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Re-FREAM

Re-Thinking of Fashion in Research and Artist collaborating development for Urban Manufacturing

Hub "Electronics and Textile"

Deliverable 5.5

Final version of four E-textile artworks and two eco-designed artworks

Grant agreement no.:	825647
Call identifier:	H2020-ICT-2018-2 – ICT-32-2018 – STARTS
Objective:	The Arts stimulating innovation
Start date of the project:	01.12.2018
Duration	36 month

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Re-FREAM is funded by the European Union's Horizon 2020research and innovation programme under grant agreement No 825647.

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Re-Thinking of Fashion in Research and Artist collaborating development for Urban Manufacturing

S+T+ARTS LIGHTHOUSE Re-FREAM

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Working Package WP5

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Due date of deliverable: 30.11.2021

Actual submission date: 12.11.2021

Lead Beneficiary for this deliverable: Fraunhofer IZM

Contributions by: -

Project co-funded by the European Commission within H2020 Framework Programme		
Dissemination Level		
PU	Public	x
CO	Confidential, only for members of the consortium (including the Commission Services)	
Type		
R	Document, report (excluding the periodic and final reports)	
DEM	Demonstrator, pilot, prototype, plan designs	x
DEC	Websites, patents filing, press & media actions, videos, etc.	

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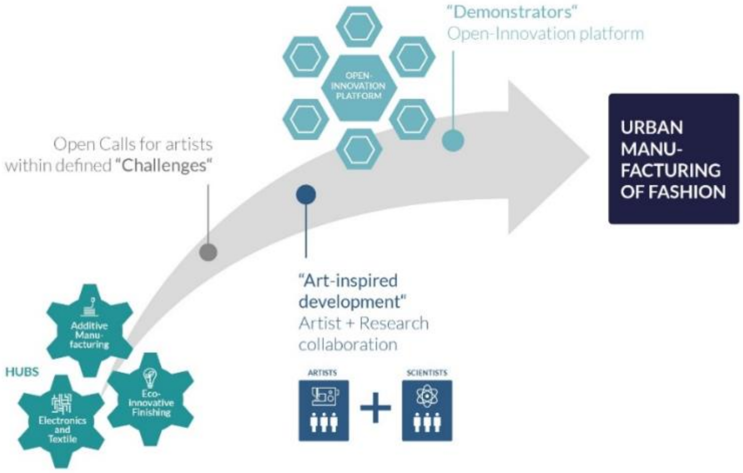
0 Context Information

0.1 The Re-FREAM Project



Re-FREAM will support **art-driven innovation** in European R&I projects by inclusion of artists in research consortia via linked third parties. The artistic community receives a strong support from art-related partners like the Art University of Linz (UFG) and the European Institute of Design (IED), creative hubs and facilitators like Wear-IT Berlin (FashionTech), AITEX, ARCA and CREATIVE REGION combined with remarkable technology from IZM Fraunhofer (E-textiles), STRATASYS, HARATECH (3D-printing), EMPA (3D body simulation), CARE APPLICATIONS (Garment nebulization) and PROFACTOR (Additive manufacturing).

Re-FREAM boosts **art-inspired urban manufacturing**, where the city becomes a new production space. Especially for **creative fashion**, urban manufacturing offers a great opportunity to create an alternative to the much-criticized production in low-wage countries.

Three technologies (additive manufacturing, electronics on textiles and eco-innovative finishing of fashion) will be explored together. **In co-creation** 20 awarded Artist/ Researcher teams, digitalized manufacturing of fashion will be developed up to TRL 5 to enable small-scale production of fashion in urban environment. An **Open-Innovation Platform** will finally link the know-how and the communities of the hubs, will offer access to relevant facilities and make the Re-FREAM art-inspired urban manufacturing working model sustainable.

0.2 Document history

Version	Date	Change/Reason for change
V1.0	07.10.2021	Draft template prepared for partner input
V1.1	11.11.2021	Input from IZM
V1.2	12.11.2021	Finalization by PRO and CRE

0.3 Purpose and Scope of Deliverable Report D5.5

This document reports on the demonstration of E-textile artworks resulting from the work of artists and technologists for the **second Art/Tech collaboration** round carried out in **2021**. Two E-textile and one Eco-Design demonstrator have been co-created within the awarded projects **Second Skins (by Malou Beemer)**, **Ignotum (by Jan Wertel)** and **Embroidered Touch/ Life Space (by Anke Loh)**.

1 Executive summary

The E-textile hub received 39 applications in the 2nd call. All projects were assessed according to the evaluation criteria and the best 6 projects were passed on to the jury, which selected the 3 winners.

The three winner projects are assigned as follows:
- E-Textile Challenge: Second Skin & Embroidered Touch/ Life Space
- Eco-Design Challenge: Ignotum

Fig. 1: Members of the Art/Tech team of the 2nd round at the Fraunhofer IZM facilities in Berlin. From left to right: Manon Montant (WIB), Christian Dils (IZM), Jan Wertel (designer/ Ignotum), Malou Beemer (designer/ Second Skin), Anke Loh (designer/ Embroidered Touch) and Robin Hoske (IZM).

With the support of the coordinating hub manager Wear IT Berlin and the technological partners Fraunhofer IZM, EMPA, ProFactor and Stratasys, the artists were able to co-research and develop textile-integrated electronic systems and applications.

The results of the collaboration of designers with scientists and technologists led to new concepts, technological developments and functional demonstrators. The 3 project applications developed and implemented as technical-aesthetic demonstrators are described in more detail below.

1.1 First version of four E-textile artworks and two eco-designed art-works D5.2

In the **first Art / Tech collaboration** round from **2019-2020**, two E-textiles and one Eco-Design co-research projects were jointly developed for **Lovewear (by Team Witsense)**, **Constructing Connectivity (by Jessica Smarsch)** and **Alma (by Giulia Tomasello)**. The relevant processes and results are summarized in the public Deliverable 5.2. or are available on the respective project websites.[1]

[1] https://re-fream.eu/pioneers/

2 Demonstrators of the 2nd art/tech round from the E-textiles hub

2.1 Project Ignotum

The Ignotum co-research project concept is about confusing artificial intelligences (AIs) that are used to analyse CCTV footage. They are gaining personal information of filmed people like gender, age, emotional state and sexual preferences, some of them with very high accuracy. In recent years, these technologies are finding their ways into retail spaces and are supposedly used for a better shopping experience. In the project, a piece of smart clothing was developed that gives the wearer the opportunity to choose whether they want to be visible to the cameras or not.

In the first **eco-design** workshops, we set ourselves the common goal of designing an easy-to-use garment that confuses AI with a minimal amount of technology. We looked for the most efficient way to create a durable and repairable garment that would protect the user's privacy in public. Wertel&Oberfell used their own AI test setup to find out which effects were most effective in confusing the AI, with light scattered over the body proving to be the most effective measure. After finding and digitally validating the contour of a suitable light effect that prevents from being detected by an AI algorithm, first attempts could be planned and carried out to 3-D print lightguides directly onto a textile substrate based on Stratasys' Agilus30™ material. The various shapes were then tested using a Chip LED and optically analysed with a spectrometer. As depicted in Figure 2, over a length of 10 to 20 cm, however, the printed light guides lose too much of their emitting light intensity, so that use for the large-scale prototype and the required size of the AI-blocking light pattern would not have been possible or would only have been possible with printed short length segmented lightguides that need too many LEDs and a lot of wiring. However, we see a lot of potential for further developments and collaborations with the direct printing of lightguides on textiles.

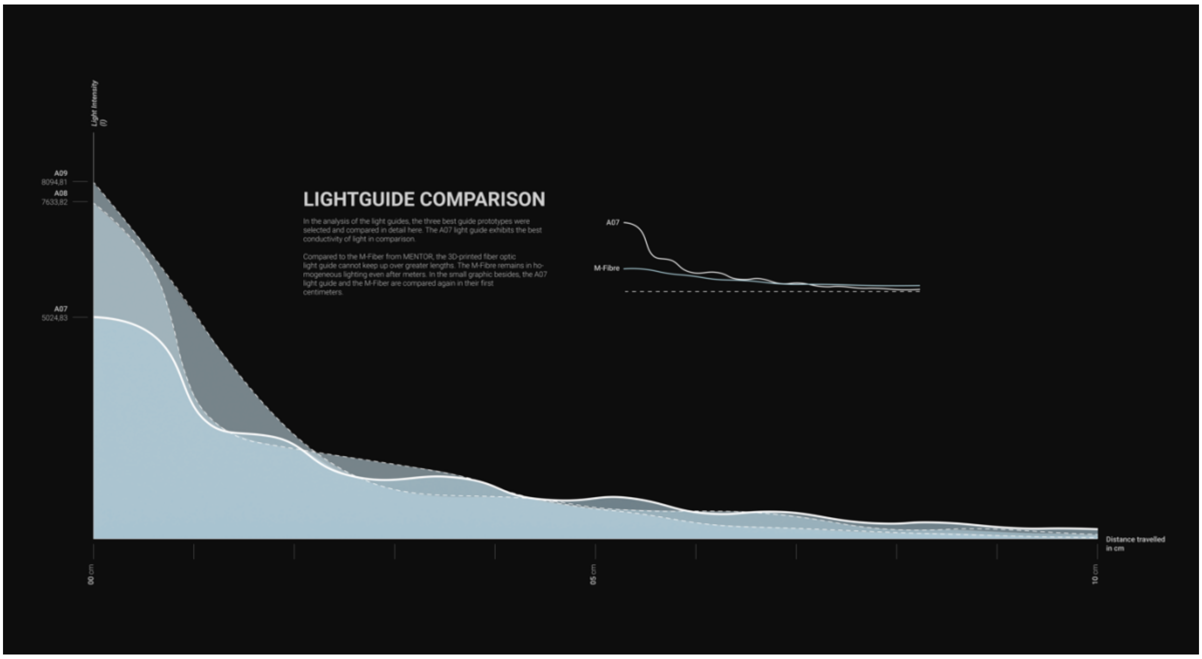


Fig. 2: Spectrometer analysis of light intensity over distance for different printed lightguide test structures.

Therefore, we used and tested commercially available lightguides for the final prototype due to the above-mentioned issues with the only short-length manufactural printed lightguides. Except for the commercially available lightguide material, all required components have been customized and miniaturized to such an extent that they can be seamlessly integrated into textiles in a modular and sustainable way. A total of 9 customized modules were bonded onto a 2 m long conductive textile cable, which are then connected to the LEDs and are used for coupling light into the lightguides.

The final stacked garment composition is shown in the following Figures 3 and 4 starting with the innermost and ending with the outermost layer. The base layer gives the garment its structure followed by a technical layer made of the textile conductive ribbon with the already pre-bonded modules for connection to the LEDs as well as a PCB with the USB-C connector for the connection to a power bank. The LED modules with the high-power chip LEDs then follow and are further covered with another layer, the moiré top layer. The last layer consists of the 9 light guides which are cut in size and finished with a crimped ferrule to avoid losing light intensity at the cable end and are held in position on the garment by means of individually designed and 3-D printed buttons. The use of off-the-shelf components in combination with 3D-printed elements and a reproducible cutting pattern also underlines the concept of resource-efficient urban manufacturing on demand, which can be reproduced and customized.

Fig. 3: From left to right: Base, Technical, LED module and Moiré layers.

Fig. 4: Left: Final lightguide layer; center and right: Final demonstrator.

This **modular approach** follows the **Planetary Design**[2] guidelines, developed at Fraunhofer IZM, and offers several advantages: Firstly, only as few materials and electrical components are used as necessary, secondly, the use of detachable buttons means that the technical components and materials can be easily removed again for repair or replacement and, finally, a different light source can be easily implemented, for example if light

[2] https://re-fream.eu/planetary-design-circle-a-holistic-and-strategic-design-tool/

should emit in the near infrared range instead of the visual spectrum, thus increasing the options of further applications without the need to build a new system.

During the Ignotum research projects, new concepts for 3-D printed light guides have been initiated and started. Novel materials and technologies for e-textile systems were tested and used in the development of the demonstrator. In this way, the flexible or textile-based conductor elements could be manufactured and the required interconnections and PCBs could be assembled onto the conductive textile ribbon using adhesive bonding technology. Other components, such as the buttons for fixing the light guides or the encapsulation/ housing of the LED modules, were fabricated using 3-D printing techniques. The project results can be used to realize also other applications, for example for light guides in automotive and interiors.

2.2 Project Second Skins

In the Second Skin project, the Art/Tech team researched various solutions for visualizing body language and movements. At the beginning of the co-research phase, two different concepts for adaptive garments have been formulated but within the co-creation phase we were only able to further develop and manufacturer one of these concepts using the novel e-textile hardware kit for a textile-integrated electronic system with IMU sensors to detect body movements and many RGB LED pixel boards for creating interactive light effects. For the other concept, a shape changing garment, we couldn't find any safe and wearable programmable soft actuator material on TRL level 5 or above. Further information about this research is summarized by the Art/ Tech team in a blog article.[3]

In order to incorporate **user needs** into the development process in parallel with the technical challenges, a **hybrid user testing** process was conducted with 12 stakeholders. The concepts were presented to potential customers and fashion experts and critically examined for their intended use. The workshop helped to consolidate proven theses and generate important design leads that proved essential in the decision-making and formulation of the final design. The user tests served to refine the two development directions that had existed up to that point (light as a material, shape-changing clothing). Potential customers were able to express their concerns about ease of use, integration into everyday activities, and about their usage patterns. **Supply chain, reusability** and **interchangeability issues** were also addressed during the workshop, which strongly influenced the final design. Due to the feedback it became clear that the concept must consist of multiple layers with different and adaptable inserts that can be customized and tailored to the needs of the wearer, rather than providing singular solution. This was also intended to link to the thesis that users build a longer-term relationship with the garment through its adaptability of the mask layers.

The two completed demonstrators react to body movements and translate these into a colour change of the projected to the outer textile layer. The final concept is based on a multi-layer structure, which is outlined in the Figure 5.

[3] https://re-fream.eu/second-skins-research-on-responsive-and-adaptive-materials/

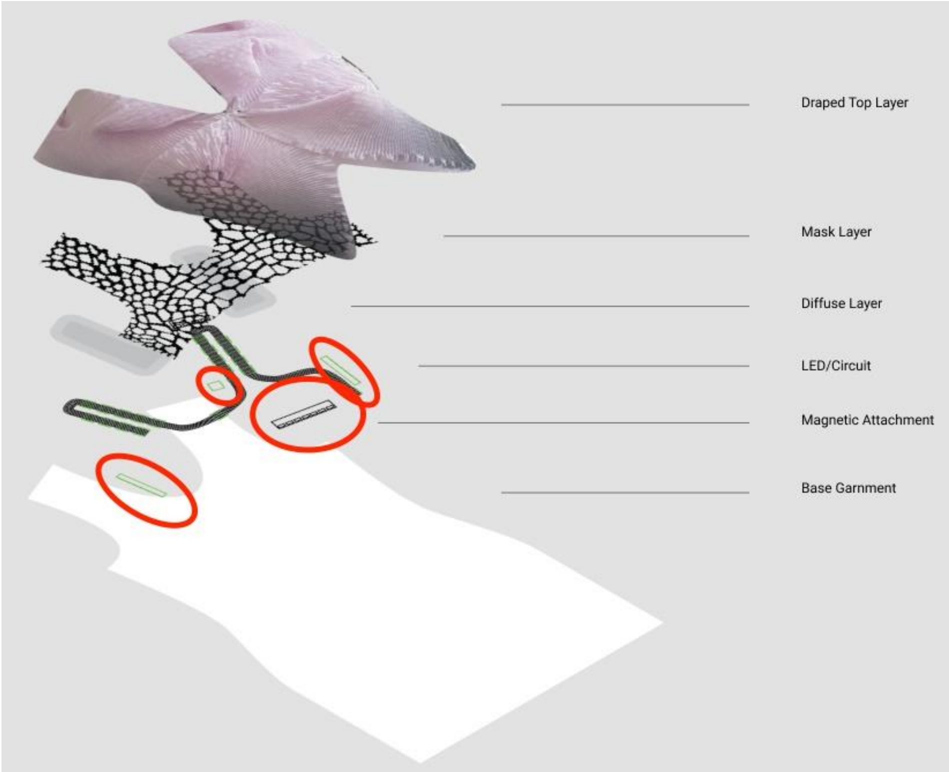


Fig. 5: Illustration of functional layers for the Second Skins demonstrator.

Conductive yarns coated with Thermoplastic Polyurethan (TPU) are embroidered onto a carrier textile as conductive tracks using Tailored Fiber Placement (TFP) technology. Embroidering the conductor allows us to design freely the track layout. The electronic modules and magnetic connectors are attached on the base layer. Two further layers are used for modular and individual lighting design. Flat light effects are generated from the point-like light cones of the LEDs by the two diffuser and mask layers. The (3D) printed mask layers can be implemented with an individual design and exchanged using the magnetic contacts. Pleated and dyed fabrics were developed as a drapeable outer layer to optimize the light effect.

The core of the electronics is the e-textile hardware kit developed for fast prototyping by IZM and implemented by an artist for the first time. In addition to already existing e-textile prototyping kits, such as LilyPad or Adafruit, the new modules allow multiple interconnection technologies that are on different TRL. In the prototype phase, the modules can be easily contacted by embroidering a non-insulated conductive thread or soldering a hybrid conductor. As soon as the development process is completed, the outer ring of the modules can be removed and the contact pads located under the core of the circuit board can be used for industrial assembly by adhesive bonding. As a result, a prototype can be quickly and reliably converted into a product with the e-textile kit. Further information on the e-textile kit and the Adhesive Bonding Technology has been published in an open access article[4] by IZM and the presented interconnection concept is depicted in the following Figures 6 and 7.

[4] *Proceedings* **2021**, 68(1), 5; https://doi.org/10.3390/proceedings2021068005

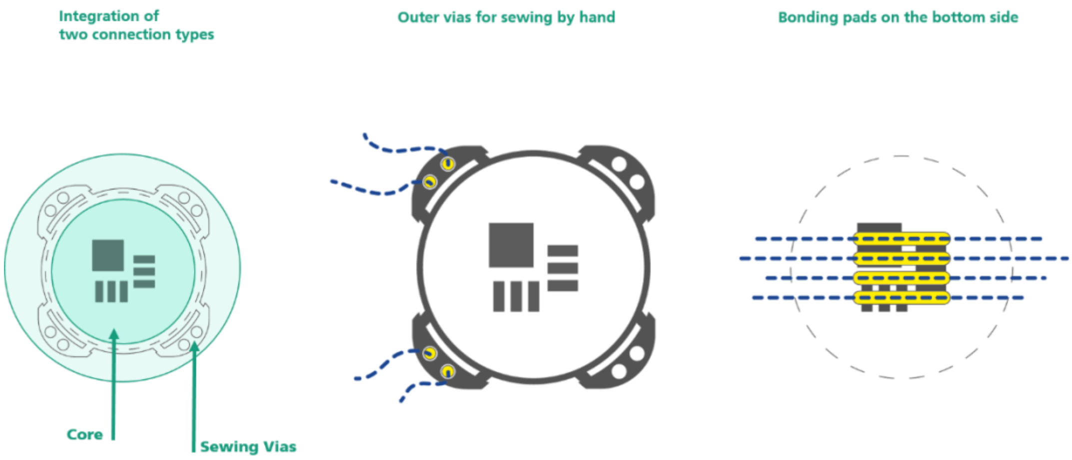


Fig. 6: Two implemented interconnects concepts for each module of the e-textile hardware kit.

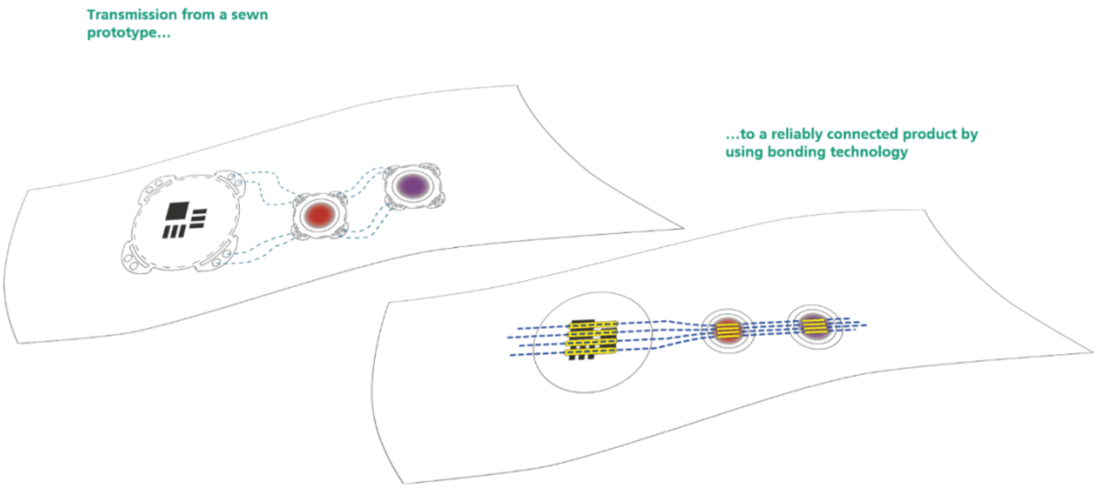


Fig. 7: The interconnection concepts allow easy transmission from prototype to industrial processes.

The prototype features new types of smart RGB pixels, a microcontroller and IMU boards. During the joint laboratory work with the artist, intensive material and process tests for embroidering the textile conductors as well as the integration of the electronic modules were tested. For the final prototype, a total of 17 electronic modules were built and successfully bonded for each of the two final demonstrators. In addition, a simple to use software tool for individual programming of the lighting effects has been further optimized so that even users without programming experience can program the modules quickly and without frustration. The next Figures 8 and 9 are showing the functional electronic layer as well as the final prototype.

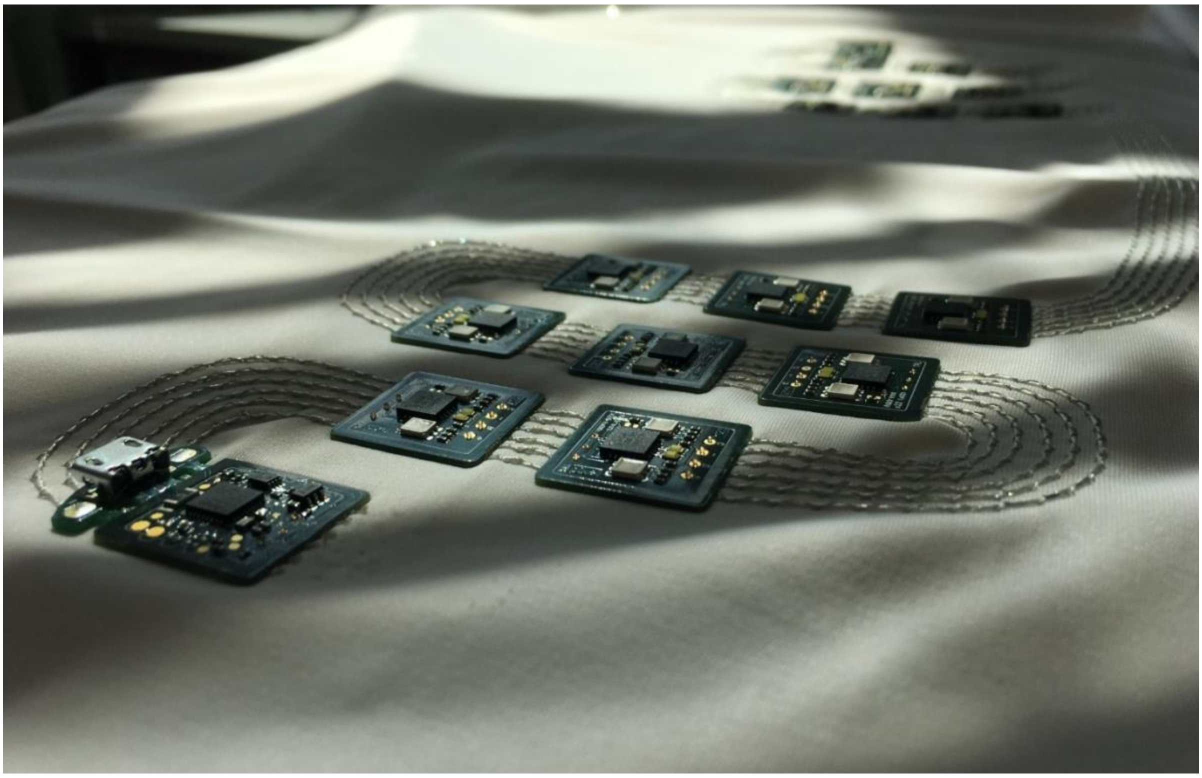


Fig. 8: Electronic modules bonded onto embroidered conductive tracks.

Fig. 9: Left: Base layer of the final demonstrator and right: Final demonstrator with all layers.

2.3 Project Embroidered Touch/ Life Space

The aim of this collaboration was to contribute to and advance the development of touch-sensitive embroidered textiles. The research explored new approaches to textile design by embroidering conductive yarns to form large area soft touch sensors that enable new ways of interaction between the user and its environment. Part of the process involved developing and testing of soft and textile materials with sensory properties that were manufactured by IZM's Textile-based Circuit Board (TexPCB) technology and laminated on jersey fabrics as well as embroidery techniques on customized knitwear. This enabled us to explore and refine integrating circuitry and sensors into the textiles we wear, through a combination of craft and technology. We produced samples of smart textiles and embroideries embedded with technologies that facilitate the input and output of sensory data elicited by touch.

At IZM, we have focused on testing different types of conductive, insulated embroidery yarns and threads on a variety of stretch jerseys and knitted fabrics as shown in Figure 10. Through this process, we found out how we can optimize the additive manufacturing process of embroidering non-stretchable conductor materials on elastic textiles and have also been able to evaluate suitable materials.

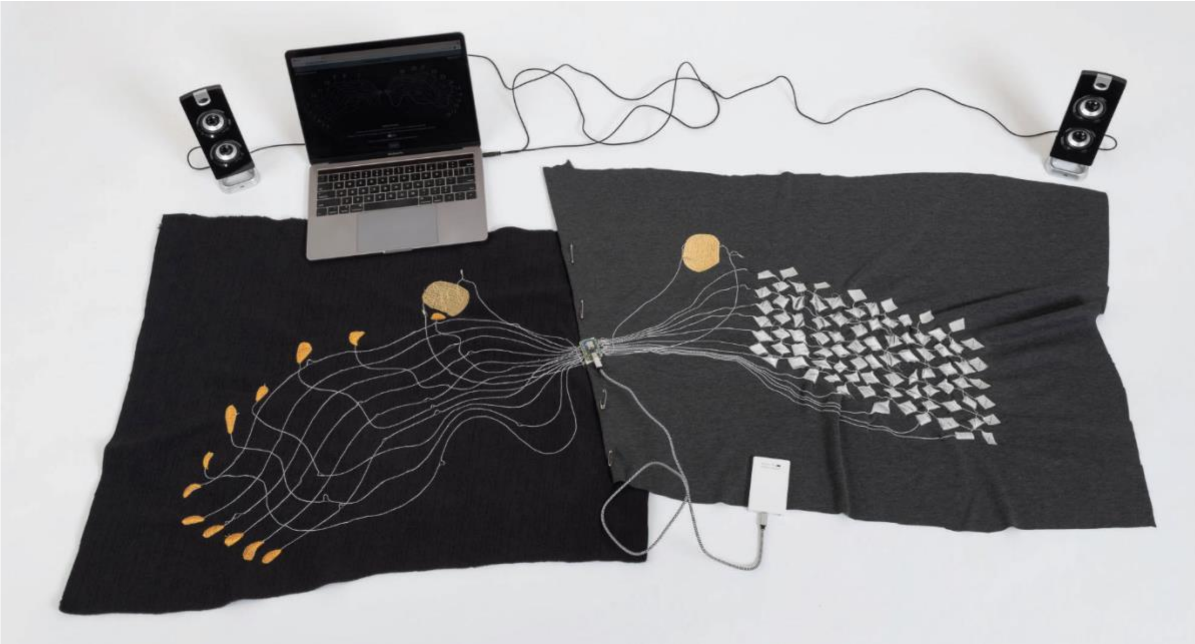


Fig. 10: Embroidered touch sensitive test setup.

Furthermore, incorporated into the design is a customized printed circuit board placed on the center back using two MPR121 capacitive sensor chips that receive the input signal initiated by touch. The PCB also integrates Bluetooth low-energy technology through an nRF52840 chip and was designed with bond contact pads for the subsequent interconnection with the embroidered structures.

For the bonding process prior to this project, modules were processed that have a maximum of 6 contact pads. In the project, the bonding technology was further optimized to such an extent that a PCB with 28 contact pads can be contacted electrically and mechanically at the same time in one work step. This excellent example is of great interest to industry as it successfully demonstrates that electronic modules with high IO counts can be contacted economically and reliably with the novel e-textile bonding technology. Figure 11 shows the bonded module onto the center back of the garment.

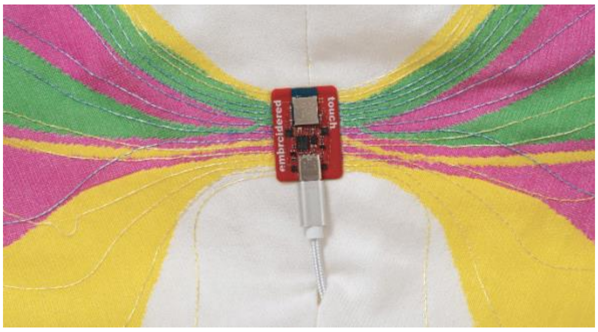


Fig. 11: Customized electronic module with 28 IOs bonded onto the textile substrate.

Fig. 12: Garment-integrated thermochromic structures as first level of output.

The final component of the design includes two output pins on the PCB that trigger the heating wire to turn on. This heat-sensitive wire has been embroidered onto the textile to spell the word LIFE, which becomes visible when worn on the body, as the thread changes color, as depicted in Figure 12. This transformation is programmed to occur when touch input is received through the right or left sleeves.

To illustrate the interaction between the wearer and the smart textile, we designed software that communicates with the circuit board to pick up signals from the embroidered textile when touched. The data collected is then sent via Bluetooth to an app on an external device (laptop, tablet or mobile phone). The signals trigger a sound file to play through the device. This enables the user to play the embroidered lines like an instrument, by improvising with multiple sound files, and layering them to create a sonic composition. The wearer can also connect with another user in a different location through the app. For example, when the first user touches their garment, the second user will hear the sounds. The latter can also send messages in the form of sounds back to the first user, creating a sonic conversation across distance. Although they don't feature heat-sensitive embroideries, the children's sweaters incorporate the same chips and software as the adult versions and include touch sensitive embroideries that turn on the sound files. Both type of demonstrators, developed with embroidery or TexPCB technology, are shown in Figures 13 and 14.

Fig. 13: The demonstrators allow interaction between users by generating and sending sound files.

Fig. 14: Touch-sensitive demonstrator realized in TexPCB technology and laminated onto a children's sweater.

3 Summary and Outlook

The fashion industry is at a very exciting crossroads where change is not only essential, but necessary. Curiosity combined with interdisciplinary thinking and making already is merging new technologies with urban manufacturing. The goal and opportunity of Re-FREAM was to create new options for connecting individuals and communities together through a fusion of fashion, art and technology to master the upcoming industry challenges of sustainability, digitalization and Made in Europe.

Dealing with material sustainability, circular economy and environmental responsibility will continue to pose major challenges for the fashion industry in the future. The project has provided exemplary approaches to how the direct involvement of the eco-design in the planning process can lead to new artworks embedded in a sustainable use scenario and eco-system. The results show a new vision in which sustainability is triggering the invention of new solutions which fulfill user needs and sustainability aspects at the same time.

The artists had to balance sustainabiity goals against technical possibilities and find strategies and synergies in terms of modularity and technological assembly. They were able to address their questions directly to the technologists and vice versa, creating an equal understanding of the possibility space for the teams and stakeholders involved, a space that has yet to be created on an industrial level. At the same time, the transparency of the co-creation process and stakeholder workshops also enabled new stakeholders to be involved in development. Overall, the imposed methods helped negotiate social, technological, and sustainability trade-offs, identify knowledge gaps on both sides, and develop strategies for technological and design implementation.

The co-creation has enabled us to develop and test new methodological tools such as the Planetary Design Guide. Tools that will continue to be important for us in our collaboration with industry and research. Many companies face the same challenges as our artists. A faster and more holistic method can help create balanced product/stakeholder systems. Therefore, the tools from the co-creation experience have become an integral part of our workshops and strategies.

It was an enriching experience to co-create and co-develop new applications and technologies for electronic textiles among a team of like-minded scientists and engineers, as well as fashion and textile designers. During the joint research, these projects further developed the interdisciplinary approach and created solutions for increasingly complex problems for the textile and fashion industry.

In addition to the dissemination and continuation of the project results, the IZM uses the co-creation experiences for new art / tech projects in a new physical space. For this purpose, the Textile Prototyping Lab (TPL)[5] at the IZM was installed and is managed together with the Weissensee School of Art. The TPL is the first open laboratory for the development of high-tech textiles in Germany and an open innovation research platform for promoting innovation and networking between research, design and industry. Partners from industry, startups and designers are welcome to use the TPL for co-creation and open innovation.

[5] https://www.textileprototypinglab.com/

Fig. 15: Textile Prototyping Lab at IZM.

4 Deviation and corrective actions

Due to the ongoing Covid-19 pandemic, the co-creation phase was only possible with limited travel and visit restrictions. All participants worked digitally together in this phase. After the restrictions were relaxed from May 2021 on, collaborations in the Fraunhofer IZM laboratories were possible and conducted by all Art/Tech teams.

No other deviations or corrective measures were necessary during the project period.