Saija Kattelus

THERMAL SHOCK
– and its perfect imperfections

Dissertação de Mestrado
em Arte e Ciência do Vidro

Orientador:	Professora Doutora Teresa Almeida, Professora Auxiliar, Faculdade Belas Artes Universidade do Porto
Co-orientador:	Professora Doutora Márcia Vilarigues Professora Auxiliar, Faculdade de Ciências e Tecnologia Universidade Nova de Lisboa
Co-orientador:	Professor Doutor José Ramos Professor Auxiliar, Faculdade de Belas Artes Universidade de Lisboa

Júri:

Presidente:	Professor Doutor Antonio Pires de Matos, FCT/UNL
Arguentes:	Professor Doutor Celso de Sousa Figueiredo Gomes, UA Professor Doutor Jorge Carvalho, FBAUL
Vogal:	Professor Robert Wiley, FCT/UNL

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

09/2011

ACKNOWLEDGEMENTS

I want to Thank You All. My loving husband Douglas, my mom Maijaliisa, my brothers Jussi and Ville and my father Jukka. My dearest friend Vivian. My friends in Finland. Colleagues Tara, Jamie, Rita, Chisa, Kojiro, Fernanda, Tiago, Daria, Luis and Sylvie. Amazing Professors and PhD`s in Vicarte, Universidade Nova de Lisboa and Belas Artes. Fernando, Marina Grande and Chrisform. My amazing advisors Teresa, Márcia and José. Visiting Artists. Galeria Diferenca and “Sisu”.

ABSTRACT

These two years have brought lots of richness to my life and to my thoughts and I have learned so much more than just a content of International Master Degree curriculum. By simplifying the situation, Glass Art and Science-program combines Me, Finland and Portugal. There are plenty of differences between Finland and Portugal and I have turned them into moments of personal growth by thinking that it is not about being better and worse, it is about being different.

In the scientific part of the thesis three different experiments are described, how float glass reacts when it is exposed to variable rates of rapid temperature change (thermal stress) and if by controlling the temperature change, the visible consequences (thermal shock) of thermal stress, could be controlled. After experimenting, the results are observed through a Polariscope and different microscopes are used to examine the 'paradoxes' of glass, to see the information it hides.

In the art part of the thesis artists who have influenced and contributed to the subject matter of my thesis are named and spoken about. These studies allowed me to find an express my feelings about being in Portugal during the International Master studies in Glass Art and Science. These were times of confusion and inner tensions as a foreign woman, the shocks caused by cultural differences between 'cold' Finland and 'hot' Portugal, and the total liberation once differences collided and adjusted. These feelings are expressed through my thesis artwork " Thermal Shock – and its perfect imperfections" exhibited in Galeria Diferença, Lisbon, Portugal, from 6th of July until 10th of September.

"Thermal Shock – and its perfect imperfections"-exhibition is part of series of Thesis Exhibitions 2011 from International Master of Glass Art and Science- students, of the Universidade Nova de Lisboa.

Artwork is produced using float glass thermally stressed in controlled ways to prouduce thermal shock.It is further looked at under microscopes, photographed, silk screen images were produced and applied using glass enamels and glass inks, and laser engraving on glass is also utilized. The optical properties of glass offer amazing possibilities to 'extend time' to transform the stillness of something 'frozen in time' like a photograph, returning it to movement again.

Key Words: Thermal Stress, Thermal Shock, Float Glass

TABLE OF CONTENTS

FIGURES AND TABLES

1. INTRODUCTION

These two years have brought lots of richness to my life and to my thoughts and I have learned so much more than just the subject matter of the International Master Degree curriculum. By simplifying the situation, Glass Art and Science-program combines Me, Finland and Portugal.

In the art part of the thesis (1.3 STATE OF ART) artists who have influenced and contributed to the subject matter of my thesis are named and spoken about. These studies (1.3 STATE OF ART, 2.1 STATE OF SCIENCE) allowed me to find and express my feelings about being in Portugal during the International Master Studies in Glass Art and Science. There were times of confusion and inner tensions as a foreign woman, stress caused by cultural differences between 'cold' Finland and 'hot' Portugal, and beautiful liberation once differences collided and adjusted. These feelings are expressed through my thesis artwork " Thermal Shock – and its perfect imperfections" exhibited in Galeria Diferença, Lisbon, Portugal, from 6th of July until 10th of September.

In the scientific part of the thesis (2.1 STATE OF SCIENCE), three different scientific experiments are described. In EXPERIMENT 1, nine pieces of float glass are heated until 550°C and gently quenched into cold water one by one after every 50°C of temperature drop. In EXPERIMENT 2, nine pieces of float glass are heated until 50°C and quenched into cold water after every 50°C of temperature rise. Experiment 3 is a version, where hot float glass is stressed with "ice cube drawing" while glass is inside the kiln in variable temperatures between 150-550°C. The aim in scientific research is to understand how float glass reacts when it is exposed to variable velocities of rapid temperature changes (thermal stress) and whether by controlling the speed and extend of temperature variation, the visual result (thermal shock) of thermal stress, could be controlled. These experiments were carried out to obtain a better control of the visual results of the thermal shock (3. RESULTS AND DISCUSSION). After experimenting, the results are observed through the Polariscope and microscopes to see the paradoxes of glass and its hidden information. Visual information is photographed and transferred as silk-screening on float glass in order to make the stress created by the shock visible.

The life wisdom that German philosopher Friedrich Nietzsche offered us when he said: "What doesn't kill you, makes you stronger" summarizes my feelings well [1]. For me this quote represents the beauty and toughness of life and forms my personal attitude towards challenges. It also relates to a toughened (tempered) glass that is made stronger by thermally stressing it. This tempering technique is applied to my float glass artwork (3. RESULTS AND DISCUSSION) together with thermal stress, thermal shock, microscoping, photography, silk-screening and laser engraving. The optical properties of glass offer me amazing possibilities to extend time, creating a feeling of stillness, as in a photograph, and then returning it to movement again. Temperature and cultural differences with extended moments in photograph have the key roles in this artwork.

1.1. FLOAT (WINDOW) GLASS

The reason why I choose glass as a material for my artwork was because glass is a very mysterious material, that surrounds us every day. It is hard and heavy, and also very brittle and fragile. Glass is a pure, transparent material, but it is made from tempered minerals and rocks such as quartz and limestone. Glass for me has its sides of truth and false [2].

After the revolutionary “molten tin float” process invention by the British Pilkington Brothers, float glass started being mass-produced in large sheets in a range of thicknesses, a technically sophisticated and relatively inexpensive, versatile material. A few of the characteristics of float glass are its virtual flawlessness, transparency and flatness, and those are properties that I needed and used in my glass artwork to create contrast, layers and 3-dimensionality [3-4].

1.2 WINDOW (FLOAT) GLASS

Float glass is also known as window glass. Architects talk about the rhythm of openings in a structure. Small boys get wicked joy in throwing stones at windows. In my country, Finland, windows extend our interior space and increase the amount of natural light during our dark winters. The evolution of windows in Nordic countries has inevitably been ruled by weather conditions, usually four layers of float glass and extremely effective isolation is needed to keep inner and outer temperatures separated. In different climates, from dry Mediterranean to steamy tropical, windows performed different functions and developed in different ways to meet those functional needs [5].

As a Nordic person, I am in some ways, still “looking through four layers” even while I am in a country of two layered windows. My nature is more distant, my personal space is wider, I do not greet people with kisses, I shake hands. Windows are also about light, the views they offer us, and the interface between the smaller world inside a house and the larger outside world. We assume that people outside our window will follow certain unwritten rules; that they will not stare in, or throw stones or climb in from an open window. In a civilized society, windows symbolize mutual trust and respect [6].

When glass is used as the interface between interior and exterior worlds, glass binds, or connects two spaces. Glass art is active. It reflects, refracts and transforms light that passes trough that delicate membrane using all types of glass, technique and language in order to express their vision at that moment. In the last ten to twenty years, artists have been manipulating the float glass in more ambitious ways but in my opinion, there is room for many more discoveries [7].

1.3. STATE OF THE ART

There are plenty of artists who have affected influenced my work. I will introduce briefly in this chapter the most important ones whose work has inspired my own artwork.

1.3.1 REBEKKA KARIJORD

Rebekka Karijord is a Norwegian musician whose artwork I learned about in August 2010. Straight away, I found myself in her lyrics, her music: her artwork. I felt that those words were straight from my life, my heart, from me. Rebekka Karijord is the main source of inspiration for my artwork. Sarah Parthemore Snavely, a Swedish musician from the band “Dag för Dag” describes Karijord her biography:

> “When I first saw Rebekka, I found myself faced with someone raw, not in a raunchy dirt-infused sense but someone new, fresh, open, unbudding. Somebody naked of pretension. And then six months after first seeing her, I saw her for real – on stage – a creature in her true element. The rawness was highlighted, the ruby red of her lips stained with the tales of past hardship, past truths and an aching for the present tense. This is not a woman offering a shield behind which to hide. She demands honesty, as she presents you her one and only life tale through the most crystalline tones I’d heard in a long time” [8].

Karijord`s biography creates a strong understanding in me. I am quoting lyrics from the song: “Wear it like a crown” which is song from the new album called: “The noble art of letting go” (2009). It gives a private insight into my one and only life tale.

> “I don’t know where this fear came from
> how I became so afraid of losing everyone
> never been afraid of being lonely
> now I’m becoming the one I’m most scared of being
>
> I don’t know where this fear comes from
> this fear of failing fear of letting everyone and myself down
> its growing deep into my soul
> making me all paralyzed and cold
>
> It’s two steps forward, three steps back again
> I’ll turn my face against it I won’t run
> Courage and belief are my redeems
> No one else can rescue me it seems
>
> Cause if I don’t follow my heart this time
> I’m gonna forget what this life is all about
> I’m gonna take that path I’m going in on my own
> I’m gonna take that fear and wear it like a crown” [8].

1.3.2 JIMMIE DURHAM

Geoff Isles writes in his article " The Glass Eye – The Float" about his visit to the Armory Show in New York March 2010. On this visit to the Armory show, Geoff Isles found an industrially produced float glass that was deftly handled in the service of significant artistic expression. This expression was from Jimmie Durham who used shattered glass panels to express his frustration with contemporary society. In "Semi-Arbitrary Patterns" (2004), Durham threw a stone at a thick sheet of standard safety glass: the random circular pattern of the fractures represents what he was seeing as the arbitrary nature of politics (FIGURE 1) [9].

FIGURE 1 "Semi-Arbitrary Patterns" (2004), Jimmie Durham [9]

This is how The Armory Show is described on its own web pages [10].

> "The Armory Show is America's leading fine art fair devoted to the most important art of the 20th and 21st centuries. In its eleven years, the fair has become an international institution. Every March, artists, galleries, collectors, critics and curators from all over the world make New York their destination during Armory Arts Week".

Damaging or breaking glass deliberately has always meant a forbidden action of violence for me. Accidental breakage of glass has meant a sad and delicate loss of material. Theodor Adorno has written that: "The impression on ugliness stems from the principle of violence and destruction" [11].

Glass is a material that is once it is broken, cannot be easily restored to its original state. Can once a stone is thrown at glass, that be seen as an act that does not represent something other than violence? Can damage or breakage be other than an ugly and unforgettable action? Is there something more to see, to be construed as constructive rather than destructive?

One of my professors once said: “The people, who work with broken glass are usually the ones who cannot work glass with talent and technique”. I partially disagree with that statement. If I think in that way, I could never see the breaking of glass as anything other than an act of violence and destruction. American artist Ralph Fabri`s way of seeing art is close to mine. He confirms my thoughts about art being so much more than seeing, with its truths and lies:

> “Art is not necessarily a joyful activity, a painting is not great because it is full of happiness: nor is it bad because if it happens to convey a feeling of a tragedy” [12].

From the beginning of my master studies, I was learning to use glass as a material. It is far easier to break a vessel than to blow one. After the work I have done here, I feel that I can become a master in breaking glass in a controlled, technically challenging way.

Making my artwork called “Light Shade” (FIGURE 2) is one of the first works where I explore the idea of broken glass and it introduced me to the optical qualities of glass. In “Light Shade” colored glass was broken with a hammer, the fracturing was not controlled, and images reflected with the help of a light projector were created using those existing pieces and fragments. An Interesting discovery for me in this work was how broken glass extended its physical size and space by reflecting the light outside its contours. The way the light was reflected depended on the shape of the broken piece and where the source of light was positioned. This was the point when I started wondering what else I could do with broken glass and light, and to what extent I could control those two factors. Will broken glass always be unpredictable in its form and appearance?

FIGURE 2 “Light Shade” (2010), Saijjatuulia Kattelus

Glass artist, Heike Brachlow wrote in a book on Contemporary Glass published 2008 about the optical properties of glass, how glass artists extensively play with those properties in their works. The optical properties of glass, when combined with light, result in constant movement and change. This made me wonder about my still pictures of “Light Shade”, how still they really were. Can one image capture more than one moment of time? One thing that bothered me about photographs had always been that they seemed to capture only one moment. But I considered moving images too rich to me. Could I extend that one still moment to convey constant movement using the optical properties of glass? Can two images, taken within twenty seconds, describe two years? [13].

1.3.3 YORGOS PAPADOPOULOS

When I researched further violence as an act of creation, and the breaking of glass, I found an interesting glass artist who controls the breakage of float glass. The article “The beauty of Broken Glass speaks of Yorgos Papadopoulos, who developed a new technique for the controlled breakage of glass while he was a student at the Royal College of Art [14].

Yorgos Papadopoulos web pages show how sheets of industrial float glass are shattered, colored, textured and re-laminated to create architectural-scale artworks that look fragile but meet all safety regulations for public use (FIGURE 3) (See also APPENDIX I). Papadopoulos describes his art with interesting words: ”Works express the in-built paradoxes of glass: that it is commonplace and extraordinary, visible and invisible, dangerous and strong” [15].

This description: “in-build paradoxes in glass” that Yorgos Papadopoulos used, opened my mind to a new way of thinking about glass. As I wrote in an earlier chapter, glass is full of both lies and truths (1.1 FLOAT (WINDOW) GLASS). How can something be visible and invisible, safe and dangerous, weak and strong at the same time? In-built paradoxes in both glass and human beings are something that I find very touching.

FIGURE 3 Coloring shattered float glass and applying the resin. Yorgos Papadopoulos [15]

Papadopoulos has taken breaking the glass to a high level and has been introduced in a book of Contemporary Glass (2008), where he explores issues around the transparent and light-refracting qualities of broken glass. In my opinion, Papadopoulos way of breaking glass is constructive and repeals the thought that violence towards glass would always be an ugly action [16].

1.3.4 ROB KESSELER

Papadopoulos makes “in- built paradoxes of glass” visible for the naked eye by fracturing. Another way of seeing the “invisible” is to use a microscope. Artist Rob Kesseler goes into the microscopic world. His way of connecting art and science fascinates me. He looks inside the structure of plants and finds exotic forms and luscious colors [17] (See also APPENDIX II). I also wanted to see that hidden world as Kesseler did in his work. When I look at Kesseler’s work, although I generally do not understand much about what I am seeing, the experience is for me, still a fascinating one. I consider the microscope a simple doorway to the world of science, but at the same time a very challenging way to really understand what is been seen.

1.3.5 JOCELYNE PRINCE

Jocelyn Prince, a Canadian conceptual artist who visited VICARTE in autumn 2010, has found yet another way of breaking and interrupting surfaces of glass. Her way of using glass in her art was encouraging for me. Prince creates cracks, scars and other deformations in glass by stressing the glass while it is still hot using various materials and processes. Jocelyne Prince’s work called “Slide Library” (FIGURE 4) is a collection of stressed glass panels where the artist compares results to the various imperfections in human beings [18]. This image is from the panel that has been stressed with water.

FIGURE 4 “Slide Library: Watermark Series, detail” (2007), Jocelyne Prince [18]

1.3.6 SUSAN STINSMUEHLEN-AMEND

After breaking the glass in the course of my work, I wanted to bring the fragments together again. Glass artist Susan Stinsmuehlen-Amend uses silk-screening on float glass, silk-screening images onto separate sheets, and then recombining them into a collage. I find her way of working quite inspiring. Her work titled "Looking Back" (FIGURE 5) is a collage of a naked man, cow, interior space, and shopping cart etc. in separate sheets of glass. Her artwork is described in a GLASS magazine in 2007:

> "By mixing circles and waves, human and insects, art history, doodles, and words, Stinsmuehlen-Amend has woven a sort of visual poem on each piece. At their most luminous, the "Vignettes" are spacious, seeming to let air and light into spaces between the panels and giving the works depth and clarity" [19].

FIGURE 5 "Looking Back", Susan Stinsmuehlen- Amend.

That description: "visual poem" with air and light between the panels adding depth and clarity to the work is something that I consider a very important inspiration for my artwork. Although Stinsmuehlen-Amend combines different sized rectangular panels, I experience the entire work as one single image.

2. EXPERIMENTAL PROCEDURES

2.1. STATE OF SCIENCE

To visualize my feelings on float glass I first created this scientific experimental design in order to understand how float glass reacts when it is exposed to different rates of rapid temperature change (thermal stress). I also varied the temperature and physical state of water (water, ice) to increase the thermal shock. This experiment is my way to related scientifically measurable process results to what may happen to human beings, exposed to both temperature and cultural shock as a result of some differences between Finland and Portugal.

2.1.1 THERMAL SHOCK

> “When glass is heated or cooled unevenly, the part of the glass subject to the temperature change will expand (if heated) or contract (if cooled) while the glass at a constant temperature remains the same size. The glass that is changing size will break away from the unchanged piece. That is thermal shock” [20].

The first of the two key factors that determine a material's reaction to thermal shock is that material’s coefficient of expansion. Materials that expand and contract more, as a result of a rise or fall in temperature of a fixed amount, are more likely to change form as a result of that thermal shock than materials with low expansion coefficients exposed to the same shock. The second factor is a material’s thermal conductivity. Materials that conduct heat well are less likely to thermal shock because, by transferring the heat quickly throughout the material, they increase the likelihood that the material will expand or contract evenly. Glass tends to expand and contract quickly when subjected to temperature change. It is also an insulator (when solid) and therefore does not readily conduct heat. That is why glass is highly prone to thermal shock. The best way to mitigate the risk of thermal shock is to heat and cool slowly [20].

2.1.2 TEMPERED GLASS

> “Modern thermal toughening, `tempering` of glass to increase strength was invented by Alfred Royer de la Bastie in 1874: He quenched very hot glass in hot oil. At the moment when the glass `solidifies` the exterior zones are colder than the interior. Therefore, they do not want to contract as much as the interior, which sets them under compression, balanced by tensile stress in the interior. The outer compressive stress acts against the opening of cracks on the surface and, therefore, increases the fracture strength” [21].

2.1.3 EXPERIMENTAL DESIGN

In EXPERIMENT 1 and 2, heated float glass is quenched in cold water. In EXPERIMENT 3, hot glass is stressed with "ice cube drawing" while the glass is inside the kiln. EXPERIMENT 1 and 2 were conducted with a room temperature of 25°C, a kiln temperature ranging from 50 to 550°C and a tub water at 20°C. Each experiment was done three times to obtain scientific reliability.

EXPERIMENT 1 follows a descending series of temperature tests. By this I mean, glass is first heated to above annealing point, and then after being lowered to selected reduced temperatures, thermally stressed by exposure to water. EXPERIMENT 2 involves the glass being subjected to thermal stressing while ascending in temperature, at various levels between 50 to 550°C. This was done to investigate whether the visual physical results of thermal stressing are different when the glass is thermally shocked while it is being raised in temperature to any given point, as opposed to when it is being shocked when the glass has been cooled to the same temperature.

Dimensions of pieces and tools used: 150mm x 150mm x 3mm of float glass, Barracha Pick-up Kiln, Thermometer, aluminum pliers and platter.

2.1.4 EXPERIMENT 1 (E1)

All nine (9) samples are heated up slowly in the pick-up kiln in vertical position until 550°C and kept there for 60 minutes to achieve uniform temperature all over the glass area. After 60 minutes in the kiln, at a temperature of 500°C, the first piece is gently picked up with aluminum pliers and lowered into water of 20°C in an aluminum platter. The piece is left to cool down in water for 1 minute and then placed to dry on a paper. Next, the kiln temperature is brought down to (450°C) in 60 minutes and kept there for 30 minutes. After that time, the same procedure as above is followed, removing the sample and cooling it in water of the same temperature. The identical process is followed at successive increments of 50 degrees C lower temperatures, i.e. the samples are thermally shocked by immersion in water at a fixed temperature for a fixed time period, when the glass samples themselves are at 550, 450, 350, 300, 250, 200, 150, 100, and 50°C.

All the pieces were left in room temperature after cooling in water for one minute. No reheating, annealing was done.

2.1.5 EXPERIMENT 2 (E2)

EXPERIMENT 2 was conducted with the same temperatures but in rising sequence, in the opposite following order, starting at 50°C, then 100°C, etc. Aside from this difference in process, the procedure was identical to that in EXPERIMENT 1.

2.1.6 EXPERIMENT 3 (E3)

As I mentioned earlier in this thesis, this experiment was conducted after getting the results from E1 and E2. Here float glass is positioned in a large kiln with the resistances at the top in a horizontal position. The glass was heated to a temperature that was found to produce the most visually interesting results (250 - 400°C) after the introduction of thermal shock in E1 and E2. When the predetermined temperature is achieved, the kiln is opened and water is splashed onto the float glass in very small amounts. The kiln is then closed for a while to reach a higher temperature and then reopened to splash water again. When the float glass was treated with splashed water to the extent that I wanted, the temperature was then slowly taken up to annealing point (515°C), and then to 720°C, and finally cooled to room temperature in the amount of time necessary for the glass samples to achieve stability.

2.1.7 HISTORICAL CRACKS

After making the experiments above, I discovered a very interesting article: “Hidden information in crack patterns on glass finds” written by Kevin Eggert, that connects my experimental design to historical Roman bottlenecks exhibiting superficial honeycomb cracking (FIGURE 6) [21].

The article suggests that some crack patterns in Roman bottlenecks might be the consequence of intentional processes like thermally toughening or decoration as in ice glass. I was not surprised to read that I was not the first person who ever noticed the beauty of thermally stressed glass, but I am very curious to continue developing my experiments because Eggert writes that there seems to be no overall scientific theory that can explain these contraction crack patterns. Through Eggert`s recount of his experiments, I began to understand some reasons for the cracking resulting from my own experiments. The same superficial network of cracks in the surface region happened because the interior of the glass still flowed like a liquid and no large stresses were built up there. Only in trials at lower temperatures where the entire mass of the glass was not plastic enough, were normal thermally induced fractures found, running through the whole thickness of glass [21].

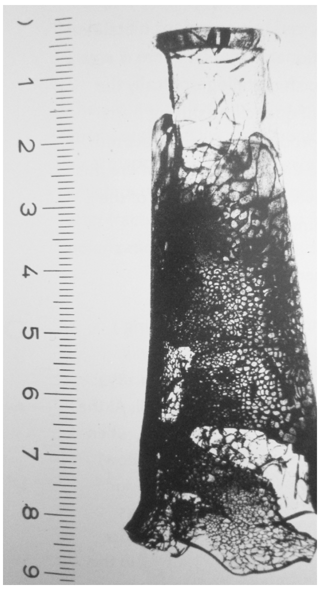


FIGURE 6 “Roman bottleneck with superficial honeycomb craquelure (scale in cm)” [21]

3. RESULTS AND DISCUSSION

3.1 RESULTS FROM E1, E2, E3

Surface changes caused by the thermal stressing of the glass as I have described it in the previous sections showed strong variations that were clearly dependent on the temperature at which the strain was introduced. Above 450°C, the pattern was almost identical, a sort “frosty-honeycomb-matte”. It is possible to see the pattern variation and residual stress (FIGURE 7) in the sample pieces with images photographed through a Polariscope.

Images taken of glass samples from E1 and E2 are photographed with a digital camera (Canon Ixus 200 IS) equipped with polarized lenses, and color tones can vary because of this. Images are from all temperatures at which the experiments were conducted and the pattern of structure change can be seen. None of these pieces cracked and broke, all remained square samples as they had originally been cut. Even after transporting the samples to Marina Grande, where they were analyzed through CRISFORM`S Polariscope Sharple Senarcon Strhin pieces did not fracture.

> “A Polariscope measures residual stress that is an intrinsic tension or compression, which exists in a material without an external load being applied. In glass, the so-called permanent residual stress is induced in the primary manufacturing process and the potential resistance to thermal stresses accessed through the material’s Young Modulus E. These stresses might be relieved through annealing or subsequently added in secondary thermal processing operations to induce desired mechanical characteristics” [22 - 23].

In E1 and E2, stress introduced at 100°C started to produce cracks that had a yellowish color when viewed with the Polariscope to the right and left of the edges of the piece and a bluish color above and below. The interpretation of the colors one sees in the Polariscope is explained in TABLE 1 (See also APPENDIX III). These two colors, yellow and blue, became more evident when temperature went higher, at 100, 150 and 200°C. From 250°C up, the yellow and blue color extended all over the pieces with the existing cracks in and on the surface (FIGURE 7). It seemed that the float glass samples displayed (cracking and stress indicated by the colors when viewed in the Polariscope) thermal stress only near the surface of the glass in tests introducing thermal stress up to an including 200°C. In these, only surfaces and edges displayed cracking and inner tensions. At 250°C, the glass samples seemed to ‘lose their battle’ against thermal stress, to start to give in to cracking little by little. From 300°C to 550°C, the cracks became smaller and spread through the sample, together with the stress signifying colors yellow and blue under the Polariscope, giving an even appearance of fine cracks and color throughout the glass. Stress was now evident throughout the piece, but the piece still seemed structurally intact.

For me, the samples produced at temperatures of 200°C and 350°C are the most interesting. There is still resistance to the thermal shock pervasive tension has almost been triggered, but still the sample has held together. Yellow and blue are distinct and separate at the sides. Tensions and stress have not reached the core; the failure of structure has not been accomplished. Polariscope images are usually employed to locate residual stress in annealed glass but in this study (E1 and E2) there was no attempt to relieve stress, only to introduce stress in glass and to analyze it.

Table 1 Quality Grade Specifications for Annealing

Violet	= very good, no residual stress
Red	= good
Indigo	= passable
Blue	= mediocre
Green	= bad
Yellow	= bad
Greenish white	= very badly annealed, lots of residual stress

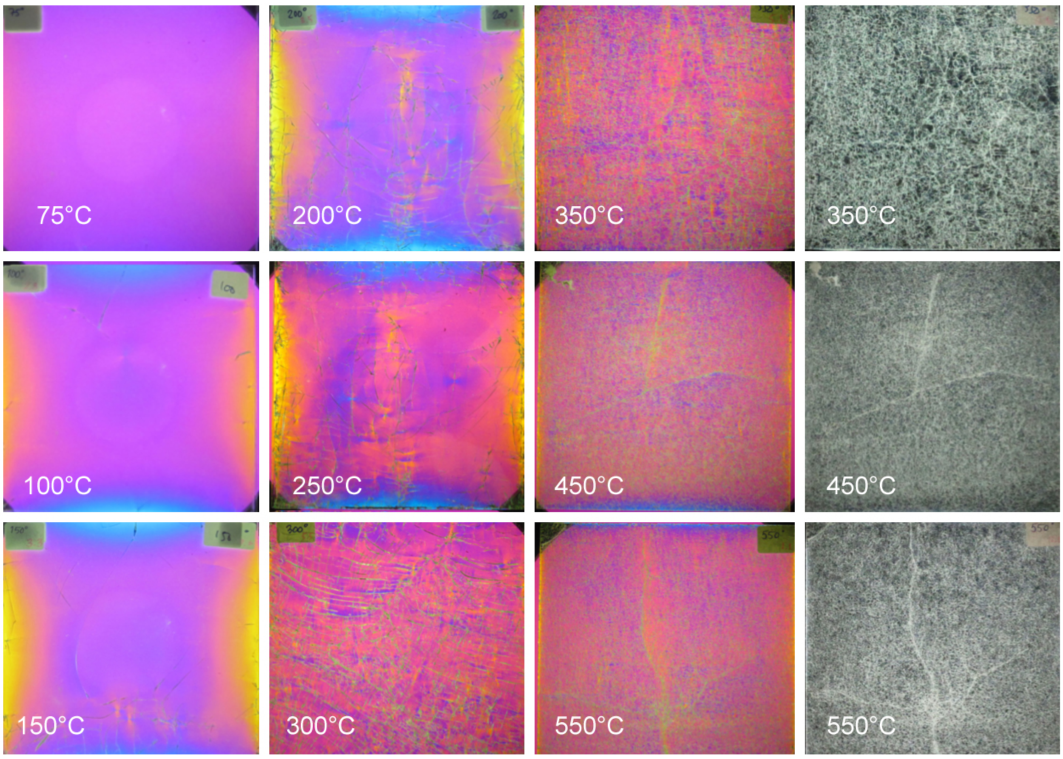


FIGURE 7 Thermally Stressed Glasses photographed through a Polariscope

In E3 I noticed that I needed to be careful not to heat the glass beyond a certain temperature as that resulted in the loss of the change of appearance in the glass caused by the thermal shock at lower temperature. In the case of the Barracha kiln I used for my experiments with resistance wire only at the top of the kiln, I found that I could heat the pieces up to 740°C for 2 minutes. Beyond that, I started to lose definition in the changes caused by thermal shock.

In the course of E3 and the consequences I observed of going to too high a temperature, I found that if I subjected glass I had stressed following the processes described above, to a second cycle of the same process of stressing the results became more visually complex and more stable. The glass is much more likely to maintain structural integrity without disintegrating than if only subjected to one 'stress cycle'. This was a discovery that I put in practice as soon as I made it, starting to raise the temperature first a little too high, and take the sample through a second heating with a lower maximum temperature of 710°C.

The results (E1, E2, E3) show that temperature where thermal stress is introduced in glass, has a huge importance for visible trace results of that stressing in float glass, most notably between the temperatures 150°C - 400°C. Higher than 400°C one starts to see no considerable change in those traces. The same pattern of cracks appears in all samples regardless of the temperature at which stress was introduced. E1, where temperature was raised above annealing point, did not yield different results from E2. In addition, through the comparison between the three repeated sequences of E1 and E2, it suggests that the true heat of glass is more controllable in E2, where temperature is raised step by step to the desired temperature. In E1, because the glass samples and the kiln itself are first raised to 550°C more heat is stored in the system and cooling to the desired temperature is relatively slow. Graham Stone says that the deformation in some glasses starts at 550°C, even though sometimes that deformation is not visible. It is also important to note that the actual temperature inside a kiln doesn't necessary equate that shown on the pyrometer, nor is that temperature necessarily equal in all areas of a kiln [24].

3.2 MICROSCOPES

I used microscopes to view details of thermally stressed glass that cannot be seen with the naked eyes. Tools used and visual results are explained in this chapter.

3.2.1 ZEISS AXIOPLAN 2, IMAGING – HAL100 – HBO100.

This microscope is a reflected-one source light microscope. The sample is illuminated from above through the objective. This microscope was used to see how light was reflected from cracks and scars Filter (Position of illumination, bright field – H) with objective 10x…100um, objective 20x…200um and objective 5x…500um were used. Images are magnified 5, 10 and 20 times bigger images (FIGURE 8).

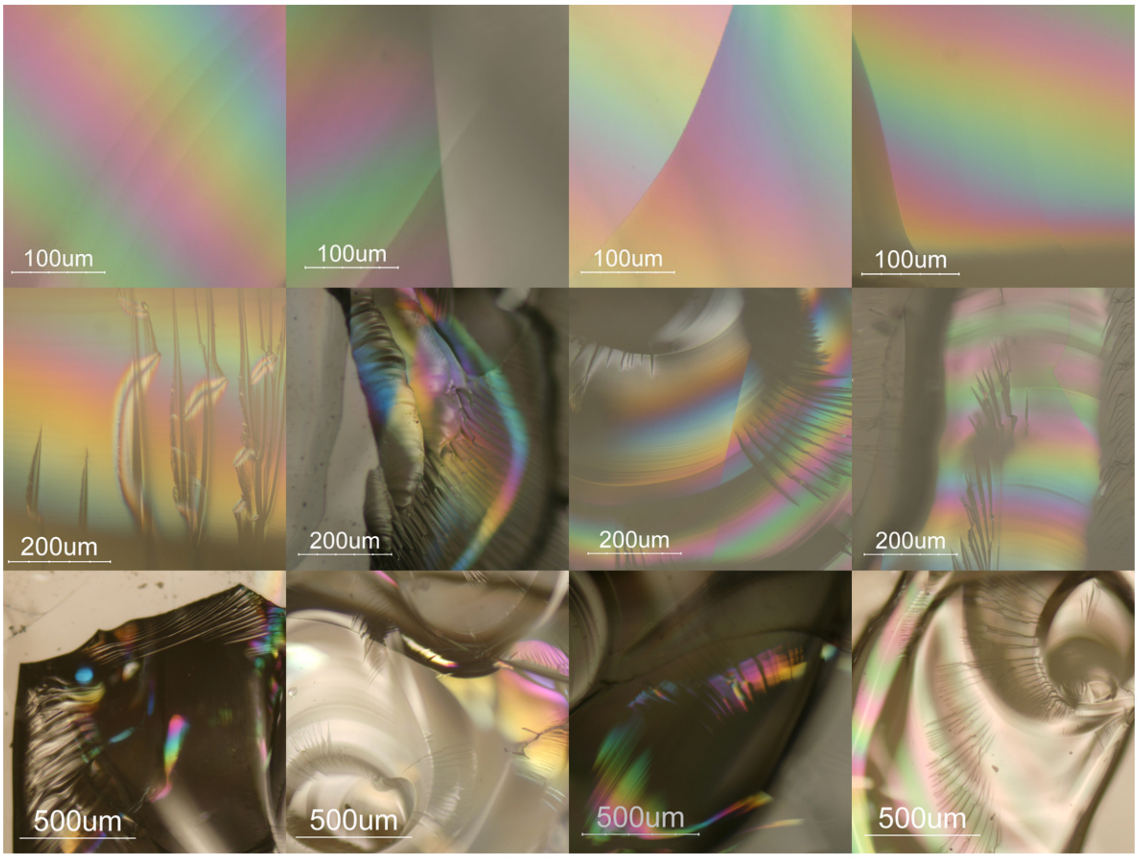


FIGURE 8 Microscopic series (12) of images from light reflections inside the thermally stressed glass

On seeing these microscopic images, I was totally stunned. These images changed my way of thinking about thermal stress in glass, in human beings, and in me. Stress in human beings is normally considered a negative state of being and I was thinking to see something more melancholic and dark. Sharp and light shapes with bright prismatic colors gave me an expression of going in to goldsmith's shop after burglar had smashed the window. Jewelry, diamonds and sparkling stones were my reward. For me, the glass where the thermal stress was limited to the surface areas was already visually very sensuously eye-catching, but now it acquired even more depth.

3.2.2 LEICA KL 1500 LCD

Images were taken with two optical fiber light source microscope. This device was used to study patterns in thermal stressed glass. Images have been taken with added black background and built with Photoshop from smaller images (FIGURE 9).

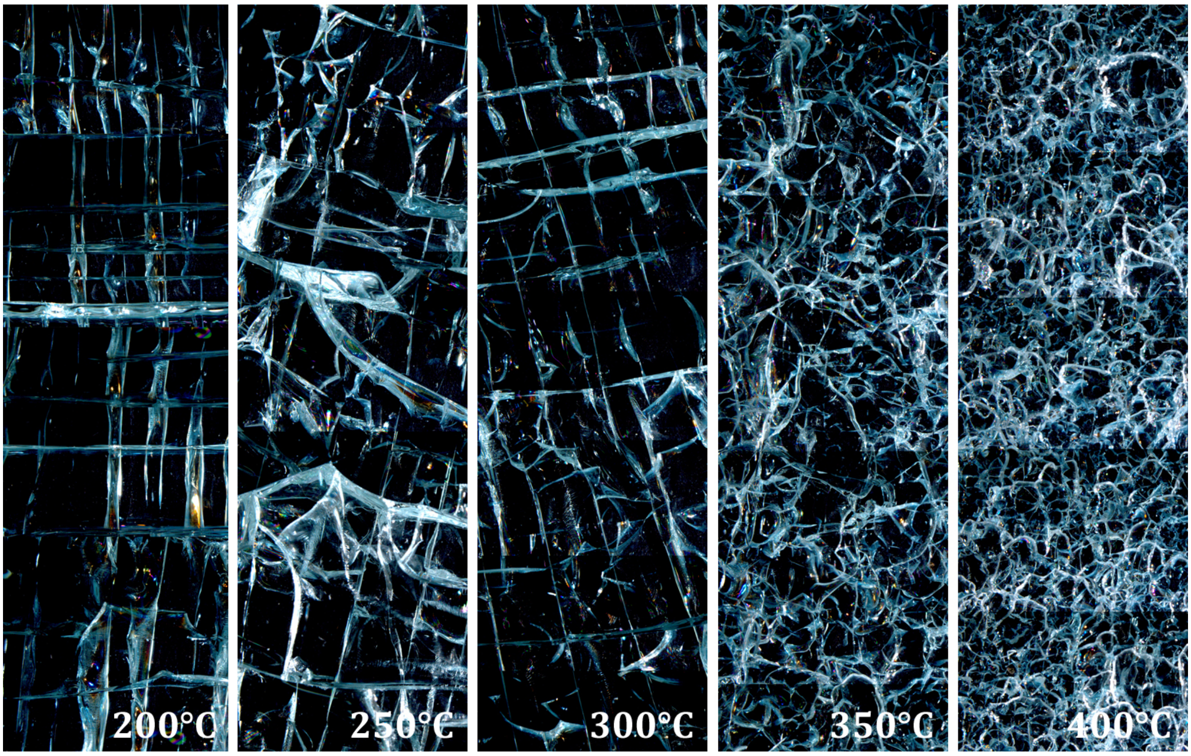


FIGURE 9 Microscopic series of the pattern of cracks by thermally stressing the glass

This time I entered into a space where layers, patterns and shapes of stresses were more colorless, but much more narrative and expressive for me than in FIGURE 8. Staring at these images, I started to see slaves carrying wooden trunks, lizards flying, parrots, men flying with balloons, men trying to support others above them and so on. Again Papadopoulos description of glass as a material with: "In-built paradoxes" was perfect to describe what I was seeing. I felt these images as restless and aggressive. This corresponded to my vision of imagined thermal stress before thermal shock. Maybe it was just because of this black background and contrast, but it made my mind more melancholic. After seeing these images, (FIGURE 8 and 9) I wanted to know more about where those luscious "rainbow"-like colors came from.

3.3 INTERACTION OF LIGHT WITH MATTER

> "In 1676, Sir Isaac Newton, using a triangular prism, separated white sunlight into a spectrum of colors. Such a spectrum contains all hues except purple. Sunlight entering through a slit falls upon the prism. In the prism, the ray of white light is dispersed into the spectral colors. The dispersed ray of light can be projected on a screen to display the spectrum. These colors are produced by refraction. There are other physical ways of generating colors, such as interference, diffraction, polarization and fluorescence" [25].

Colors result from light waves, a particular kind of electromagnetic energy. The human eye can perceive only light of wavelengths between 400 and 700 millimicrons. The human eye only ‘filters’ out most reds and violet. The Carl Zeiss Microscopy Manual states that: “In spite of all technical progress, the eye as the visual organ - its combination with the brain behind it – is the most efficient image-processing system available to date” [25-26].

The colors that I saw in glass after thermal shock are reminiscent in appearance of soap bubbles or the rainbow. The soap bubble phenomenon is called interference. My purpose is not to research this phenomenon further, just to name it. As I mentioned earlier “colors are a particular kind of electromagnetic energy” [25], that means that in describing the colors saw under the microscope, thermal stress had produced electromagnetic energy as colors to enjoy In my glass art pieces. “Earthquakes of mind traps” (2011) (FIGURE 10) three squares of 150x150mm with varying thickness between 3-6mm are employed. These pieces were made possible through the knowledge gained in EXPERIMENTS 1-3. The pieces are tack-fused afterwards.

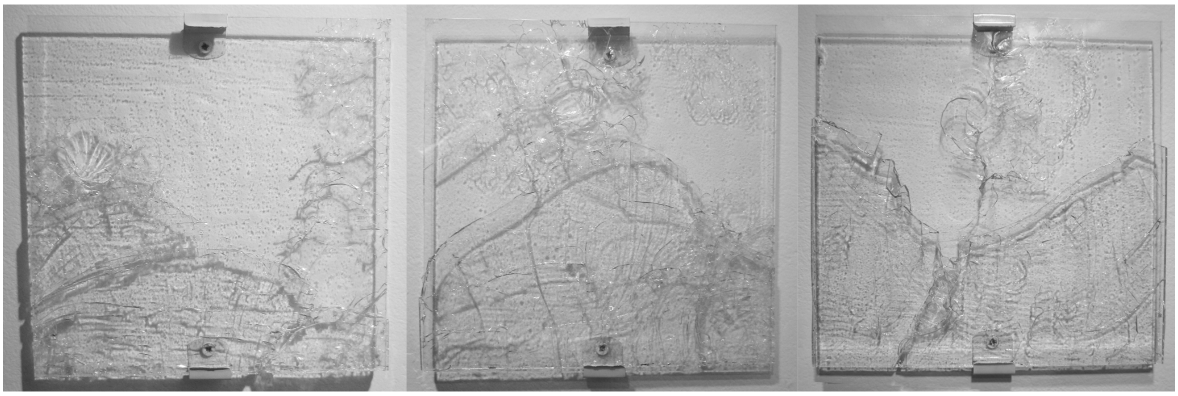


FIGURE 10 “Earthquake of mind traps” (2011), Saijjatuulia Kattelus

These pieces show strong and stable bedrock that can shake if inner tensions are too strong to handle. Cracks in every artwork of mine refer to the feeling after thermal and other shocks. It is about the beauty of understanding the inability to control the real matters of nature and the earth and human beings. Mind traps are states that occur when differences between cultures create misunderstandings and confusion. After the bedrock shakes, they are all relieved.

This for me is analogous to cultural differences I experienced. I experienced confusion and inner tensions as a foreign woman arriving and living in Lisbon, stress caused by cultural differences between ‘cold’ Finland and ‘hot’ Portugal and beautiful liberation once differences collided and adjusted. This artwork “Earthquake of mind traps” tells about that moment after collision and adjusting, where confusion and tensions are relieved.

3.4. TACK – FUSING

This method involves heating different pieces of glass until they become molten and fuse together. This sounds wonderfully simple, but different types of glass have different chemical compositions and annealing requirements, and expansion characteristics making it challenging. In addition, different kilns have very different heating characteristics; pyrometers are very often inaccurate with respect to actual temperatures in the kiln. In short, fusing glass is complex. That complexity has been the downfall of many ambitious efforts to fuse glass. After coming out of the kiln, sometimes LONG after, the fused glass will sometimes suddenly crack or fracture [27]. I used consistently only one type of glass in my thesis artwork, so I do not have incompatibility problems. Usually two glasses are considered compatible when the difference between their thermal expansion coefficients (COE) is less than $0.5x10^{-6}$ C^{-1} [28].

My main technical challenge was to find out the right temperature to fuse pieces together without losing the reflecting optical properties of the thermally stressed glass. In my artwork "Earthquake of mind traps" (2011), (FIGURE 10), glass is heated to 300°C and thrown into cold water. Pieces are broken and set on the top of the plain float glass in a large Barracha kiln with the resistances at the top. Components are fused together following the temperature schedule below (TABLE 2).

TABLE 2 Firing Profile for Tack-Fusing used in Figure 10

FIRING PROFILE	TEMPERATURE °C	TIME min
STEP#1	450	30 raising
STEP#2	515	30 raising
STEP#3	680	30 raising
STEP#4	720	10 raising
STEP#5	720	5 staying
STEP#6	515	30 (as quickly as possible)
STEP#7	515	60 holding
STEP#8	450	120 (kiln is switched off, cooling to 100°C in whatever time that takes)

I noticed that fusing at too high temperatures caused the pieces to lose reflections and refractions I had obtained by thermal stressing. By experimenting, I found that the right fusing temperature for float glass is the one that just tacks the pieces gently together. To find this temperature, many trials were made, and I discovered that a temperature of 720°C held for 5minutes worked well. Here is good to notice that temperatures are always dependent on the type of kiln used, the type and thickness of the glass being fused, the position of the glass in the kiln relative to the heating elements. Tests must always be made to arrive at the proper conditions.

Since the use of kiln-formed glass in architectural glass art is still in a relatively early stage, the artist who can take the most daring approach is the one who has practical knowledge of the different temperatures and rates for heating and cooling glass, which vary according to the size, depth, surface area and composition of the pieces [27]. This is something that I find very encouraging, that float glass still has many undiscovered areas to research and work with.

3.5 SILK-SCREENING

Printing on glass first emerged in the eighteen century and is now an important technique for both industrial and artistic practice. Over the last 250 years, glass and print processes have offered various solutions for the decoration of glass. Screen-printing is perhaps the most common method of printing on glass. It allows for the production of a broad range of imagery, from a very loose hand-drawn style to photographic images and text. It is particularly useful for printing flat sheets of glass [29].

Paulo Lourenco from the Faculty of Belas Artes University of Lisboa prepared screens for my print work on glass. Traditionally the mesh of a screen for printing was made of silk, hence the origin of the term silk-screening. I selected mesh size 120, which allows me also to reproduce fine and smooth lines. I had to keep in mind that inks and enamels for glass might be more viscous than inks for paper, and so I wanted to be sure that colors would pass the mesh. The frame with the selected mesh stretched over it, was treated with light sensitive emulsion and left to dry. After drying, the frame was positioned under UV-lamps, with the desired black and transparent design being placed directly over the emulsion and weighted down to maintain a close contact with it. The black areas of the design will be washed away from the screen after exposure to light, the areas on the design that were transparent, will be hardened and won’t wash away from the emulsion layer on the screen. When printing, the black areas will be the areas where the ink or enamel can pass through the mesh because there is no emulsion layer on the screen there to stop that passing. Enamels are forced through the screen with the help of raclette, which is a tool a bit like a squeegee, made especially for silk-screening. You can see some designs I used in my work in APPENDIX IV and V. Designs are selected from the images taken using the ZEISS and LEICA microscopes. Images are threshold treated with Adobe Photoshop.

3.5.1 ENAMELS, COLORS

Enamel paints consist of powered metal oxides mixed with powered glass. When fired in the kiln, they fuse with the glass surface on which they are applied by brush, silk screening or quite a number of other possible application methods. After the enamels are applied, the glass may be fired and annealed in the normal way [30].

I made some color tests with transparent glass inks and opaque glass enamels. One thing that I found problematic in addition to change in color after firing was that when I applied to the glass surface, it pulled back together as a water drop, it did not spread as an even thin layer. I tried to reduce this phenomenon called surface tension by mixing gum Arabica as a medium with enamel and water. It helped a little and results after firing were smoother than before. I used gum Arabica also with glass inks and the results were very smooth and well bonded. Another problem I encountered was that when removing the silkscreen frame from the top of the glass. The mesh caused a kind of “suction effect” sometimes causing the enamels to appear more grainy and uneven after firing. After some color experiments, I choose yellow and blue inks as my working colors. These were transparent, water base and translucent glass inks from Ferro Company.

> “The Artist is interested in color effects from their aesthetic aspect and needs both physiological and psychological information. Discovery of relationships, mediated by the eye and brain, between color agents and color effects in man, is a major concern of an artist. Visual, mental and spiritual phenomena are multiply interrelated in the realm of color and the color arts” [31].

Because float glass is flat glass, I also experienced silk-screening very 2-dimensionally. In the early stages of developing this thesis artwork, I intended to integrate (by printing for example) photographs onto float glass to make 2-dimensional glass more 3-dimensional, but I later found this too direct a way of showing my feelings and thoughts. I have always photographed a lot and images are very important way to express myself. This time I wanted to learn and try something new, and try to use the 2-dimensional images in layers to insulate the feelings inside the glass. I chose yellow to symbolize the warmness of Portugal and blue for the cold Finland. In addition yellow and blue are the colors I described seeing under the polariscope that indicate the highest degree of residual strain in glass! Those colors symbolized for me in the best possible way my feeling of being in Lisbon as a Finn. Blue and yellow are also antagonistic to each other and visually complementary colors. The psychological value of a color is a very important aspect of the impact of a work of art. It is true, that colors can affect us emotionally. The emotional values, which we give to colors, make us realize that color is not experienced alone but with an object. Color and color associations are an essential part of the total design [32].

I applied blue and yellow prints on plain glass sheets, low-fired them (530 - 600°C) and after annealing the pieces were heated again and thermally stressed by splashing water on them as described in E3 at the desired temperature (FIGURE 11). Silkscreened sheets were positioned in layers, giving air and space between them.

FIGURE 11 "Antagonists" (2011), Saijjatuulia Kattelus

After this, different tones of greens were mixed with existing blue and yellow and printed on plain sheets of float glass. My art work "Understanding" (2011) (FIGURE12) is listed last in my exhibition for a reason (APPENDIX VI). Mixture of yellow and green alludes to compromise an extended moment of collision and adjusting. All my exhibited works have black frames except "Earthquakes of Mind Traps" (2011). I did this to indicate that only certain points of thermal shocks are shown and they are selected and pointed out carefully.

FIGURE 12 "Understanding" (2011), Saijjatuulia Kattelus

Pieces in FIGURE 11 and 12 are glued together with UV-glue. This is an area in which current technology has been of the greatest benefit to artists working in glass. Clear silicon, resins, epoxies and ultra-violet glues now on the market make it possible to adhere almost any type of glass to another [33].

3.6 LASER ENGRAVING

Laser engraving is quite an expensive technique to use, but it has many possibilities on glass because of the engraved imaged retains transparency. Being interested in photography and playing with Photoshop, laser engraving become a very interesting tool for me. I had been bored for a long time with standard photography because the final image on paper seemed to remain so inactive. I was additionally not interested by the possibility of simply transferring a photographic image straight onto glass. I wanted something more complex and clever. This question, the selection of techniques that suit an artist and the themes the artist deals with is touched on by Rene Huyghe:

> “When the artist looks at nature, he deliberately selects a certain subject rather than another. This choice is itself already the affirmation of his own sensibility, of his own personality. Conversely, there can be found in these lines, colors and shapes of his invention, not only a quest for beauty, but also the imprimatur of the artist’s own inner and visible nature. By creating that image which is the work of art he makes it visible for other people” [34].

I photographed my colleagues at University and asked them to pose for me in a way that would depict their answer to my question: “How this Master has made you feel?” I asked for two poses, but usually got more after the initial confusion. With this work, I discovered that with two images I could capture more than just two poses. I succeeded in my attempt to ‘capture time’ for longer than just those 20 seconds it took to create these images. As Umberto Eco writes: “We can measure time, but this gives us no guarantee that we understand what time is” [35]. This for me offers a very good description for this artwork. Is it time that I am really measuring and extending here? And why do I want to make it longer than a moment? And how is a moment measured? I think that because I know the people I photographed here, I can try to capture all of their characteristics in two images, and when I succeed, the images I get capture more time than just a moment in time.

This artwork “How this Master has made you feel?” (2011), where seven colleagues of mine are posing for me can be seen in APPENDIX VII. Every photograph of each person becomes a single work and the works are positioned randomly, just making sure that there will be one empty gap between. That gap is for Chisa, who was in Japan and could not take part. It also shows that even if one of us is not present; we keep the place for her or him. I chose to further develop this theme by using the photo of Fernanda, a Portuguese woman and fourth person from the right in APPENDIX VII. I increased the size of the image of her to use in the work: “Stress1” to better focus on some details in that image.

My work “Stress1” (2011), is an image of Fernanda (FIGURE 13), titled with a number and not with a name to make clear that actually these images are not only about the selected persons, they are also expressions of my own my thoughts and feelings. Fernanda`s life experience is broad; she accepts unpleasant things in herself, in others and in her country. Through the use of her faces I could express some of my very personal feelings about this Thermal shock; how small things sometimes seen with a magnifying glass can become bigger and more problematic. This work speaks also about my concentration on science and it’s challenging state, and about asking forgiveness when all the energy has been used.

FIGURE 13 “Stress1” (2011), Saijjatuulia Kattelus

I have chosen the next two persons as subjects for works I made because they are two most important persons in my life here in Lisbon. They have stood by me, taking care of me, carried me, loved and respected me during the whole time I have been here. They are my husband Douglas (FIGURE 14) and my very good friend Vivian (FIGURE 15). They are the light in my dark moments, understanding my experiences. They have given me the assurance that I have the right to my own personal feelings, when others have dismissed or underestimated my experiences.

While choosing the colors for my artwork: “Antagonists”, I was very aware that blue and yellow are antagonistic to each other as nerve impulses but visually, they are complementary colors. This relates very well to my experiences and feelings here in Portugal. I am a Finnish immigrant. I might be treated complimentary but the true nature is antagonistic. Denying the problem of bad behavior towards someone is not the solution for the problem. Admitting our own faults can start the development towards equal, open-minded co-operation.

Through this work, “Stress2” (2011) (FIGURE 14) I am expressing visually my opposition towards the unconcerned and careless behavior I have experienced in Portugal towards a black Brazilian man. This behavior goes back in history, to the time when Brazil was a colony under Portuguese rule and Portugal took natural and human resources from Brazil to enrich their own country. Brazilians have had to work long and hard to get their country back on its feet and finally. After that long, hard work, Brazil is becoming an important country in the world, leaving Portugal behind it.

FIGURE 14 “Stress2”, Saijjatuulia Kattelus

Vivian is my closest friend in Lisbon and we have been a very important support for each other during these two years of the Masters study in Lisbon, Portugal. Vivian is also Brazilian and she has been with me witnessing situations, when unfair behavior has occurred. She has said to me, that before meeting me, she did not have an idea, how it is to be blond in a Latin country, where men follow you everywhere, shouting, whistling, touching you. And where, as a result of that women become jealous, angry and bitter towards you. That kind of behavior happens mainly with so called adult people. Yes, everyone who reads this thesis can perhaps wonder: ”Who does this woman she think she is?” My answer to that is: “ I know who I am, but who do you think I am?” I have positioned led lights as part of my artworks “ Stress1, 2 and 3”, the lights have switches so that they can easily be turned on or off. These are the spotlights that I feel I am under.

In this work, “ Stress3” (2011) (FIGURE 15) Vivian is sharing my feelings, taking some weight from my shoulders. At the same time, this artwork speaks about me, trying to close my eyes and mind off from unpleasant experience, trying to keep myself strong enough to work through this difficult time so that I can just return home, where I am respected and treated fairly again.

FIGURE 15 “Stress3”, Saijjatuulia Kattelus

The word “frosted” describes the light diffusing, mat white surface produced by the even abrasion of the surface of glass. That is what the laser engraver does. In these three artworks, I have used the same techniques. The lower layer of glass has been laser engraved and afterwards tempered glass has been positioned and tack-fused on top of the laser-engraved images. The reason why tempered glass is positioned directly on top of the subject’s hair is because hair for me is the crown with diamonds of a human being. Without our crown we have lost our pride. Again, from Rebekka Karijord`s song “ Wear it like a crown”…

> "..Cause if I don't follow my heart this time
> I'm gonna forget what this life is all about
> I'm gonna take that path I'm going in on my own
> I'm gonna take that fear and wear it like a crown" [36].

I am sure that when people move to another country, everyone has their good and bad moments and that is natural. However, it is not natural if you do not have permission to feel hurt after you have experienced something bad. Everyone has the right to feel their feelings, no matter who they are, despite the free choice to come and live as an immigrant in foreign environment and culture. I do not know if this is a question of being an immigrant or more a question of being me, a blonde Finnish woman in Lisbon, but it hurts in any case, when people underestimate one's experiences and deep feelings. The solution for this is not to say: "If you are not happy, return to your country". The solution is that we all learn to take others seriously, and treat them with respect, regardless of their origin, gender or way of being.

In order to really understand my graduate thesis artworks, you must be able to look deeper than the surface and follow an amazing thought of René Huyghes:

> "If you want truly to advance, you must not just go forward, but you must aim at transcending your very self. Such is the great lesson of art. That is why you must learn to read pictures, not only discover in them superficial entertainment, those more or less frivolous pleasures which they give the eye, but in order to discover that they are pregnant with substance and particularly with the wealth of the human spirit. Where else could we better learn the essential lesson of life? The only complete man is he who can join to his gift of lucid action the power to descend fearlessly into his own depths, where he can direct them and use them and weigh them for his own benefit" [37].

4. CONCLUSIONS

I can conclude as a result of this research that it is possible to control the thermal stress and its visible results, thermal shock. As a result of EXPERIMENTS 1 and 2, where heated float glass was quenched in cold water, I discovered that the most interesting visual results were obtained between 200°C and 350°C. Between those temperatures the visual results were specific type which I'd call "predictably unpredictable". With EXPERIMENT 3 where hot glass was stressed with "ice cube drawing" while the glass was kept inside the kiln at temperatures between 200- 550°C, the results were more specific. It was possible to draw on larger areas, but not in very detailed way. Below 200°C the glass exploded quickly into big pieces. In this experiment if the glass was stressed by 'ice cube drawing' at or above 500°C the glass sample simply developed a whitish mat surface.

I conclude that when glass is exposed to thermal stress, the visual result is largely unpredictable, but with practice, I was able to achieve repetition in certain forms. This I was able to achieve more easily at higher temperatures (350-550°C) than at lower ones (150-350°C).

With respect to what I have noted about the extension of time in my photographs, I was surprised to discover how layered images worked to deepen the expression of that effect. However, any conclusions about the concrete extension of time I achieved is impossible for me to suggest or quantify. Humans feel different feelings at different moments and maybe that is the essential nature of this time-extension.

From science, I found strong facts, useful to my art. Even though I consider science a cold world, I found that I was able to heat it up to suit my artistic temper. After the experiments I conducted and described here, I found that the collaboration between art and science is not only possible, but became fundamental for my written thesis and artwork. In my graduate artwork, the interaction of art and science became like measuring the depth of my being. One cannot be measured without the other. Paradoxes in art, in science, in humans, in glass, are amazing worlds to discover together.

This International Master program of Glass Art and Science has the potential to grow and to produce interesting results. Having been a member of the first graduating class of this Master, I accept its imperfections, and I hope that we students were not the only ones to learn. I hope that we also thought and gave something back to our Professors. The world of scientists is very different from the world of artists, it is not about being better or worse, it is just different.

I feel that professors and students should know each other's backgrounds and history a little more, that students could then be better guided to the right fields of science and art. I do not believe that humans can only make art inside the University and I think students should be encouraged to live their personal lives alongside their studies. More than anything else, students should be encouraged to think about who they are as individuals and made to understand that Art is not only created by happy-hippies. Art can, for example, be created by a successful businesswoman, who has her clothes clean and ironed. Art is a universal language just as Science is. We need to be aware of what happens in the world at the same time we study art and science.

We all can say that we are different from the others artists and scientists and that our work is unique. I will not deny anyone the right to think and feel this. Even I, a Finnish person, who is not predisposed by her cultural upbringing to often or easily give credit to herself, can say that I think my work is very unique and that I have really succeeded well. Dedo von Kerssenbrock-Krosigk, who is the curator of the Glasmuseum Hentrich, Stiftung Museum Kunst Palast, in Dusseldorf, Germany, told me after seeing my artwork that he has never seen this kind of work before (FIGURE 10).

I think this thesis research into thermal stress and shock in glass could be taken much further, even be the subject of a doctoral thesis. And just to be more Finnish and organized, I knew before I came to do this study that in the future I would have a Kiln at my disposal and that I would be able to continue this work that I have started here in Lisbon. I have caught myself already recently a few times thinking “It is a shame that I figure this all out just now, when I am so close to the end” but quickly realizing with a pleasant feeling, that I was clever enough to make sure I could continue after my studies, before I started them here.

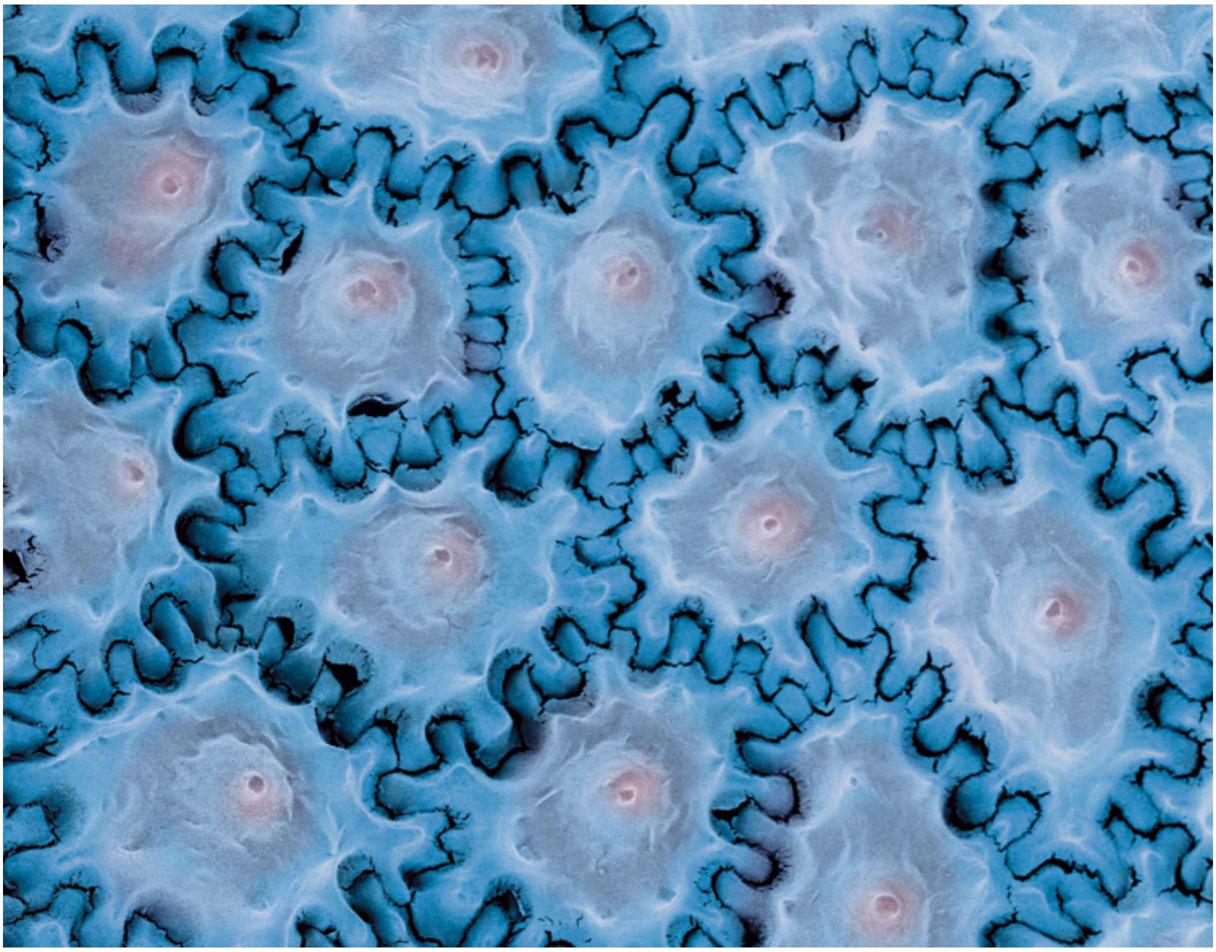
If I am very honest, these two years in Lisbon Portugal as Finnish woman have been very challenging and sometimes even a harrowing experience for me. I can never thank enough the people who have been there for me, helping, understanding and supporting. I also thank the people that have not been so helpful, with whom I have experienced some of the worst moments, because I have also learned many things from those situations.

I conclude that this “Thesis” has developed my thought and skills very many times; that I have started to consider that this journey has become as important as the result itself.

APPENDIX I

““OWD VII” (2004), 2.4m x 0.7m (each panel) - Private pool London UK, Yorgos Papadopoulos, Image taken from artist web page: http://www.yorgosglass.com 14.7.2011.

APPENDIX II



"Allium-seed", Rob Kesseler. Image taken from Artist web page http://www.robkesseler.co.uk 14.7.2011.

APPENDIX III

Especificações da Qualidade

Grau de Recozimento

1. Objectivo

Definir os limites de aceitação do Grau De Recozimento das peças de vidro

2. Observações ao Polariscópio

Cor	Classificação
Violeta	Muito Bom
Vermelho	Bom
Anil	Passável
Azul	Medíocre
Verde	Mau
Amarelo	Mau
Branco esverdeado	Muito Mau

3. Observação no Polarímetro

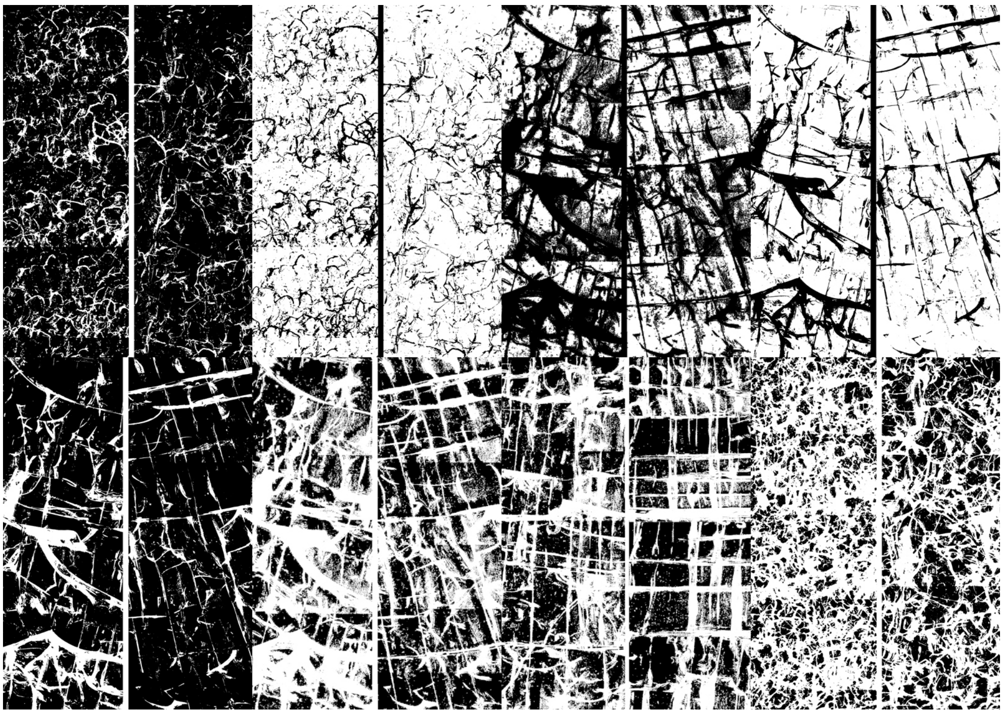
Cor	**Graus de rotação (Retardação Óptica)**	**Grau Recozimento**	**Conformidade**
Verde amarelo	85	**C**	**Não Conforme**
Verde claro	73	**C**	**Não Conforme**
Verde	60	**C**	**Não Conforme**
Verde escuro	50	**C**	**Não Conforme**
Azul/Verde	40	**B**	Conforme
Azul	25	**B**	Conforme
Azul escuro	12	**B**	Conforme
Violeta/Azul	7	**A**	Conforme
Violeta/Vermelho	0	**A**	Conforme
Vermelho	7	**A**	Conforme
Vermelho/Laranja	12	**B**	Conforme
Laranja	35	**B**	Conforme
Laranja/Amarelo	40	**B**	Conforme
Amarelo Ouro	50	**C**	**Não Conforme**
Amarelo	60	**C**	**Não Conforme**
Amarelo claro	73	**C**	**Não Conforme**
Branco	85	**C**	**Não Conforme**

Sidónio Silva 1999

APPENDIX IV

Stencils for silk-screening (images taken with microscope ZEIZZ)

APPENDIX V



Stencils for silk-screening (images taken with microscope LEICA)

APPENDIX VI

TECHNICAL INFORMATION (EXHIBITED WORKS)

1. “Antagonists” (2011)

   2 pieces, silk screened and thermally treated float glass

2. “Stress1” (2011)

   laser engraved and tack- fused float glass, led-light

3. “Stress2” (2011)

   laser engraved and tack-fused float glass, led-light

4. “Earthquake of mind traps” (2011)

   3 pieces, thermally treated and tack-fused float glass

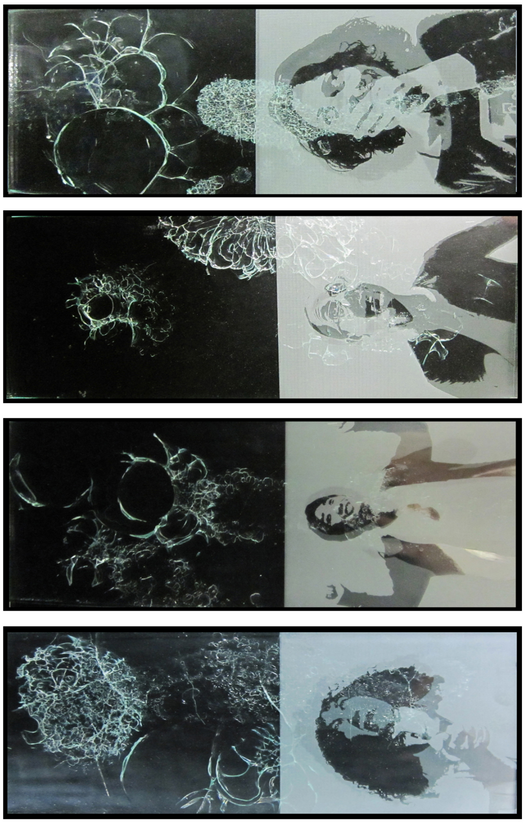
5. “Stress3” (2011)

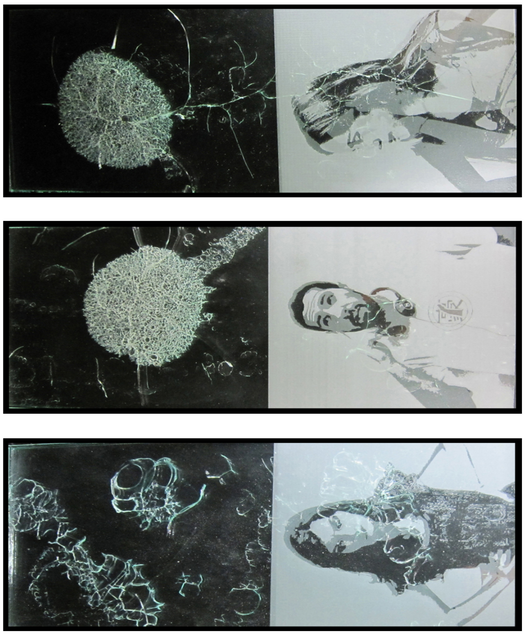
   laser engraved and tack-fused float glass, led-light

6. “Understanding” (2011)

   silk screened and thermally treated float glass

APPENDIX VII





" How this Master has made you feel?" (2011), Saijjatuulia Kattelus

[1] Laine, Jarkko. Suuri Sitaattisanakirja, Otava 1989, Finland. P.32.

[2] Moor, Andrew. Architectural Glass Art, Form and technique in contemporary glass. Published by Mitchell Beazley, Reed International Books Limited 1997. P.13.

[3] Klein, Dan; Lloyd, Ward. The History on Glass. Orbis Publishing Limited 1984. Forward: Robert Charleston. P. 243 – 244.

[4] Moor, Andrew. Architectural Glass Art, Form and technique in contemporary glass. Published by Mitchell Beazley, Reed International Books Limited 1997. P.25.

[5] Innes, Jocasta. Windows - the complete art of window treatment. Practical instructions by Cassandra Kent.Orbis Publishing Corporation 1986. P.9.

[6] Innes, Jocasta. Windows - the complete art of window treatment. Practical instructions by Cassandra Kent.Orbis Publishing Corporation 1986. P.9;20.

[7] Moor, Andrew. Architectural Glass Art, Form and technique in contemporary glass. Published by Mitchell Beazley, Reed International Books Limited 1997. P.10; 26

[8] Karijord, Rebekka. In the Internet: http://rebekkakarijord.com/biography/ Writer: Parthemore Snavely, Sarah. 25.3.2010 Stockholm, Sweden. Taken 12.7.2011.

[9] Isles, Geoff. Article: "The Glass Eye - The Float". GLASS, The Urban Glass Art Quarterly, No. 119, Summer 2010. Published by Urban Glass: New York Contemporary Glass Center. P.16. Image taken from P.19.

[10] The Amory Show. In the Internet: http://www.thearmoryshow.com
America's leading fine art fair devoted to the most important art of the 20th and 21st centuries. Taken: 17.5.2011.

[11] Adorno, Theodor W. Aesthetic Theory. Adorno, Gretel and Tiedemann, Rolf. Editors, The Athlobe Press, London 1997. Newly translated Hullot-Kentor, Robert. P.46.

[12] Fabri, Ralph. Color a complete guide for artists. NY: Watson-Guptill Publications,1967. P.6

[13] Brachlow, Heike. Article: "On Color, Glass and Light" for "Surface/Light"-section, Contemporary Glass, The Artist and Authors. Black Dog Publishing Limited 2008, London, U.K. P.85.

[14] Article: HourGlass: "The Beauty of broken glass". GLASS, The Urban Glass Art Quarterly, No. 101, Winter 2005-06. Published by Urban Glass: New York Contemporary Glass Center. P.20.

[15] Papadopoulos, Yorgos. In the Internet: http://www.yorgosglass.com/index.htm
Taken: 15.5.2011.

[16] Papadopoulos, George. "Surface/Light"- section, Contemporary Glass, The Artist and Authors. Black Dog Publishing Limited 2008, London UK. P.112.

[17] Rob Kesseler. In the Internet: http://www.robkesseler.co.uk/index.php/about
Taken: 15.5.2011.

[18] Prince, Jocelyne. In the Internet: http://jocelyneprince.com/
"Slide Library: Watermark Series, detail" (2007). Photo: Litherland, Paul. Taken: 20.4.2011.

[19] Buckley, Annie. Article: "Reviews – Susan Stinsmuehlen- Amend". GLASS, The Urban Glass Art Quarterly, No.108, Fall 2007. Published by Urban Glass: New York Contemporary Glass Center. P.85.

[20] Tarlow, Paul. In the Internet: http://www.glassfacts.info/indexf286.html?fid=210
Published 14.8.2005. Taken: 28.4.2011.

[21] Eggert, Kevin. Article: "Information hidden in crack patterns on glass finds". Glass Science in Art and Conservation. 19-20 September 2005. An International Conference, New University of Lisbon, Campus Caparica, Portugal. Published by ITN and Universidade Nova de Lisboa, Faculdade de Ciencias e Technologia. PP.47-50

[22] Bartener, M. The Structure and Mechanical Properties of Inorganic Glass, Wolters-Noordfoff Editors, Groningen, The Netherlands, 1970.

[23] Research Article: " Stress Analysis in Glass Artwork" written by Joao M. P. Coelho, Catarina Silva and Teresa Almeida. Hindawi Publishing Corporation, International Journal of Optics Volume 2011, Article ID 215404, 7 pages. Doi: 10.1155/2011/215404. P.1.

[24] Stone, Graham. Firing Schedules for Glass. First Edition Melbourne, 2000. PP.21-25.

[25] Itten, Johannes: The Art of Color - The subjective experience and objective rationale of color. Translated by Ernst van Haagen. Reinhold Publishing Corporation, New York 1961. PP.16-18.

[26] Microscopy from the very beginning, Carl Zeiss Mikroskopie - Manual. P.2.

[27] Moor, Andrew. Architectural Glass Art, Form and technique in contemporary glass. Published by Mitchell Beazley, Reed International Books Limited 1997. PP. 55-58.

[28] Navarro, J.M.F. El Vidrio, Consejo Superior De Investigaciones Científicas, (2ª edition). Spain, 2003.

[29] Petrie, Kevin. Glass and Print, Glass Handbook, A&C Black Publishers Limited 2006, London, UK. P.12, 42.

[30] Moor, Andrew. Architectural Glass Art, Form and technique in contemporary glass. Published by Mitchell Beazley, Reed International Books Limited 1997. PP.41-43.

[31] Itten, Johannes: The Art of Color - The subjective experience and objective rationale of color. Translated by van Haagen, Ernst. Reinhold Publishing Corporation, New York 1961. PP.16-18.

[32] Gerritzen, Frans. Theory and Practice of color – A color Theory Based on Laws of Perception. Studio Vista Publishers, London 1975. PP.167-169.

[33] Moor, Andrew. Architectural Glass Art, Form and technique in contemporary glass. Published by Mitchell Beazley, Reed International Books Limited 1997. P.29.

[34] Huyghe, Renè. Three lectures on Art. National bank of Egypt, Cairo 1965. Printing office of the French Institute of oriental archaeology. Translated from the French by Magdi Wahba. P.62.

[35] Lippincott, Kristen with Eco, Umberto, E.H Gombrich and others. The Story of Time. Holberton, Merrel. Publishers London in association with National Maritime Museum.

[36] Karijord, Rebekka. In the Internet: http://rebekkakarijord.com/biography/ Writer: Parthemore Snavely, Sarah. 25.3.2010 Stockholm, Sweden. Taken 12.7.2011.

[37] Huyghe, Renè. Three lectures on Art. National bank of Egypt, Cairo 1965. Printing office of the French Institute of oriental archaeology. Translated from the French by Magdi Wahba. P.81