EMERGING MATERIALS & TECHNOLOGIES

New approaches in Design Teaching Methods on four exemplified areas

edited by Venere Ferraro, Anke Pasold

D.I. FrancoAngeli DESIGN INTERNATIONAL OPEN ACCESS

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Introduction

The world of contemporary materials presents a great variety of choice for material solutions. The materials, from passive entities to choose from, have become active elements that participate entirely in the design process, becoming objects of the project themselves. Starting from the shelves of the material library, where the samples are only closed and catalogued, the samples of the materials have gone on to be considered the main protagonists of the design process and the experimentation guided by design. Besides, the designers have shown that they want to be more and more independent in the design and prototyping of self-produced material solutions. They no longer want to depend totally on other professional figures such as engineers and chemists mainly, to get their hands-on and experiment with the materials. The phenomenon of self-production of materials by designers that have appeared in recent years has been formalized in the DIY-Materials approach which today leads to the development of original and innovative material solutions to which companies also look with interest (Rognoli et al., 2015). The materiality of the world where we live is changing under the influence of technological advancement and social requirements. The diffusion of the Open source and the spreading of fab labs, workshops, and platforms for experimentation and prototyping, the democratization of technological practices is conducting to easier access to data and technologies both owned, through cheap and flexible tools, and shared, also for non-specialized users. As a result, the design is becoming computational and interactive, exploring trans-disciplinary approaches, and merging with computer engineering and biology (Parisi et al., 2018).

The designers, therefore, want to actively participate using their creative skills in shaping the material of which the objects will then be made and are aware of how the material is the principal element in determining the user experience of the artefact. As the products of our time are and will increasingly be interactive and smart, the designers have also begun to work on connected and interactive materials and on their hybridization with technology (Pandey, 2018).

In the panorama of contemporary design, we have increasingly faced with design needs strongly influenced by the technological system characterised by the ubiquity and connectivity of everyday artefacts that give rise to increasingly Intelligent, Connected and Smart systems. The designers are called to imagine new material experiences in daily life, through communicating and interactive devices that will be future everyday objects (Giaccardi, 2015). Even the multidisciplinary HCI community, after projecting research towards the dematerialisation of technologies, is re-evaluating the value attributed to sensory/perceptual involvement with physical matter, promoting the role of materials as a material lens through which to look to the future of dynamics of interaction.

Due the fact that digital and material are not separate but entangled elements of the same process, the chapter aims to contextualize the interactive, connected and smart materials in the theoretical framework of materials experience, presenting the possible and designable dynamism of materials as an emerging materials experience.

From technical properties to expressive-sensorial qualities

In the last 30 years, the domain of design research converging on Materials and Design has turned its focus from technical and engineering properties of materials to their expressive-sensorial qualities that define and affect the users' experiences of artefacts (Ashby & Johnson, 2002; Rognoli, 2004; Rognoli, 2010; Karana et al., 2008).

In a recent publication, where the authors built a literature review study on experiential characterization in product design, in which they described the current state of the art and identified gaps or opportunities for further research in this domain (Veelaert et al., 2020), it is clear that there is still much to be done and investigated in this domain. Therefore, it is now acknowledged that materials need to have qualities that go beyond the fulfilling of practical needs. They must have intangible qualities that captivate appreciation and that affect the experience of an artefact beyond its functional value. These qualities were firstly named, expressive-sensorial qualities of materials and then Intangible Characteristic of Materials (ICM) (Karana, Hekkert & Kandachar, 2010; Karana, Hekkert & Kandachar, 2007), and later intangible sparks of materials (Karana, Pedgley & Rognoli, 2015); they are qualitative, non-technical, and intangible characteristics related to emotions, personality, and cultural meanings.

Rognoli defined the sensorial, subjective, qualitative, and unquantifiable, profile of materials as their expressive-sensorial dimension. This notion looked at design materials as instruments to characterize a product from the points of view of perception, interpretation and emotion. By means of the expressive-sensorial qualities of materials, designers can embody in the product sensorial emotional references that trigger a particular material experience. The Expressive-Sensorial Atlas (Rognoli, 2010) supports designers in their understanding of the material qualities and unfolds their relations with engineering properties. It is a mapping of the technical, objective and measurable profile of materials, into a sensorial, subjective and qualitative one. The atlas is a collection of charts or tables, which report information in a structured yet flexible manner, without grading or privileging material. The atlas has a purposeful 'work in progress' format, rather than a completed entity – intended to grow according to the users' requirements and experiences.

Examples of the qualities are texture (smooth/uneven), touch qualities (warm/cold, soft/hard, flowing/stilted, light/heavy), brilliancy (gloss/matte), transparency (transparent/translucent/opaque).

At the didactic level, the atlas is an interactive tool used to teach future designers about the existence of a sensory dimension of materials, consisting in tactile and photometric sensations that people perceive because of interaction with (sensorial exploration of) materials. These aspects are divided into top-level parameters (texture and touch for tactile sensations; brilliancy and transparency for photometric sensations), which in turn are divided into qualities (texture: smooth/engraved; touch: warm/cold, soft/hard, light/heavy, sliding/sticky; transparency: transparent, translucent, opaque; brilliancy: gloss/matte). These characteristics may be also used to describe the sensorial level of materials experience.

From expressive-sensorial qualities to the materials experience concept

Elvin Karana introduced the concept of materials experience in 2008 (Karana et al., 2008) and then it was further investigated and developed. In general, the term 'materials experience' describes a holistic view of materials in design, emphasising the role of materials as simultaneously technical and experiential. Taking materials experience as an entry point, it is possible to understand and describe how people experience materials and how physical, biological, social, and cultural conditions constitute these experiences. Furthermore, it is possible to inspire innovative material applications as well as new materials and design research trajectories.

The concept of materials experience describes the experiences that people have with, and through, the materials embedded in a product. This definition acknowledges and emphasises that, through shaping what we feel and think, materials have the power to foster meaningful experiences.

In comparison with the expressive-sensorial dimension of the materials, the concept of experience includes the interaction between user and materials possibly incorporated in an artefact. Experience is an episode, it is a time-lapse, it is a story that emerges from the dialogue that a human being establishes with his world through action (Hassenzahl, 2010).

The materials experience framework at the beginning was composed of three different levels affecting each other. The first one is the sensorial level (i.e. the aesthetics of materials) that is the experience that originates from perceiving and noticing material sensorial information by senses. The sensorial experience of a material is related to sensorial information, such as softness, warmth, smoothness, sound, weight, stickiness and so forth. This level is very linked with the expressive-sensorial characterization of materials. Then, the designer has to reflect on what the material may represents, its meanings (interpretative level). The interpretive experience, related to the meanings evoked by the material and are associated to abstract concepts, e.g. materials are modern, cozy, etc. Meaning is linked to judgment: about what the material represents to us, and emotion is connected with how the material makes us feel (emotions). The affective level is related to emotions elicited by the material, e.g. feeling surprised, bored, etc. (Karana et al., 2014; Karana et al., 2015).

In HCI community Giaccardi and Karana explored how the framework of materials experience exhibited the active role of materials play in shaping people's interactions and practices. In fact, to complete the previous framework it was necessary for the designer to include also "the active role of materials on shaping our ways of doing and ultimately, practice: the performative level" (Giaccardi & Karana, 2015). Sensorial perception, emotions and meanings significantly influenced the performances the human beings establish around material objects. The unique and peculiar ways of doing are mediated and affected by the material character and their qualities. For that reason, he performative experience, acknowledges the active role of materials in shaping ways of doing, physical actions and practices, e.g. to scratch, finger, squeeze, etc.

When the scholars in the field of materials for design had already stressed the central role of materials in shaping meanings, sensorial and emotional interactions, highlighting how the right choice for material and process affects the user-product interaction, and often contributes to give to products the features that are mediators of the quality of the interaction itself (Wiberg & Robles, 2010; Rognoli et al., 2011), the HCI community still considered only the functional properties of materials, and they didn't believe their power as signifiers (Regier, 2007; Fernaeus & Sundström, 2012). We have to wait until the formalization of the "material turn" (Robles & Wiberg, 2010) for HCI to put a particular emphasis on the methodological importance of closeness to the materials-at-hand and on underlining the importance of actively working with materials. In fact, it was established that thanks to the material interaction, it is possible to activate “a knowledge-generating process inseparably intertwined with, and enabled by, a material discovery process” (Wiberg, 2014). Wiberg stated that materiality could be a framework to understand computational artefacts and their social impacts, which describe how the interactivity of digital computing manifests itself in a material form. The key feature of this notion is the dynamic relationship between people and interactive systems in relation to the materiality of artefacts (Wiberg, 2018). Finally, HCI research shifted its attention from materiality of information to materiality of interaction in the context of material-centered interaction design (Zhong et al., 2020).

Dynamism of materials as an emerging materials experience

The materials themselves are dynamic entities because they always change. This change can be slow or fast, reversible or irreversible, it can involve the material whole body, or it surface, it could be supported by chemical or mechanical properties of the components of materials or it can be related to its shape. Anyway, it is always synonymous of dynamism. This can be enhanced by the use of different kinds of materials (ICS Materials) that change over time or interactive with which the user interacts dynamically, creating meaningful, with a high symbolic and emotional value. The key issue of dynamism is fundamental because we consider the temporal dimension that influences the material experience. The sample of material is no longer considered as something static and immutable that can be closed in a closet or attached to a table, but it is a dynamic entity that interacts with the external conditions influencing the properties and qualities of materials, and then the materials experience.

In the New Penguin English Dictionary, the word *Dynamic* is defined as “something pertaining to or characterized by energy or effective action; vigorously active or forceful; energetic; … something marked by continuous activity or change; something related to variation”. Taking into account the above definition, it is easy to realize that there are a lot of shades of meaning for the concept of dynamic, above all if we decide to associate it to the world of materials for design.

There is a particular class of materials that are dynamic and changeable thanks to their intrinsic properties; that is the smart materials. The smart materials are well known by scientists and also by the designers. They are generally defined as highly engineered materials that respond intelligently to their environment (Addington & Schodek, 2004). These materials “have changeable properties and are able to reversibly change their shape or colour in response to physical and/or chemical influence, e.g. light, temperature or the application of electrical field" (Ritter, 2007). The smartness is referred to their ability to sense the environment and at the same time transforming themselves in a controlled way. These materials are fundamentally different from traditional materials since they are dynamic and active. The distinctive qualities can generate unique interfaces supporting a new way of interacting with the users. They can also create a new form of physical interactions based on new affordances and communication languages. If we think to apply these unique material qualities applied to everyday objects, play a big role in people's social behaviour and practices, thanks to their ability to build affective and emotional interactions (Minuto et al., 2014).

Many researchers from different disciplines have studied smart materials from different perspectives and points of view, finding original names that each time highlight the qualities of this class of materials which is able to create many different material experiences. Not only these materials are considered as reconfigurable and dynamically respondent to use or context, but smart materials can change their identities over time. To highlight the dynamism of smart materials over time, some scholars in HCI defined them as *becoming materials* (Bergström et al., 2010). The quality of dynamism is obviously in progress and develops in a temporal dimension. Dynamic materials can also be called "becoming" because they are fundamentally temporal and can assume multiple states of expression that can be repeatedly and minutely controlled over time. As Bergstom et al. (2010) affirmed, the world of materials where the designer chooses the right combinations of features to concretize the intended experience, can be described in terms of being (what is the material?), doing (what does it do?) and also becoming.

Other scholars in their studies highlighted different aspects of smart materials class and decided to call them as *information materials* (Kretzer, 2017). This name is mainly due to their inherently dynamic nature, thus not only carry and visualize information but are also based on information, being artificially created from pure intellect. "Information materials, wants to establish an awareness of a new materiality that can actively change its properties over time, that can be produced and programmed to display a particular performance, and that emerges across multiple disciplines, including nanotechnology, materials science, genetic engineering, or synthetic biology. Most of all, however, it aims at mediating an understanding that these materials are fundamentally distinct from traditional ones. Therefore, they should not only be contemplated in isolation but also lead to profoundly new concepts in terms of architecture and spatial design, attributing value to processes, temporality, and transience". The dynamism of the information materials is linked with the possibility the have to change and transform themselves.

The investigation around dynamic materials continued and also led to the formulation of the concept of *ICS materials*, defined as materials or even hybrid material systems or composites with sensitive, smart or gradually varying properties lead to new and complex ways to design. This opens up new possibilities on the level of concept, form, structure and surface, and paves the way to consider material properties and qualities as dynamic and ever-changing. Materials become the dialogical carriers of a wide variety of information – they become informative and intuitive (Parisi et al., 2020). ICS Materials are not limited to computational, electronic, and digital. Indeed, this definition also encompasses interactive materials using chemical, mechanical, and biological means. It is possible to enrich the ICS Materials definition telling that they are hybrid material systems that work by establishing interactions among their constituting components, and with people, objects, and environments, through the combined use of electronic, chemical, mechanical, and biological components (Parisi et al., 2018). In this case, the dynamism is included in the concept of interaction at the basis of the design of this kind of material or hybrid system.

At least, the dynamism as an emerging materials experience that can change the users' experiences of everyday objects is presented also in the recent publication edited by Skylar Tibbits titled Active Matter (2017) as a result of the Active matter Summit held at MIT in April 2014. In the summit participated researchers from seemingly unrelated disciplines but with the same aim, create active, intelligent and dynamic materials. "Active Matter is a newly emerging field focused on physical materials that can assemble themselves, transform autonomously, and sense, react, or compute based and external information" (Tibbits, 2017). From the collection of case-studies contained in the book, it possible to realize how the dynamism of the materials can take many different physical and concrete forms, going from microrobotics to programmable bacteria, to computational skins. This list of dynamic materials provides evidence, which then turns into awareness, of how the user experience with these materials is dynamic and how dynamism passes through the four levels of materials experience listed above. These are the materials with which the designer will have to deal soon and with which she/he will have to give shape to our future the world.

Conclusion

In this chapter, we talked about how materials are evolving and how the research of materials for design evolved consequently.

From an engineering approach, that only considered the properties and performances of the materials, we moved towards a more user-centred approach considering perceptions and feelings, up to the focus on the quality and the experience of the materials. The concept of materials experience was presented by relating it to an emerging experience: dynamism. Since digital and material are not separate but entangled elements of the same process, the chapter aimed to contextualize the interactive, connected and smart materials in the theoretical framework of materials experience, presenting the possible and designable dynamism of materials as an emerging materials experience.

The materials that will shape the world of our future will be different from those to which design has shaped so far. Technology is hybridizing all physical media and therefore, also traditional materials will have to become more interactive, connected and intelligent. Digital, materials and design are no longer specific and distinct and separate things but are porous elements of the same process of research, design and invention (Pink et al., 2016). These evolving, informative, ICS, active, digital and dynamic materials lead to new expressions and a new sensuality in design. The work of blending the technology and materials, which are elements with different properties, qualities and also affordances, for creating new emerging materials experiences, becomes the task of the designer.

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Authors' Affiliation

Venere Ferraro, PhD Assistant Professor, Department of Design, Politecnico di Milano.

Anke Pasold, Associate Professor, Material Design Lab, Copenhagen School of Design and Technology.

Pirjo Kääriäinen, Associate Professor, Department of Design, Aalto University.

Sara Lucia Rueda Mejia, Doctoral Candidate, Department of Design, Aalto University.

Tarja-Kaarina Laamanen, PhD Postdoctoral Researcher, Department of Design, Aalto University.

Jari Laine, PhD Senior Innovation Advisor, The School of Chemical Engineering, Aalto University.

Paz Morer-Camo, PhD, Associate Professor, Department of Mechanical Engineering and Materials, University of Navarra-TECNUN.

Aitor Cazón-Martín, PhD, Associate Professor, Department of Mechanical Engineering and Materials, University of Navarra-TECNUN.

María Isabel Rodríguez-Ferradas, PhD, Assistant Professor, Department of Mechanical Engineering and Materials, University of Navarra-TECNUN.

Robert D. Thompson Casas, Scientific Director of Materfad, the Barcelona's Materials Centre of FAD (Fostering Arts and Design).

Stefano Parisi, Doctoral Candidate, Department of Design, Politecnico di Milano.

Valentina Rognoli, PhD Associate Professor, Department of Design, Politecnico di Milano.

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The present book contains the preliminary findings of an ongoing research project "DATEMATS" (Knowledge & Technology Transfer of Emerging Materials & Technologies through a Design-Driven Approach Agreement Number: 600777-EPP-1-2018-1-IT-EPPKA2-KA) funded by the the Erasmus+ programme of the European Union aimed at developing novel teaching methods for both design and engineering students in the field of Emerging Materials & Technologies (EM&Ts).

It focuses on four exemplified EM&Ts areas as results of the methods, gaps and issues related to their teaching methods.

It provides a summary of the four literature reviews conducted at respectively Aalto University on Experimental Wood-Based EM&Ts, Design Department of Politecnico di Milano on Interactive Connected Smart (ICS) Materials Wearable-based, Tecnun University on Carbon-based & Nanotech EM&Ts and Copenhagen School of Design and Technology (KEA) on Advanced Growing.

It will present the synthesis of the four EM&Ts highlighting similarity, differences for all of them; it will give an overview for each area in dedicated section presenting the meaning, the different approaches used and developed for each EM&Ts area, finally it will provide the setting up of a common and advanced methods to teaching EM&Ts within HEIs, to create new professional in young students, and to develop new guidelines and approach.

Venere Ferraro, Ph.D. 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.

Anke Pasold is an Associate professor at the Material Design Lab, Copenhagen School of Design and Technology, where she is developing the methodological and technological side of the lab and structuring new educational programmes. Pasold's academic and research focus is on material practice, in particular advanced design methodologies and material fabrication processes by means of experimental prototypes making things tangible between the digital and the physical.

FrancoAngeli
La passione per le conoscenze