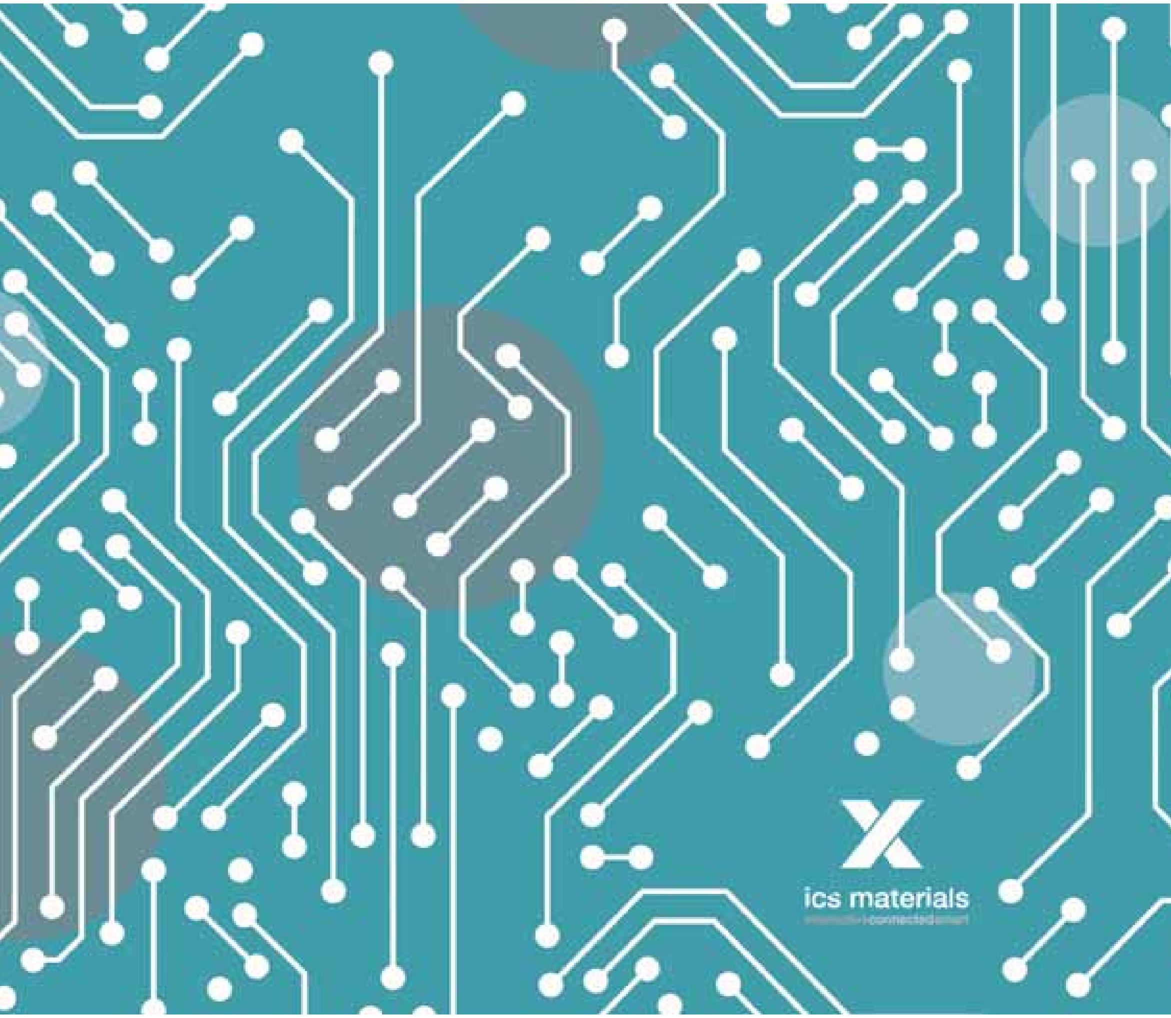
ICS MATERIALS

Interactive, connected, and smart materials

edited by Valentina Rognoli and Venere Ferraro



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by *Marinella Ferrara*
Politecnico di Milano, Department of Design

The mutual contact between humans and objects or environments happens through surfaces. Testing surfaces with senses, human beings experience the world, understand its characteristics, and the relationships between the different parties. Through the interaction with surfaces, we appreciate or despise the world around us. Experiencing surfaces arouses a variety of emotions.

Since ancient times the role of surfaces in the perception-based process has been investigated. The Epicurean philosopher Lucretius (c. 99 - 55 BC) described the surface as the manifestation of the substance of things and as the place of the imagination. For artists, architects, and designers, the surface has been the main mean of expression, support for imagination, and visual and tactile modeling for aesthetic enjoyment.

The surface in itself is a complex entity that includes textures, patterns, and a variety of other *soft qualities* (colour, smell, temperature, weight, etc.) that convey a message about the design intention. Given a specific context and a beholder, the sensory interaction with the surface actives an intimate touch and an interpretation process that generate the meaning to space or a product.

If in contemporary times, the surface-screen has achieved the role of the leading media of communication, sharing, and expressing emotions (Bruno, 2014), in the digital era, the phygital (phisical + digital) is opening a new potential to reshape human experience. In everyday life, the interactions between peoples and objects trought the IoT can happen in two parallel channels, the physical and the digital one. In this last channel, we interact through small surfaces like screens, touchpads, keyboards, and device interfaces systems. The limited dimension and poor sensory qualities of these interaction surfaces, is often alienating because they distance us from the multisensory richness of the tangible physical world. For this reason, the design community has drawn attention to a new hybrid materiality to rediscover the pleasure of the world, increasing our experience with the digital potentialities. From Design to Humanities, from Human-Computer Interaction to Electronic Engineering, the scientific communities are now focusing on this new materiality that includes digital and analogical dimensions, and its relationship to aesthetics, technology, and temporality.

Investigating the possible relationship between the physical and digital dimension of new surfaces has been the main task of the activities we conducted within the ICS Materials research. After approaching subtle link connecting surfaces, design, and emotional experience, we move on according to design praxis, applied during the workshop *Ultra Surfaces*. The materials of reference in our analysis are the industrial laminated surfaces cellulose-based, currently produced by two of Italian companies that were invited to collaborate in the educational activities/ /research, to be inspired by new visions and future scenarios.

1. The Material Surface Industry Technical Research

Nowadays, a market approach based exclusively on costs and technical properties is outdated. New industrial approaches take customer or consumer request as the primary key to enables more effective models of product-service system innovation. The attention to physical appearance and user satisfaction assumes increasing importance because it is strictly related to human expectations, connecting the aesthetic dimension to functional reasoning.

Meanwhile, in several material industries (from glass to laminated composites), the electronics integration into phisical components by embedding a growing number of economically ready-to-use technologies, is acquiring a strategic role to compete in the market. This is a big opportunity to increase product usability, aesthetics and customization. The integration of smart layers, sensors technologies, and patented AI is a suitable and versatile approach to augment product performance starting from the material surfaces and generate updated, proactive, and tangible user interfaces. Such innovation is capturing a grooving consumer interest, especially considering applications in fashion, product and interior design where smart behaviors, interactivity, and connectivity are intriguing concepts to raise the value of the products.

Among the most promising technologies, thin-films offer a host of advantages such as high compatibility with various materials, high scalability, and addition to seamless heterogeneous integration. There is considerable scope for flexible electronics of thin films applications in the health sector, in environmental monitoring, human-machine interactivity, energy conversion, sensor support communication, and wireless networks (Nathan et al., 2012). With the achievement of large dimensions production, thin-films offer opportunities for product innovation. Thanks to films applications, product surfaces are reaching multi-touch capacities making closer and based in sensory perception the relationship with users. Thanks to thermochromic and photochromic layers, the transparency of glasses can vary. In architecture applications smart glass can separate or connect inside and outside, proposing a variable and controllable on time vision, making possible the evolution of usual perceptive experiences (Ferrara and Bengisu, 2014).

Another promising industry for the integration of electronics into materials is the paper one is the paper manufacturing. In the last decade, the scientific research proposed printed electronics to enrich paper-based surfaces with barcodes, QRCodes, RFID tags, and conductive traces, and also electroluminescent foils or segments, showing the possibilities to increase the connectivity and the perceived value of such an underestimated material (Klamka and Dachselt, 2017). Today this industry is particularly interested in imbuing elements with sensing capabilities applying instrumental materials, like conductive paints, silver drew lines, copper stickers/tape, printed inks. These enable capacitive touch-sensing elements, such as buttons and sliders, without wires or visible electronics and connectors. New surfaces for interior can integrate interactive wallpapers, made of conductive paint, and thin electronics, without losing the sensory richness and flexibility of paper, supporting several applications, including interactive educational tools. Experimental examples of wallpapers serve as ambient information displays, giving feedbacks with light-emitting surfaces (Huang and Waldvogel, 2005), or communicating with other networked devices.

Start-ups are standing out along the strategy of seamlessly merging the physical matter and data without the need for keyboards, buttons, or touchscreens. Among the most interesting example, Hypersurface (2018) applies advanced sensor tech and AI to convert any surface into a smart one able to recognize gestures and other events. This patented technology - based on fog computing and composed of a chip connected to a network of vibration sensors controlled by algorithms - increases the surface performance. The system detects vibration patterns from human gestures interaction (like knocking, pinching, taps, swipes, etc.) or object collisions on the surface. Instantly, the "Mogees" embedded AI interprets the data vibration, converting them into a digital command that activates a specific feedback, like a designed sound or a speaking voice. As regards the integration possibility, Hypersurface uses

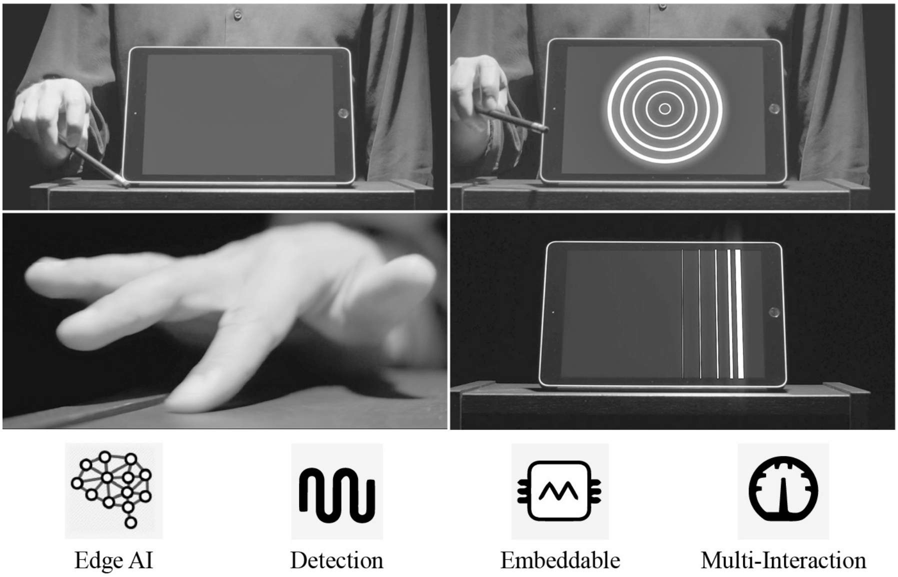

Fig. 1 - Hypersurface video frames. Courtesy Hypersurface

standard vibration sensors, and the software is a platform-agnostic so that it can run on standard chipsets. This technology offers a new *open platform* to add to any surface functions and features, transforming it into an almost-living-entity, with which interact through a gestural language, customized for each application. At the same time, it augments users' experience by adding a living touch, an interactive behaviour.

We are already experiencing a massive interest in new creative entrepreneurship opened to fabrication reshaping processes for a next products generation. Today, the design discourse about *ICS Materiality* (Rognoli et al., 2016; Ferrara et al., 2018; Parisi et al., 2018) allows to go beyond the previous experiences of innovative materials, to dive into the benefits that technological advances can bring to the user's experience, fully experimenting the multisensoriality that the *phygital* allows.

2. The Ultra Surfaces Vision

Ultra Surfaces (USs) is a unique design vision we have been adopted within the framework of *ICS Materials* to generate Next Design Scenarios of material surfaces. The vision was achieved thanks to the research carried out in recent years within the Material Design Culture Research Centre (MADEC)[1], which is deeply investigating the relationship between material for design and pragmatic aesthetics[2].

The USs vision enables a seamless fusion of physical matter and digital performance. Digital computationally augmented surfaces acquire intelligence and extraordinary interactive qualities. These are likely to enrich the users' perception with a multisensory involvement. The USs can contribute to augment the interaction between man-object and environment-people in a meaningful way.

In the USs vision, the possibilities to overcome the limits of human perception, with the aim of improving daily interaction in term of psycho-physical well-being are limited only by creative imagination. Connecting Design-Driven Material Innovation Methodology (D-DMI), Research-through-design, and User Experience - based analysis allow us outlining USs next future scenarios and concepts in which the human interaction with surfaces turns into a pervasive everyday *Smart Aesthetics Experience* (SAE). This last is a new kind of experience, mainly originated by interactive technologies, impacting at the emotional level, encoding new attitudes, feedbacks, gestures, and communicational issues (Ferrara and Russo, 2018). SAE relies on both mind and body stimuli, as well as being rooted in the socio-cultural context of people's everyday life. It promotes curiosity, engagement, and imagination in the exploration of an interactive system.

Designing the USs requires the designer's emphaty to users multisensory involvement during the interaction. It need to understand the user pleasure coming from the sensory perception as well as the interpretative process, and consequently evaluate emotional responses, aesthetic judgments, and on product value. If well designed, an USs could *materialize* pleasurable Smart User Experiences through full-body involvements.

[1] MADEC is also an international network that was founded in 2013 in the Design Department of Politecnico di Milano, thanks to the homonymous research FARB 2013.For more information: www.madec.polimi.it.

[2] Regarding this specific topic, the research conducted in 2018 by Anna Cecilia Russo (fellow researcher) was fundamental. This study has been carried out in partnership with ABET Laminati, a leader company in the production of plastic laminated surfaces, characterized by a wide variety of textures.

3. Workshop Scope and Approach

According to the approach of Politecnico di Milano Design School that integrates scientific research with didactic, in the academic year 2018-2019, we involved forty-five designers-to-be during their Product Design Graduation Lab, in a design workshop. The goal was to envision Next Future Scenarios of the US. During a month, students experienced a cross-disciplinary design process in cooperation with two manufacturing companies of laminated materials (paper and cellulose-based), jointly with a microelectronic company. These were called to collaborate in didactic activities following an open innovation approach.

Planning the workshop required a preliminary phase for the agreement with and among the partner companies, and the team of teachers and tutors. In this phase, we applied a Design-Driven Innovation approach, referring to the D-DMI model, as a way of promoting open innovation processes in the materials field (Ferrara and Lecce, 2017). In a cross-disciplinary and collaborative perspective, D-DIM can activate an osmotic exchange. It helps the design process to fluently put in action critical and speculative thinking about the choice of technologies, questioning the meaning of innovation, and proposing a new vision on the user experience. We shared the vision of Ultra Surfaces and define the design exploration boundaries.

Moreover, according to market trends, we decided to contextualize the design process in two different type of living spaces, domestic, and "alternative care locations" (in outpatient, hospital contexts or located in gyms and schools), focalizing the analysis on everyday human activities. Choosing this generic context, not specific at all, means avoiding any reference to existing products and spaces genres or narrow functional applications. Our aim was triggering a design process where the US performance benefits were the real generators of lifestyle innovation towards a desirable future. We focused on the emerging megatrend "Health and Well Being", investigating with the lens of user experience, to introduce into user's daily life sensitizing, be aware, healthy, social/individual activities. The hybridization of *passive* and *proactive* materials, i.e. dynamic/ reversible/ connected/ is a powerful opportunity to design solutions capable of: engaging user in self healthcare; rising comfort and psycho-physical wellbeing; enhancing a meaningful experience in everyday life

We started the design phase sharing the workshop brief with the students and an overview of smart technology applications in different sectors, from automobiles to urban spaces, and from office to hospitals. Another step was the instructions dispensed by the CEO of the partner company operating in the field of microelecthronics. He introduced students to intelligent systems, provided them with basic knowledge on the possibility of the application of smart technology-ready to use and how implement a smart system on conventional surfaces. It was a starting point to inspire an initial brainstorming about innovative and feasible implementations in terms of smart solutions or even augmented interfaces.

During the workshop, we promoted the discussion about USs vision, the desired SAE*,* and the *Natural Interaction*, to delineate potentialities and limits in accepting and appreciating the hybridization of the physical dimension with the digital one. Afterwards, we carried out a special session of multisensorial perception exploration with selected materials from the industrial partners.

Multisensorial Perception Exploration

As already discussed in previous studies, multisensory stimulation and involvement now have a big part in the whole Design Thinking approach (Ferrara and Russo, 2019). Providing students with inspirational settings by products and materials multisensory stimulation trains their awareness and aesthetic sensibility, and challenges them in interpreting their full perception. Then, we have gradually moved to a method emphasizing on the individual designers' subjective multisensorial aesthetic experience, starting from haptic interaction to icrease their sensibility and skills to design for the whole perceptive experience.

During the workshop exploration phase, we proposed our students a session of tactile investigation and multisensory analysis. We chose four samples of laminated materials produced by the partner companies according to their tactile characteristics (roughness, type of texture, direction, rhythm, etc.), and then about visual aspects (colors, decorative pattern, and other bidimensional effects). This tactile and visual exploration was elaborated by the tutor Anna Cecilia Russo and undertaken by students first blindfolded, and only later with open eyes. We pushed young designers to explore surfaces (touching, observing, feeling), and let them express referring to their own experiences (Schon, 1984) to allow their design thinking thriving off surface affordances. We have focus the attention on the experience as a result of a multisensorial/cognitive/affective process and its dual nature as a pleasurable as well as a meaningful dimension (Warell, 2008).

Despite the tacit nature of bodily experiences, for these young designers wasn't that hard to articulate verbally about their sensations, from testing, as well as letting past experiences memories create meaning about surfaces. During the test, we have also highlighted the use of metaphors to express emotions. These play an important role in existing archetypes and forms of fundamental importance for designing smart products. The materiality awareness actives a construction that involves affordances and symbolic meanings. This construction happens interacting with inactive surfaces, and even more with the proactive ones. Moreover, we considered meaningful teaching the participants to share their perception experiences, to create a common ground of experiences of which inter-subjectively construct meanings (as Josef Albers practiced in his basic design course at the Bauhaus).

Experience-driven Scenarios Envisioning

The multisensorial testing facilitated the accomplishment of crucial design decisions, and during the scenario definition phase was accompanied by a student desk-research on functional opportunities offered by smart technologies and computational systems (search for ready-to-use implementable technologies), ending with the envisioning phase.

In line with a tested approach we already gradually perfected in different workshops (Russo and Ferrara, 2017; Ferrara and Russo, 2018; Ferrara and Russo, 2019), the students were asked to answer the question "What can an Ultra Surface do to increase our experiences?" embracing an interpretative perspective from the initial phase of envisioning scenario. According to design culture, it is not the user the one that must adapt to technology but is the technology that we should shape to create positive experiences for the human being. In such a perspective, we fostered a multidisciplinary attitude, creating an osmotic exchange between design and pragmatic aesthetics, helping the students to structure more critical and speculative thinking.

The envisioning phase was pursued through the definition of the application field, research of inspirational images, and a choice of keywords describing feelings, emotions, and interaction modes along the SAE. The envisioning process had iterations, as suggested by the tutors. Each choice was discussed and detailed according to a Human-Centered Design (HCD) perspective evaluating all the possible implications and the level of emotional involvement generated. Each scenario was presented through conceptual mood boards, collecting reference images from different fields of creativity, envisioning SAE key concepts, and expressive language of the product/surface/space to design.

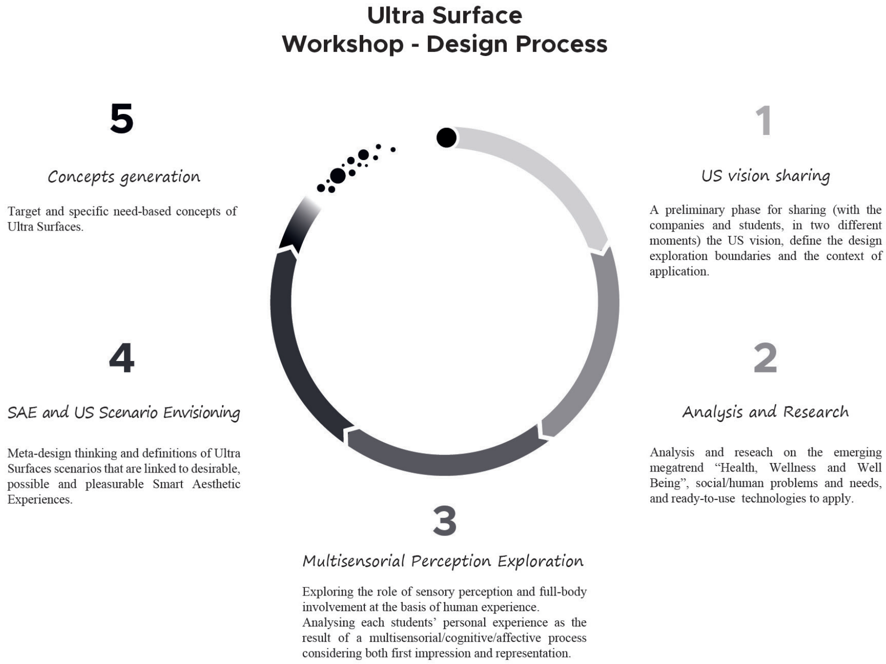

Fig. 2 - Scheme of the design process with different phases

4. USs scenarios and concepts

We will now present a selection of five scenarios of USs within domestic spaces and care contexts, based on users' experience-driven innovation activities.

The first one, "Empathic Haptic Grace", came from an exploration of body language and gestures, especially about how children and teen-agers creatively interact with invisible forces of their thought. A team of students with art-dance experiences chosed to envision a full-body movement interaction that triggers personal space and kinetic sensations-based experiences (as input and output). Rather than passive users in meaningless space with a screen bringing all the actions from the elsewhere, the scenario envisions an alternative mode to interact with products, where the body is shaping a harmonic and empathic conversation.

The scenario recalls the *kinaesthetic interaction* framework of Fogtmann (2007) for two reasons: to deal with the growing problem of unhealthy life-style caused by a lack of motion; and to take advantage of stress releasing movement, which is also influence our wellness. Therefore, using the whole-body during interactions gives the user a physical and emotional experience.

In the following design phase, this scenario generated, among others, the *Euritmia* concept, a system of interactive boards for haptic emphasizer areas, designed for a childcare center. The design of this system is inspired by the Eurythmy, the art of movement therapy by Rudolf Steiner (1921), useful for rehabilitation, during convalescence, and the prevention of various physical diseases. The surface is made of a soft-touch paper with integrated light led. While the interactive input is a gesture, the output is a flowing visual sha-

Fig. 3 - Empathic Haptic Grace Scenario

pe and a light movement. It helps children to reproduce movements or sequences related to their healing sessions. An embedded system of proximity sensors activates LEDs that turn gradually to light shaping elegant lines to enhance users' kinetic involvement.

The second scenario is "Conscious Diet Surface", a surface able to support users in the everyday diet experience. It helps to increase the competence on a diet, and the awareness of user food choices. In this scenario, the kitchen surfaces at home or tables at the restaurant can deal with users' needs in terms of daily intake of water and nutrients and suggests the right meal. It can give feedbacks trough information and advice to push the user to start a healthy diet, providing data about the right portions, cooking methods, and the nutrients intake. The concepts by students also include *I-Tabula*, a table with a smooth wood surface able to recognize users, and suggests meals de-

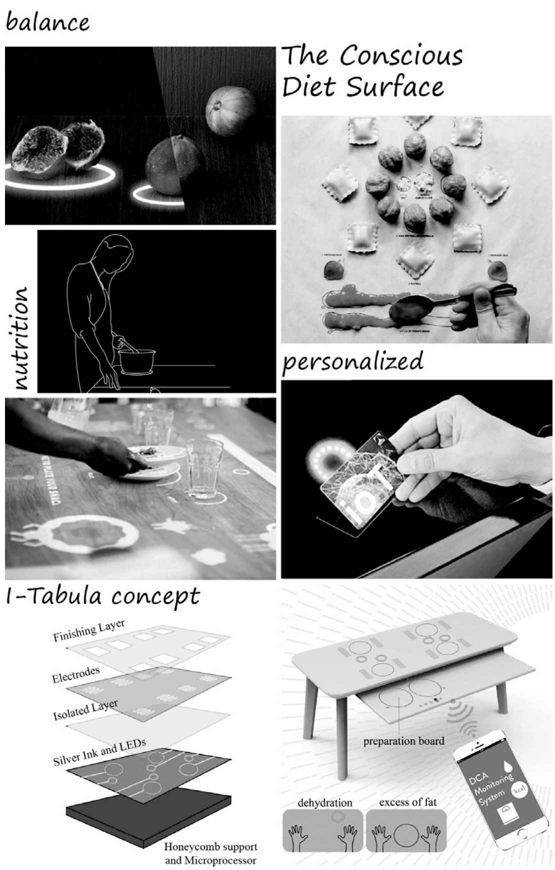

Fig. 4 - Conscious Diet Surface Scenario

pending on the user's health state and diet information. It supports the person in the right meal choice evaluating a suitable match of ingredients, using a light, and others signals languages to stop the meal.

The third scenario is "The Home Breath", based on a comfort experience at home, where USs of wood, or other conventional materials, is augmented with an intelligent system, able to monitor the interior environmental conditions and accordingly reacts. The surface can change shape to increase the interior ventilation, temperature, and light, and increase communication among different spaces. Its shape and color change informing the users about the air conditions in the interior space. The surface can detect substances floating in the air and shows their presence and the direction from which they are coming. It can detect a variety of air pollutants showing their concentration. The surface can also be used to create customized environmental atmospheres for convivial moments producing a sequence of calibrated released light effects and aromatic essences.

The fourth scenario is "Play Sense Vividness", a sensory perception amplifier. It gives a playful experience, engaging users in an augmented multisensory interaction that stimulates two or more sensory channels simultaneously (cross-modality). The experience related can more in-depth catch attention with effects in the learning and neurally-inspired experience. The surface can surprise with colorful and whetting soft, rough textures, vibration, sound, smell, and other stimuli. The feedback on the surface can be immersive.

Based on this scenario, the "PlaySense" concept deals with issues concerning visually impaired children, that in line with Maria Montessori inspired practices, encourage a deeper multisensory, through the mainly tactile and acoustic approach. A system of an interactive and playful wall of laminated surfaces is activated by touch. Thanks to a slightly rough texture 3D printed, it stimulates curiosity, energizes, and excites responding with sound and vibration feedback. The panel can be programmed to carry out 4 different educative games. Sounds consist of reproducing animal verses, rather than musical instruments, the narration of interactive fairy tales, or just the modulation of different vibrations. Thanks to an *Arduino* microprocessor, it was possible to create a basic circuit and a prototype where sensors turn the tactile experience also into an acoustic one.

Fig. 5 - Play Sense Vivdness

5. Conclusion

If today physical and digital worlds are still separate, appearing in our life as parallel universes, in the next future, they will seamlessly merge. The Ultra Surfaces Vision enables this merging on a new manufacturing paradigm.

Touchscreens, keyboards, and mice that today work as connection points between the two parallel universes, still forcing people to act in unnatural ways, will be overcome by the USs. Thanks to the emerging development of microelectronic tech and related manufacturing processes, USs is expected to combine in a single solution edge AI, multiple sensors, and connectors directly embedded in the material surface.

Designing USs, we have the opportunity to help users to resolve current problems and satisfy their needs, making life smarter with meaningful experiences. In such a perspective, collaborating with different but complementary partner-enterprises, and providing students with inspirational settings to imagine future scenarios, play an essential role in the university. We are starting to improve approach leading together research and didactic in material sectors. We have adopted an open innovation approach to co-design with three different enterprises, according to the D-DMI methodologies, emphasizing a market evolution perspective.

We focused *Ultra Surfaces* workshop on sharing technical knowledge and value chain in industrial products as well as stimulating young designers-to-be to develop next future USs scenarios, making them generating SAE.

The design process took advantage of a cross-disciplinary approach, robust design methodologies already used in the field, and a multisensory perception exploration. We dealed the topic with the attention of disclosing a whole system of possibilities able to advance functionality as well as mainwhile enhance a highly multi-sensorial perception for users. The strength of this approach is letting design thinking be nourished by a more profound comprehension of surface soft-qualities and the body-mind process perception. Our method also focused on expanding the palette of senses' involvement while introducing the idea of emotions and judgment in line with applied Aesthetics and *Somaesthetics* (Shusterman, 2013).

Thanks to the method applied, all the participants, with no previous knowledge of USs, and SAE won the workshop challenge. The Ultra Surfaces vision was discussed and detailed in different scenarios, according to the SAE that the students wanted to embody.

Each Scenario and detailed concepts of a novel surface with different degrees of complexity, combine inactive and proactive components. The USs vision was improved during the workshop. The concepts were appreciated by the companies, and some of them are now in the feasibility evaluation stage for design development.

What opportunities does the USs vision open in terms of design innovation and user experience design?

- The USs can reduce the number of screens, buttons, and make the room more user-friendly, easy to understand and approach with natural behaviour. The human-machine interaction is coming implementing new functions and change the experiences on how we spend time in our living spaces. The smartness of surfaces impacts on user everyday live in terms of rituals new gestures, languages, and relational communication.

- The USs can increase the conversation between humans and objects or spaces in a pleasurable way. A USs, as a collaborative partner, can empower people in situations where they are unable to act or are unaware that action is possible (Rozendaal, 2016). They will detect events and transform them into SAE. Open platforms will help users to define the different events to detect and enable. Users will experience data through a user-friendly physical interface.

- USs vision benefits from new processes making technology *disappear* and materiality *bump up*. The electronics augmentation phenomenon has contradictory processes. It reduces the quantity of products physicality (by the miniaturization of computing industries) and increases qualities of physicality, in term of the user solicitation with a rich palette of senses. This new physicality augments the social significance of materials and draws more user satisfaction. USs exploits the materials' potential, influencing the user's emotional involvement. They generate a multisensory full-body involvement. They engage users in SAE, featured by communicational resonances, semantic perception, epithetical feeling.

Following the rapid development of IoT as well as edge and fog computing, in the future, the interaction with Ultra Surfaces could happen in several products environments influencing our daily life.

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Laura Clèries is a designer, strategic design researcher, editor and curator in transformative innovation through design research-led strategic foresight and with an additional focus on materials. She holds a PhD and an extensive international academic and work experience in industry, academia and Think Tanks. Her recent work is addressed at generating content and strategies at international level through management of public and business research projects that bring actionable growth, and through the curation of events and exhibitions, conferences and publications. She is currently professor and Head of Research at ELISAVA School of Design and Engineering, as well as director of the Master in Design through New Materials.

Marinella Ferrara, PhD in design, is associate professor of product design at the Design School, Politecnico di Milano. Since 2015, she has been coordinator of MADEC, the Research Centre of Material Design Culture, Department of Design. Her research focus on design for materials and methodology, design-driven innovation. Since 2014 she has been a member of ADI Permanent Observatory of Design, and currently coordinates the scientific committee for long-life professional training of design professionals. She is the authors of more than 150 scientific publications, including Materials that Change Colour (Springer 2014), Materials that Move (Springer 2018) and Ideas and the Matter (ListLab 2017).

Venere Ferraro, PhD in Design, she is untenured researcher at the Design Department of Politecnico di Milano. Visiting researcher at University of New South Wales of Sydney and at Media Lab of Massachusetts Institute of Technology she is Coordinator of the European Project "DATEMATS" and holds national and international patents. Her main research activity is focused on interaction design practices and on how to exploit the potential of disruptive technologies (Wearables, smart materials and AI) to design experiential systems both in private and public sector; this by using a user-centred approach.

Marta González Colominas (PhD) is professor and senior researcher at Elisava. Technical Engineer in Industrial Design, Materials Engineering and PhD in the field of Materials Science. Marta is the head of the Elisava Research Academy Functional Unit at Elisava Research Group. She is the responsible of the Materials Narratives, a materials knowledge and interpretation platform aimed at researchers, teachers and companies. She has published the results of her research in several indexed international journals and has participated in numerous national and international conferences. Marta is accredited as a contracted doctor lecturer by the Spanish National Quality Assessment and Accreditation Agency (ANECA).

Markus Holzbach is professor at the Offenbach University of Art and Design since 2009. There, the qualified architect and materials and process engineer heads the IMD Institute for Materialdesign. Doctorate at the University of Stuttgart. 2016 to 2019, Dean at the School of Design at HfG Offenbach. The focus of his work is the role of the material in the design process. Lectured a.o. at RWTH Aachen University, the Berlage Institute in Rotterdam, Netherlands, and the Massachusetts Institute of Technology MIT in Cambridge USA. Visiting Professor at Politecnico di Milano, Italy.

Elvin Karana is professor of Materials Innovation and Design in the Faculty of Industrial Design Engineering at Delft University of Technology. Giving emphasis to materials' role in design as experiential and yet deeply rooted in their inherent properties, Elvin explores and navigates the productive shifts between materials science and design for materials and product development in synergy. Her recent research activities revolve around designing materials that incorporate living organisms and exploring their potential in fostering an alternative notion of the everyday.

Martin A. Koch is a trained biomedical engineer. He gained experience in software and hardware development and as a quality system manager for a medical device company. After receiving his PhD cum laude in the field of Tissue Engineering with synthetic biomaterials at the Institute of Biomedical Engineering of Catalonia IBEC in 2010, he worked in the bioengineering department of technology transfer centers as a R&D engineer. Since 2016, Dr. Koch is a professor at the Elisava Barcelona School of Design and Engineering and is the head of the Science and Technology lab.

Manuel Kretzer is professor for Material and Technology at the Dessau Department of Design, Anhalt University of Applied Sciences and founder of the Materiability Research Group with associated Materiability Lab. The group's work focuses on exploring novel material fabrication in unison with digital design and fabrication processes. A particular emphasis is on adaptive or smart technologies as well as biological materials and their impact on our future environment. From 2015 until 2018 he was visiting professor at the Braunschweig University of Art. Since 2016 he is MAA senior lecturer at the Institute for Advanced Architecture of Catalonia, since 2019 lecturer on Materials and Technology at the Institute of Design, Faculty of Architecture Innsbruck University, and since 2020 assistant lecturer at the School of Architecture, Technical University Dublin. Manuel is also founding partner of responsive design studio based in Cologne.

Richard Lombard is a materials consultant working with both industry and academia. With a career that has wandered from The Metropolitan Museum of Art to the Middle East, and most recently as a Visiting Professor at Politecnico di Milano School of Design, Richard has spent the past 20 years working with designers, architects, artists, and faculty and students on issues related to material sourcing, selection, fabrication, and utilization.

Sina Mostafavi is a practicing architect, researcher, and educator with expertise in computational design and architectural robotics. He is the founder of the award-winning studio SETUParchitecture. At TU Delft, He is currently a senior researcher, where he also has completed his PhD. in the Hyperbody group. In Dessau Institute of Architecture, he has initiated and led DARS.hub, a unit that focuses on Design Systems, Architectural Robotics, and Interdisciplinarity in design research. He has lectured and published internationally, and the results of his work have been exhibited in numerous venues such as V2 gallery, NAi in Rotterdam, and Centre Pompidou Paris. An overview of his work can be found at www.setuparchitecture.com and www.sinamostafavi.com.

Carlos Salas Muñozcano, industrial designer expertise in material design. He has worked as an industrial designer in different fields such as furniture, arts and the automotive industry, collaborating with SEAT. In 2018 he received a scholarship from Cosentino to research in dynamic materials at Elisava's master in design through new materials. Since then he has been working as a CMF designer and Industrial designer in the R&D automotive area of Altran Spain, where he is working to improve the sustainability paradigm of mobility services.

Stefano Parisi is a PhD candidate and research Fellow at the Department of Design of the Politecnico di Milano. He researches in the area of materials for design, focusing on emerging materials and processes, mainly smart materials, material systems with embedded electronics, and biomaterials. He investigates innovative design, knowledge transfer, and training methodologies for design students and practitioners about emerging materials with an emphasis on materials experiences and future scenarios. On this and related topics he has written publications, participated in conferences, given lectures and workshops, and carried out research and consultancy activities.

Barbara Pollini is a PhD candidate in Design at Polimi. Since 2010 she's dealing with sustainable design, with a master in Ecodesign and Eco-innovation and a MA in Computational Design. Since 2015 she has been investigating sustainable materials, focusing on the relationship between materials and design for sustainability from different perspectives (circular materials, biomaterials, living materials, made in waste materials and bioinspired materials). For her doctoral research she isfocusingon biodesign, an approach arising from the intersection between design, biology and technology, investigating living matter toredefine some key sustainable aspects for future productions.

Andrea Ratti (m), architect, PhD, and publicist, is researcher and associate professor of nautical design and architecture technology at Politecnico di Milano, Department of Design. He is currently Chair M.Sc. Yacht & Cruising Vessel Design and director of Master in Yacht Design, operational manager of the Laboratory for boating (SMaRT-lab), and vice president of the Italian Naval Technical Association (ATENA) Section Lombardy.

Valentina Rognoli is associate professor in the Department of Design at Politecnico di Milano. She is a pioneer in the field of materials experience, starting almost twenty years ago and has established internationally recognized expertise on the topic both in research and education. Her mission is raising sensibility and making professional designers and future designers conscious of the infinite potential of materials and processes. The investigations of her research group focus on pioneering and challenging topics including: DIY-materials for social innovation and sustainability; bio and circular materials; urban materials and materials from waste and food waste; materials for interactions and IoT (ICS Materials); speculative materials; tinkering with materials; materials driven design method; CMF design; emerging materials experiences; and material education in the field of design. Since 2015, Valentina jointly leads, with Elvin Karana, the international research group Materials Experience Lab. She participates as principal investigator in the European Project Made, co-funded by the Creative Europe Program of The European Union, which aims to boost talents towards circular economies across Europe. Valentina is the author of over 50 publications. She has organized international workshops and events and has contributed as an invited speaker and reviewer for relevant journals and international conferences.

Davide Spallazzo, PhD in Design, is assistant professor at the Department of Design of Politecnico di Milano. Active in the field of Interaction Design and HCI, his research focuses mostly on design-driven and technology-supported approaches to valorize cultural heritage sites. Over the years, he took part in several national and international research projects dealing with mobile devices and mobile gaming dynamics to enhance the cultural visits' experience maximizing learning and social engagement, tangible and embodied interaction. His teaching activity is carried out in the field of Design both at Bachelor and Master level.

Vasiliki Tsaknaki is an assistant professor in Interaction Design at the IT University of Copenhagen, working in the Digital Design department and in the AIR Lab. Her research combines affective and bodily engagements with technologies, materials experiences, computational crafts and soma design methods in HCI. Through design studies she investigates and reflects on intersections of these areas with a critical view on bodies, technological values and data. She has a PhD in Interaction Design from KTH Royal Institute of Technology in Stockholm, Sweden, on the topic of crafting precious interactions.

Ilaria Vitali is a product designer and PhD candidate at Politecnico di Milano who graduated with a Master's degree in Product Design for Innovation and a dual honors degree from Alta Scuola Politecnica. Her research focuses on smart connected products and devices with conversational interfaces and explores how to design them, creating guidelines and tools for didactic and professional activities. In particular, she developed the Mapping the IoT Toolkit (mappingtheiot.polimi.it), an accessible kit to aid in the design of IoT devices.

This present book covers a series of outstanding reputation researchers' contributions on the topic of ICS Materials: a new class of emerging materials with properties and qualities concerning interactivity, connectivity and intelligence. In the general framework of **ICS Materials**' domain, each chapter deals with a specific aspect following the characteristic perspective of each researcher. As result, methods, tools, guidelines emerged that are relevant and applicable to several contexts such as product, interaction design, materials science and many more.

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