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0. EDITORIAL #20

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New Advanced Clothes

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Keywords
Interactions, Advanced Materials, New Body Functionalities, Bio-Design, Bio-Technology.

Abstract
The Textile-Fashion System was investigating its impact on the environment, moving towards sustainable innovation solutions. The Covid-19 gave an acceleration to this reflection, agreeing on sustainable ways but also relying on technology through wearable devices, virtual reality, 3D printing, robotics, artificial intelligence, extending the vision of fashion to a place of research, beauty, and experimentation. Fibers are being selected and modified, new goals are being defined by interpreting research through the creation of textiles made specifically for humans. Progress with textile fibers that have been developed for the fashion industry has been remarkable, it will continue with smart, high-performance textile fibers, conductive inks, and nanometer electronics applied to garments for every need. Fashion companies are collaborating with industries specializing in technology, sustainability, biomedical, healthcare, cosmetics, electronics justifying examples such as fitbits, smartwatches or other devices designed to collect and monitor data on users personal health and physical activity, which help engage with their health, which help fight bacteria and viruses, regulate body temperature, heal skin and which also contribute to a responsible culture that makes textile design a distinctive and exclusive mode of socio-cultural inquiry from which tangible results are obtained. New body relationships therefore will lead to the creation of *new homes* by promoting healthy lifestyles.

1. Past/Post Pandemic

The Textile-Fashion System was investigating its impact on the environment, moving towards sustainable innovation solutions. COVID-19 has accelerated the ongoing reflection by agreeing on sustainable paths between production and distribution: it is said that every major crisis shapes the course of history and that difficulties can also have positive impacts, quickly bringing alternatives to the status quo, revealing new opportunities and also revealing the resilience of the parts that have resisted. In the aftermath of a sudden global disruption, for months the only way we could connect with others was digitally, underscoring that only technology allows us to restart our lives with tools that will still help us respect the rules of social distance, as well as write a possible future in different areas. Thinking about wearables, for example, it is exemplary how design integrating with technological innovation is activating new dynamics useful to improve the quality of life of both humans and the environment, offering opportunities to collect and share information, emotions, experiences, contributing to social awareness as well as generating new interactions with the body. Sustainable companies today, according to Francesca Romana Rinaldi (2020), professor at Bocconi University and author of *Fashion Industry 2030*, are those that manage to integrate ethics and aesthetics in the supply chain and in the single activities of the value chain, with repercussions on consumption models, on new economies and on the world of needs. As mentioned in a *Lifegate* article, the road to 2030 includes transparent value chains, greater consumer focus and involvement by fashion companies, data collection and analysis, and a gradual shift from product to service. Innovation, using tech-

nology, is going to define new scenarios through experimental materials, blockchain technology, virtual reality, 3D printing, robotics, artificial intelligence, machine learning, configured in *ad-hoc* wearables for a *sophisticated body* that responds to new functionalities and using design as a distinctive and unique mode of socio/cultural inquiry, to materialize and experiment. The pandemic, disrupting the fashion industry, has forced us to reconsider the role of clothing in our lives and everything will change in view of the continuous evolution that both humans and the Planet itself will undergo. In search of new and right configurations, wearables today are advancing with smart textile fibers, bio-fabricates, conductive inks, nano-metric electronics for e-textiles, with advanced materials and new functionalities.

2. Wearable Concept Between Past and Actuality

World of wearables in a combination with design and technological innovation, activates new dynamics useful to improve the quality of life of both man and the environment, offering opportunities to collect and share information, emotions, experiences, also contributing to social awareness as well as generating new interactions with the body promoting a progressive liberation from the limits determined by the body through processes of *hybridization* (De Biase, 2016). In search of new and fair configurations, wearables today make progress with intelligent textile fibers, bio-fabricated, conductive inks, nano-metric electronics for e-textiles, with advanced materials and new functionalities. Aesthetics/Economy/Ecology, in the current scenario are pushing Fashion System companies to establish collaborations

with industries specialized in technology, sustainability, biomedical, health-care, cosmetics, soft electronics, expanding the boundaries of *Wearable Technologies* (WT) compared to the original ones for which they were born: with WT, according to the most recent definitions, refers to those intelligent, electronic and technologically sophisticated devices, to any type of machine with computational capacity that can be used by man and that interacts directly with his body with which he must be in contact. These technologies, configured in devices can be connected to other devices such as smartphones, through the wireless network system or through Bluetooth technology allowing the detection, storage and exchange of data in an immediate way and without the need for human intervention. Their main function is to capture any type of data, display it, make it understandable and share or communicate it (Rajan, Garofalo & Chiolerio, 2018). Bringing it to its current state, the reference to wearables outlines configurations that, fruit of technological evolution, aim at the well-being of man and Planet in a cycle also of sustainability. It can in fact be said that their history has advanced over time thanks to the transition from analog to digital, to critical points that hard electronics has shown, which was followed by an accurate analysis in order to minimize the difficulties related to excessive energy consumption compared to the capacity and size of batteries, to doubts related to the difficult interpretation of a regulatory framework between data, privacy and harmfulness of electromagnetic waves, or even the use of new materials more sustainable making these products easy to wear and transform normal clothing into *Advanced Clothes*: in a market that promotes healthy lifestyles (Tsao, 2020) along with new aesthetic possibilities, the concept

of wearable is in fact understood as an *integral structure* with which man lives in a complex environment; man who, by not adapting, revolutionizes the ways of living – called behaviors – in a continuous relationship and internal/external interaction that improves the processes of functionality and which respond to advanced materials specifically created. Reflection reinforced by the slogan that Rudofsky (1947) uses for architecture, confirming the integral open work, namely that *we also wear a second dress*: the second dress follows, hosts and facilitates – in an almost natural way – the affirmation of ways of living in a changing space, which interacts with the body; the first dress instead because in close relationship with the inhabitant is the result of the very re-design of the naturalness of the body. Therefore, living is fundamental, inducing us to assume habits that develop in our reciprocity with space, between intelligence and matter, between idea and things, within a complex system that is both functional and symbolic, a process in which body/habit/environment are called to advance.

3. New Body Relationships

Every time a living being in the during its lifetime is faced with new conditions, problems, unknown and often not easily adjustable, it is forced to "adapt" in order to survive physically and/or psychologically. Adaptation is a change of self, of the structures and of the means at one's disposal to deal with the novelties that arrive from the environment, generating a system of relationships that is never constant. All humans coexist with other living beings, living connected but through not connected relationships and above all live in a social, human and speciesism dimension (Morton, 2019). It is a process

as complex as frequent, but above all of fundamental importance for the maintenance of an essential balance for humans. The Human being is one of the living beings that can adapt most successfully to environmental conditions, certainly not for its potential and biological-physical characteristics, but rather for the enormous variety of behavioral responses that can put in place and for the high plasticity that characterizes them. Adaptation in everyday life, therefore, where relationships, situations and problems are always new and evoke behaviors and responses that are just as changeable; but adaptation also in the most unusual, difficult, extreme situations, related to the physical environment but also to the psycho-social conditions that are created.

Thanks to the progress of scientific research and technology, human life is made possible even in very hostile environments, even in those situations that push humans to the limit. If we tried to analyze the entire front of progress compared to past eras, it would be evident that the human body itself has undergone an evolution, that it has adapted to change through the centuries until today it has become a dynamic entity that interacts by responding to complex stimuli together with a highly sophisticated body integrated in the design of a structure and in a system of tangible and intangible relationships that make specific operations possible (Iori, 2010).

The human body is part of a system that places it at the center among structures configured typologically to respond to specific functionalities and materials that interact in a system that helps it fully meet its every need, whether physical or cognitive. There are many artifacts configured for humans that are not intelligent but then become so only through the integration

of a small chip. Conventional fibers, classic cotton, pure wool, used in the production of textiles, for example, have undergone a process of evolution that has seen them once respond to the unique need to keep warm the body configured in classic pattern, then in basic structures to accommodate innovative materials, finally still become fibers in intelligent fabrics, e-textiles, with performance coatings, which have enabled them to respond to some specific human need.
At the center of technological and material progress, the human body is therefore a determining factor in new evolutionary processes and theories for a future in which unnatural risks such as environmental pollution, radiation, widespread disease, will condition the design for humans - the pandemic Covid-19 emergency being an example; technology playing a dual role, both in cause and cure, will support designers in identifying the best solutions through behavioral analysis of user characteristics, with different bodies, different needs, functional analysis with respect to the physical environment of use – including environmental and human health criticalities (Langenhove, 2007); it will involve appropriate manufacturing technologies such as rapid prototyping and additive printing, it will involve the choice of more efficient and manufactured materials in order to produce new homes in a new relational system human body interacting with the outside world. To date, wearable devices, high-performance and intelligent fabrics dress a human body altered because placed in a relational dialogue with the contexts of life, with solutions outside the conventional schemes, relationships established as a result of the changing world and in which the body is exposed to constant danger, integrating various design propos-

als that sometimes combine innovative materials compatible, recyclable and/or compostable in a perspective of circular economy and sustainable applications of wearable electronics, prosthetic solutions to extend human performance.

4. From Materials to Advanced Clothes

In a fast-growing market, there is a rising demand for more functional and eco-sustainable garments where innovation and research are pushing for an interconnected system, driven by players – including designers – who are increasingly attentive to external factors, including socio-cultural ones. If the first ten years of wearable technology emphasized research into the engineering of sensors and wearable systems configured into electronic objects and components, now wearable futures are investigating ever softer sustainable alternatives, directed at improving the quality of life and pursuing the creation of homes tailored for humans. Examples outlining this advancement with challenges related to the body, the environment, go beyond 3D printing and housing to house electronics, fabricating the materials, advanced for specific configurations, a scenery from which it emerges a fundamental role for materials, both as enabling a variety of solutions and as key tools to reach them (Moretti et al., 2019).

Since 2006, the Canadian company Hexoskin and the German company Ambiotex have focused on advanced wearable technology or rather biometric clothing, poured into soft models and not the classic gadgets, working alongside designers and researchers in the medical field: a light and breathable fabric becomes smart by means of a microcontroller – Hexoskin

Figure 1. Hexoskin: *Health Sensors Ai*, Hexoskin Pro Shirt for Men and Women, 2019. www.innovationsoftheworld.com.

mounts it on the hip (Fig. 1), Ambiotex under the sternum – to be removed at the time of washing the garment with ECG sensors (measures the peaks of electricity generated by heart and muscles), accelerometer and respiratory rate that allow continuous monitoring of the human body with data collection, a function so adopted by the classic smartwatches (Moriarty, 2018); a research process for *Advanced clothes* also looks at the possibility of fibers to become high-performance for humans thanks to synthesized processes in the laboratory that explore the technological innovation of the original material in the manufacture of real advanced clothes: from the regeneration of agricultural waste exemplary is the case of fibers born from the waste of Sicilian oranges of the company Fashion Tech Orange Fiber

Figure 2. *Orange fiber*, from orange waste to orange fiber and fabric, 2017. www.orangefiber.it.

that has conquered the collections of Ferragamo (Fig. 2) with alternatives to synthetic jersey also supporting the environment; still the synthetic fibers of the Californian start up Bolt Threads example of fibers created at a textile pharmaceutical laboratory that reproduces in an innovative way the silk starting from the cultivation of microorganisms, modification of DNA with synthesis genes in order to obtain proteins then transformed into threads recalling specifically the silk woven by spiders (Fig. 3); also, solutions that allow the cultivation of fabrics using biomasses from the mixture with glycerol, water and gelatin as the case of researchers in the *Valley zone*, who have explored alternative solutions and human-friendly, implementing the *kombucha* in a process from which you get a material comfortable to skin contact, durable and easy to shape (Fig. 4).

Today, mushrooms are emerging as a promising candidate for the production of sustainable textiles programmed for use as environmentally friendly bio-wearable.

Across all boundaries of biology, organic electronics and bioelectronics with living substrates this category of materials lend themselves to a variety of functionalities including sensing and information processing capabilities of natural systems for future wearable devices, as the research work led by Andrew Adamatzky, future developments in the field of fungal wearables may be along several directions, from fungal colony that implement a range of Boolean function to fungal cultures, which are apparently preferred for the production of sturdy fungal skins, such as fungal leather or mycoleather (Fig. 5); or direction would be to culture fungi directly onto the pieces of clothing to achieving full response cloths and garments (Adamatzky et al., 2021).

Figure 3. *Microsilk: vegan silk inspired by spider silk*, Bolt Threads factory, where synthetic spider silk and mushroom root-derived leather materials are produced for the fashion industry, 2018. www.businessinsider.com.

Figure 4. Lillian Donahue/Cronkite News, *Kombucha couture*, Focus on kombucha, fermented tea drink that can be used to make a sustainable leather-like textile, 2018. www.cronkitenews.azpbs.org.

Figure 5. Andrew Adamatzky et al., *FUNGAR H2020 Building with mycelium-based technologies*, Reactive fungal wearable, 2020. www.researchgate.net/publication/344245263_Reactive_fungal_wearable.

Another direction in the development of fungal wearables could be in using fungal hyphae as wires and programmable (with e.g. light) resistor or electrically activated resistive switching devices in hybrid architectures incorporating conventional flexible electronics and live fungi. Routing the direction of the fungal wires can be done by arranging sources of attractants and repellents. Isolation of fungal wires, as well as localized connections when ordered arrays like the crossbar array arrangement are required, could be done using inorganic materials, such as metal oxides of the proper work function deposited by means of atomic layer deposition or digitally printed over a large scale, also in case of uneven. Still, prominent among the innovations is the development of yarns that are functional because they are flexible, electro-chemically and electro-mechanically active. Most attempts to transform textiles into wearable technology have always used rigid metallic fibers that alter the texture and physical behavior of the fabric or still prompt environmental concerns and fail to meet performance requirements.

A group of U.S. researchers at Drexel University has developed an innovative method for creating textiles with technological properties using MXene (Fig. 6), a carbon-based conductive material, to create conductive yarns that can be processed on industrial looms, are resistant to washing and everyday wear, and have the same comfort as natural ones, to produce clothing with the highest level of electrical performance (Zhang et al., 2019); or again, in a research project of the team of designers of the University of Campania Luigi Vanvitelli developed at Officina Vanvitelli, in which exploiting the ability of titanium carbide MXene to be processed in various sizes (flakes of

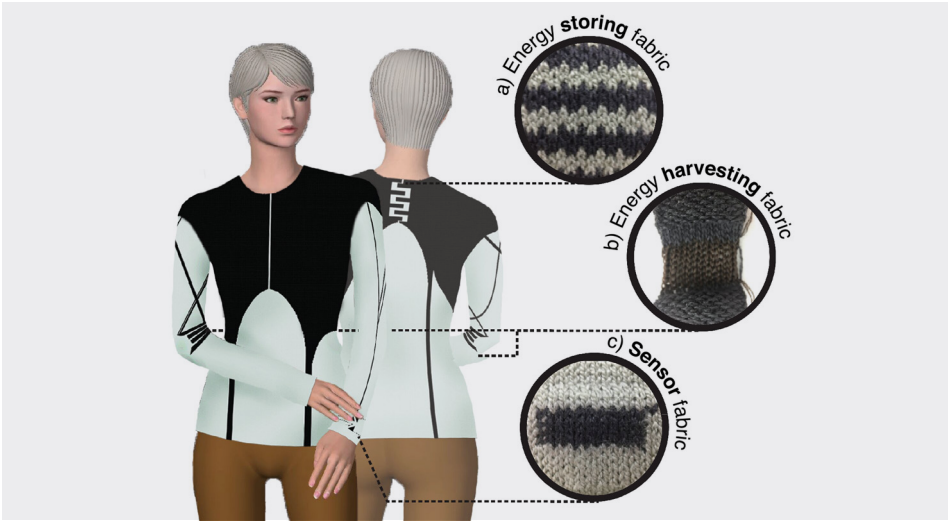

Figure 6. Simge Uzun et al., *Multifunctional MXene Coated yarn*, illustration about application of MXene for conductive yarns for wearable devices that are both functional and fashionable, 2019. www.onlinelibrary.wiley.com.

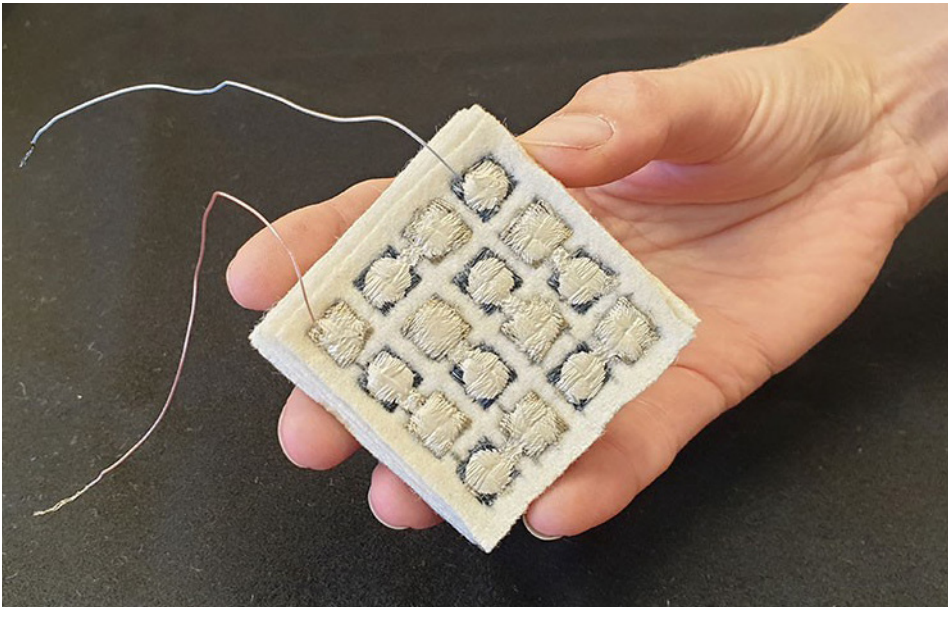

Figure 7. Anja Lund, *ThermoTex application*, this silk embroidered thermoelectric generator could power wearables through body heat, 2020. www.horizon-magazine.eu.

the thickness of a few atoms to more important thicknesses), it would come to consider the yarn Ti3C2MXene, treated in a blend with bio-compatible polymers, allowing to have a yarn treated in a 3D printing process for the manufacture of e-textiles, i.e. textiles that have electronic components and interconnections woven into them, presenting physical flexibility and typical dimensions that cannot be obtained with other existing electronic manufacturing techniques; the latter in the form of MXene combining aims to overcome any compromise in terms of flexibility, ergonomics, low power consumption, integration and possibly autonomy: it would be configured for an advanced wearable for PPE (personal protective equipment) that falls under medical use and can inherently act as a pressure sensor – through a knitting sample – or power external sensors, thus covering functions for monitoring human vital parameters (Fig. 7).

In fact, many researchers are focusing on the best way to power sustainable wearable devices by exploiting, for example, the same heat produced by the human body that would functionally power soft electronics: known for almost 200 years, the thermoelectric effect, according to prof. Christian Müller (Chalmers University of Technology in Sweden), would make it possible to convert thermal energy into electrical energy when there is a temperature difference, such as the difference between a person's skin and the outside temperature - the electrical potential would be the result of electrons moving from the warmer part of a material to the cooler one, generating a movement of charge. Another project, *ThermoTex* (2020) is extending the functionality of humans in the design of polymers thanks to a special dopant that would make thermoe-

lectric effects perform; the team has published a paper in Nature Materials showing that combining polymers with a low ionization energy – the energy required to release an electron – and a dopant (a molecule added to the polymer) with a high electronic affinity, it was possible to double the efficiency of doping. In early applied experiments, they used commercial polymer formulations to coat the silk, and although these coatings were not efficient, they allowed the project team to begin making textiles and conduction devices using the doped silk to power body monitoring sensors. Highly scientific projects that show the importance of collaboration with the textile industry to initiate innovative processes.

Another front investigates the implementation of passive actuated materials: protecting the body from ultraviolet radiation from the sun is a project part of Noumena Design Research Education S.L, on smart materials and their applications, in which the advanced is in the wearable that becomes an active and additional skin that in protecting the human body extends its functions such as greater freedom of movement and breathing (Sollazzo, 2018). The design, custom configured, allows the smart material to detect and exchange data with the environment by passively activating a system that regulates the relationship between the body and the surrounding environment while maintaining balance. This is a wearable technology that addresses the elimination of hard electronics, leading to reactive wearables with zero energy consumption (Fig. 8), investigating alternatives of photo protection due to the presence of direct sunlight; a similar theory is explicated in Wearpure.Tech (https://wearpure.tech), an environmentally friendly

garment made by combining fabrics and 3d printed elements with properties capable of capturing CO2 from the atmosphere (Fig. 9): by designing and digitally producing a garment, partially composed of fabrics and partially of 3d printed elements, the challenge of Wearpure, by the company Noumena.io (https://noumena.io/) based in Barcelona, aims at expanding the boundaries of fashion precisely through the use of 3D printing methods on fabric but with materials (like Wearpure) that, by transforming CO2 into non-harmful minerals, would reduce the contaminated air in our daily space, transforming a classic piece of clothing into a multifunctional garment, active for the well-being of human and the Planet.

5. Discussions

It is obvious from the above cases and theoretical/reflexive notions that biology, advanced manufacturing, robotics, materials technology and computational design are some of the disciplines that can create an alternative solution for both a more sustainable future and a future where human well-being is at the center of everything; we have the opportunity to reformulate the way we generate, manipulate and program the raw materials of this industrial process: technologies can point us in a new direction for more sustainable, efficient, customizable, and durable management; the very design of innovative solutions will address contemporary trends in pollution, safeguard the Planet by offering human-comforting treatments from technologies and materials; sustainable thinking and human-centered design will complement design by monitoring human-environment interactions. The Fashion System will require new homes for the body, no longer

equipped with classic fabrics but more and more performing as the needs of the human body change and determine new conditions of adaptation.
These are the result of programmed and intelligent materials that intervene by offering solutions to face common human problems (generic respiratory problems, harmful body postures, disabilities, stress) or that react with the environment by reducing air and water pollution.
The New Advanced Clothes, therefore, will refer to dress/behavior/environment, designed on the antinomic adaptation of the human body to the space, immersed in a dimension of life itself to be re-designed. Therefore, from this process, innovation will mainly concern materials, configured in new artifacts, through advanced technologies, in relation with a human body able to react and absorb changes.

Therefore, although structured in a real process, the new advanced clothes will be the result of a design methodology, of prototyping that integrates digital production technologies, that supports sustainability; they will push the fashion system to reflect on the potential of materials because the human body evolves as well as its needs; from the materials now reused/composted/programmed experimental approaches and innovative strategies will arise that in relation to the body determine new functionalities.

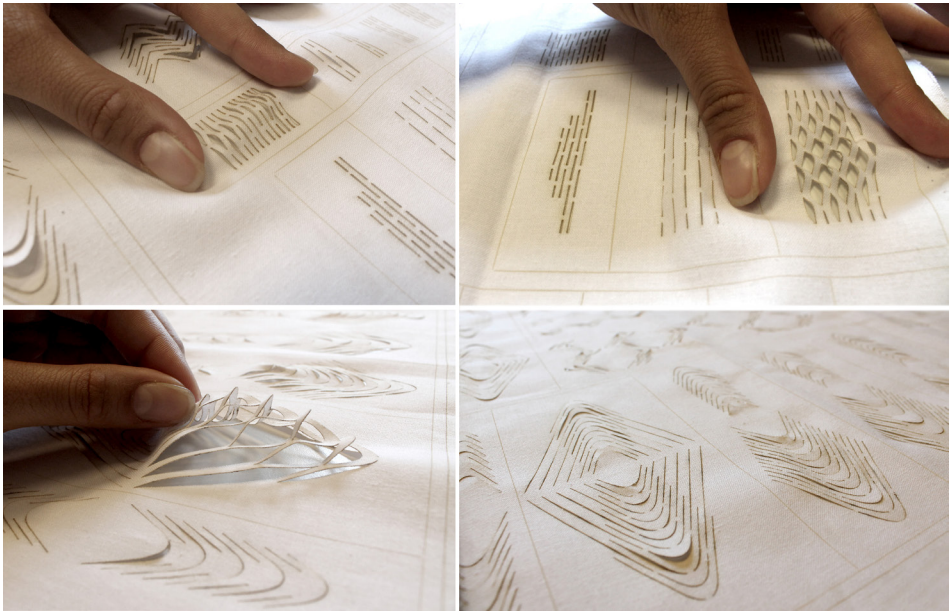

Figure 8. Efilena Baseta et al., *Photoreactive wearable: A computer generated garment with embedded material knowledge*, Physical test and deformation of computer programmed material. Material Studies - Methodologies – Vol. 2 - eCAADe 35 | 323, 2017.

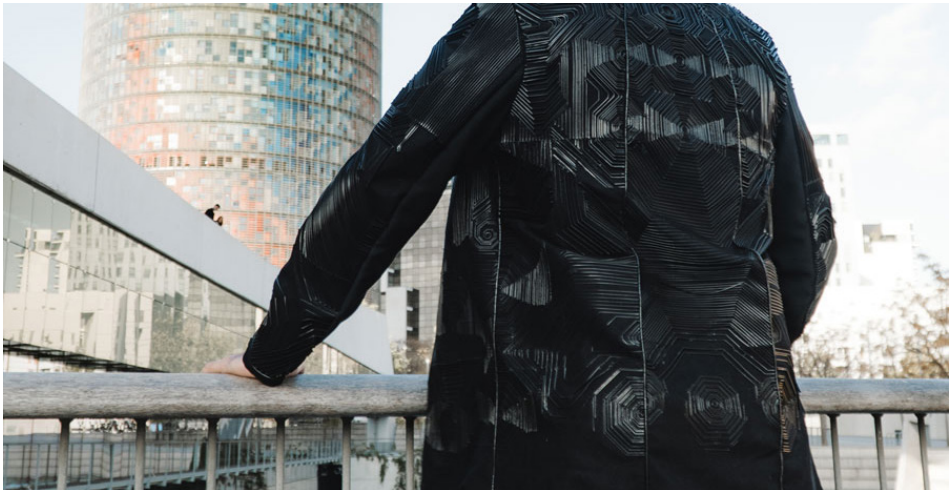

Figure 9. Noumena.io, *Wear pure: an environmentally-respectful garment*, this product is the result of new material capable of capturing Co2 from the atmosphere (Co2pure mineral powder + 3D biodegradable polymer) and 3D printed elements combinated with textile, 2018. www.wearpure.tech.

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Since 2015 she has been teaching fashion and communication design courses at the Accademia delle Belle Arti di Napoli.
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For several years she led sewing workshops for children and supported the student sewing lab at HAW Hamburg.
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