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Theme: Procedures of Making (Materials & Processes in Transformation)

Crafting Conductive Circuits and Capacitive Surfaces in Glass

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with contributions by:

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Louise Mackenzie Fine Artist, Phd candidate, Northumbria University

Liz Waugh McManus Glass Artist, MPhil candidate, University of Sunderland

Janis Meissner Computer Scientist, maker, PhD candidate, Newcastle University

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Helen Pailing Glass Artist, PhD candidate, University of Sunderland

Angela Thwaites Glass Artist, PhD candidate, University of Sunderland

Tina Webb Glass Artist, MPhil candidate, University of Sunderland

Rachel Welford Glass Artist, PhD candidate, University of Sunderland

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Introduction

Engaging the theme Procedures of Making, this paper describes and reflects on methods and processes used in the development of circuits in handcrafted glass and conductive materials, combined with interactive sensors. Demonstrating the potentials for blending techniques of artisanal glassmaking with digital manufacture and electronics, a series of cross-disciplinary workshops yielded a body of objects. These results, and the group of researchers collaborating to produce them, shared a common goal of experimenting with interactivity.

The project seeks to provide a demonstration of how the combined skills of makers might expose new opportunities for forms of interaction with crafted objects, and for traditional craftspeople to form a connection with digital possibilities in creative work. While there are many potentials for digital interactions and experts who can produce them, the exploration of handcrafted conductive glass constructions offer exciting possibilities for crafting interfaces with rich material characteristics.

Glass is a material that can be formed through skillful blowing, casting, cutting and kilnforming. It adds potential uses of colour, transparency, weight and potential for optical effects. More specifically in this research it can be combined with copper and other conductive materials through a range traditional and more contemporary fabrication processes. Combined with open-source electronics platforms (e.g Arduino and Touchboard) and their associated sensor arrays a myriad of effects can be prototyped. Encouraging the sharing of practice using both digital and physical making, the project seeks to consider craft as a way of thinking in a range of different media both electronic and analogue, rather than as distinct areas of practice.

This paper is navigated by the following: a description of the project background and aspirations, development of an approach, illustration of results, reflection on the collaboration and possibilities for further research.

Background & Aspirations

This short project was born out of conversations started within the 2016-7 Craft Futures event series instigated by Northumbria University's Design School. Participants in these lectures, seminars and practical workshops include staff and PhD students across the Faculty of Art, Design and Social Sciences, as well as by academics from the University of Sunderland and Newcastle University. A number of sessions held earlier in the academic year focused on printing interactive designs on paper and fabric. Led by Dr Justin Marshall, Associate Professor in Design at Northumbria, the workshops have grown out of his research in India[1], which sought to combine principles of wooden block printing with laser engraving to create patterns in conductive ink on textile surfaces. Connected to a Touchboard[2], these textile designs serve as scalable and flexible interfaces in which sounds drawn from the local area were mapped onto visual elements of designs and 'released' through touch.

Northumbria and Sunderland share an AHRC-funded Centre for Doctoral Training, and an opportunity was identified that could provide cross-institutional educational experiences and research. The context for the craft medium chosen in this study sits in both the history of glassmaking in Sunderland that dates to the late 7th Century, as well as research at National Glass Centre. Digital fabrication in glass has been the subject of several PhD studies at University of Sunderland, focused primarily on the creative use of waterjet cutting[3]. More recently 3D printing approaches have been applied to recent research in glass casting[4], and a shift toward digital craft has been central to the curriculum in Sunderland and the broader field of glass art education (Josslin 2017). At the same time, analogue craft skills are still valued highly and compliment 21st Century digital techniques. In this sense, technology in glass encompasses both new and old ways in which humans manipulate the material.

Jeffrey Sarmiento, Reader in Glass at Sunderland, built on the initial Craft Futures sessions providing demonstrations of glass making processes that had the potential to translate into glass some of the approaches explored with the paper and textiles.
This led to both Marshall and Sarmiento recognizing the potential value for further exploration of this area and developing new forms of 'crafted' interface to digital interaction. Both Crafting the Digital (Marshall et al 2015) (i.e. bringing the sensitivities of craft to the sphere of digital interaction) and Digital Crafting (i.e. using the opportunities afforded by digital design and production tools within art/craft practices) have been a preoccupation of Marshall for a number of years and this project can be seen to sit within these broader areas of interest. In Sarmiento's area of research, an expertise across a broad range of processes (which include glassblowing, screenprinting,

kilnforming, cold assembly, and waterjet cutting) allows for rich visual outcomes and possibilities of meaningful object making in glass.

Approach

The project consisted of two four-day explorative workshops. Key to our approach was the bringing together of staff and students with diverse skills, interests and aspirations, but keeping the broad theme of conductive/capacitive[5] glass at the core to all activities. Participants included academic and student researchers from both universities as well as Newcastle University's OpenLab[6]. The activities, though not explicitly framed as collaborative, would then act as inter-institutional knowledge exchange opportunities. With backgrounds in digital craft, fashion, glass, computer science, product design, fine art and creative technology, diversity was certainly achieved. The sharing of knowledge and approaches across these domains was evident in the conversations, demonstrations and facilitations. A key feature of this project was the opportunity for researchers to begin to understand practices and processes in which they had no previous experience, working directly and first-hand with the material. This was universally appreciated and extended both the aspirations and the practice of many, as is evident from the resulting works and their ongoing development.

The first workshop in May 2017 was focused primarily on PhD students. An introduction to interactive sensors was given at Northumbria School of Design with Thomas Dylan[7], a creative technologist whose input was invaluable to this research. The remainder of the workshop was conducted at National Glass Centre, where students were exposed to a survey of techniques and then supported in developing individual experimental works incorporating copper, into blown, waterjet cut, printed and kilnformed glass. The second workshop, held in July 2017, brought to National Glass Centre staff and students from both institutions as well as one visiting artist. Pooling the knowledge and expertise within the group, lessons learned from the first workshop were used to expand on material tests (graphite was added as a potential conductor) as well as to prototype functional objects, interactive artworks and conductive glass interfaces embedded with sensors. The results of these workshops were demonstrated both at the annual Sunderland/Northumbria AHRC student conference and again at the Making Futures conference.

We took a practice-based approach to this project from the start. With a clear emphasis on experimentation with materials, the artists, designers and makers in the workshop pursued solutions though creative practice. Such a methodology and the physical outcomes of this research could be seen to echo the 'epistemic artifacts' approach Hansen (2009) took in developing digital processes in designing ceramics. Process demonstrations in glass manipulation and digital interaction were given by the experts within the group, followed by material tests. These set the stage for participants to choose and develop individual explorations within an intensive short workshop environment. Both Marshall and Sarmiento had the broad aim of extending the understanding of how potentially conductive materials (e.g. copper in various forms, graphite and steel alloys), might be integrated into glass to create conductive or capacitive surfaces and forms. Combined with sensors, the glass circuits and surfaces formed a palette of processes and effects that can be used by other artists, designers and makers in their work. However, we did not apply a reductive method of formal material and process testing to gain this knowledge. Through the diversity of projects undertaken, some with an explicit conceptual intention, others led by material qualities, shared understandings were gathered together rather than explicitly defined. This approach privileges a type of material and process knowing that recognizes the value of context and its relevance to the creative practices for which it is intended, rather than a more systematic but potentially less relevant approaches. We are therefore not aspiring to, or claiming, significant technical and/or scientific advances in the area of conductive glass, but, through creative art and design practice, providing examples of some initial work that has explored this field and demonstrates avenues for further development.

Results

The outcomes from this study are as diverse as the researchers who participated. These include; material tests, developing artworks, design prototypes, as well as glass interfaces with embedded sensors to explore possible interactions. The following examples include descriptions, images and statements from the participants.

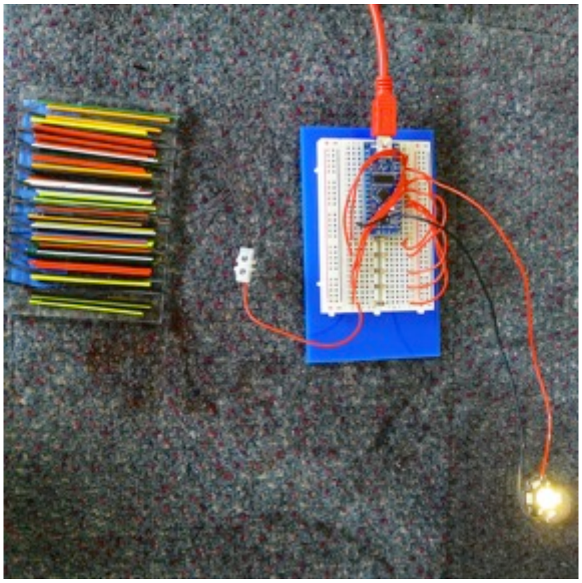

Figure 1. Thomas Dylan, stroke sensor, kilnformed glass, copper, Arduino, light

Thomas Dylan: integrated sensors

Dylan was an essential conduit of the knowledge exchange, in which he demonstrated and facilitated the use of the Arduino platform, and associated sensors and actuators (inputs and outputs), for creating a variety of interactions. These included sensors for movement, light, spatial orientation, and actuators for variables in light, sound, heat and movement. He supported nearly all of the projects with his technical knowledge. In his own experiments, several glass and copper interfaces were created, including a 'stroke' sensor exploiting textured kilnformed glass (see Fig 1), a rotational touch sensor, and the integration of resistance wire[8] fully fused inside glass sheets. The resistance wire functioned both as a conductor of radiant heat (not unlike a windscreen defroster) and as a thermocouple to measure temperature. The next step for this work might be to combine both heat and the thermocouple to control temperature, as well as exploring different patterns and interactions in both flat and three-dimensional glass constructions.

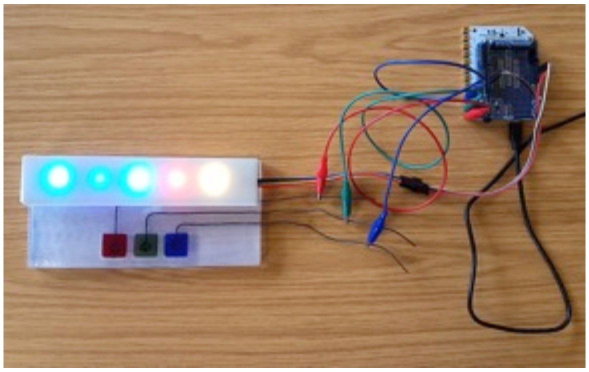

Figure 2. Janis Meissner, Light Writer. Waterjet cut and fused glass with embedded copper, LED strip, capacitive Touchboard

Janis Meissner: Light Writer

Meissner is currently a PhD researcher in Digital Civics with a background in computer science and craftivism. She is exploring the intersection of traditional and digital craft through the creation and implementation of a portable makerspace, a project in which skills exchange plays a major role. Therefore, it is not surprising that her contribution to the project involved the sharing of her knowledge of designing capacitive touch sensor electrodes and generating new Touchboard sketches (code). For her individual project, she hacked the Touchboard to change the default actuator output from sound to light and connecting an RGB-colour LED-strip. To house this, a three-dimensional form was designed and fabricated using a computer controlled waterjet cutter, integrating a conductive material, in this case copper, to provide the capacitive capabilities. She describes the artefact as a 'Light Writer, a semi-transparent fused glass object resembling a piano with three static keys in the colours red, green, and blue. The keys would serve as RGB component inputs for mixing and "writing" coloured light' (Meissner 2018). This allowed the mixing of secondary colours through using different combinations of the three primaries (see fig 2).

Figure 3 Colin Wilson, Caged blown extruded shape, blown glass with copper, arduino, light

Colin Wilson: Glass active

Colin, a highly-experienced metal worker and senior lecturer in 3D Design, experimented with copper wire and strip to make a conductive ‘cage’ form. This was then heated in a kiln to a temperature at which a hot glass bubble could be blown into the cage with support from Sarmiento. The glass expands as it is inflated, while the copper maintains its rigidity. The cage constrained the glass at the points of contact and allowed fluid bubble forms to expand beyond the bounds of the cage as well as permanently attach metal to glass. The copper shape was gathered[9] over again, forming air pockets around the wire giving a variety of refractive light structures within the shape. The void was illuminated and connected to a touch sensor, which activates and dims the light as a hand is drawn back and forth across the form (see fig 3). Wilson states:

> Working with glass offered new experiences in watching and learning the hot processes and being actively involved in working the cold processes. It

> has given me a new material to add to my library as a design practitioner, and will inform what I would design and make with future projects.

Figure 4 Louise Mackenzie, Biotechnological Vessels of Nur/torture, blown glass in copper wire, touchboard and speakers

Louise Mackenzie: Biotechnological Vessels of Nur/torture

Louise is a PhD candidate in Fine Art exploring Bio Art. As with Colin's project, copper wire cages form 'electric veins' that constrict unique blown glass vessels and can be used as capacitive sensors. However, this sealed vessel is designed to hold bacteria. She states:

> *Biotechnological Vessels of Nur/torture* is a first step in developing a long-term dwelling for E. coli bio-assemblages; living assembled objects that are the result of many actors both human and non-human. The bio-assemblages contain synthetic DNA that include embedded textual information that can be translated as the message; "What will happen if I store this thought safe within you?"[10]

Figure 5. Justin Marshall, Henna Hands, sandblasted and fused glass and graphite

Justin Marshall: Henna Hands

One of the unexpected results of the materials testing came about through the attempt to screenprint copper powder and oxides onto glass to create a conductive/capacitive surface. For reasons including oxidation and the format of the copper (in particle suspension as opposed to a solid wire), conductivity was not achieved. However, graphite powder (as used by artists for image making) was found to both survive the kilnforming process as well as produce a printed graphic image within the glass. Marshall's experimental works relate to the patterns inspired by his research in India. He hopes to pursue this work and both develop a set of more controlled set of technical characteristics and expand the visual language of fused glass and graphite.

Figure 6 Assortment of material tests during second workshop, including Kitchman’s layered copper powder and wire drawings in glass

Fiona Kitchman: Exploration of texture within a layered pattern.

Kitchman, a senior lecturer in Fashion, developed a design based on intertwined patterns inspired by the embellishment on a Victorian child’s dress in the archive of the Discovery Museum in Newcastle. The curvilinear pattern consists of loops and twists through flowing lines formed inside a square. There are three layers: a continuous line, a line with solid dots and a line with the outline of the dots. The intention was to create a multi-layered piece with textured strands running through, one of which would be conductive. Tiles of glass were cut and screenprinted and copper powder was chosen for the continuous line due to its dense colour and its link back to the original research. To create lightness and a sense of depth, copper oxide, with its blue ‘bubbly’ visual quality when fired, was used for both the solid dot pattern and the outline dots. They were then fused with the copper oxide tile in the centre. The desired visual effect was achieved with the copper powder producing some interesting colours ranging from blues to dark coppery tones and the copper oxide creating light blue bubbles. Layering the tiles created a fluid pattern with depth and movement. Although the copper oxide continuous pattern tile had a piece of copper wire inserted, it only transmitted a signal in the loop directly attached to the wire. A second tile was constructed by exploring other processes. The continuous line and the solid dot pattern were cut in vinyl, applied to glass and sandblasted. The line was filled with blue glass powder and the dots with yellow. These were then fused together with a twisted and looped copper wire running through the centre. She states:

> ‘Exploring and experimenting with the qualities of glass, observing how glass reacts when hot fused and investigating the possibilities of conductivity has inspired me to develop my research ideas incorporating textiles and using the new knowledge acquired in this workshop’.

Figure 7 Tina Webb, Old Age Ain't No Place for Cissies, kilnformed and glued glass, copper, Touchboard and speaker

Tina Webb – Old Age Ain’t No Place For Cissies

Tina, an Mphil candidate and experienced glass artist, and relative novice when it came to digital interaction, stated:

> This collaborative workshop has proven to be an exciting introduction to the possibilities of interactive art works. I chose to make a work using text and sound. The text, attributed to the famously ascerbic Bette Davis, is made using letters cut out of glass, with the individual characters of each word stacked together to make a three-dimensional representation of the word.

The text is mounted onto a sheet of glass and when a word is touched a voice can be heard saying the word. The words are mounted onto opaque white glass. Behind each word, on the back of the white mounting sheet, is a strip of copper which is linked to a Touchboard, which then played the spoken sounded clips recorded by the artist through a small speaker.

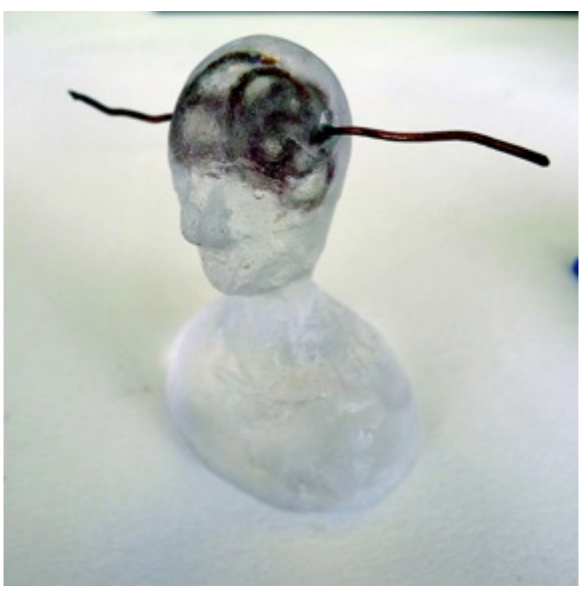

Figure 8 Liz Waugh McManus, Glass Head (IOT object), cast glass, copper wire and Arduino.

Liz Waugh McManus: IoT object

Liz, a glass artist and MPhil candidate, worked with Dylan and cast a glass object embedded with a copper wire as an proximity sensor to call up a webpage, so exploring the possibilities for creating new IoT interfaces that have new aesthetic and symbolic meaning. She reflected:

> I planned to make a touch/proximity sensitive screen made with glass and conductive material that will trigger video projection. I then wish to develop this system by linking it up to respond to data from the web, both to trigger projection and also to create a physical reaction in glass.

Conclusion

This short project was an exploration of how the material and aesthetic qualities of glass can be combined with the opportunities that digital interaction affords in order to create artefacts as meaningful moments in art, craft and design. By bringing together and working with researchers and practitioners from a range of subject specialisms, with a breadth of skills and knowledge, we were able to rethink how materials could be brought together to create new avenues of exploration for studio glass practice and beyond.

Our approach was not intended to be based on systematic technical testing; instead we worked through material experiments led by artistic and design approaches to exploring aesthetic characteristics and desired functionality. Through the playful approach taken, and the diversity of projects undertaken, we began to understand the complexity of the materials, their combinations and their ability to function as conductive and/or capacitive amalgamations. As to be expected we had failures as well as successes, but even within the ‘failures’ often value was found in the visual effects achieved. From this work we have created the beginnings of a palette of processes, appropriate for art, craft and design studio practices that have potential to be developed into richer, and more robust and reliable interactions.

The significance and value of this hands-on and communal approach that celebrates and encourages open-ended exploration as a way of scoping a broad field of opportunities was reflected on by Dylan:

> Having shown examples in demos and following initial experiments a number of people were looking for ideas in what they had seen or experienced, asking questions in order to formulate some kind of relationship to questions in practice. Most notably I put together an experiment were resistance wire was fired into glass, meaning the glass would heat up when a current was applied. I hadn’t really thought about what it was for – but before long – someone else had taken it on and formulated an idea relating to transience. The importance of taking material approaches to the presentation of digital technology seems important. I mean, demos were people can get hands-on, digital swatches of digital interactions and outputs like heat, cooling or colour sensing (tangible examples). This relates directly to visibility or at-handness where potential is not hidden behind code or engineering principles.

Next steps

From the collection of work produced by the group as a whole and in various stages of completion, there are a number of avenues that have been identified as of potential value.

- From the open ended informal approach to gaining material understanding, take a number of promising materials and processes into a more structured set of tests in order to generalize results and improve reliability and repeatability.
- From an informed position, think more critically about the ways in which glass interfaces to digital interactions have meaning and significance.
- Produce pieces of work with greater fidelity and finish that draw on the shared knowledge gained of both the digital and analogue processes.
- Create a documented ‘toolkit’ of digital interactions including the resources needed to facilitate them.
- Produce a ‘plug and play’ digital hardware and software system that provides a low barrier to access for creative practitioners to explore this toolkit.
- Explore more formal interdisciplinary collaborations to extend and deepen investigations.

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[1] http://unboxfestival.com/ (see video of highlights)

[2] The Touchboard is an Arduino based board specifically designed to allow sound files to be played by touching sensors and be simple to set up and use. https://www.bareconductive.com/shop/touch-board/

[3] Key examples include Cutler, Vanessa (2006) *Investigating the creative uses of abrasive water jet for glass in architecture* and Dickson, Erin (2015) *The Quirks Of Intimate Space: Architectonic Art Practice Translated Through Digital Technology In Glass*

[4] Workshop participant and researcher Angela Thwaites is completing her PhD in Sunderland, *Towards Making the Unmakeable: How 3D Printing Can Inform Kiln Formed Glass Practice in the 21st Century*.

[5] Capacitive surfaces, such as those found on smart phones and tablets, allow touch based interactions based on the change in capacitance created by the proximity of a conductive element (e.g. a finger).

[6] https://openlab.ncl.ac.uk/

[7] http://tommydylan.co.uk/

[8] 'Resistance wire' is a high resistance wire that heats up when current flows through it but does not burn away, e.g Ni-chrome wire.

[9] Gathering entails dipping and turning a steel pipe in a pot of molten glass, a process akin to using a honey dipper. Successive gathers, along with blowing/inflation, allow the artisan to increase the scale of their work.

[10] http://www.viralexperiments.co/bioartefactuality