoning since they employ different approaches. These approaches are divided into representational and non-representational modes. Regarding these modes, Camilla Groth (2017), ceramic artist and a postdoctoral researcher at Aalto University, defines this division by explaining that representational mode refers to an abstract ideation process tending to objectify what is observed using imaginary exploration tools, such as sketching, 2D-3D modeling, symbols or language that enables ideation process. In contrast, non-representational mode relates to the physical, concrete exploration of ideas involving bodily interactions of designers with the external world and materials. However, she notes that the latter tends to be a more subjective sense-making process comparing to the representational mode (Groth, 2017, p. 64). Regarding this distinction, architect Stan Allen (as cited in Nilsson, 2013) highlights an intriguing point, Allen names these modes as hermeneutic and material practices and states that hermeneutic activities majorly focuses on the past, because they interpret and represent what is already known by using imagery. In contrast, material practices concern now and the future because they study material in real-time and intend to learn from it for the future.

The subjective nature of representational mode emerges as the key point of this discussion, in terms of its role in the creativity and the expressiveness of the artifacts. On this point, Groth (2017) highlights that sense-making process in non-representational mode widely incorporates sensual and tactile experiences of medium in the sense-making process. Therefore, this mode of thinking involves a broader understanding of the intrinsic character of the medium in use and this wider awareness of medium fundamentally affects the decision-making process and even might suggest new, unpredictable opportunities or constraints at creative developments of artistic processes. The intention of my research was to explore this dimension of unexpected possibilities throughout the material exploration and artistic production phases.

As it was explained above, the representational mode primarily involves an abstract ideation process, which relies on descriptive and illustrative means of concept development whereas non-representational mode embraces bodily interactions and sensory experiences as essential parts of the sense-making process. Although they seem like independent processes, in a creative process they often tend to function to complement each other. Considering this, Groth (2017) notes that pendulum in between mental ideation and physical actions constitutes an essential part of the sense-making process where making and re-making process occurs concurrently; and even further, since earlier imagination process relies on designer's preceding bodily experiences with the medium, embodied knowledge is incorporated in every part of the creative process. My study acknowledges this approach and incorporates representational and non-representational modes of thinking in a constant interaction along the period of creative development of the artifacts. Considering this discussion, when I referred to my studio diaries, I found an intriguing log from the period of my artistic ideation process, in which I happened to articulate the role of pencil and paper:

" Pencil and paper function like glue. They can successfully shape the outline of the overall shape. However, their importance is somehow, they, pen and paper liquify thoughts and intuitions helping you to mix with the creative juice. Whenever I grab a pen and paper I feel, my thoughts start to melt like butter on a hot pan, ready to mix with anything. Although the capability of these instruments is far from the shaping supposed tactile or visual properties of a physical form, its true power lies in its binding and liquefying effect of the thoughts behind a form. " Personal Studio Diary 27.2.18

As I recall now, on the day I recorded this log, my creative development was congested with many vague and rough thoughts without a clear direction. As I reflected, pen and paper - indispensable tools for the representational mode - are great for developing thoughts efficiently and rapidly, and perhaps the cheapest way. However, paper is only two-dimensional and does not enable practitioners to conceptualize actual sensations of materials. Therefore, I personally tend to think around outlines and silhouettes as I sketch, then I continue with hands-on prototyping to discover what the medium can offer me to fill in my silhouettes.

As my studio record reveals as well, representational and non-representational modes usually tend to follow each other. Considering that, it can be argued that especially a material-inspired creative process might require a unified version of these two modes. Following that idea, I tested a sampling method as a combination of these two approaches for my creative process. The sampling method primarily aims to encapsulate conceptually valuable tangible elements, such as intriguing material fragments, indicators of different moods, or expressive elements, on a sample or in a collection of samples, as tangible memories of certain experiential knowledge or unexpected coincidences. Each sample or sample collection can be considered as quick three-dimensional sketches. This method provided me with two main benefits. First, it helped me to organize a tangible material library for critical embodied knowledge and a footprint of vital artistic elements in the process. This way, I could use these samples as if browsing in a library of experiences and visual representations of different artistic directions. Secondly, these bricks of visual fragments were so convenient to match, combine or arrange in composition to see how they related to each other in terms of visual coherence between them. This helped me to realize raw conceptual images in three-dimensions quickly. In this process, non-representational methods were used to sketch representational ideas in a tangible way to create new inspirations for the next stage of creative development in a circular manner. It widely supported my decision-making process in terms of color palette, mood and concept development.

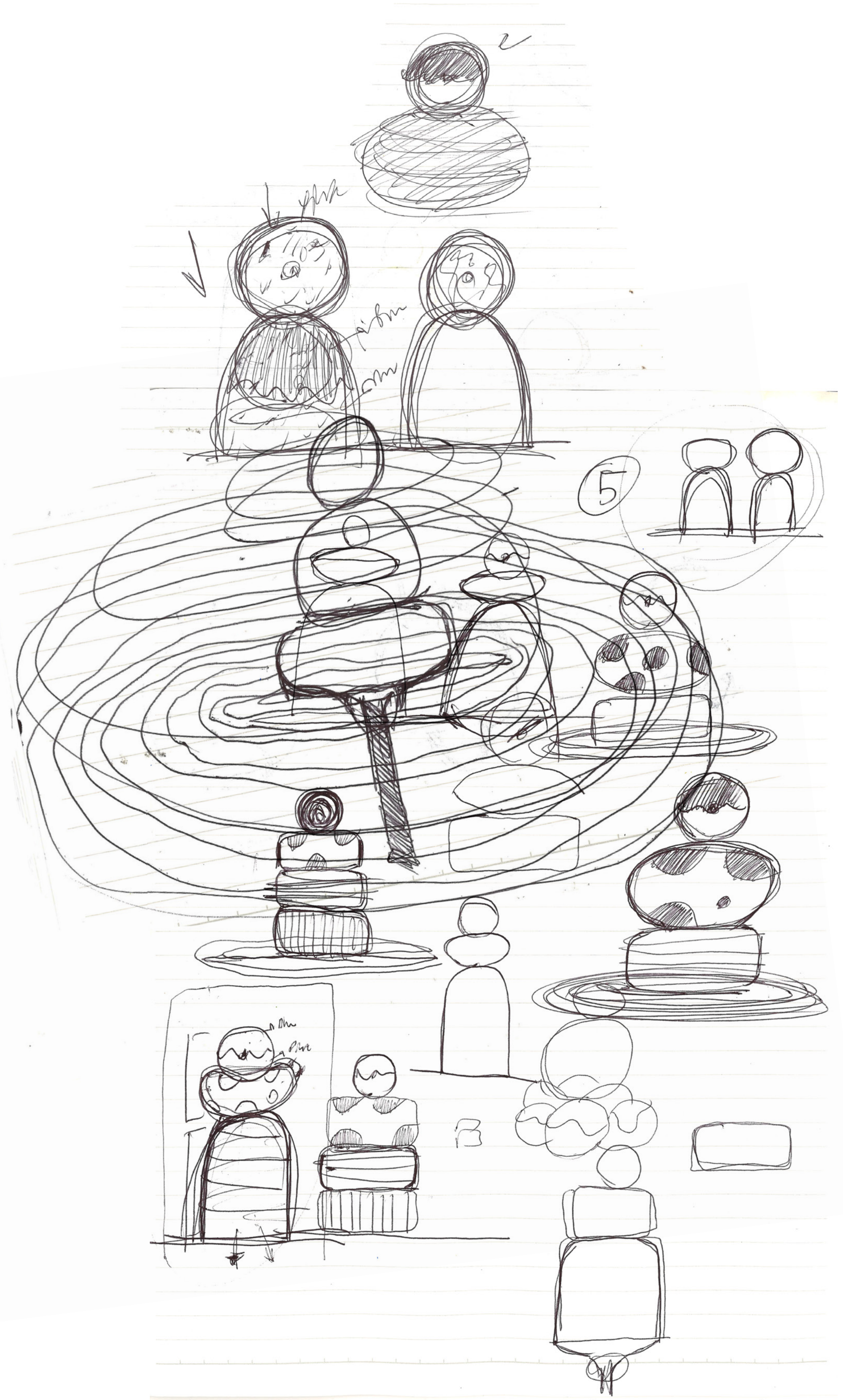


Fig. 65. *Ideation sketches, example for representative creative methods*

To conclude, as it was discussed above, representational and non-representational modes essentially perform different aspects of the sense-making process and they fulfill different, complementary roles in a creative process. However, non-representational modes rely on bodily interactions and sensory experiences where they widen the designer's subjective vision on the intrinsic character of the medium. Therefore, in this particular project, non-representational methods occupied a greater portion of the creative development process, although these were still generously supported with sketching, 2D-3D models and mood boards.

Fig. 66. *Overlay bars and various form of glass colors*

Fig. 67. *Creating material libraries, example for non-representative creative methods*

4.3 Limitations of the Research

Regarding the limitations of this research, I need to point out a few points about the accuracy of the information presented in this study.

First, I conducted this material research as an empirical study in the conditions of an art glass studio; hence, the presented numerical data should be regarded as approximate values and by no means can be compared to precise results of a laboratory setting. Due to challenges of the glassblowing practice and empirical data collection methods, I could only share my impressions and estimated figures rather than exact statistics and they contain a certain margin of error. Moreover, since I conducted this research by only using Aalto University's glass studio, the data can only reflect specific results of its particular setup. The appendix section presents detailed information about the technical specifications of the workshop. Therefore, I suggest that the information presented in this research should be regarded as guidelines and which require others to test and adapt them according to their specific purposes and studio equipment.

Second, I conducted my experiments on silver glass colors according to the proficiency and know-how I had at that time. If I would repeat them now, I assume that my results would be different, due to the progress in my experiential knowledge on the topic. Therefore, I believe comparing test bubbles in each other to find out major differences in their making could provide more reliable insights than focusing on blowing sequences of individual test samples.

Third, my theoretical findings on conducting a hands-on color and material exploration and the following artistic production can only be limited to my personal experience in this particular study and may not be entirely valid for other materials or craft practices. However, I have paid attention to detect more generalizable information about the material based artistic ideation process throughout the process and have presented my findings in previous sections.

4.4 Future Research

As I discussed in the chapter of material research, the annealing process significantly affects reflective quality and color tone of mirrored coating. In that sense, finding proper annealing equipment in every studio may not be possible every time.

Therefore, for further research, I could test ways of modifying existing annealing equipment to create a neutral or reducing atmosphere inside. Within the time limit of this study, I could not find a chance to work on this idea. However, I believe designing special annealing equipment for the use of sensitive surface applications could be an interesting challenge. In principle, changing the atmosphere in the kiln from oxidative to a reducing character depends on the amount of oxygen involved and oxygen can be burned by gradually adding some organic material inside the kiln. For instance, a system in the kiln may periodically drip oil to burn the excess oxygen to keep the atmosphere neutral or at a reducing level, which may help to have more reliable and successful results. However, this idea requires research that must include a series of tests to explore a balance between the type of conditioning agent, amount, timing and temperature. Otherwise, over-reduction or over-oxidation might occur easily. These issues require a precise analysis of the atmosphere in the kiln and could be a topic for another research.

Another direction for further extension of this material research could be to search for combinations of silver glass colors with other materials, such as ceramics, wood or sand. During the early stages of my material research, I tried a few samples that combine silver-coated glass with wood and ceramic cups. However, the ideation process took a different direction later on.

Fig. 68. *The cherry on Top, 2019, photo installation for the Collection of Plastic Crush*

5. Conclusion

In this research, I had an opportunity to dive into the craftsperson's world. This exceptionally eye-opening experience taught me the meaning of mastering a craft and provided me with great practical and theoretical tools that extend my artistic vision beyond product design into the world of art and craft. During this research period, I developed my glassblowing skills to be a versatile creative tool in my artistic repertoire while learning different methods of utilizing silver glass colors in order to create a wide spectrum of mirrored coatings in hot glass applications. I supported my hands-on artistic practice in glassblowing with theoretical background, which includes notions of 'making is thinking', reflection in action and expression theories of art. My bodily involvement with glassblowing has led me to break boundaries in between arts, craft, and design and taught me to switch in between them to flexibly create intended results. This way, I believe I could combine practical and theoretical ends of an artistic process and examine my creative process as a complete circle.

This thesis project significantly contributed to my understanding of material-based ideation processes. Even though I participated in many projects and study modules related to the artistic material exploration during my master's studies, the evaluation of the results was focused on outcomes and could hardly exceed the line of visual aesthetics. In this project, I had an opportunity to widen my vision from final artifacts to the artist's journey regarding not only their visual aesthetics but also the expressive and creative development process behind them. Throughout my journey, I realized that a material based artistic process does not continue as a linear path and includes distinctive stages. These stages include numerous options, which involve possible opportunities, facilitators or time-consuming obstacles. Therefore, each step requires an artist's careful and conscious decision-making process to constantly check short and long-term objectives and an ability to change their scope between micro and macro perspectives flexibly. At the end of my process, I can define three major stages of a material exploration as: the explorer, the inventor, and the magician. Each stage demands a different mindset and I believe being aware of them may help other artists to evaluate their current position more accurately in their process.

Besides, the results of material exploration revealed that silver glass colors can provide a wide range of visual palette and color variation/degradation depending on the precise working conditions. Their application process takes place in the hot work and does not require additional cold-work process. My experiments show that they are a convenient option especially for local applications and for creating naturally flowing metallic lustered patterns during hot work. On the other hand, depending on the purpose, their use may become notably restricting for certain projects, especially if the silver glass color will cover the entire glass body. Moreover, their use requires a certain level of experience and knowledge to be able to assure satisfying and reliable results.

In conclusion, this journey not only helped me to develop my skills in glassblowing but also gave me a general understanding of how to master any other craft. Thanks to this experience, I could widen my understanding about the craft and material world. This learning period reminded me of how the nature of hands-on artistic process is different from the digital means of creativity. The nature of digital creativity may be faster, safer, more accessible, and produce great results without spending anything. However, hands-on work still remains as a great reminder of how challenging and fragile, yet, joyful and fulfilling achieving something with our hands can be.

Appendix

The glory-hole
Type GS 2000

Diameter of the opening into the front part...... 250mm
Inside diameter of the Glory-hole................. 300mm
Depth of the working part.......................... 350mm
Duration of heating up................................ Up to 20 minutes
Maximum working temperature.................... 1420°C
Fuel.. Natural gas
Required gas pressure................................ At least 10 kPa
Fuel consumption.................................. 3.5 – 5 Nm3/hour
Supply of the blower...................................380V / 400V
Required power of the blower....................... 0.37kW

Technical Specifications of Farbglashütte Reichenbach Silver Glass Color used For Experiments:

144RW Iris Dark Blue
Coefficient of expansion: 96(+/-2) x 10-7/ K (20 – 400°C)
Transforming Temperature: 470 – 530 °C
Annealing Point: ca. 510°C

Überfangglas aus Reichenbach / Oberlausitz für USA, weltweit. Retrieved March 10, 2019, from https://www.farbglas.de/en/overlay-colours/overlay-products.php

Clear glass used in the Studio:
Cristalica Premium Studio Glass 100

Cristalica | Datenblatt | Studio Glass. Retrieved March 10, 2019, from https://cristalica-studioglass.com/Datenblatt/?lang=1

Kiln 3

KERAKO 160 th
power 9 kW
400V, 3N / ~
volume of 160 liters
maximum temperature 1280 ° C
exterior dimensions cm 80S x 123L x 97K
incubation space cm 46S x 69L x 50K
weight 220 kg
STAFFORD ST215 control
thermocouple S (1300 ° C)
gas spring on cover
3 pieces of plate 40 x 40 x 1.3 cm
Pillar 20 series
Warranty 2 years
Arkkumallit. Retrieved March 10, 2019, from https://keracomp.fi/keramiikkauunit/arkkumallit/

Green Kiln

A modified version of Kerako 160 to be used as a pick up kiln during hotwork sessions. Designed by Kazushi Nakada

Round Kiln

Wepatherm / WT45 Ceramic Oven
External dimensions: width 605mm, depth 740mm
Height with stand: 690mm
Inside dimensions: diameter 400mm, depth 380mm
Capacity: 45L
Power: 3.6kW, 16A fuse
Weight: 66kg

WT45 Keramiikkauuni SE600 pyörät. Retrieved March 10, 2019, from http://varnia.fi/product_details.php?p=12106

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