CASE STUDY: MODULAR BLIND COLLABORATIVE DESIGN AND PRINTING USING THE CREATIF SOFTWARE SUITE AND FUTURE PERSPECTIVES

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Target Design Concept: The Diffus Modular Blind is a system of geometric shapes that can be assembled in different ways in order to create different sizes, shapes and functionalities. The idea is to provide a smart and flexible system where functionalities such as light/sound emission and colour change can be controlled by proximity and touch. Thereby the modular blind becomes a facilitator for interactive experiences. The blind can be used for creating smart and adaptable spaces and surfaces. This could be in private homes or offices, as window blinds, space dividers or smart advertising surfaces. Scalability allows the project to range from a table sized space to large scale exhibition enclosures.

Diffus Design have been working, since 2013, on an embroidered modular blind called SpacEmotion. The embroidery is conductive and, in that way, it is possible to include interaction and functionality into the blind. The modular blind is based on a LEGO-like concept of starting with basic functionality and then, over time, adding on new functionality. Therefore new findings within the world of smart inks, such as from the CREATIF project, can gradually be integrated in the system without the need to restart or discard existing functionality. New functionality is simply added by including a new module that connects and communicates with the existing modules. Figure 1 shows the SpacEmotion blind which was produced before CREATIF without using printing technology.

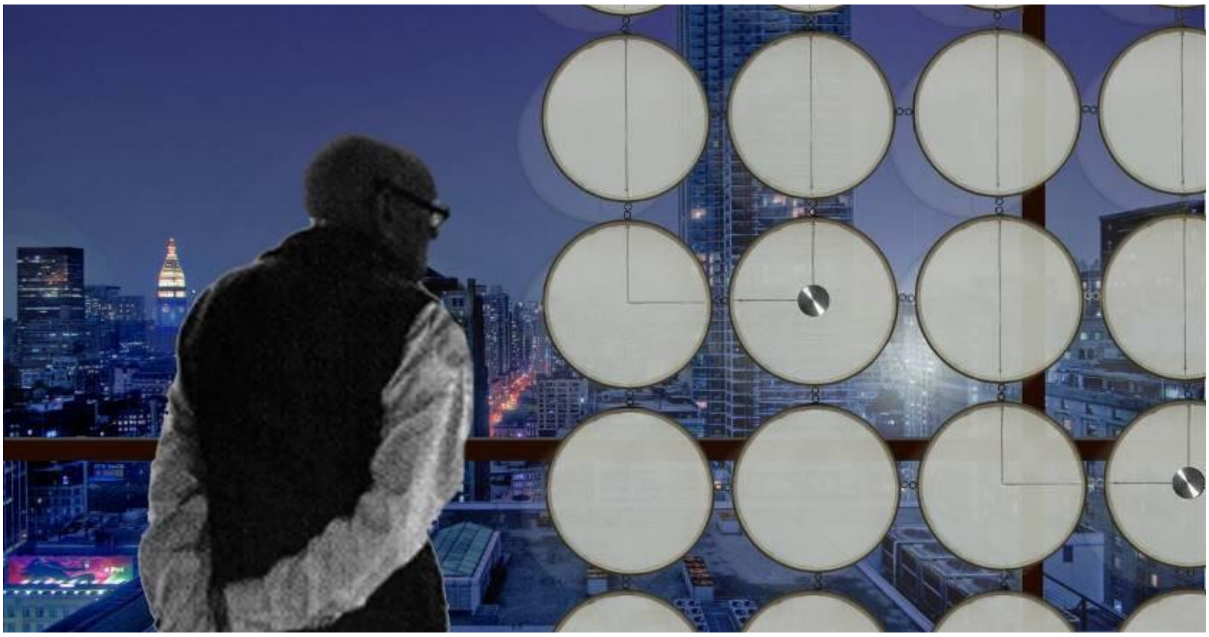


Figure 1: *Blind using non-printing technology showing sound emission*

Figure 2 shows how the interconnects were produced using embroidery and small specially designed metal screws as interconnects. Light emission is achieved by individually mounted light emitting diodes.

Figure 2: *Blind using non-printing technology showing interconnects and light emission*

Within CREATIF, the University of Southampton have printed, using the CREATIF printer, smart fabric discs integrated with electronic circuitry to realise a modular blind printed and designed using the CREATIF software. These 25 cm x 25 cm modular pieces as discs are integrated within one 1m x 1m blind structure and two 1.25m x 1.25m blind structures.

Design refinement for printing: Diffus started the process of mapping different tessellation possibilities connected to the fact that we are using a modular approach with a 25cm x 25cm disc area. From the basic geometries we decided to continue with the circle with 4 connection points. There were different reasons for that choice, among them the fact that we knew how this could be produced, this shape could be integrated in our already existing modular blind, and last but not least the drum skin effect, that we have obtained in our existing solution by stretching the fabric onto a metal circle, is perfect for the speaker module, as the tension of the surface works as an amplifier of the sound.

In the initial phase we were also looking into different structural ways to go. We looked into three possibilities: Flat suspended modules, Flat 'side by side' sliding modules and three dimensional building blocks. The first is connected to surface, the second to superposition and the third to a spatial structure. We chose to go for the flat suspended modules that are suspended from a rail to be hung from a ceiling or wall. The connection system is based on the solution developed for SpacEmotion, with some further development. This choice was made because we wanted to explore the printed surface and the circuits as modular. We see potential in superposition and the 3 dimensional structures, but first we wanted to solve and refine the issues of 'building' with the electronic drive circuit.

In order to use the functional inks as aesthetic elements we decided to work with three geometric shapes: a square inside a circle with one diagonal line passing through the centre of the disc as a continuous conductive line. The smart ink is contained by the square, the circle is defined by the metal ring holding the shape in place and the diagonal line as an embroidered connecting line. The square in the middle is 8 cm and the disc + connectors are approximately 25 cm diameter. This way a certain balance is obtained between functional and non-functional surface from an aesthetic point of view.

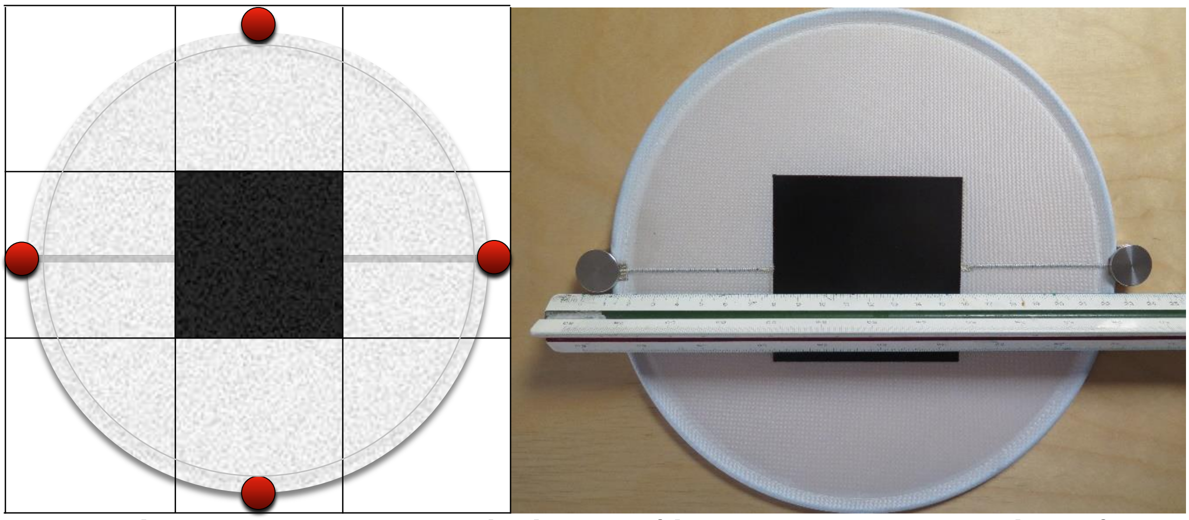


Figure 3 and Figure 4: *Geometric principle: diameter of disc + 2 connectors 24cm and size of square 8x8 cm*

The following 2D illustrations show the final design of the printed areas for the discs that we based on the geometric principles in which the geometric principles have been combined with the requirement for printed functionality:

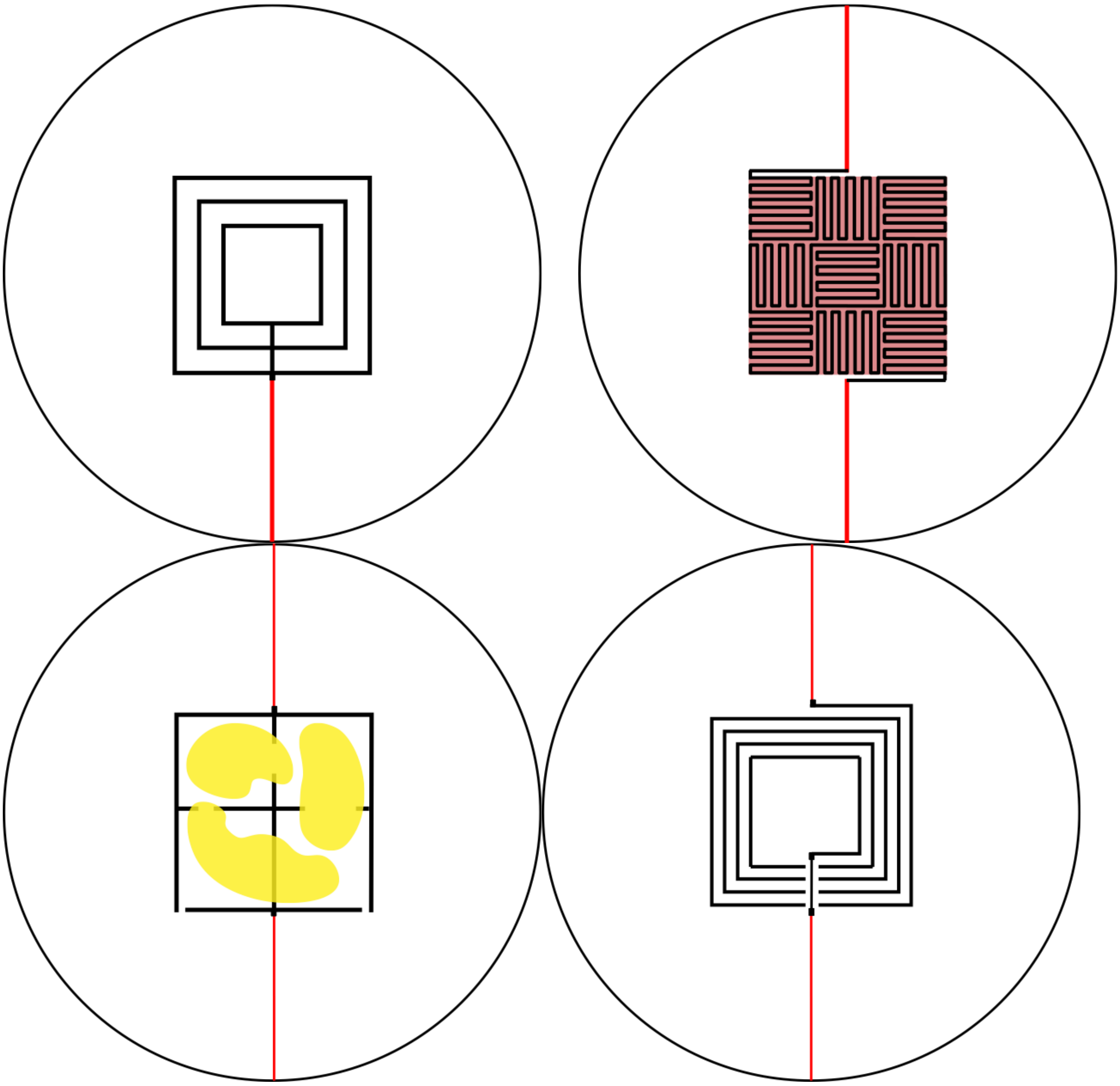


Figure 5: *2D illustrations of proximity sensor disc, thermochromic disc, speaker disc and electroluminescent disc.*

The proximity sensor became a small square inside a medium size square inside a square with an outline of 8 cm in order to strengthen the proximity area and at the same time minimize the need for conductive ink. The thickness of the lines is based on advice from the University of Southampton. The fact that the squares gradually get smaller indicates different scales and thereby proximity. **The thermochromic** ink covers the entire square but the pattern below creates a complex meander pattern that distributes the heat as equally as possible and has the quality of starting as a pattern lighter than the thermochromic surface in the beginning of a heating process and ends as a pattern darker than the thermochromic surface when it is fully heated. **The speaker** disc follows the outline of the chosen square format and makes 4 1/2 full turns inwards. In **the electroluminescent** disc we wanted to work with a more free form. The fact that the light emission area is printed makes it possible to print in almost any shape and to underline that fact we wanted to choose shapes that were not squares or circles that are the shapes of commercially available OLED or EL-lamp devices. Therefore the outline of the circuit needed for feeding 3 EL-lamps with power follows our 8x8 cm functional square but the light is allowed to ‘flow’ as free ‘morphing’ shapes on top of the strict geometry.

Designing implementation and printing using the CREATIF software: After an initial sketch, Diffus made an Adobe Illustrator file which was used as guideline for prototype building and also as a background image for a processing sketch where Diffus planned and tested the principles for interaction. The designs provided by Diffus, via the CREATIF Adobe Illustrator add-in, were all configured to be within an 8 x 8 cm square in the centre of the disc. This was chosen because it fitted with the Diffus design aesthetic, blending the printed tracks with the embroidered pathways through the other discs to connect to the control electronics.

The existing CREATIF library files were manipulated by The University of Southampton in the CREATIF software to create basic trial prints to identify potential problems and establish functionality before Diffus created the full designs in Adobe Illustrator and Grafixoft added them as library files to the CREATIF.cc software. For these advanced bespoke prototypes, the aim was to use the process of the CREATIF software suite but expand on this as expert users because of the extra knowledge Diffus, the University of Southampton and Grafixoft have of the printing process and the electronics. It was therefore possible to produce within the CREATIF software the **proximity sensor** design shown in Figure 6 for printing trials.

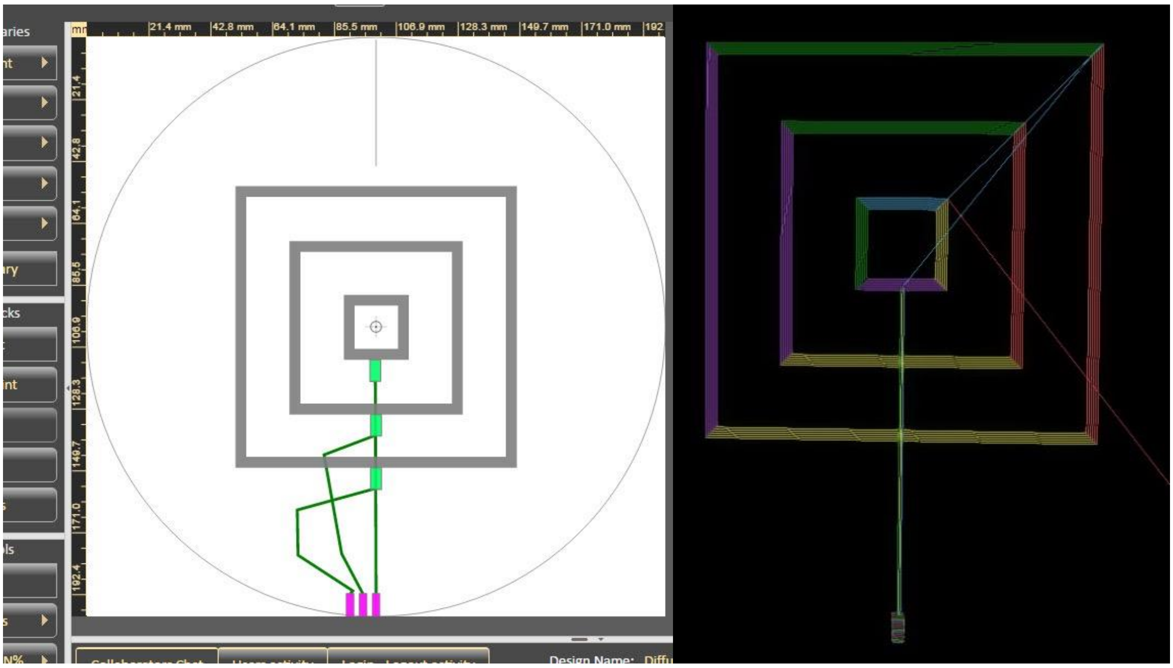


Figure 6: *Concept design created by the University of Southampton in CREATIF software for Diffus (left) and simulation of edited printing code to allow it to print as desired (right).*

The design was printed on to the CREATIF fabric for testing and the printed sensor was then connected to the CREATIF electronics and shown to operate as a proximity sensor based on the output values measured via the proximity module. Therefore a library file version was created by Grafixoft to the specific dimensions requested by Diffus for their design. Figure 7 shows the realised proximity sensor on a Diffus disc. These were successfully operated with the CREATIF electronics and an example video of testing the proximity disc before shipping to Diffus: https://youtu.be/c76gI3Jf-sU.

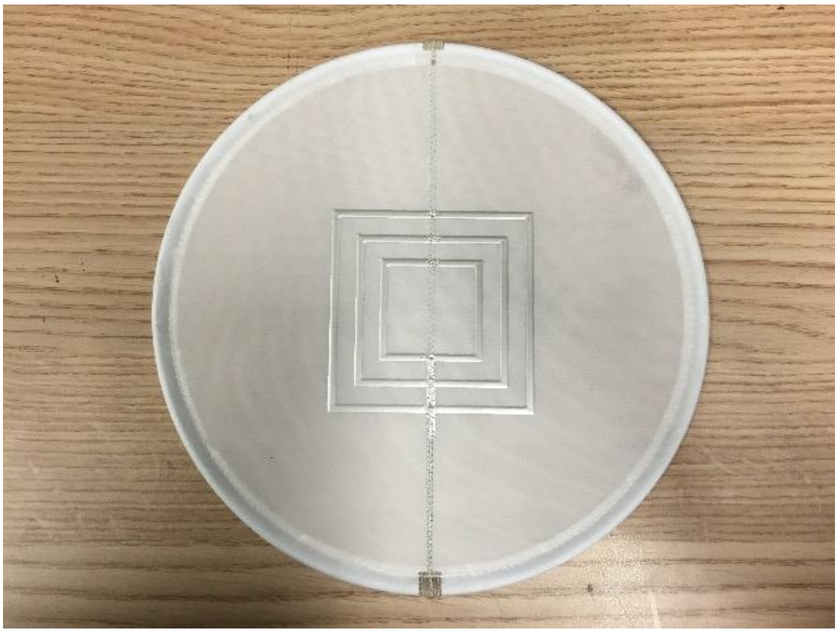


Figure 7: *Proximity sensor on Diffus disc*

The print for the proximity disc is very precise and has sharp edges. Even in a close up, as below, the ink has a smooth and continuous appearance inside the lines and a clear border. The transition between ink and embroidery is elegant and precise. This discovery of the mixing conductive ink and conductive yarn is really positive and opens up to a lot of possibilities.

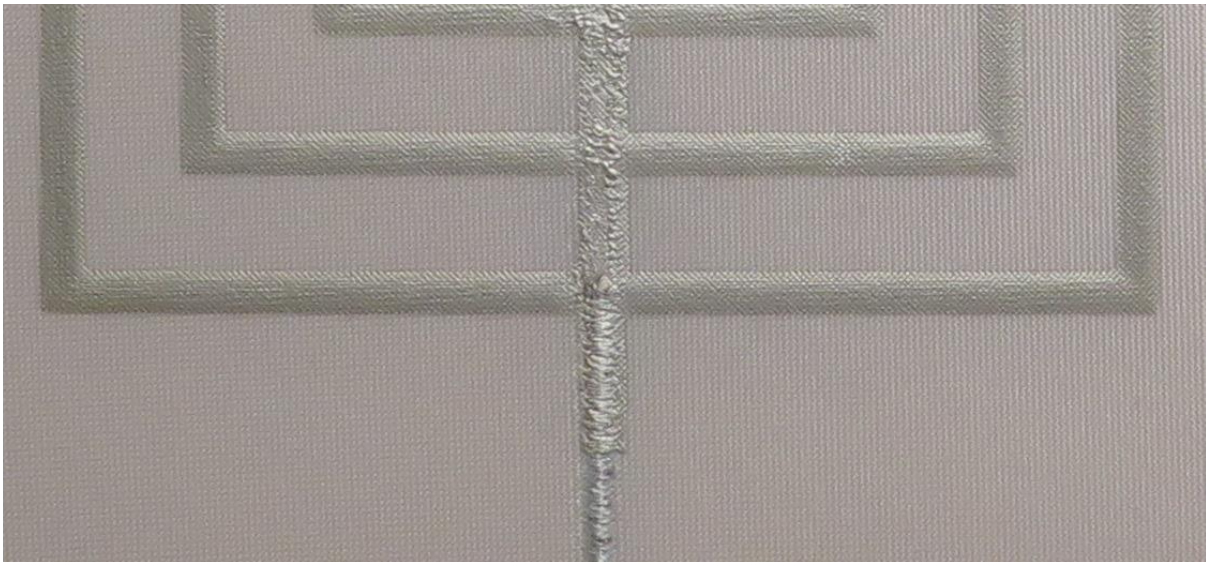


Figure 8: *Detail of proximity sensor. In the bottom of the image the transition between conductive ink and conductive yarn can be seen.*

For the speaker disc, Diffus required the speaker to connect to the top and bottom of the disc and with a longer connecting track than had previously been used and therefore again a library file was used for this initial trial, as shown in Figure 9. The design final design was implemented in a bespoke library file made by Grafixoft using an Adobe Illustrator layout produced by Diffus. The speaker was effectively a scaled up version of the standard library file

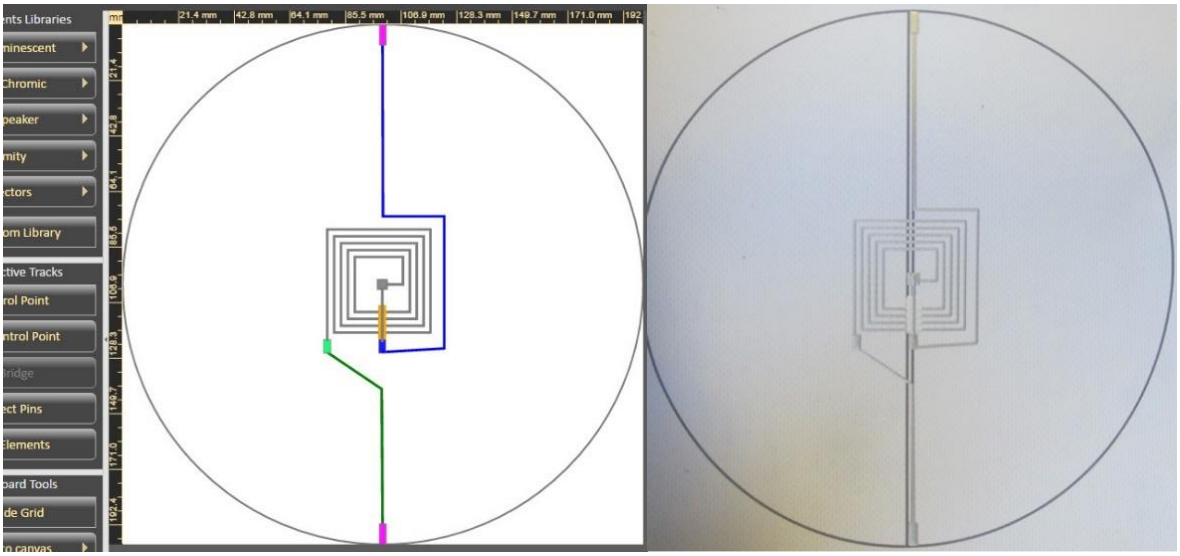


Figure 9: *Speaker design (left) and print result (right) trial for Diffus, testing top and bottom connections as required for Blind 3.*

The speaker design was printed successfully and tested with the CREATIF electronics and Figure 10 shows the realised speaker on the Diffus disc.

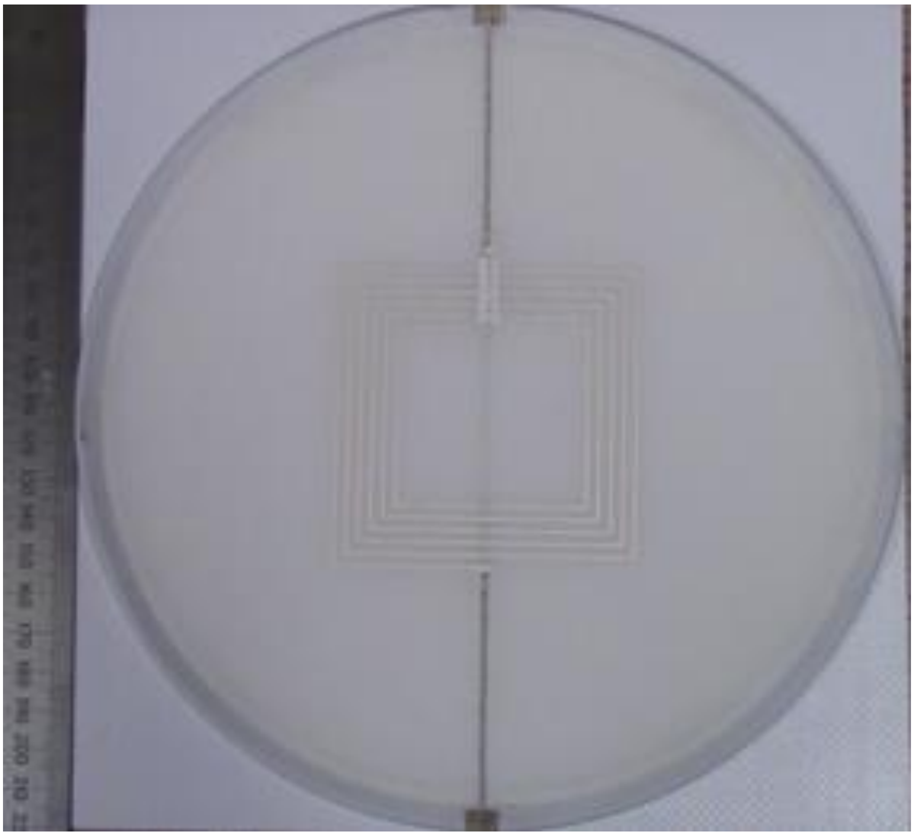


Figure 10: *Realised speaker on Diffus speaker*

The spiral of the speaker disc is perfectly and regularly printed with sharp corners and edges. The bridge that is needed for the end point of the spiral to be able to connect to the edge of the disc is a little wide but for now it is about making sure no short circuits appear and we believe that this can be improved in the future. The ink looks different on the bridge compared to the ink printed directly on the fabric. The smoothness of the ink seems more difficult to obtain on the surface of the bridge compared to the surface of the fabric chosen of the discs. The transition of the conductive ink and the conductive yarn is not as smooth as for the proximity sensor and the thermochromic disc. These details are only visible if you look very close – at a normal viewing distance the speaker discs look great.

Figure 11: *Detail of the bridge on the speaker disc.*

For the realisation of the **thermochromic design**, once again, rather than using the auto-generated library file, a bespoke library file was created by Grafixoft. To fit within the desired 8x8 cm central area of the disc, it was necessary to manually modify the printing code to allow printing in the centre. This is possible because the printing code is generated and can be viewed and manipulated in a G-code simulator first which is available to expert users within the CREATIF software suite and which allows greater user control of the final printing path. Once this was achieved, the design was ready for use to allow automatic generation of the printing path in the CREATIF suite for the University of Southampton printer. The design in the suite is shown in Figure 12.

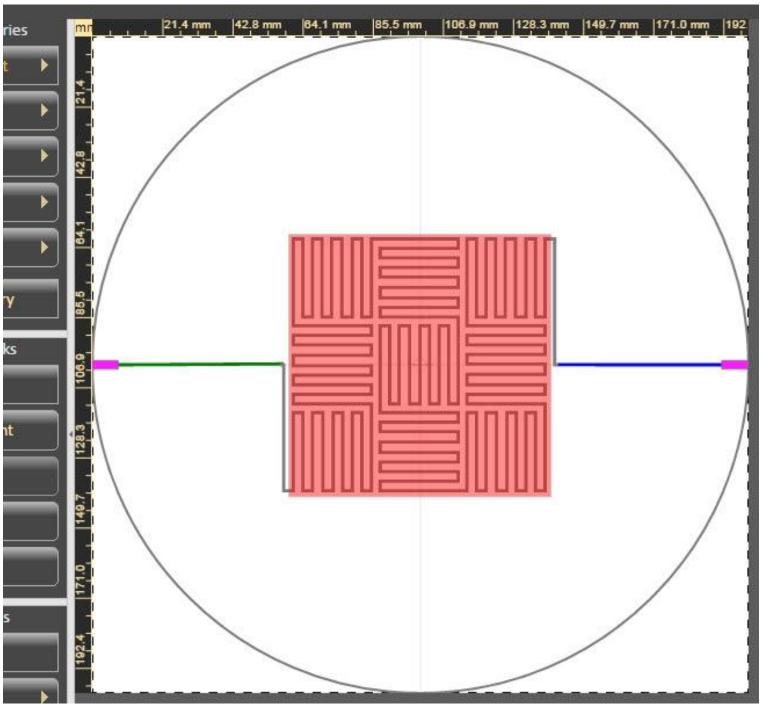
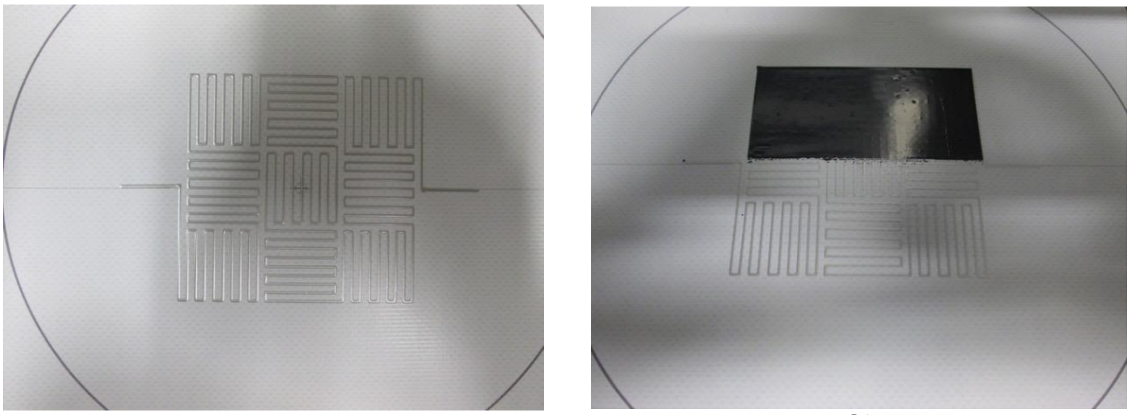


Figure 12: *Thermochromic design imported into the CREATIF design tool ready for printing.*

Figure 13 shows a test print of the thermochromic design with the bottom electrode heater and the top black thermochromic ink printed over half the heater to cover the pattern. The final print of the thermochromic disc was printed using from the CREATIF software and is shown in the example video of operation is available here: https://youtu.be/xV80xf8zYa8.



(a) (b)

Figure 13: *Test prints for Diffus thermochromic design on G2 printer – (a) heater layer and (b) showing half the thermochromic layer printed on top, covering the heater layer.*

The thermochromic disc is very even and smooth. The meander pattern can be seen as a variation of light reflection when it is looked upon in a certain angle. The edges in one direction of the woven fabric seem to be a little uneven. Probably because of the direction of print. These small irregularities - that are regular in their own terms add to the materiality of the disc and, from Diffus Designs' point of view, add to the aesthetic quality.

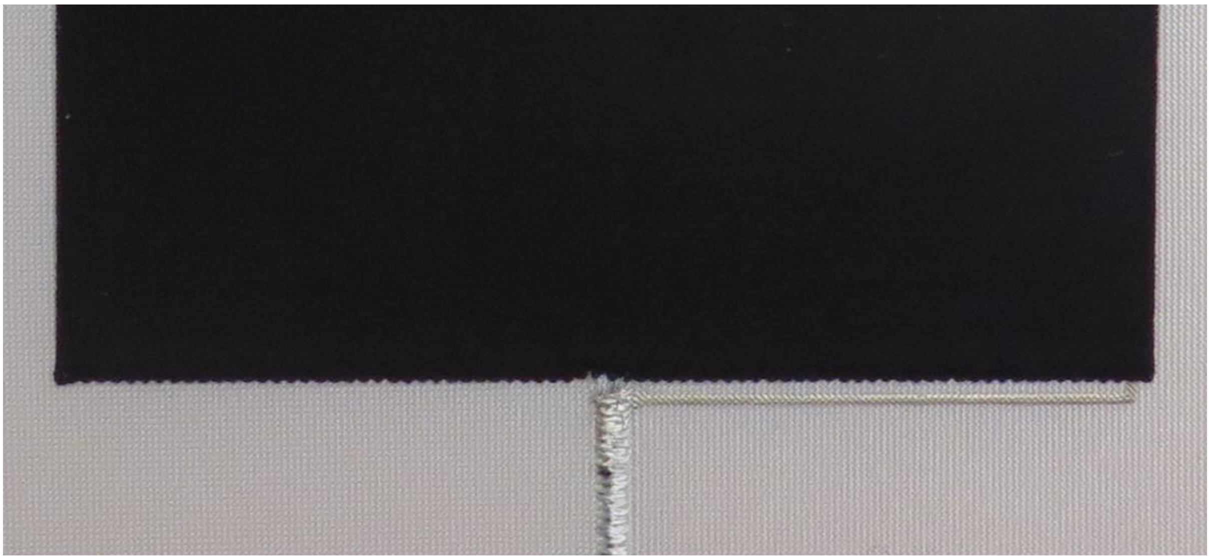


Figure 14: *Detail of thermochromic ink showing how the edges differ in the x and y directions.*

For the **EL lamp design** there was again the requirement to break the standard user software rules because Diffus required their EL lamps to be closer than is normally advised and also required conductive tracks to be used for aesthetic as well as functional reasons. The design was imported via the CREATIF Adobe Illustrator add-on as normal but would produce warnings in the software so a bespoke library file for the design was constructed shown in Figure 15.

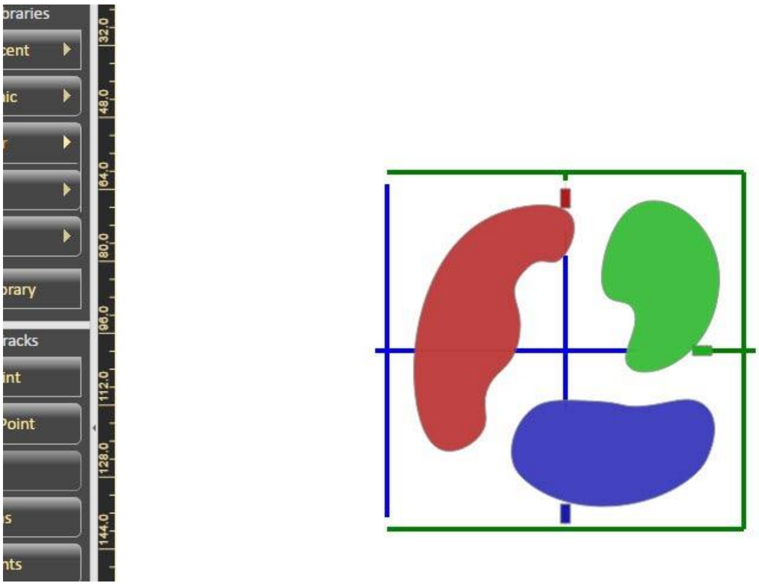


Figure 15: *Final library file created by Grafixoft to allow printing of the Diffus EL design for Blind 2.*

The design was printed using the CREATIF printer and an example video the EL lamp operation: https://youtu.be/7fTVEwAeRCE.

The EL discs are the most inconsistent of the prints if different discs are compared. There are significant differences between them. Therefore each disc is unique with its own personality. There is definitely something interesting about the fact that the EL ink is a little unpredictable. In all cases the light gets a beautiful depth and materiality. Often light blinds the eye in a way that the light emitting material cannot be seen when turned on, or the evenness of the substrate makes it uninteresting. In this case the materiality of the light emitting material stays visible, creating a very special light that almost resembles a candle light or a gas flame more than electric light.

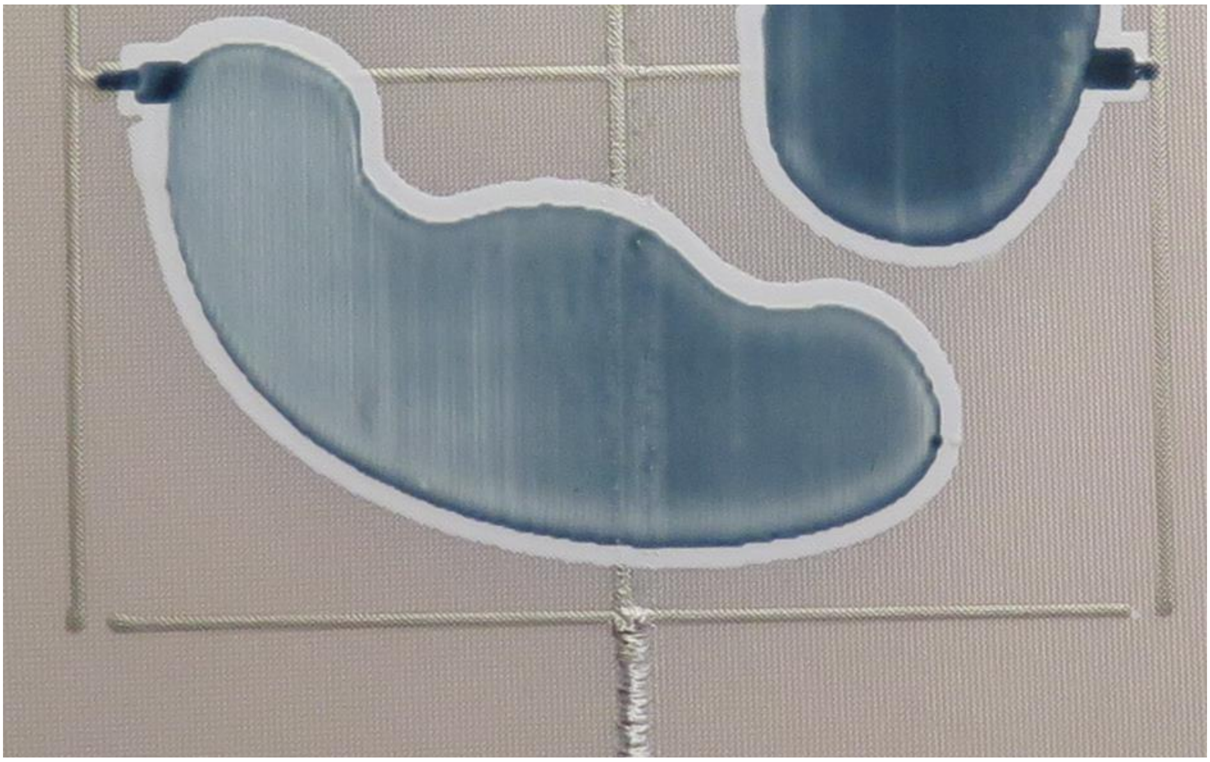


Figure 16: *Detail of the EL disc showing the materiality of the light emitting substrate when off.*

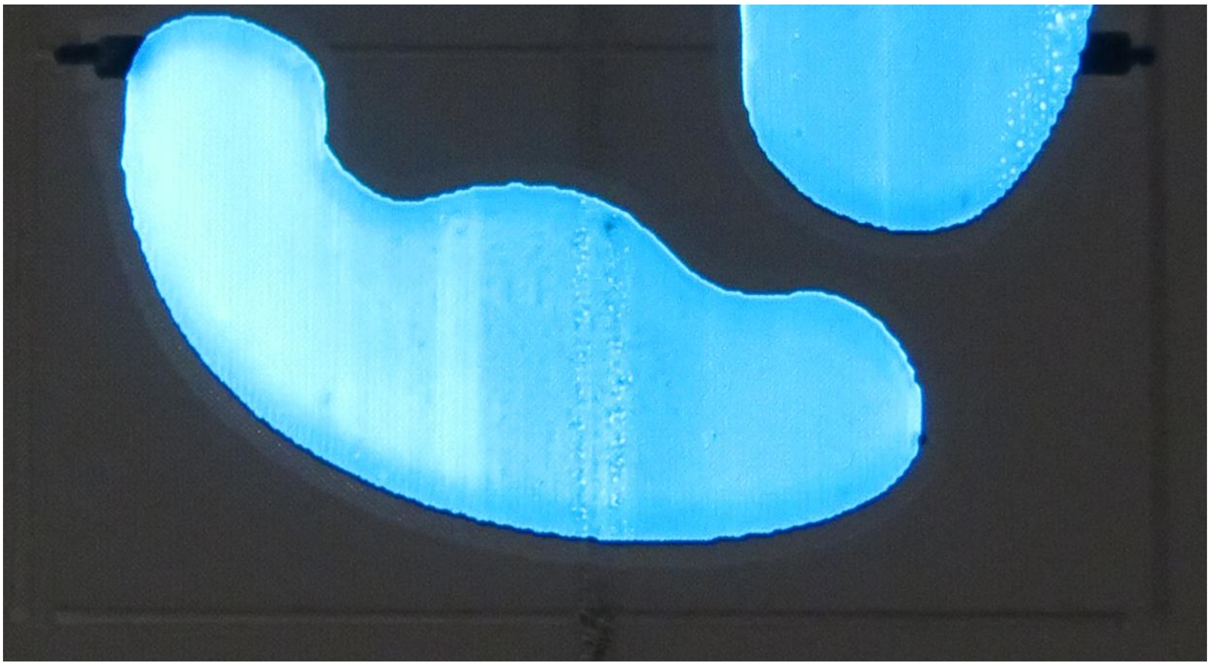


Figure 17: *Detail of the EL disc showing the materiality of the light emitting substrate when on.*

Below shows how all the designs look in the final printed textile discs for comparison with the initial designs from Figure 5.

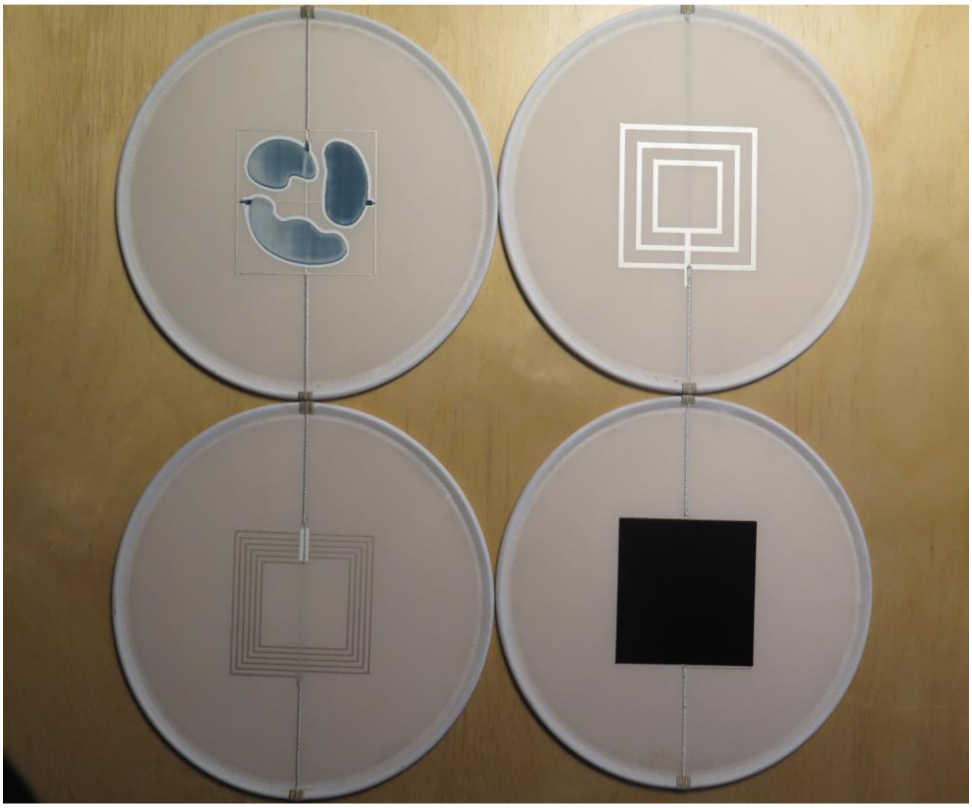


Figure 18: *Photo of the electroluminescent disc, proximity sensor disc, speaker disc and thermochromic disc.*

Blind Construction: The blind has 4 constructive elements: a rail, a steel wire for each row of discs, a number of discs and a number of connectors depending on the number of discs. The steel wires have three functions; they form a structural connection between the rail and the discs, they convey power and data, and they can be adjusted in order to change the distance between rail and blind. The connectors connect the discs structurally as well as electrically.

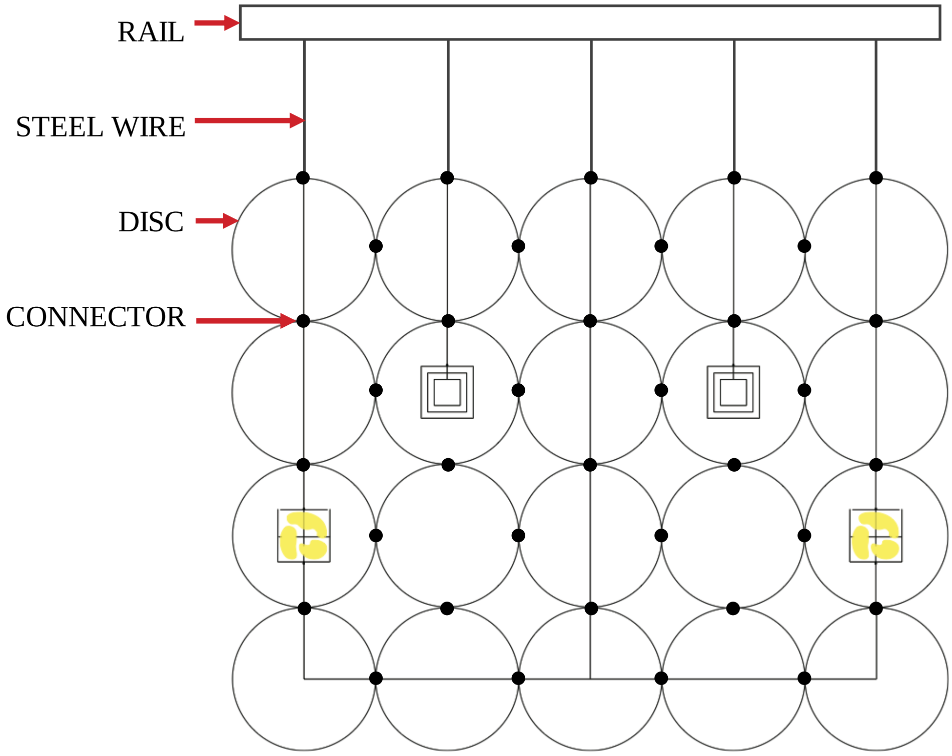


Figure 19: *Schematic overview of the constructive details of the blind.*

The blind is free hanging which highlights the translucency and the sound quality. Also having the electronics in the rail makes it easy to connect and adjust. The modular control electronics used was developed by the University of Southampton and can be programmed directly from the CREATIF software. The electronics control boards are located in the rail above the blind. Cables run internally from each control board to the individual hanging points, where they are connected with the insulated steel wires. All signal and power runs through the insulated steel wires, through the stainless steel connectors and from here into the embroidered circuits on the discs. This solution needs the stainless steel connecters to be insulated with a clear dielectric to minimise the risk of electric shock, shorts and interference.

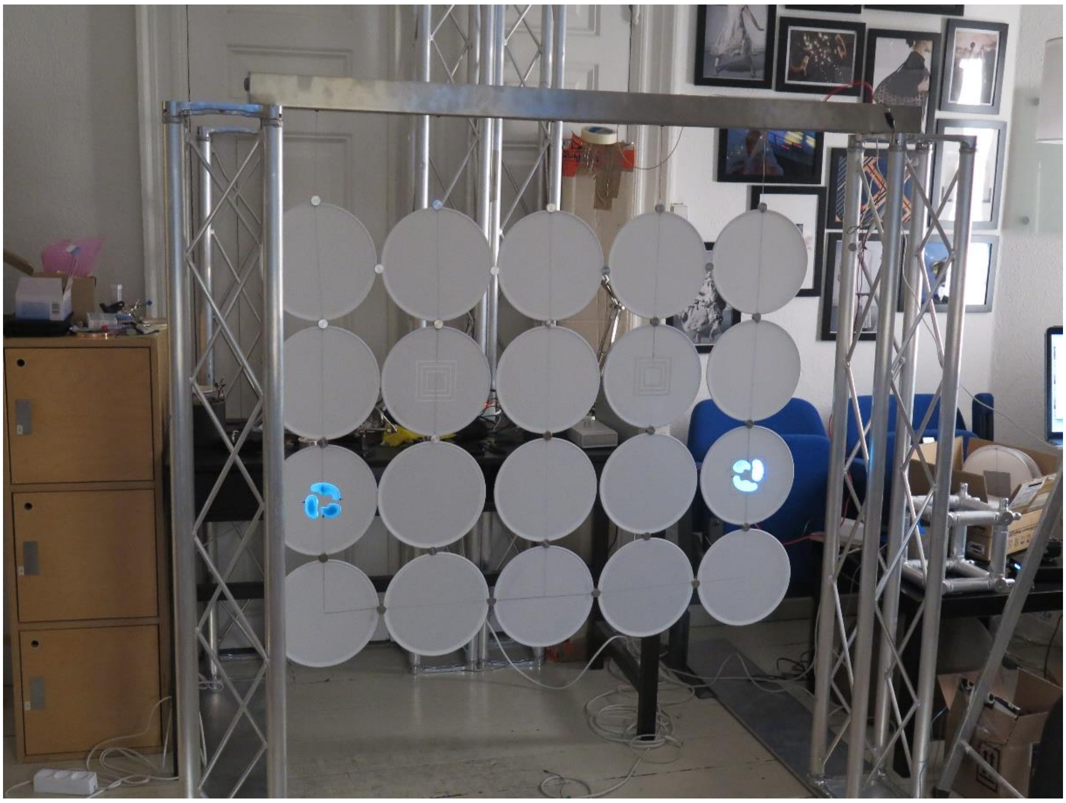


Figure 20: *Blind with 2 proximity sensors and two EL-lamps*

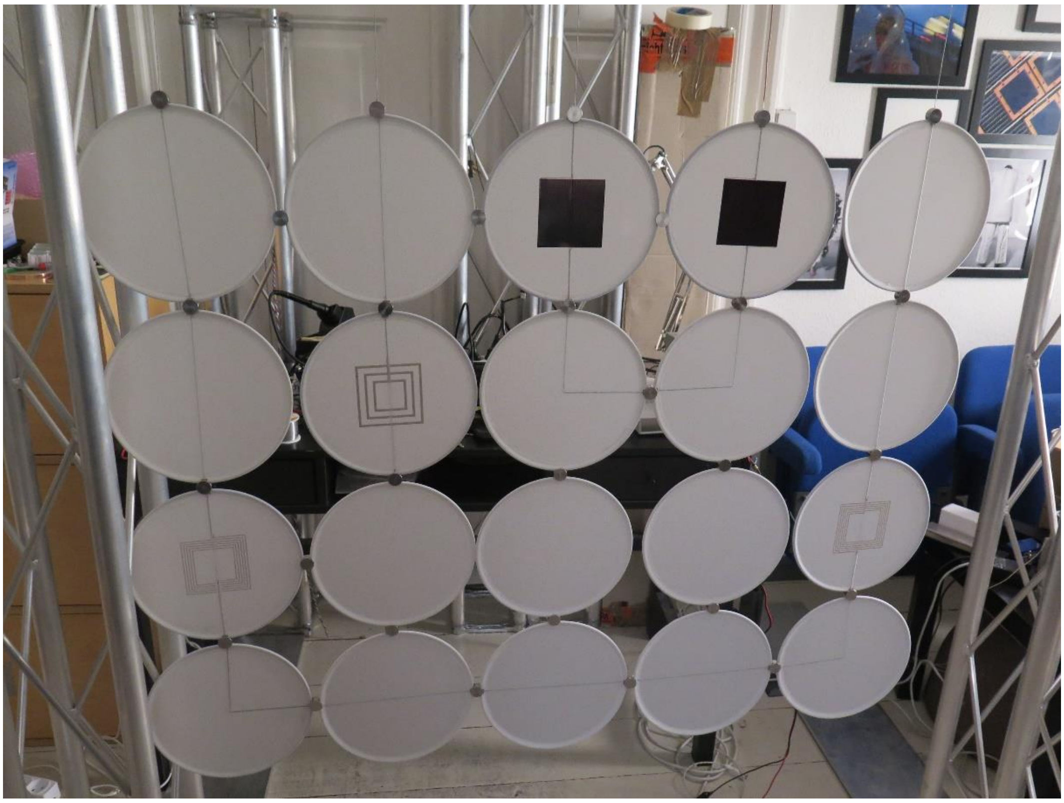


Figure 21: *Blind with 1 proximity sensor, two thermochromic discs and two speaker discs*

Follow up success and future perspectives: Working with a modular approach with printed devices and circuits has great possibilities. When Diffus started working with SpacEmotion in 2013 we began a journey in this specific area. The idea of adding new functionalities as the system is modular, adaptable and flexible. We are aware that more functionalities means more complexity in the circuits and therefore the CREATIF project have given us a great potential to investigate not only new functionalities but also different ways of dealing with hardware and software complexity. In the following we describe the near future of the Modular Blind and more long term perspectives.

ELAC (Embroidered Light for Acoustic Ceilings) exploits the advances of OLED and LED technology in the area of acoustic ceiling tiles. Figure 22 shows a standard tiling system mounted on invisible metal frames. The tiles measure 60x60 cm.

Figure 22: *Standard ceiling of acoustic 60x60 cm tiles*

Diffus have surface mounted light emission technology and the associated circuitry to avoid complex light installations effecting the acoustic performance and to ease the technical installation. The traditional solution for integrating light in acoustic ceiling tiles is to remove acoustic material whenever light is needed; the installation process is complex and requires an electrician to establish connections from above the tiles. With ELAC we apply the circuitry on textiles through a soft embroidery process and then mount it onto the tiles. A central tile is the ‘brain’ for 8 surrounding tiles and a multiplication of ‘islands’ of 9 tiles can be achieved to allow the light surface to become larger. The brain tile allows wireless interaction with built-in sensors to monitor the surroundings and adapt accordingly. In the solution we have chosen we have found inspiration in the coffer ceilings of the past.

The essence of coffer ceilings is an interplay between light and absence of light systematised in regular, geometric and scalable shapes, which is exactly what we are aiming for in the ELAC project. Each tile in the system became an interplay between 3 types of light: (OLED 5 x 5 cm, OLED 10 x 10 cm and LED sequins), the structural embroidered circuitry, and areas of no light. The circuitry is made in a way that several contract points are placed at the edge of the tile in order to be able to touch the contact points of the neighbouring tile. This principle makes it possible to transfer electricity and data from tile to tile. Figure 23 shows four different views of a tile - from the first circuit drawing made in Adobe Illustrator, to a needle movement instruction for the embroidery machines, then a version used as a basis for a processing (software) sketch for testing the interactivity to a photo of the finalised tile.

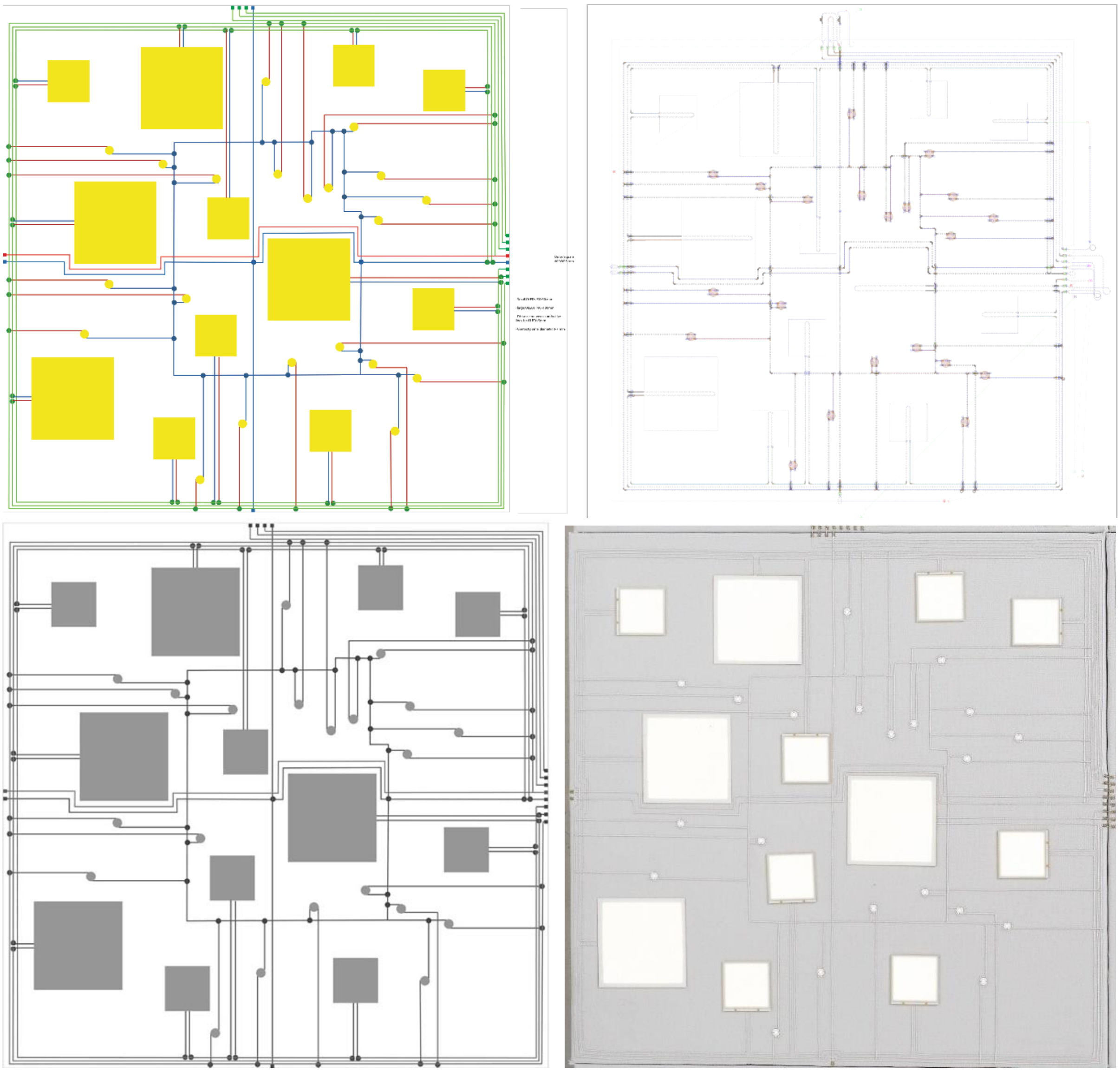


Figure 23: *4 versions of the circuit for ELAC, from top left to bottom right: 1) the initial schematic drawing with colour code for lights (yellow), ground (blue), 5V (red) and data transfer (green), 2) The circuit translated to stitches for the embroidery machine, 3) graphic representation used to simulate the light functions through the software processing and 4) a photo of the functioning prototype.*

The ELAC prototype is now finalised and below is four images of the finished and fully functional prototype.

Figure 24: *Final ELAC prototype installed in an office (top) and details of the embroidered circuitry (bottom)*

As the printed solutions were not yet fully tested for commercial use we decided to use embroidery as a circuit rather than print as the embroidered solution is market ready. But the investigations of the CREATIF project are in principle the same if we use either embroidery or print. The process is more or less the same from the add-on to Adobe Illustrator, to the tracking of circuits in the CREATIF software the simulation and design interaction, the creation of Arduino code, all the way to the output for a machine producing the circuits. The biggest difference comes in the file produced for the printer movements compared to a different file which is produced for the needles of the embroidery machine's movements. Therefore Diffus see ELAC as a great example of future use of the CREATIF process.