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

Hub "Additive Manufacturing" (WP4)

Deliverable 4.3
Optimized material application prototypes

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www.re-fream.eu

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S+T+ARTS LIGHTHOUSE Re-FREAM

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Optimized material applications prototypes

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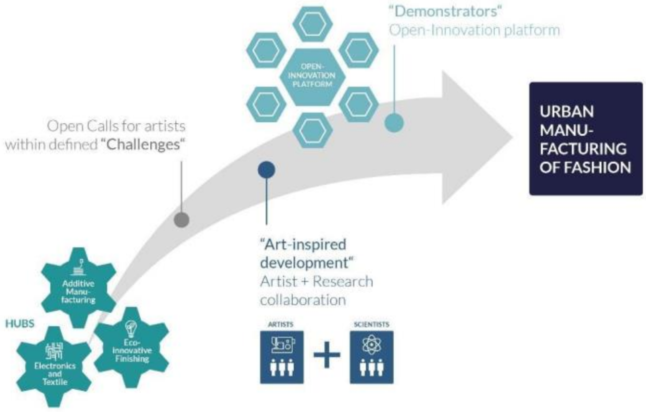
Dissemination Level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
Type		
R	Document, report (excluding the periodic and final reports)	
DEM	Demonstrator, pilot, prototype, plan designs	x
DEC	Websites, patents filing, press & media actions, videos,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

Contents

1. Context Information

1.1 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 (Garement 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.

1.2 Document history

Version	Date	Who	Change/Reason for change
V1.0	02.08.2021	PRO	Draft template prepared and sent
V1.1	30.08.2021	STR	Preparation of first draft to review
V1.2	15.09.2021	PRO	Review by PRO
V1.3	28.09.2021	STR	Update according to feedback from PRO
V1.4	02.12.2021	CRE	Finalization and submission

1.3 Purpose and Scope of Deliverable Report D4.3

Demonstration of four art work prototypes using new optimized printing processes and new material colors (vivid opaque and colored agilus), which have been optimized for Polyjet printing and exhibit optimal compatibility with support material, textiles and skin. The application enables enhanced properties for fashion or accessories due to composition with the textile fibers, enhanced elasticity, skin compatibility or mechanical stability.

2. Introduction

The report will review the technological aspects related to 3D printing within the research, development and design management for the artwork of the following collaborative co-creation projects:

 Ganit Goldstein	WeAreAble 	 Julia Körner	Arid 
 Assa Ashuach	Footwear Time Based Design 	 Filippo Nassetti & Vincenzo Reale	Thalassic mask 

The following topics will be highlighted in further detail:

- 3D Design research - design solutions for 3D printing.
- Material research – physical properties, full-color and digital materials.
- Production method research – integration of industrial methods to 3D printing.
- Embedded electronics.
- Integration of fashion elements and objects in 3D printing on textile.
- 3D printing on textile.
- Integration of 3D printing in the fashion market and urban manufacturing.
- Standards and testing.
- Sustainability.

3. Collaborative co-creation projects

3.1 WeAreAble - Art project in collaboration with Ganit Goldstein

Figure 1 WeAreAble-Protoype by Ganit Goldstein.

Ganit Goldstein learnt interweaving in Japan and was inspired by Asian craft embroidery and textile painting. Her kimono design follows the Japanese ‘ikat’ coloring method. While Japanese embroidery is the soul of the project, direct-to-textile multi-color 3D printing is at the heart of it. The kimono follows an algorithm that is composed by way of a 3D body scan and translated to the print surface during the 3D printing process. For her Re-FREAM project Ganit was very curious about the integration of fiber threads into the 3D print and about combining the Agilus and Vero materials, softness and hardness, to follow the curves of the body with digital material patterns.

Figure 2 Agilus material in different shore values highlighting the curvature. Soft at extensive curvature, harder at low peak.

Ganit used a combination of Agilus and Vero materials by Stratasys to combine the color language with the physical performance of the surface. Her research had begun with the idea to study the induced kinetics of the polyjet 3D printed model as a function of humidity or temperature and in respect to the topology and the curvature of the body. Areas highlighted with high curvature on the body gained higher flexibility that translated in the digital materials.

Figure 3 Different printed fiber colors represent different physical properties of flexibility and stiffness. One imitating wool properties and one representing the polymeric fiber.

Ganit wanted to study the relationship between weaving and 3D printing. Her research questions were: Would it be possible to compose the 3D print with fiber inside? Would it be possible to attribute different physical properties to the 3D printed fiber? (Figure 3)

Figure 4 Ganit inserted cotton threads woven inserted in the 3d print

So, actual fibers were integrated inside the 3D printed model. This has been achieved by insertion during the printing process. The insertions were made with insertion guides (Figure 5, a frame to hold the fibers in place) and structures framing the fibers to be held stable while the printing is executed. (Figure 4)

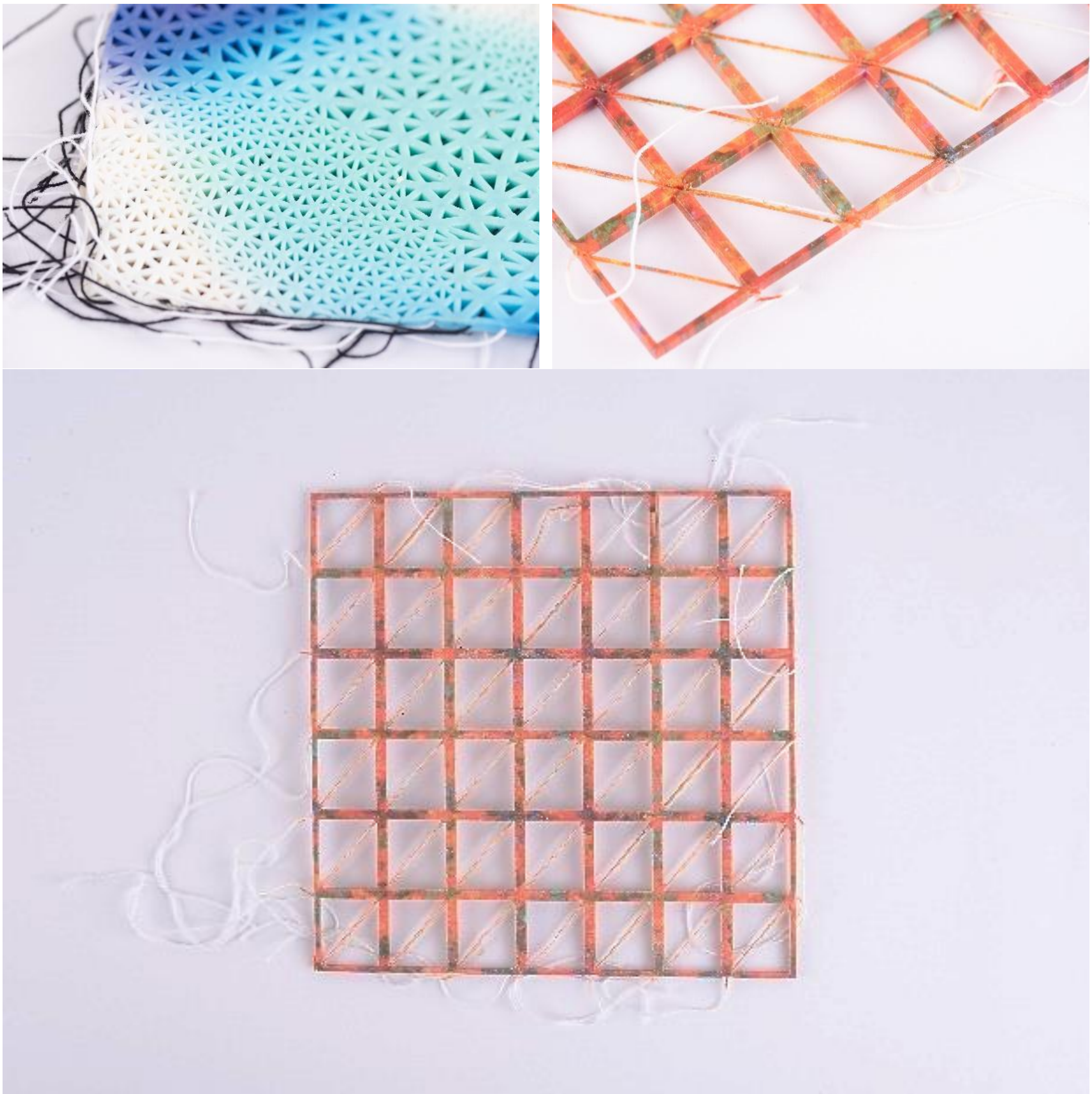


Figure 5 Insertion guide.

Ganit was keen to redefine the physical properties of the 3D printed composite structure in such a way that it resembles the flow and fluidity of actual textiles, Polyjet reinforced with fiber power.

Figure 6 Left: Dove tail joinery to streamline the connectivity between the textile 3D printed patches.

In the final project, the research topics reviewed were textile flow, printing format and joinery, the combination of transparency and opacity, vivid materials and ultra-clear and paving 3D printing along with other embellishment manufacturing processes. For the textile to remain fluid in movement, the geometry printed over the textile should enable a movement trajectory. There is a fine balance between the size of the elements, geometrical shape, distance between the 3D printed elements and their curvature and angulation.

The printing format of the 3DFashion J850 printer is limited to 36 x 46 cm. In order to create a larger segment or garment, solutions had to be sought. Either an extension of the platform or joinery integrated in the 3D print to allow extension of the surfaces. In the example above we used a dove tail joinery to streamline the connectivity between the textile 3D printed patches. Ganit wanted to pave embroidery and 3D printing in assemblage. This was only possible at post-process, since the J850 print head is not able to flow on non-continuous surfaces. Bumps integrated with embroidery would not enable smooth transition of the print head over the print surface.

3.1.1 3d printing wins and learnings from the project WeAreAle:

- Combination of textile fibers and digital materials
- Printing directly on textile
- Joinery between the printed patches as post processing as dove tail

3.2 ARID – project in collaboration with Julia Koerner

Figure 7 Digital Vogue

Julia Koerner's research "Digital Vogue – Between Organic and Synthetic Processes" focused on digital processes from 2D to 3D for nature-inspired geometries and the connectivity and adaptability of textiles with multi-color 3D-printed parts with an underlying focus of material efficiency and sustainability.

The design process was driven and inspired by imagery of natural artifacts with a juxtaposition of oceanic and arid environments. The digital designs are 3D printed in an innovative way, without any support material and directly on sustainable fabrics and in full-color, creating an enigmatic visual effect when the garment is in motion while maintaining the comfort and wearability of fabric garments. We used the 3DFashion PolyJet printer by Stratasys.

Together with Julia Koerner we studied solutions for Urban manufacturing along with ideas to enable production of 3D printed samples that can be assembled by the customer. These 3D printed parts, would together create the garment, a dress, which could be puzzled together in a do-it-yourself genre. For this project, we sought, together with Julia, methods of connection. We researched together, line joinery , zipper connectors, button connectors, sliding connectors and more. Julia Selected the "Lego" button connector.

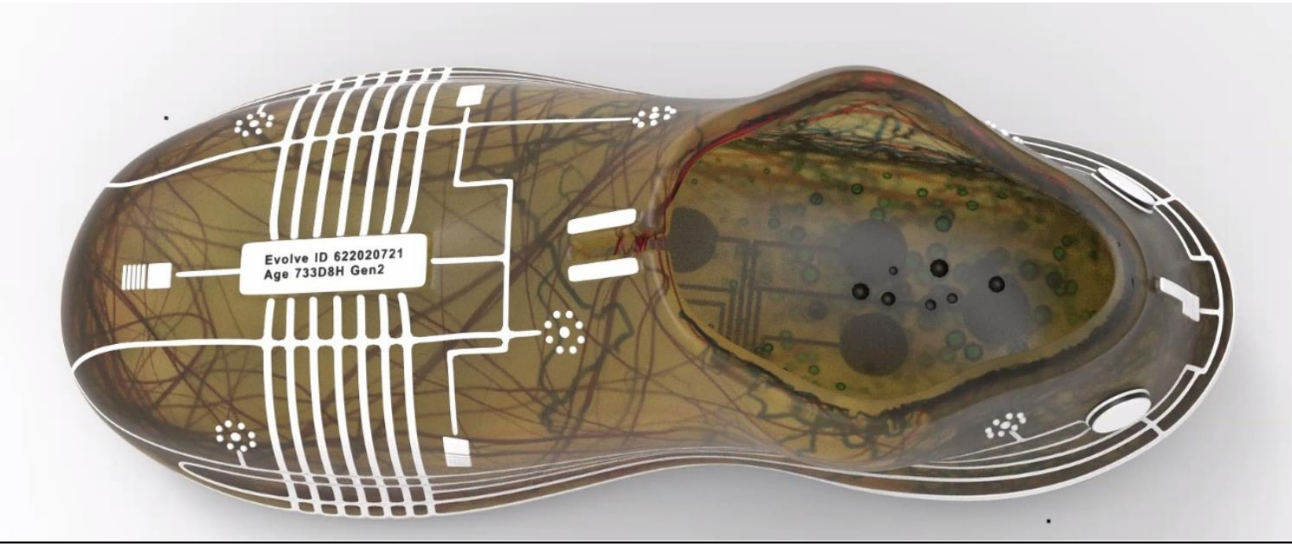
Figure 8 Cut for the dress and pillars on the textile.

3.2.1 Technological and design wins for STRATASYS from the Arid Project:

- Printing directly on textile
- Joinery between the printed patches
- Urban manufacturing DIY.

3.3 Footwear Time based design - Art project in collaboration with Assa Ashuach

For the Assa Ashuach project (Figures 9) STRATASYS searched for materials according to their volumetric combination in order to create a functional degree of varying behaviors. During the material research process, we also looked for material colors and aesthetics that would match the functionality since some materials would appear as opaque and some were expressed as transparent.



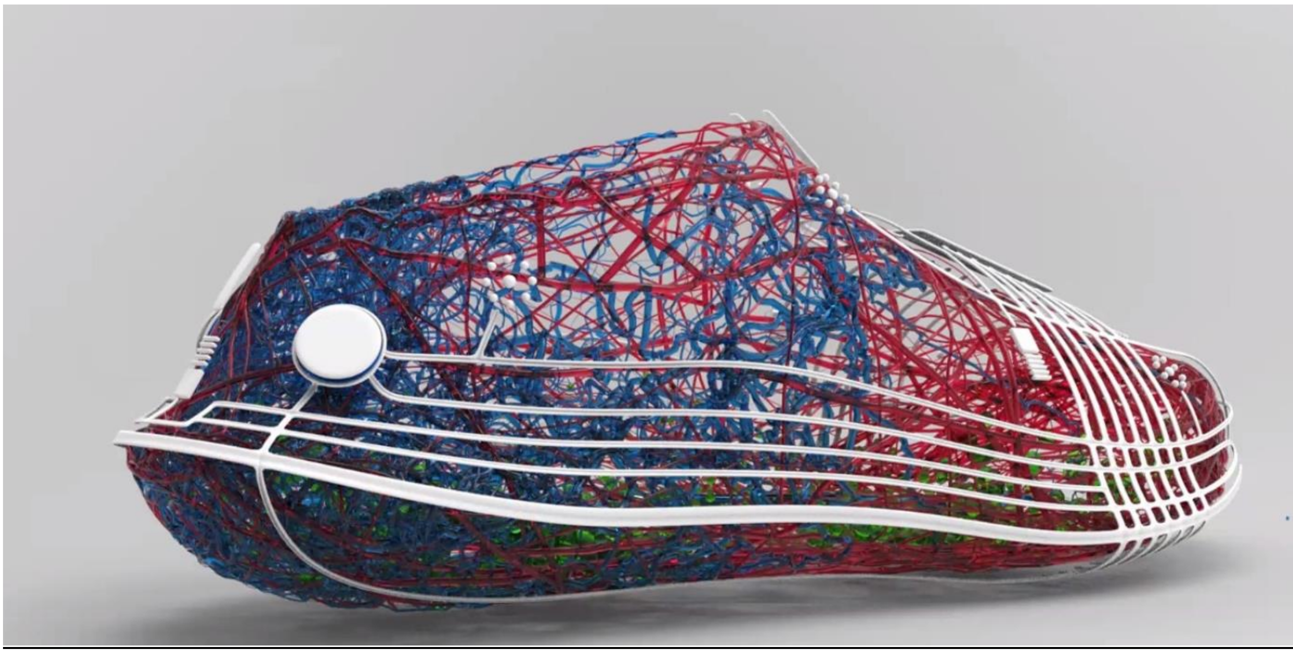


Figure 9 Shoes designed by Assa Ashuach.

In order to reach the required material response, we identified the ratio between the geometry and the mechanical properties of material A and material B, for example if material B is soft and the inner material A has a rigid structure.

In addition, we challenged different geometries and inserts; slices, plates, dots, fiber, stripes, hexagonal and three-dimensional mesh matrix, thin and thick skin, to identify the correct overall functionality as well as analyze the necessary density for the desired pattern to offer the right physical properties during specific movement flow and compression (Figures 10-13).

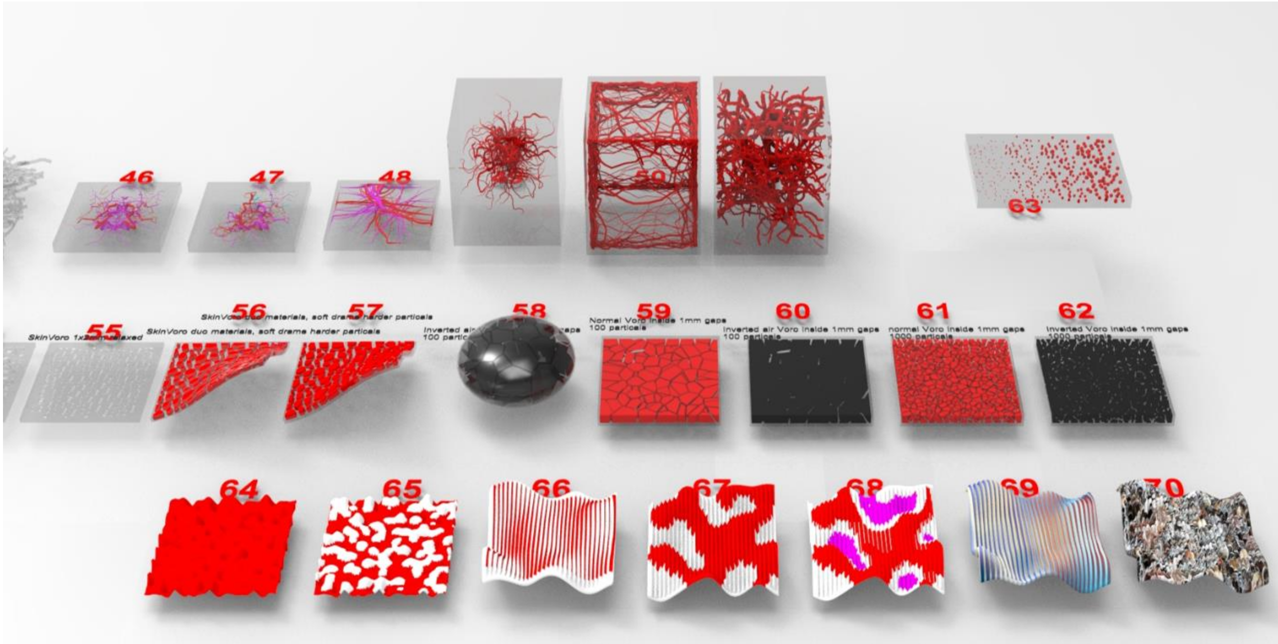


Figure 10 Insert map (of more than 70 different tests per round) from top left to right: fibers flat, fibers 3D, dots, large to small plates on a flat surface, sphere, in different densities and physical properties. etc.

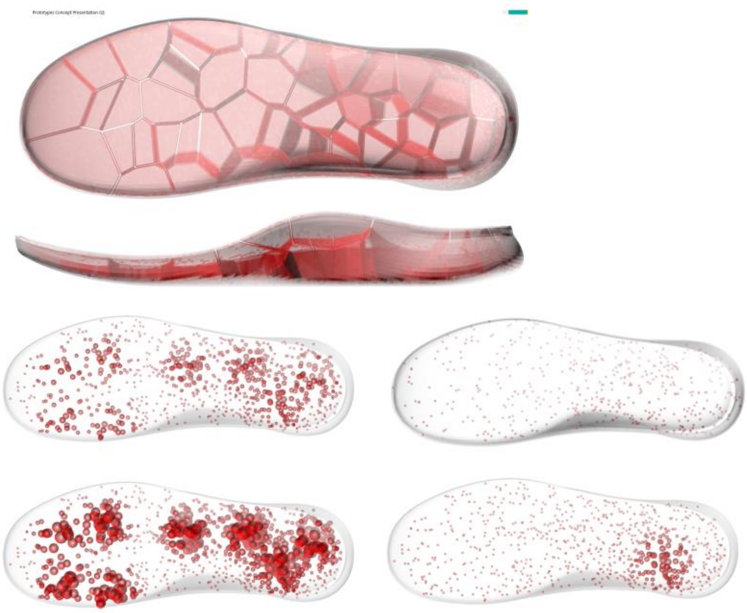


Figure 11: various shoe design iterations playing with the insertion of flexible insertions

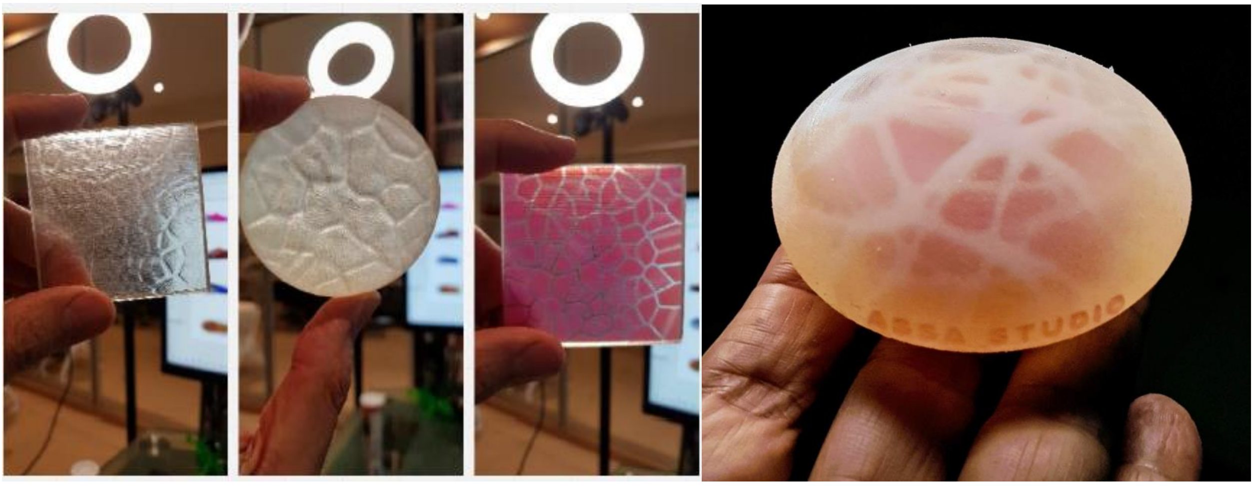


Figure 12: printed test samples based on respective design iterations for insertions playing with stiff and flexible material

Figure 13 Examples of the geometrical analysis for the right density and functional flow.

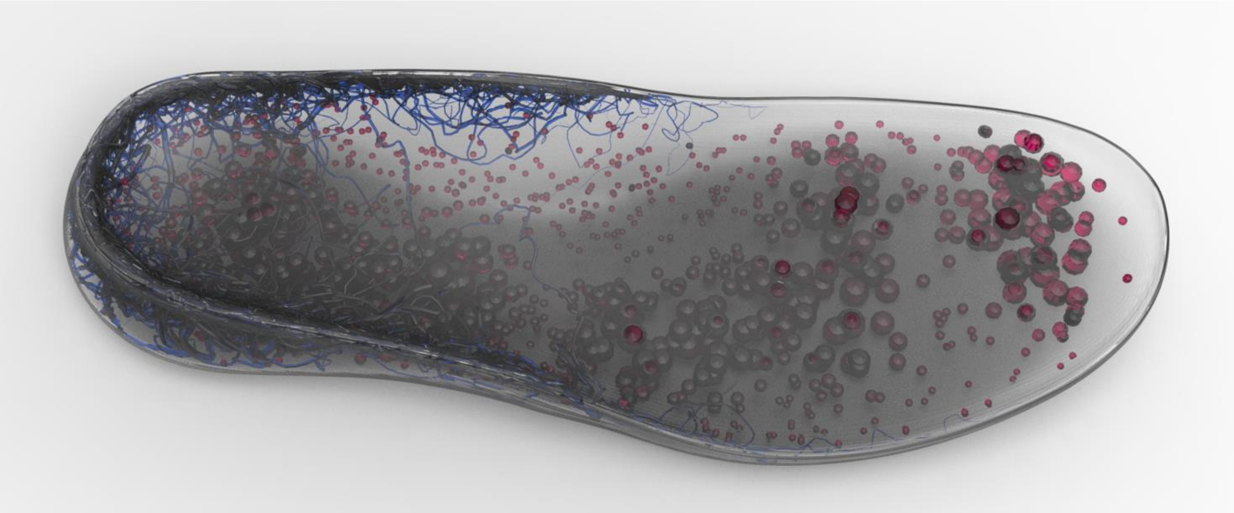


Figure 14 The combination of the various geometries that allowed us to focus on different mechanical properties and functionality in the shoe, in different areas of the sole.

Finally, in order to achieve the varying functionality to research how the mechanical functional balanced with appearance, we integrated different materials simultaneously. We combined a minimum of 3 of the following material types: rigid lattice, the inner structure rigid (bubbles), the external envelope elastic and a medium material between these two, rigid and elastic as well as a gel type material. In total this material matrix offered 729 combinations from which the ideal solution was to be sought. (Figure 14)

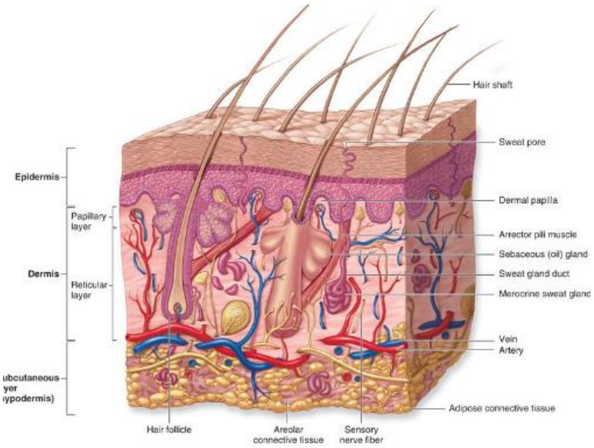


Figure 15 epidermis structure

Assa's design concept, focused on the epidermis structure (Figure 15) as a starting point for the research and his source of inspiration supported us here, as well the geometrical solutions and elements that were made possible when combined inside the unique material blend.

The materials we used are the following Stratasys Digital anatomy materials (Figure 16):

 **Tissue matrix**	*skin soft and contractile material* TissueMatrix is soft and flexible, but durable enough for suturing, cutting, inserting, and deploying devices. Combined with Agilus30, it creates a range highly extensible to stiffened tissue material, able to simulate fatty tissue, fibrotic tissue, soft organs and tumors.
 **Bone matrix**	*strong and flexible, rigid material* BoneMatrix is a tough, flexible material with memory allowing it to maintain its shape. Musculoskeletal models match bone density characteristics and behave like native bone when force is applied such as discectomy, drilling, reaming or sawing
 **Gel matrix**	*Gel like material* The unique GelMatrix material and GelSupport™ deposit patterns that allow you to print large and small, complex vascular structures with easily removable internal support material.

Figure 16: printed shoe part including already various design elements

Once we had defined the form, function and appearance, the next step was finding the production method that answered the following questions: Could we inject Polyurethane inside the shoe cavities or dip the entire shoe in a Paralyne coating as a post process?

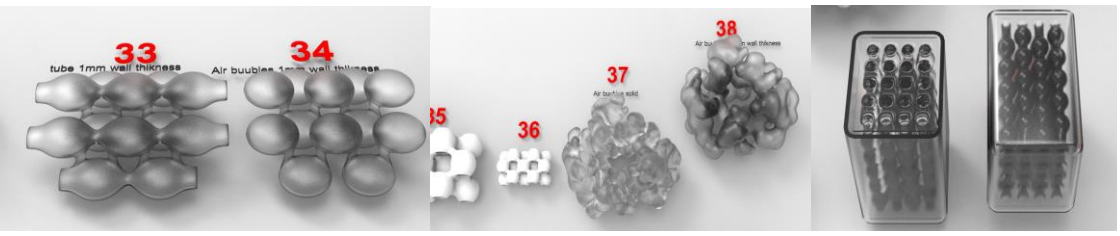


Figure 17: infill design variations

<u>Paralyne coating and embedded electronics:</u>

An industrial solution that could offer us the ability to enjoy Stratasys' multi- material competences and at the same time create a coating that offered enhanced strength with high-quality surface durability and longevity. These applications composite technology and materials will be an asset for the realization and enhancement of the 3D properties and will benefit the series production at a later stage.

Moreover, to introduce an electronic structure inside the sole, a carrying sensor was integrated via 3D printing.

Besides the structural functionality our aim was to introduce an electronic structure inside the shoe sole or the shoe composure, carrying sensors that would communicate data digitally to the PCB.

Stratasys solutions for the integration of electronics with the 3D printing can be made in various ways:

Insertion of the electronics after the 3D printing process. This process has numerous disadvantages such as, lack of coherence, intricate fit of the electronics and model geometries, reduced functionality due to possible misalignment.

Integration of the electronics during the 3D printing process. For this process we utilized the Stratasys product "Research Package" that was developed specifically for advanced research institutes. The research package enables the integration of foreign objects (such as electronics, batteries, cables, ready-made items, air, liquids, metal elements etc.) during the 3D printing process inside the 3D model. There was an extra challenge with the use of the Research Package, the integration of electronics during the 3d printing build. The process of encapsulating the electronics inside the model requires fully thought through design preparation. More so if the electronics have a three-dimensional multi layered composition. Preparing the electronics to be embedded in the 3D printing model requires a full application design process which is a real novelty and requires further research and development.

Figure 18 Assa's shoe has been designed to incorporate this latter capability.

3.3.1 Learnings in terms of technological aspects for STRATASYS from the project:

- Printing directly on textile
- Embedded electronics

3.4 Thalassic mask – Art project in collaboration with Filippo & Vincenzo

Figure 19 3D printed masks

The focus of this project by Filippo Nasseti and Vincenzo Real is urban masking. For their project they have researched different masking and camouflage solutions, as urban expression, and interwoven the head form, the draping and the head body structure in the veiling with 3D printing.

Their research focus sought the balance between textile fit and screening vision and visibility with geometric flow. The geometry of the design had to be in line with the textile flow to enable the correct draping on the facial surfaces and the readability of the facial senses underneath from the eyes, mouth and ear areas. The design study incorporated an ongoing understanding of the weight, rigidity and geometry. These factors influence the pull on the textile, the unique folding and the facial fit.

Building height with Agilus and Vero materials:

Our challenge with Agilus material was to direct the build height of the model and to balance and limit the height. Agilus is a flexible material by nature and may have destabilized as the build progressed in height. The thicker the build of the

Agilus material, the more stable it becomes, therefore the aspect ratio of the thickness and height had to be researched carefully. In comparison, Vero Material can be built easily in height. The challenge here was that the higher the build of the model the heavier it becomes and may pull the textile when draping. Here too the design balance was important with respect to the mask performance and choice of textile.

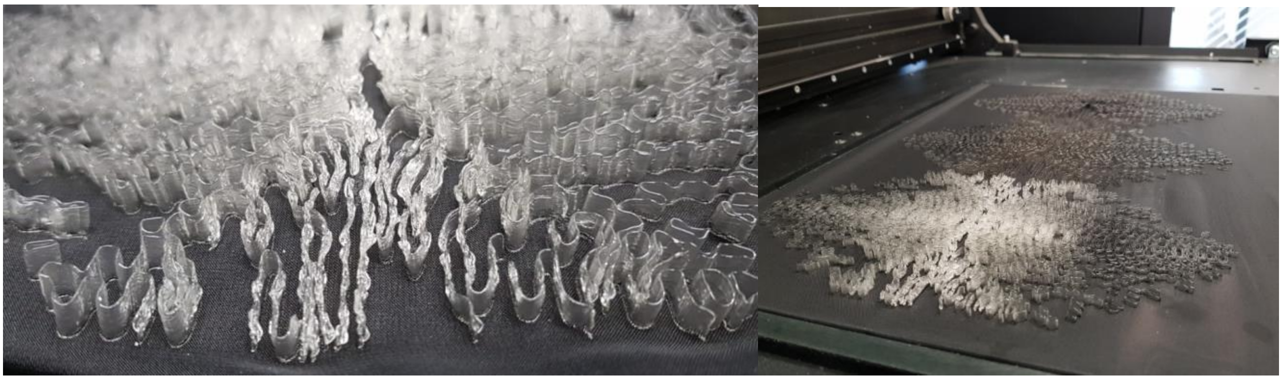


Figure 20 – Agilus (flexible) material

Figure 21 – vero (stiff) material

Material research: The ideal printing ratio with Agilus indicates a base height ratio of 2:1 (figure 22). The game of transparency and opacity is relevant to the mask's artistic findings, the subtle color has an enormous effect on the readability of the underlying geometry and identity of the person during the textile and facial flow (figure 22).

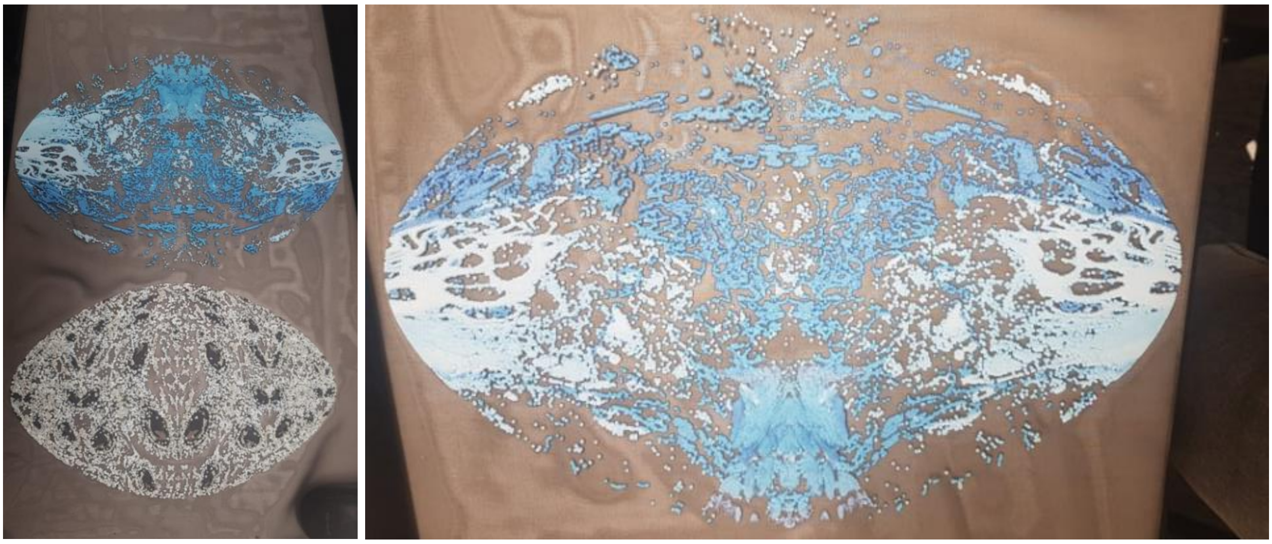


Figure 22: material mixture of Vero and Agilus

Contact with skin: During the printing process on textile, we chose to implement a post process to guarantee that the absorbed resin in the textile is fully cured. This fully cured resin is compliant with skin contact standards. In this scenario, clearly for a mask being worn on the face, these principles are of high importance. We have optimized the process of curing according to each type of textile.

Adhesion: The adhesion of the Vero material to the textile is mechanical, depending on the textile fiber structure and surface tension. This is often affected by the textile treatment, coloring or other processes. The Vero material is able to penetrate the fabric and 'grab' itself around the textile fibers. The Vero fluidity has an optimum, when not absorbed too quickly or too slowly into the textile allowing the resin to consolidate hermetically in alignment with the print speed. We also acknowledge that the Agilus material in high and thin builds. The ideal building ratio is 2:1 (base to z axis). The light vibration deflecting from the statics of the printed wall caused a certain imperfection on the surface and a discontinuation or noise in the geometry. However, when printing low structures, the geometrical stability is excellent and the adhesion of both materials is very good.

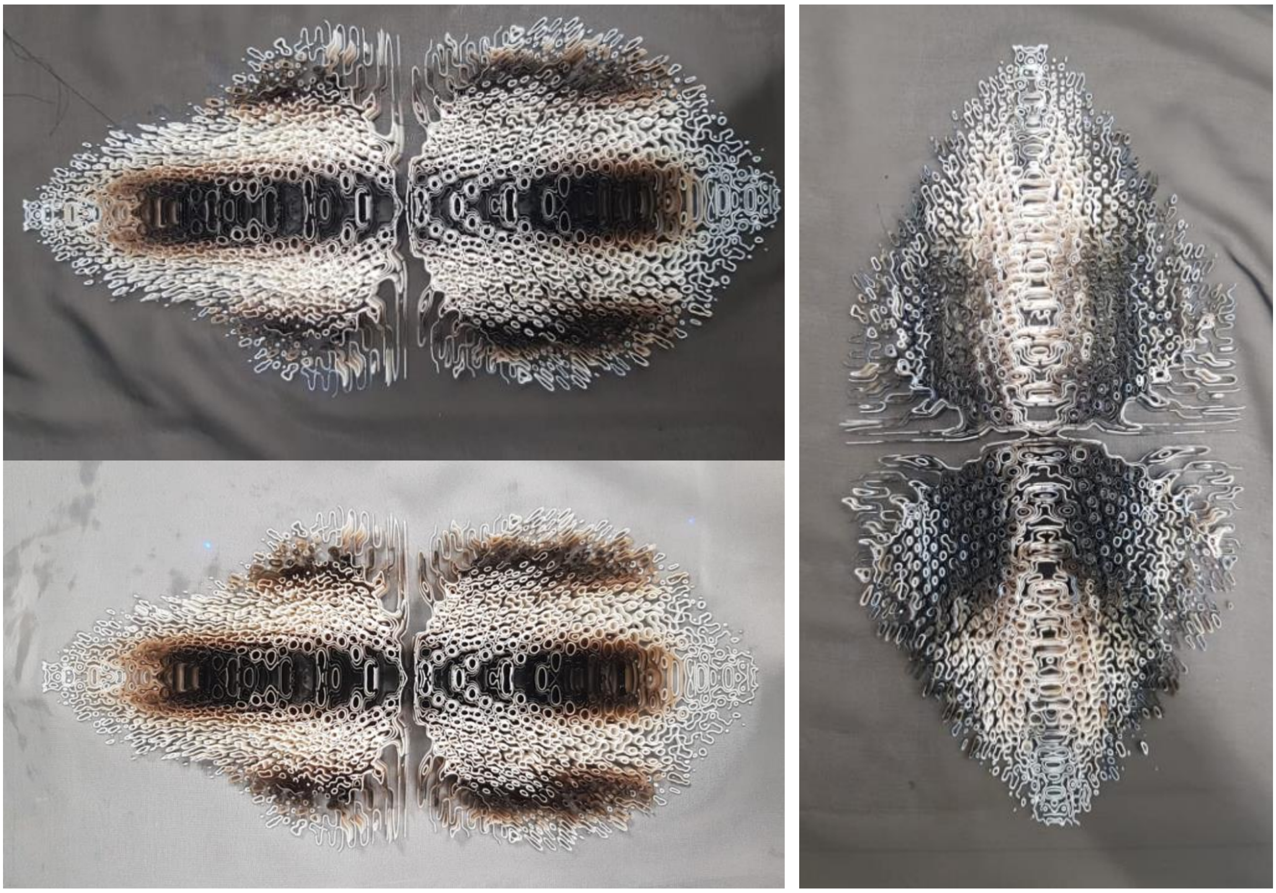


Figure 23: Sample printing of mask design including color profiling

Color profiling: There are various color profiles that can be applied when printing in full color with GrabCAD: RGB, CMYK, Pantone. The profile software translates the original color scheme to the printing colors. There are various translation possibilities to cover the smoothness saturation and gamut of the tonality which is controlled by the software's color profile system. For each print, we select the desired color profile in relation to the file of origin and the choice of materials, colors, shape and surface of the model.

Building color in layers: In order to communicate the color according to its pigment, transparency and translucency, we varied and modulated the matrix choices of material color layers and thickness of these layers. Since color is relative, we also control the color the matrix of background and underlayers to enhance and deepen the color vibrancy of the upper layers.

Movement and geometry: In order to enable the movement of the textile, the geometrical elements had to be streamlined with the desired textile fluidity. This requires a study between choice of textile, printed elements and choice of 3D printed material and the body curvature on which the textile is draped upon.

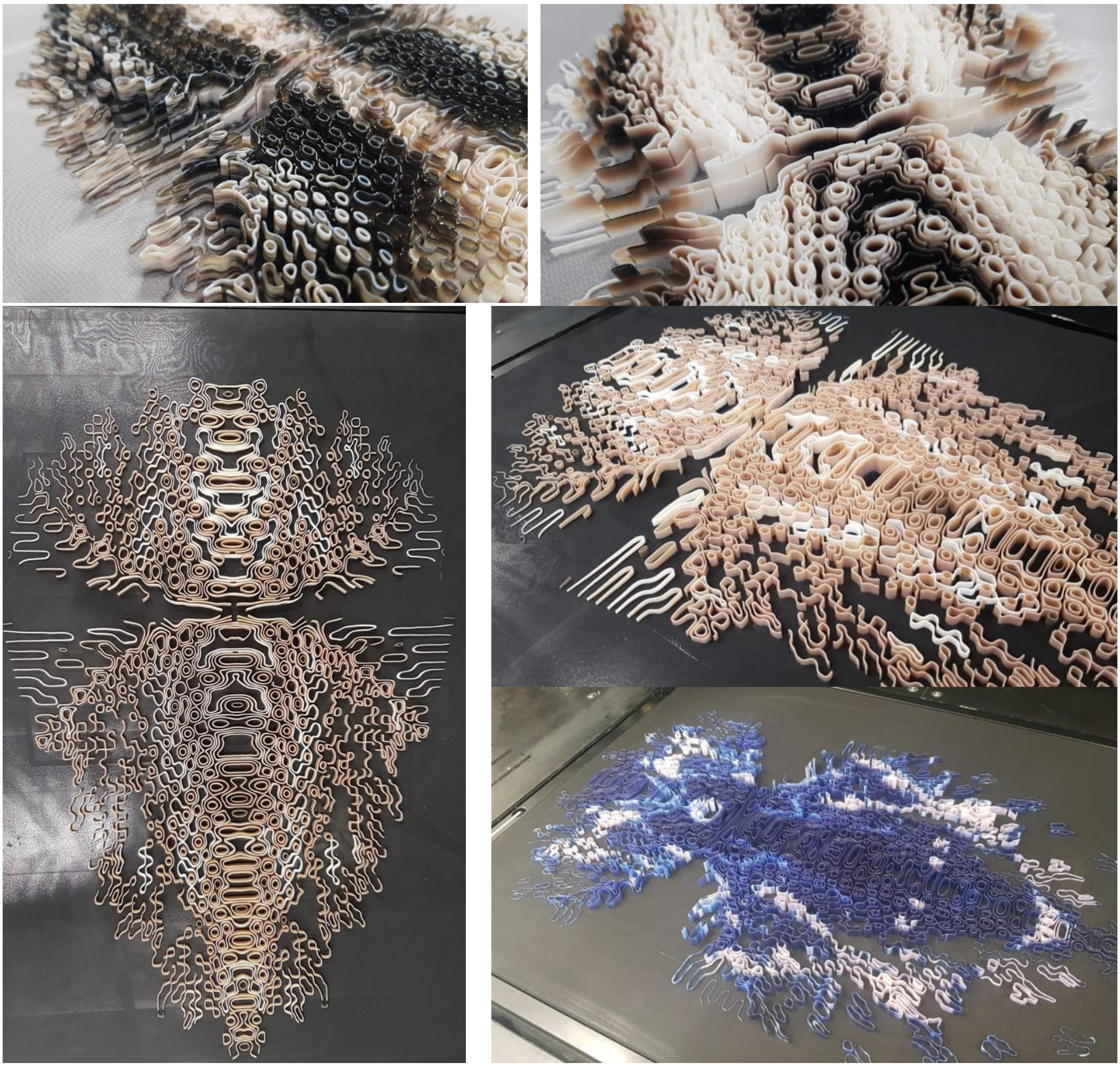


Figure 24: Sample printing of mask design including color profiling including variations

The embellishments combine different color materials. The ultra-clear is in fact a digital composite material, fully transparent, which offers a glass effect to the surface. This material is a composition of two materials, which together enable both photosensitivity and the necessary light refraction and reflective properties to create a solid full glass see through solution.

Stratasys has been diligently crafting a partnership with Dyloan. See https://www.dyloan.com/. Establishing a manufacturing partnership for the high-end fashion market. Dyloan is an Italian company specializing in the production of innovative high-end fashion solutions. Among their clients are Kerning group, Givenchy, Dolce Gabbana, Chanel etc. Together with Dyloan we have been processing the testing to match the market standards for 3D printing on textiles, these tests include laundry, drying, rubbing, fatigue, friction , UV , aging etc. The results have been positive showing that we can match 30% out of a range of 100 different textiles the demands of the high-end fashion brands, for accessories, shoes, bags and clothing. At the end of 2020 a new institute opened in Milan, in the format of a maker hub.

This institute D-house is the innovation hub for the high-end fashion market. Stratasys installed its Beta fashion printer in D-house in November 2020. This will operate as fashion laboratories and research for urban manufacturing. In December 2020 Stratasys set up 3 PolyJet fashion printers at the facilities of Dyloan in Chieti Italy. See https://d-house.org/.

3.4.1 Technological wins for STRATASYS from the project:

- Printing directly on textile
- Material research: build height of the model and to balance and limit the height
- New material colors

4. 3D printing on textiles

During those projects, we have developed solutions at Stratasys to enable 3D printing directly on textile, namely **3DFashion™**.

The 3DFashion materials are based on the Polyjet multi-color multi materials and can be applied on a variety of substrates. During the Re-FREAM project our research focus has been on the analysis of adhesion and substrate capability, the adjustment of the hardware and software drivers to enhance the print quality necessary for the application and for the design aesthetics. We also considered the future market needs of the application including, platform, usability and formats. The development of this application has been set as a registered patent. The patent offers solutions for durability, print quality and enhancement, adhesion properties, workflow and production processes.

4.1.1 Market Certification – durability standard tests

Applying 3D printing on textile for the fashion market requires conforming to market standards in the different categories by the certified laboratories. In general, these tests inspect a series of examinations such as, material for fashion standard including material chemical composition, certified materials and material testing. Durability standards for fashion applications include tests such as: friction, fatigue, UV, aging, drying, laundry, water resistance, rubbing etc.

4.1.2 Exemplary Case: shoe uppers

The Assa project involves 2 suggested designs that would use the 3D printing on textiles application:

- A total solution involving a 3D printed shoe on textile with a pattern foldable layout. (“Furoshiki style” design)
- A partial solution integrated with the lower industrially produced shoe parts.

Special substrate feature: while printing on the irregular textile surface (hexagonal mesh matrix) a multi layered effect is created by the landing of the Polyjet droplets on the multi layered substrate and a fascinating “error” based pattern influenced by the mesh immerged. Together with Assa we applied various simple geometries to achieve the results below (Figures 16-20):

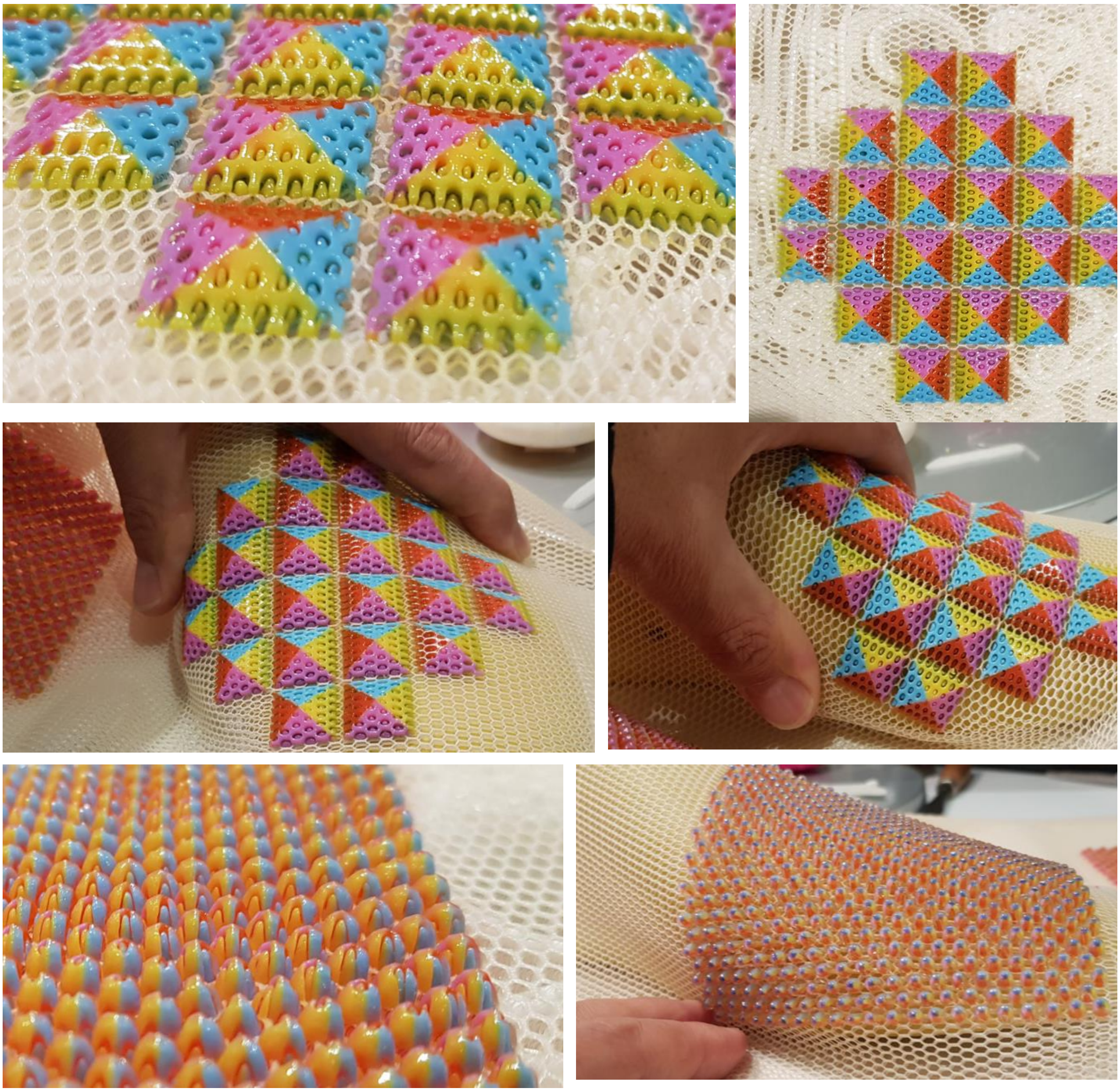


Figure 25: Multilayered effects realized on selected fabric

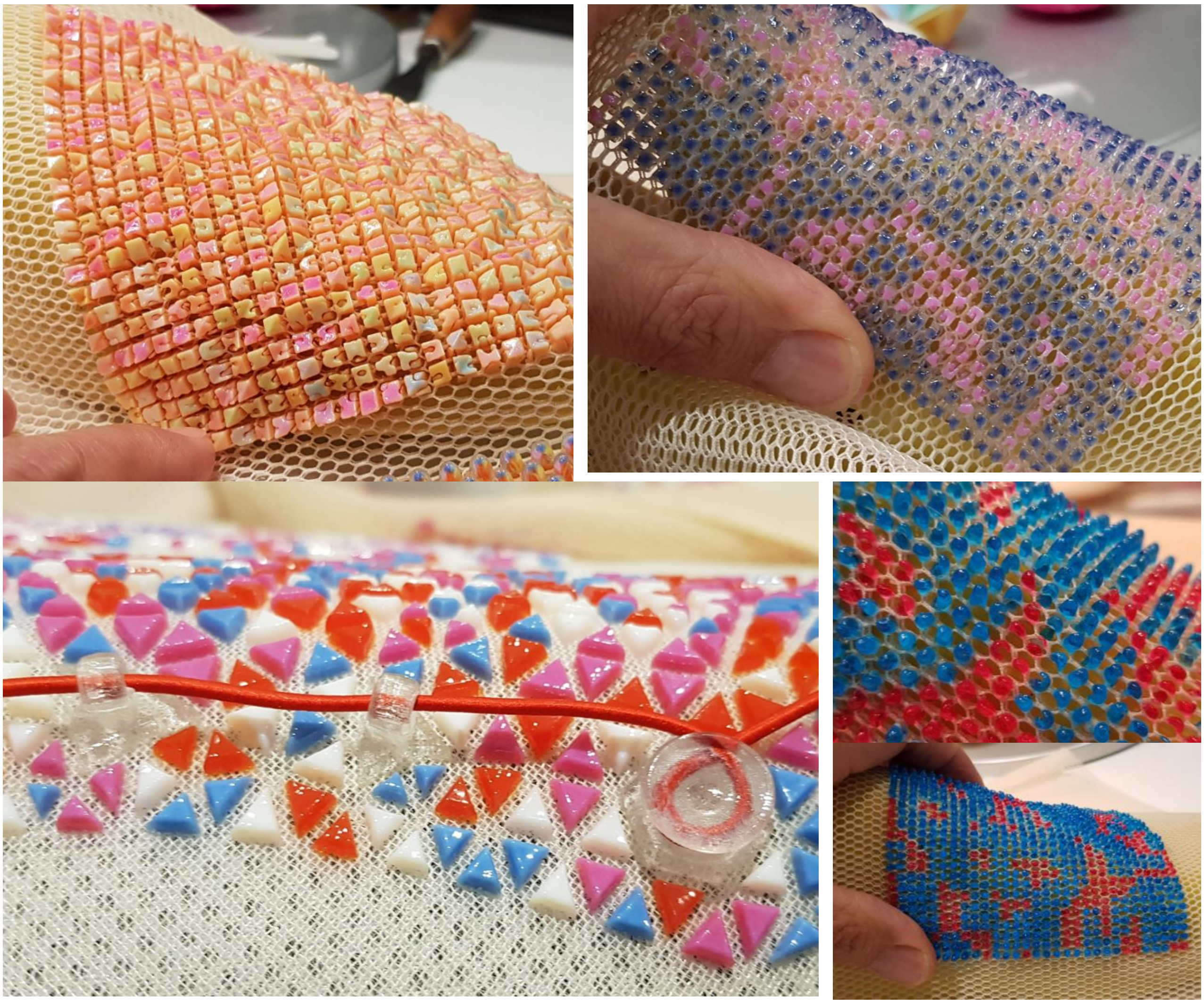
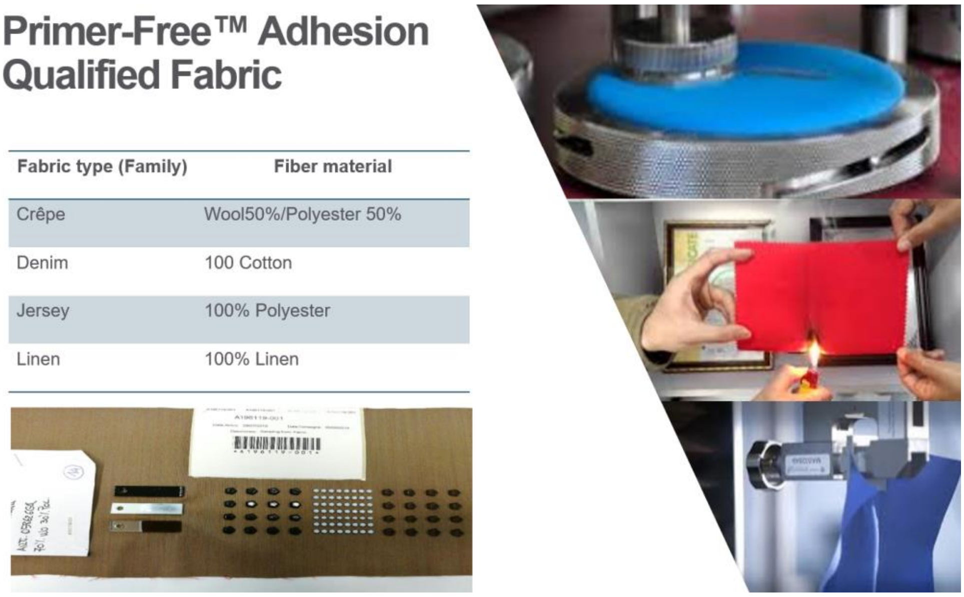


Figure 26: different printed geometries printed on selected fabrics.

4.1.3 Market standards testing for 3d printing on textile:



Fabric type (Family)	Fiber material
Crêpe	Wool50%/Polyester 50%
Denim	100 Cotton
Jersey	100% Polyester
Linen	100% Linen

Stratasys together with Israel Institute of Standards and with its fashion innovation and production partners, has run a series of standards testing. These tests include, washing, durability, fatigue, UV resistance, chemical resistance, drying and friction. The discovery shows that the 3D printing on textile is matching the norm and needs of the market applications for apparel, handbags and shoes. Tests have also been performed by collaborative high-end brands according to their own high-level requirements.

Stratasys is working on material certifications known in the market, RSL and MRSL with Eurofins, confirming that no forbidden or hazardous materials are used in the manufacturing processes. Stratasys is also working on ECO Sustainability adaptations of its hardware and materials.

The certifications passport registered with OEKO-TEX:

1. *Standard ECO Passport* - Eco Passport by Oeko-Tex is a certification system for textile chemicals. Chemicals awarded the Eco Passport label meet the requirements for sustainable textile production.

2. *Eurofin - RSL & MRSL*

RSL

RSL stands for Restricted Substances List and is often used as a chemical checklist when testing finished products for the presence of restricted substances. An RSL is applicable to finished articles and/or components. On the solid form (end product)

MRSL

The ZDHC (zero discharge of hazardous chemicals) Manufacturing Restricted Substances List (ZDHC MRSL) is a list of chemical substances banned from intentional use in facilities processing textile materials, leather, rubber, foam, adhesives and trim parts in textiles, apparel, and footwear.