MAKING 'GLASS ROAD' MUQARNA WITH DIGITAL ROAD PROCESS

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ABSTRACT

This paper relates to the ISEA2014, Dubai conference theme of 'Technology, Science, Art and East-Meets-West.' Five iterations of a system for sculptural glass installation will be described. This system is inspired by mould-pressed glass and Islamic architecture. These ancient decorative serial production techniques are integrated and enabled by digital manufacturing and electronic art. This revival and reinterpretation of ancient Eastern and Western creative precedents is analogous to the Silk Road, but here, the route is referred to as *The Glass Road*. This substitution problematizes specific creative practices along the road, which in this research lies figuratively between England, Hungary, Dubai, China and the United States.

The creative precedents to this process are digital manufacture and waterjet cutting, electronic art, molten mold-pressed glass and specific elements from Islamic architecture, namely, muqarna, which are ornate stalactite-vaulted ceilings. To make the new muqarnas, molten glass is transformed in digitally manufactured molds into sculptural components. Once assembled, these muqarna, which are still a work in progress, can be used in mixed sculptural and electronic media installations. Here, they are electrically illuminated in an interactive way that is inspired by traditional muqarna as tangible metaphors for celestial light and spiritual communication. This means that transmitted and reflected light is being tested as one potential source of communication in future artworks.

THE GLASS ROAD AND MUQARNA

The Glass Road is a term coined by Sinologist Victor H. Mair to offer an alternative material, one far older and perhaps more consequential than silk, to rename the Silk Road. [1] His renaming refers to the trans-eurasian spread of hot glass working that originated around 3500 BCE in Syria, Egypt and Mesopotamia then moved throughout the ancient world to the Far East. Much later, what is now more popularly known as the 'Silk Road' was established between 206 BCE-220 CE.

The significance of Mair's glass road to this paper, in addition to its material-specific focus on glass art, is that this project also utilizes a methodology of historical problematization, while focusing on art practice contexts. Here, in the fields of glass and electronic art, ancient craft practices are revived and reinterpreted for contemporary sculptural use. This use of the term Glass Road also emphasizes certain ancient creative precedents that flowed from West to East. This West to East examination is aimed at inspiring new ways of making sculpture using electronic art and other material-specific practices such as glass.

The art practical focus of these concerns is the muqarna prototype. Muqarna are also known as mocárabe, stalactite vaulting or honeycomb ceiling vaulting from Islamic architecture. [2] They are decorative corbels and squinches – architectural support structures for domes that began to proliferate in 1100 CE. While the actual muqarna are not the most developed artworks in the paper, their casual pursuit over many years has driven numerous innovations in my mould pressed glass artworks. Pressed glass and muqarnas are significant here because of their transformation, with the help of electronic art techniques, from two obscure antique processes, to reinterpreted creative assets for conceiving and making sculpture.

Fig. 1. Muqarnas at the Masjid-i-Shah mosque at Isfahan, Iran, 17th century. Hiroki Ogawa. http://hirokiogawa.client.jp/Travel.html

Evidence of these benefits is offered by practical examples from my 2011-2012 Fulbright fellowship to China. During the 16-months of my Fulbright, I was based out of Tsinghua University, Beijing. This was simultaneous to my first year as a researcher in glass, at a distance, at The National Glass Centre (NGC), University of Sunderland, UK.

The objective of this paper is to describe innovations that have arisen surrounding the gradual development of a system for sculptural installation that is based on pressing and forming molten glass into components for building muqarna structures. This is supported by the following aims; to creatively revive and reinterpret ancient decorative serial production techniques; to use digital and electronic art techniques to design, manufacture, exhibit and disseminate the new system; and to demonstrate the benefits of interdisciplinary making amongst eastern and western, glass and electronic art contexts.

To support these aims and objectives, the creative and practical processes behind the following four iterations of the system will be described: A *Jaali* perforated screen made by manual mold-

making; a first muqarna attempt made from a CAD/CAM waterjet cut mold; reproducing ancient chinese bi disks with pressed rather than carved holes; a second muqarna attempt with pressed-in holes; and a way of making molds entirely out of glass rather than metal. The paper concludes by suggesting further practical uses for glass that could be of interest to electronic arts practitioners and by discussing how Glass and Digital Road Muqarna addressed the preceding aims and objectives.

PRECURSOR TO MUQARNA: JAALI ITERATIONS

Perforated Screen: Jaali

In 2008, at Alfred University I made a glass architectural screen inspired by both pressed glass process and Indo-Islamic architecture; this was a perforated screen, called *Jaali*. While I had made architectural pressed glass screens before at my glass studio Hurstin Studio Glass and Metal, this one was different. Here, the mold I had made contained notches and flanges for joinery elements. It also was more suitable for forming the molten glass.

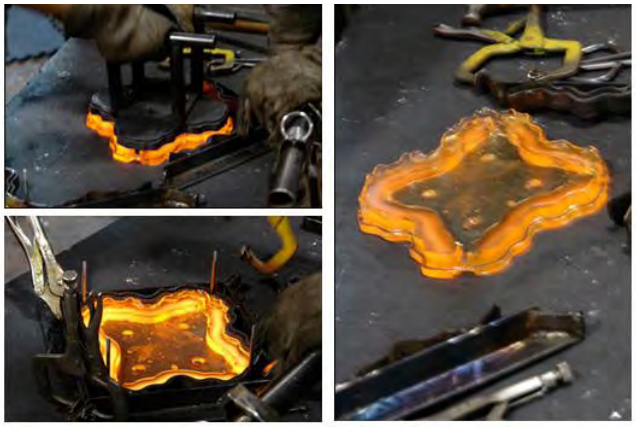

Fig. 2. Sequence of mold pressing glass into tiles for Jaali screen, © 2008, Hursty. The pressed glass tile on the right is still hot enough to be shaped after mold removal.

These pressed-in elements allowed the *Jaali* patterns to fit together and to fit on a metal framework. The design permitted me to solve technical issues by adapting their shapes for easier exhibition and mold pressing. My aesthetic options also increased from making impenetrable wall-like surfaces to perforated ones like the *Jaali*. The mold's creation was entirely manual despite its complexity. No computers were used to design the glass tiles or make the graphite and metal molds or supporting structural framework. While pressing these flat shapes out of molten glass I realized that, once released from the mold, they stayed hot enough, for long enough, to be bent or folded into different shapes. While I did not exploit this potential for making the *Jaali* screen, I would use it four year later for the first iteration of pressing glass muqarnas.

Reinterpreting the Jaali

My artistic concept for the *Jaali* installation was to reinterpret the perforated screen as a metaphor for a type of permeable membrane. [3] To support the reading of organisms permeating a cell, the structure was placed, as many *jaali* screens are, at the entrance of the space. The experience was that upon entering the gallery, the visitor or -organism, would see a partially obscured view of the gallery through the glass membrane. To enter they would have to take a left or right through cruciform-fringed portals. While the flat screen was meant to provide filtered views of the gallery, an unexpected result occurred. Because the screen was folded in four directions around the doorway (Fig. 3) viewed from its sides, the screen also obscured itself (Fig. 4). This visual layering provided me with a first glimpse of how glass muqarna structures might be made. I had become acquainted with muqarnas while researching *jaali* and found them to be compelling structures. Formally, I was struck by how they sculpted the space around them in a way that upset what was positive and what was negative space. [4] The spatial disorientation of these seemingly unfathomable structures seemed to be inversely proportional to their ability to draw a viewer's gaze over every peak and into every crevice all at once.

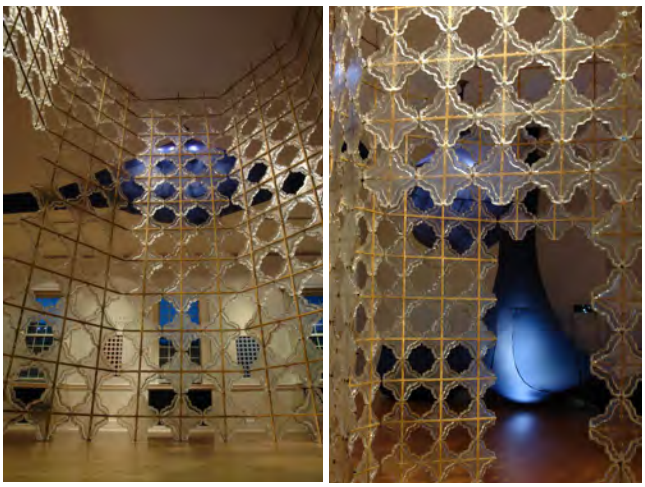

Fig. 3. left, *Jaali*, 2008, Hursty, 5 pressed glass panels folded four ways.
Fig. 4. right, *Jaali, detail,* 2008, Hursty overlapping panels inspired work with muqarna.

I have since realized both practical and conceptual benefits for combining pressed glass and muqarna in two areas. The first is by reinterpreting the spatial lessons of the muqarna as metaphors for sculpting positive and negative form. The second is by using positive and negative ambiguity as a practical concept to expand the role of what a mold can be; which could include becoming an integral part of the finished artwork. [5] The final works discussed in this paper, the *Puzzle Boxes*, are an example of treating molds this way. The *Puzzle Boxes* are essentially molds made out of sheets of fusing glass that melt with the poured glass to become one object. They can be found in the "Areas for future research" section.

COMMENCING RESEARCH ON MUQARNA

As a researcher in creative pressed glass at the National Glass Centre (NGC), I began to formally develop my ideas of mold pressing glass muqarna. This research commenced in 2011

alongside a sixteen month Fulbright fellowship to China. After my experience making the *Jaali* screen four years earlier, I wanted to exploit the post-pressed, hot glass malleability that had intrigued me to make more complex shapes. I chose to tackle muqarna after I was reminded of their ornate structure while visiting Chinese Buddhist temples. There, I witnessed a similar, spiritual and geometrical fixation with roof and ceiling architecture that was concurrent with how muqarnas were being used in Islamic architecture.

Fig. 4. Jinci temple, Shanxi province, built 1023-1032 CE, Song Dynasty corbels and post and lintel roof structure. Image, Hursty.

When viewed as assembled, completed structures, muqarna are formidable to duplicate. My approach, in attempting to fathom how they could be reinterpreted in glass, was to scrutinize each component. After doing so, the prospect of making them with mould-pressing still seemed possible. I was encouraged due to my previous experience pressing glass, in particular, creating the *Jaali* screen. One as yet unrealized result of that project was the benefit of secondary forming of the hot glass into folded shapes. Because muqarna are always concave shapes it became obvious that I should try to take advantage of folding hot glass to make them.

Practically this meant developing a new glass technique. Pressed glass has not been used for sculpting glass art in this way. Reasons for its artistic disuse lie in the Industrial Revolution. It was then that pressed glass was automated for mass production of commercial and decorative glass. Such industrial emphasis used expensive and elaborate molds and presses with little creative input from the workers pressing. [6] As a result, pressed glass eventually became sequestered in factories. I witnessed this creative commercial conflict from my own early experience working on a factory pressed glass team. [7] There I witnessed firsthand how, due to industrial practice, the potential artistic benefits of pressing eluded sculptural uses in the hands of artists. Interestingly, this type of creative disuse also had parallels in muqarna architecture. Oleg Grabar, in his book about the Alhambra palace, attributed a lack of evolved muqarna forms, amongst other features in the palace, to an "insecurity of power and lengthy building programmes" and equated them to "a formal dead end." [8], [9]

"Muslim artisans were to develop in a truly sophisticated manner the architectonic possibilities of the muqarna and also its potential as a cheap replacement for complicated ceiling masonries. The latter aspect is at times present in the Alhambra, but the more interesting and historically significant side to its muqarna is that even though complex and sophisticated in its versatility, it is almost never innovative." (Grabar, 181).

Taking into consideration the creative pitfalls in antique pressed glass and muqarna practice. It is especially challenging to reinterpret both in a way that revives, sustains and *Innovates* both in a contemporary art context. This prospect was made even more likely after implementing them with digital manufacturing and electronic art techniques.

Fig. 5. Paper and wax maquettes showing muqarna structure, 2011, Hursty.

Prototyping muqarna: First models and CAD/CAM mold attempt

Tsinghua University in Beijing lacked molten glass facilities, so my early muqarna forms consisted of making folded paper and wax maquettes. Using paper and wax was a simple way to get the shape right before testing with hot glass. It was also necessary to make a steel mold to press the hot glass into. The ideal shape for the final press molds was based on these early maquettes made at Tsinghua. [10]

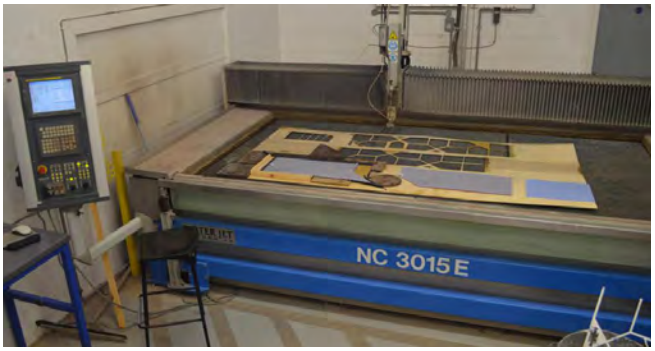

Fig. 6. *Waterjet machine at National Glass Centre*, University of Sunderland, Waterjet Sweden.

It was while making these final steel molds at the National Glass Centre that I was first exposed to computer assisted drafting, CAD and waterjet cutting. At the time, with no CAD experience, I produced a schematic drawing on paper. My thesis advisor,

Jeffrey Sarmiento, effortlessly entered its geometry into Lantek, the waterjet machine's CAD software, then cut it. This digital manufacture permitted my muqarna designs to rapidly enter the hot-glass-testing phase within one day. This sat in stark contrast to the *Jaali* mold, which had been painstakingly made by hand over the course of a month.

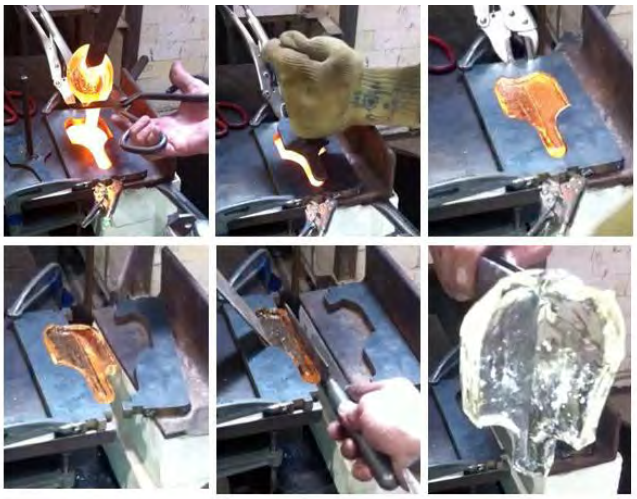

Fig. 7. Muqarna mold sequence, © Hursty, 2012. First attempt at pressing glass muqarna, then folding it in a waterjet cut mold.

Despite quick implementation and demonstrating proof of concept, the initial muqarna design was not successful. Though the hot glass folded well, these first muqarna were problematic as modular components because they lacked joining nodes or holes to affix them to each other or to a framework. It was only after learning the lessons from subsequent projects that the muqarna project would progress.

Chinese Celestial disks: Problematizing bi for joinery purposes

The challenge of pressing in holes while the glass was hot was overcome after experimentation with making glass versions of ancient Chinese jade 'bi' disks. Historically, when jade was scarce, these disks were pressed out of hot glass, with their center holes being carved out by hand after the glass had cooled. I reinterpreted these ancient pressed glass objects for contemporary pressing by problematizing them. I required that the bi holes be hot pressed, rather than carved, by a mold that could have been made with Han Dynasty technology (206 BCE-220 CE). That being said, though my mold could have been laboriously carved using ancient methods, I used CAD and waterjet. Despite that, the ancient technology crux of the problematized design was intact – this bi mold had a removable post/central hole former. Glass would be poured around the post to make a hole.

This way of forming holes and bi disks at the same time worked. The significance of pressing holes in while hot was that the location of holes could be planned in a way that avoided extensive drilling or carving afterwards. With this technique at hand, further experimentation on other objects could be pursued. One design that benefitted from this improvement was the muqarna.

Fig. 8. Reinterpreting the making of ancient Chinese bi disks, © 2013, Hursty. Top left, CAD drafting, Middle left, waterjet cut graphite mold, bottom left, finished glass bi with press formed hole. Right column shows bi pressed from molten glass.

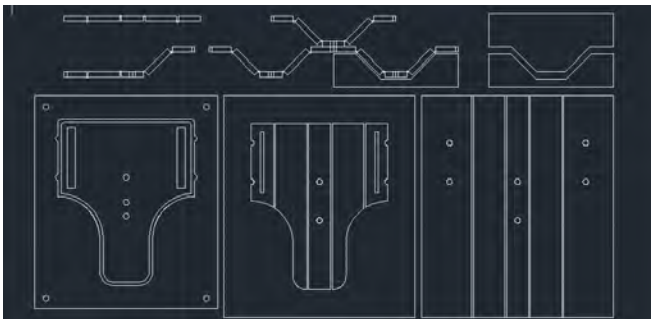

Fig. 9. Muqarna press mould CAD drawing, © 2014, Hursty. This design featured a broader spade-like design that allows for compression into an angled base mold.

Muqarna: Second mold attempt designed with joining features

The next mold took advantage of lessons learned after the first muqarna mold and from pressing holes into the bi disks. This time a broader spade-shaped design would be attempted while a bent 3D metal form would ensure that the angles were folded uniformly. Also, six different hole formers would be used to hot-press multiple holes all at once during the same operation. The mold was comfortable to use, worked well and was used to produce twenty muqarna components in under an hour. The factors that worked well were: its flat profile was easy to pour glass into and quickly remove the glass from afterwards, in preparation for the next pour; the six holes were deep enough and registered correctly; and despite human error, even mispressed glass was still hot enough to re-maneuver and re-press several times until it was pressed correctly. What lacked consistency were the edges of the muqarna.

Though they were hot enough to form properly, sometimes they melted too much resulting in distorted shapes. Despite the distorted edges, the properly registered holes still allowed even warped muqarna to fit together well. These first viable pressings were then fit together and used to form an array of muqarnas that would be used to test with electronic art components.

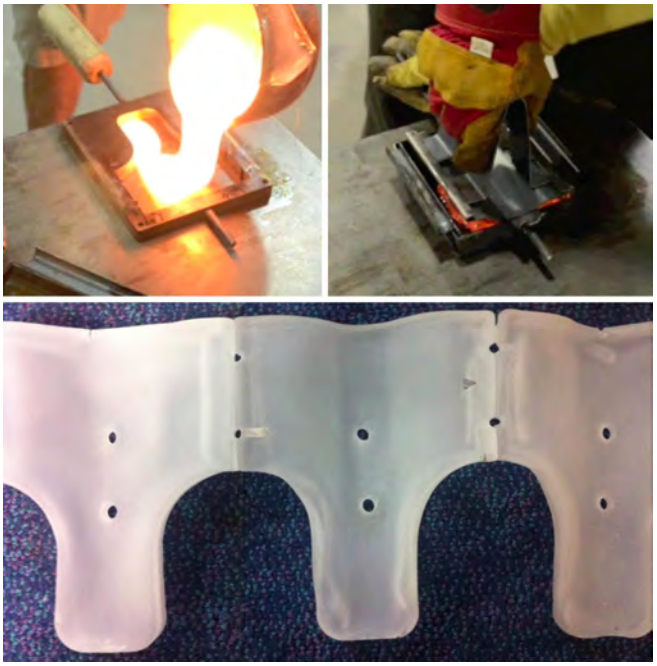

Fig. 10. Mold pressed muqarna, second attempt. © 2014, Hursty. Top left and right, mould pressing the molten glass. Bottom, adjoining glass muqarna with properly aligned glass fastening and registration holes.

Muqarna: interactive illumination

These first twenty muqarna were pressed quickly and aligned well. At this stage they were brought to Attaya projects in Newcastle, UK, where I worked with Lalya Gaye to test their suitability for sound reactive lighting. [11] This was achieved using two software programs and four pieces of hardware. First, an LED strip was placed underneath the muqarna. These were connected to an ENTEC DMX USB interface, a 12volt DC power supply and an LED dimmer. These were controlled using Modul8 and MadMapper software. These worked in concert by providing the LEDs data that was created in Modul8, assigned by MadMapper, transmitted through the ENNTEC and the dimmer and powered by the power supply.

LED CONTROL SPECIFICS

Controlling the lights occurred in stages. First, they were toggled in real time using a white square displayed in Modul8. There, the colors change depending on the position of the square. To make the lights react to sound, the white square interface was shared between the two programs as live video through the Syphon protocol in the MadMapper software. Once in MadMapper, we created a 'fixture' that assigns data, in this case, sound, to LEDs using DMX hardware. Gaye made the MadMapper fixture assign the Modul8 video feed to a specific DMX channel. From there, the DMX gears sent the data to the hardware, an ENNTEC interface that was connected to an LED dimmer. There the dimmer was assigned the same channel as the original fixture created in Modul8. The result was that the lights dimmed and brightened in relation to the sound received by the computer's microphone.

Fig. 11. A dry stacked, unfastened muqarna array with LED lighting, 2014, Hursty.

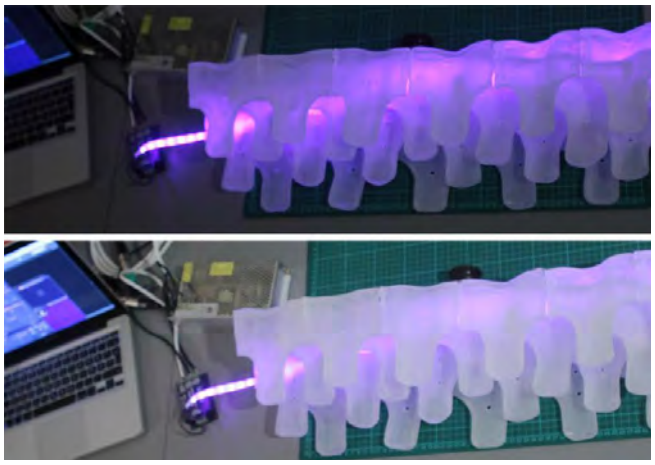

Fig. 12. Prototyping a muqarna array at Attaya Projects with sound reactive LED strip controlled by Modul8 and MadMapper software, 2014, Hursty.

The sound reactive muqarna were a promising introduction to integrating digital techniques in the conceptual phase. This could extend the range of glass and electronic art collaboration in terms of content generation, rather than simply a design and manufacturing relationship.

MUQARNA: FUTURE ITERATIONS AND GLASS MOLDS/ PUZZLE BOXES

Other promising avenues for glass muqarnas have been tried as well. Most recently, at the Shanghai Museum of Glass, I have exhibited groupings of 48 *Puzzle Boxes.* [12] The *Puzzle Boxes* are the result of the sculpting of interior and exterior space that was suggested earlier in the *Reinterpreting Jaali* section. The boxes are actually sheet glass press molds that when poured into, fuse with the molten glass as one object. Eventually they will be used as tessellated wall sections leading up to glass muqarna domed ceilings. Evidence of the muqarna inspiration can also be directly found in the box' structural ribs.

Fig. 13. Puzzle Box mold formers, 2014, Hursty. waterjet cut fusing glass, enamel transfer decals. These glass boxes are really molds and are meant to fuse with the glass poured into them.

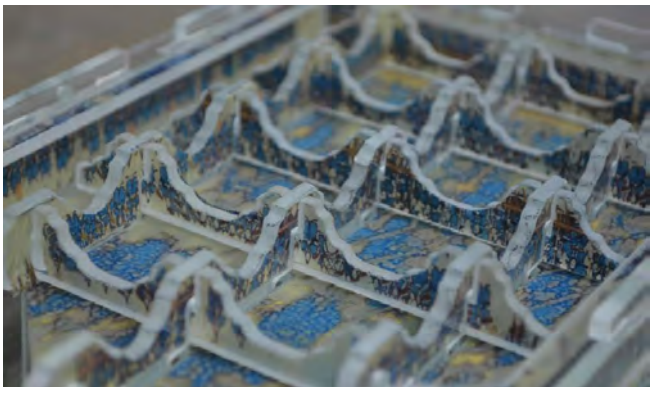

Fig. 14. Puzzle Boxes, 2014, Hursty, screen printed glass molds. This inverted view of the mold reveals interlocked muqarna ribbing that holds the mold together. The screenprinting on the ribs are of formations of soldiers from the Eight Banners 'Blue' army of the Qing Dynasty.

AREAS FOR FURTHER RESEARCH

This paper's objective was to describe the creative process behind the pursuit of a sculptural glass installation system inspired by muqarna. It showed how reinterpreting ancient creative techniques could enhance current creative practice. This aim was strengthened in interdisciplinary fashion by integrating digital manufacture, pressed glass and electronic art techniques. The reinterpreted techniques were *Jaali* perforated screens, Muqarna vaulting, Chinese bi disks and mould-pressed glass. Their reinterpretation was aided by digital practice, including waterjet cutting and electronic art.

This paper has highlighted glass' unique hot forming potential. However, of potential interest to electronic arts practitioners and something that has not yet been emphasized is a reminder that glass is an electrically inert, versatile structural material for making fasteners and mold elements. The glass component based *Puzzle Boxes* are an example of this. Once joined and assembled, glass fasteners and mould elements can be heated and fused together. The implication of making things this way is that objects, utilitarian as well as artistic, can be made modularly from component parts of a homogeneous glass material, then melted until the components coalesce into one form. While homogeneous, the constituent parts retain the tangible memory of their original function in the form of discrete zones of color. Chemically, these zones could be made from electrically reactive rare earth elements or metallic foils, so that in addition to providing color, these zones could be seen as circuits and respond in specific ways to being used electrically.

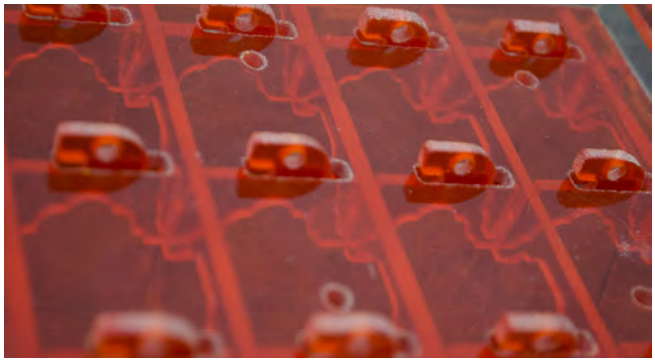

Fig. 15. Puzzle Box mold former, detail from plunger with interlocked .muqarna ribbing visible underneath. 2014, Hursty, waterjet cut fusing glass.

CONCLUSION

The advantage of mining and reinterpreting pressed glass and muqarna are that precedents from ancient analog making can benefit current electronic art methods. They provide ready-made adaptable infrastructures that can ensure that rapid manufacture and electronic art retain invaluable hand and material feedback. These are not merely manual techniques with nostalgic appeal in an era of rapid manufacture. With reference to the hand and fingers, they are the *original* "digital technology," and serve as potentially prolific, invaluable sources of innovation for applying rapid manufacture and electronic art techniques to the making and conceiving of material-specific artworks.

This work is being produced through my PhD research in digital manufacturing of press-moulded glass at the International Institute for Research in Glass at the National Glass Centre, University of

Sunderland, UK. It was also undertaken and continues after a 2011-12 Fulbright China grant in Beijing, China at The Craft Department of the School of Art and Design at Tsinghua University. Through studio collaborations, workshops and lectures, the study also took place at other schools: in Hungary at ELTE University, Budapest; in Canada at Sheridan College, Toronto; and in China at Guangzhou Polytechnic, Suzhou Polytechnic, Hong Kong Baptist University, Xinchejian MakerSpace in Shanghai and several private glass companies in China.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

Grabar, Oleg, *The Alhambra*, Harvard University Press, 1978.

Hursty, Mark, *Pressed Into Service: Pressing Studio Glass Art in the US, UK and China.* Glass Art Society Journal 2014.

Mair, Victor H, ed., "Introduction: Reconsidering and Reconfiguring the "Silk Roads" *The 'Silk Roads' in Time and Space Sino-Platonic papers* 228 (July 2012). Department of East Asian Languages and Civilizations, University of Pennsylvania.

Zembala, Dennis M. "Machines in the glasshouse: The Transformation of Work in the Glass Industry, 1820-1915." Ph.D diss., George Washington University, 1984.

Author unknown, Profile: K Schlamminger, Arts and the Islamic World, 3, 3, Autumn 1985.

Takahashi, S.,1973. Muqarnas: a three-dimensional Decoration of Islamic Architecture. Online, consulted December 15, 2014. http://www.tamabi.ac.jp/idd/shiro/muqarnas

Hursty, Mark. 2013, *The Glass Road* to Tang China.

http://kinaiszak.elte.hu/HIREK/TANG%20SUMMER%20SCHOOL.pdf. Budapest: ELTE University, July 6, 2013.

Mair, Victor H. (2013) Tang Dynasty and the World Outside China. http://kinaiszak.elte.hu/HIREK/TANG%20SUMMER%20SCHOOL.pdf. Budapest: ELTE University.

ENDNOTES

1. Mair, 2012. p. 3. "Yet, even during this period, many other goods and products were traded by stages along the so-called Silk Roads: Glass, Beads, silver, gold, medicines, spices, wool, furs and so forth."

2. Other names include mocárabe, Arabic: al-halimat al-'uliya which means an "overhang." In architectural terms muqarna structures are called corbels, which are cantilevered supports at the top of a column or wall and squinches, which are the series of overlapping structures that support domes.

3. Arts and the Islamic World, p. 28. This profile of artist Karl Schlamminger has an interesting quote related to his interpretation of perforated screens and Islam. "The screen thus serves as a sort of membrane between the outside and the inside[…] It reminds me of the Hadith which says that man and all creation would be annihilated by direct exposure to the Divine Light; and so God in His mercy veils it with the 70,000 veils of creation."

4. Some interpretations of Islamic art and architecture relate its ornamentation to Horror Vacui or fear of empty spaces. Other interpretations characterize intense decoration as an acknowledgement of the infinite power of God.

5. This concept, exhibiting casting molds and process as art objects themselves is not new. It has famously, been addressed by: Duchamp's Wedge of Chastity, 1963, a vulvic cast attached to its mold; Nauman's A Cast of Space Under My Chair 1965-1968 and Whiteread's oeuvre of casting interior spaces as solid form. But here it is has been updated to include two obscure ancient decorative arts processes; molten pressed glass, a material specific casting medium, with its transparency and semi-to- full automation during the Industrial Revolution adding to conceptual discourse; and muqarna, also an ancient and intensive mold process with its spiritual and architectural origins.

6. After Zembala, 1984. Pressed glass workers were considered unskilled labor. This, despite their intimate and, as some would argue, creative, knowledge of how the mould pressed glass behaved.

7. From Hursty, 2014. Pairpoint Crystal in Sagamore, Massachusetts, USA, is a namesake factory that ties, through the Mt. Washington Glass company and the original Pairpoint factory's press equipment, to Deming Jarves, a glass factory owner and designer who received the first pressed glass patent in 1824 and is best known as an inventor and later an author, who espoused the use of semi-automated pressed glass equipment. As of Autumn 2014, Pairpoint still presses glass using the antique presses.

8. Grabar, 182.

9. Grabar, 160. "Many monuments, especially palaces, were built rapidly, either because the insecurity of power made lengthy building programmes unlikely to reach a conclusion or because they tended to be personal rather than dynastic and were not meant to survive their original patron."

10. While developing pressed glass, this research innovated techniques for using hot wax as a proxy for hot glass. Forming molten wax has similar material constraints as hot glass. Both have a time limit before they cool and harden. Additionally, molten wax is too hot to touch so, like glass, must be carefully handled and worked with tools. These methodological factors promote using wax, which is also inexpensive, as a proxy for hot glass. By doing so, the logistics of mold pressing a particular object -its apparatus, procedures and timing, can be deduced.

11. www.attayaprojects.com

12. The Shanghai Museum of Glass exhibition is entitled, Now/Then, Influences of Qing Dynasty Glass on Contemporary Glass Art. It runs from November 8, 2014-August 31, 2015. It is curated by Shelly Xue, PhD, from The Shanghai Institute of Visual Arts, at Fudan University, Shanghai. http://en.shmog.org/cp/html/?118.html