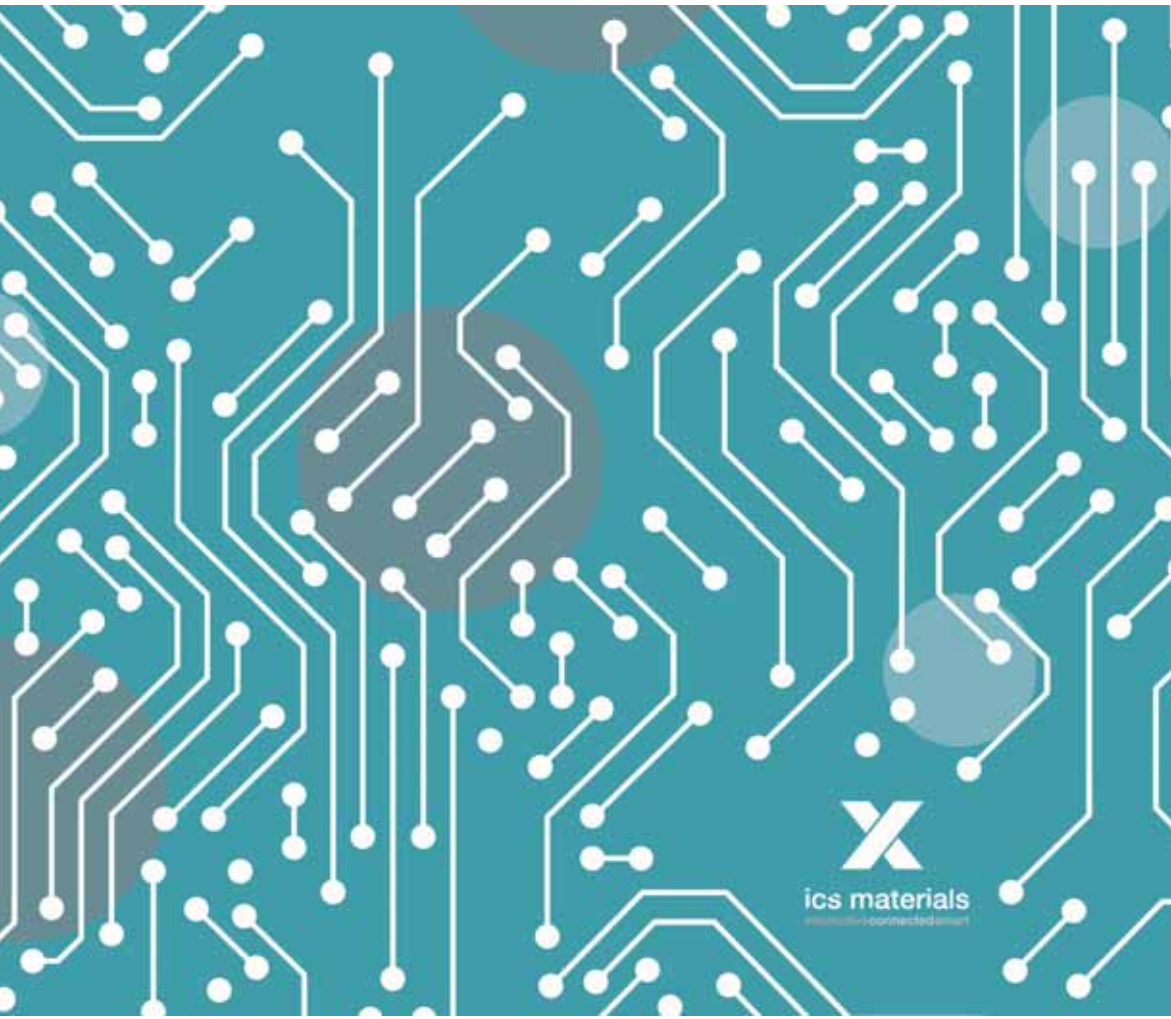
ICS MATERIALS

Interactive, connected, and smart materials

edited by Valentina Rognoli and Venere Ferraro



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by *Valentina Rognoli, Venere Ferraro*

1. About ICS Materials Project

In the panorama of contemporary design, there are evident needs strongly conditioned by the technological system characterized by the ubiquity and connectivity of everyday artefacts that create material systems always more Intelligent, Connected and Smart. Designers are asked to imagine new material experiences in daily life, through communicating and interactive devices that will be future everyday objects (Giaccardi, 2015; Giaccardi, 2018; Chuang et al., 2018).

Even the multidisciplinary Human-Computer-Interaction (HCI) community, after having pushed the research towards the dematerialization of technologies, is re-evaluating the significance attributed to the sensory/perceptive involvement with physical matter, promoting the role of materials as a lens ("material lens") through which looking at the future dynamics of interaction, by recognizing the value of tangible side (Wiber, 2014;).

In the last few years, new classes of advanced smart materials are emerging, expanding the available domain of materials for design and applications. This evolution is encouraged by a growing technological development that feeds miniaturization of components, such as sensors, microprocessors, and actuators, and allows operating on a micro-and nanoscale (Valgarda et al., 2010; Razzaque et al., 2013). Also, it fuels a continuous democratization process that fosters knowledge sharing, open-source technologies and trans-disciplinary collaborations between design, material science, computer engineering and life sciences, to some extent.

The materials emerging from this conjunction of factors are overpassing conventional smart materials by showing higher degrees of intelligence, thanks to the seamless integration of embedded and seamless technologies that allows them to sense, process and respond to external inputs, and being

programmable and re-programmable (Andreoletti and Rzezonka, 2016; Tibbits and Cheung, 2012; Tibbits, 2017; Scott, 2018).

We call this novel class of materials as **ICS Materials**, an acronym for **Interactive, Connected and Smart Materials** (Rognoli et al., 2017; Ferrara et al., 2018, Parisi et al., 2018 (a); Parisi et al., 2018 (b); Parisi et al., 2020). The concept of ICS Materials leverages the meaning of Material Experience (Karana et al., 2014; Karana and Giaccardi, 2015) that consider the material as "*being simultaneously technical and experiential*" expanding it to the multidisciplinary context of HCI.

This book aims to disseminate a research project focused on ICS (Interactive, Connected, Smart) Materials and the results of the research concerning this particular typology of design materials. The study, funded by FARB (Fondo di Ateneo per la Ricerca di Base), Politecnico di Milano, and carried out by a multidisciplinary team of researchers of the Department of Design, is situated in the intersection of design, new materials, and interaction, to define and support the theoretical and practical development of such a cutting-edge research area.

The questions the research intended to answer are: how will the everyday objects be in the future? Will they still use the contemporary conventional materials? Will they always have the functional characteristics and the performances sufficient to meet new needs? What will be the material experiences emerging in this context, and how will they evolve in perspective? Are there any methodologies that can facilitate the design process towards meaningful material experiences in the field of design?

With such premises, the research on ICS Materials proposed an adaptation of the traditional methods, skills and knowledge already developed in the field of materials for design. It favours the progressive transition towards an increasingly interactive, connected and smart dimension of design products and services (Wiberg and Robles, 2010; Hummels and Frens, 2008; Zimmerman et al., 2007; Frens, 2006), which unfolds in the IoT, Internet of Things (Kuniavsky, 2010).

The definition of ICS Materials encompasses material systems that are:

- Able to establish a two-way exchange of information with human or non-human entities.
- Linked to another entity or an external source, not only through the internet and digital network.
- Able to respond contextually and reversibly to external stimuli by changing their properties and qualities.
- Programmable, not only through software.

They can do that through the combination of electronic, chemical, mechanical, and biological means. By using integrated and seamless technologies, such materials can be used as reprogrammable material interfaces for many sectors (transportation, consumer electronics, wearables, smart objects, architecture, cultural heritage, etc.), showing enormous potential in terms of customization, sustainability and reduction of resources, and complying with the Internet of Things, Artificial Intelligence and Industry 4.0.

Throughout a bottom-up approach, labs and companies around the world are developing samples, demonstrators and prototypes of such materials. There is the necessity to set a boundary and frame the complexity of such phenomenon and critically reflect on their sustainable development, their innovative potentials, and their integration into the industrial framework, the social context, and the design space.

The research here presented contributes to building the foundation of an emerging area of research promising to make research groups and departments more competitive at a national and international level. More investigations require to be addressed for identifying innovative guidelines, scenarios, and methods facilitating the development and integration of advanced hybrid materials systems, considering creativity, manufacturing, sustainability, and application issues.

These innovative tools to approach such emerging materials are a competitive factor in the field of **research, education, and industry**; in anticipating and facilitating their industrial development, market deployment and spread in the user's everyday environment, having a social and technological impact.

The results of this research, i.e., knowledge, models, tools, guidelines, scenarios, and method, are expected to benefit and contribute to the transition towards a more resilient, adaptive and connected future. The book means to be a valuable resource for **academic researchers, educators, industrial managers, designers, engineers, interaction designers and materials experts**, who want to discover more about new materials and technologies and need knowledge and tools for their development and teaching.

The research project was divided into four main stages informed and inspired by the ***Double Diamond Process Model***, i.e., Discover, Define, Develop and Disseminate[1] (Hunter, 2015).

Following such phases, the results of the research could be framed as follow:

- State of the Art about the topic, mapping literature, theoretical concepts and models, existing best examples and the actors that are involved in the phenomenon.

[1] https://www.designcouncil.org.uk/news-opinion/double-diamond-universally-accepted-depiction-design-process

- The exploration of the grounding and border disciplines and concepts concerning the new topic of research, thanks to the contribution of international guest experts from education and practice in the fields of Design, New Materials, and Interaction.
- Proposes innovative guidelines, techniques and scenarios for the ideation, development and multi-sectors application.
- Proposes and applies a new method to ideate the design of such materials for intended application contexts, tested in an innovative format of design education workshop for multidisciplinary students.

2. Contents

The book is shaped into three main sections by giving a general overview of the research's findings.

In the first part, external guest authors are called to contribute by bringing their research topics as grounding or border notions to the research project. Some of the authors already presented their contents during a series of open lectures organized by the research team in 2017-2018, such as:

- **Gaia Crippa**, Senior CMF Designer and Materials Specialist at Chris Lefteri Design, London, UK: The new material experience. Interactive, connected and smart materials.
- **Daniela Petrelli**, PhD, Professor of Interaction Design at the Art & Design, Research Centre, Sheffield Hallam University, UK: Arguing the case for holistic design. Unpacking the relationship between materials and interactive experience.
- **Barbara Pollini**, PhD Student at Polimi and Sustainable designer and professor in Materials and new technologies for the project innovation at Naba Design University, Milan, Italy: Sustainable design and biomaterials. Exploring interactivity, connectivity and smartness in nature.
- **Marta González Colominas**, PhD, Coordinator of the Materials and Sustainability area for the Degree in Engineering in Industrial Design at ELISAVA, Barcelona, Spain: Smart materials driven design. Design to achieve dynamic experiences.
- **Oscar Tomico**, PhD, Head of Studies of the Degree in Engineering in Industrial Design at ELISAVA, Barcelona, Spain: Designing for soft interaction. Designing products that are worn (everyday).
- **Vasiliki Tsaknaki**, PhD, interaction designer and crafter, teaching at KTH Royal Institute of Technology at the department of Media Techno-

logy and Interaction Design: Exploring materials and making processes of computational artefacts, through studio craft practices.

- **Manuela Celi**, PhD, Associate Professor at the Design Department, Politecnico di Milano, Italy: Exploring the futures. How design shapes next directions.
- **Seetal Solanki**, Founder and Creative Director of Ma-tt-er, London, UK: How materials matter. The past, present and future of ICS Materials.
- **Manuel Kretzer**, PhD, Professor for Material and Technology in Design, Dessau Department of Design, Anhalt University of Applied Sciences, Cologne, North Rhine-Westphalia, Germany. Founder of Materiability. Partner at Responsive Design Studio: Materiability. Educating smart materials for design and architecture.
- **Maurizio Montalti**, Designer / Researcher / Educator / Entrepreneur | Founder&Director @Officina Corpuscoli | Co-founder & Director @ mogu: Growing design & growing materials. The everyday practice, its outcomes and opportunities and the related implications.

Seven chapters constitute the first section of this book and will guide the reader into the understanding of the vast panorama that examines the intersection between materials, technology and digitization.

In the first chapter, a case study developed inside Elisava will show how engaging interaction through smart materials and a sensory language by using ***Smart Material Driven Design Method***. While, in the second one, experimental case studies using interdisciplinary processes deploy the increasing overlapping of the ***digital with the real/hybrid materials*** proving that there are no classical categories to associate to the materials anymore.

Further, the book will give a hint on the topic of ***sustainability***. It does it through two more chapters respectively dedicated to bioplastic and robotic fabrication describing customized methods of fabrication, parametric design modelling and the potentials of do it yourself (DIY) bioplastic in combination with cutting edge robotic fabrication. Case studies on ***biomimicry, bio fabrication, biomaterials, biodesign*** by using co-participated design activities with living organisms, will be presented.

Besides, three case studies related to ***digital craftsmanship***, practices that combine physical with computational materials will be described by highlighting future scenarios such as sustainable practice and the value of craft, the sensorial and the impermanent aspects of craft materials, and program smart materials.

After that, there is a chapter focused on Light. Touch. Matters (LTM) project[2], a collaboration between designers and materials scientists aimed at

[2] https://www.tudelft.nl/en/ide/research/research-labs/emerging-materials-lab/lighttouch-matters/

providing insight related to underdeveloped smart materials composites, and how to facilitate communication between designer and materials scientists and the importance of experience prototyping.

Finally, the first section concludes with a chapter that will instead exploit the meaning, opportunity and potentiality to really know materials through materials libraries: an example of how organizing an ICS Material collection in functional groups (composites and wearable) will be provided.

The second section of the book will present the State of the Art and the map of the ***ICS Materials phenomenon***. In the first chapter, the definition of the phenomenon of ICS Materials as the main output of the research, is described and contextualized. In this chapter, **the notion of Materials Experience** is explained and used as a lens to interpret ICS Materials. The experiential patterns that ICS Materials enable and imply are presented and discussed.

In the second and the last one, a ***map of materials and a map of practices*** are presented. The main sub-classifications of ICS Materials according to their complexity degree and behaviours, are here provided.

In the third section of the book, the researchers taking part into the research project focused on anticipating scenarios for the development and integration of ICS Materials in their research areas, addressing the multidisciplinary dimension and impact of the project. Different sectors of application will be addressed, such as: Material surfaces industry; Exhibition and Smart Environments; Transportation, in particular, the Nautical sector; smart objects, in particular, advanced home appliances; Wearable Technologies. For each area, state of the art, case studies from research and education activities and future scenarios will be presented. This, to set the potentials and limits of the application of ICS Materials in that specific industrial area and design space. In this part, the participants to the project used the meaning and classification of ICS materials, considered as the main result of the project itself and they utilise it in different fields of application and design workshops with students with diverse backgrounds, including engineering, design and architecture.

The first chapter of this part describes five scenarios of visions developed during the workshop Ultrasurfaces. The meaning of the term utrasurface as a sensorial interaction with the surface (today's relationship between phy sical and digital) will be given, the added value of the electronics augmentation, merging physical matter with data worlds without the need of keyboards, buttons or touchscreens, multisensory stimulation will be provided.

Afterwards, four chapters will go through the use of ICS Materials in (i) exhibition, (ii) smart products, (iii) wearables and (iv) yacht design:

- The use of technologies in museums, smart materials in the exhibit design field (3 dimensions: exhibition space, the cultural assets, the visitors) will point out the need of interaction both at the micro and macro level and the conception of the exhibition space as an ever-changing organism.
- The chapter will give an overview of the concept of smartness (smart qualities), smart product (3 categories), limits and opportunities of ICS materials for intelligent products, the most formidable challenge of standardization of smart materials and exciting opportunities in extra small and extra-large scales of applications.
- The description of a new class of electronic devices: stretchable electronics, will be highlighted. The need for lighter and more flexible materials for wearable design will be explained through the connection between wearable technologies and ICS Materials.
- The trend of full sensory experience in yacht design (part of the luxury design), a new practice of interaction between the yacht, the sea, and human behaviour, will be framed. In this case, the results of 5 workshops "Design for NautICS Materials" related to the use of ICS Materials for yacht design are presented..

At the end of the book, a survey on Materials Design methods and tools is presented to depict their limits and potentials, to introduce the '***Design for ICS Materials***' approach. The methodology and its supporting tools and activities are here described.

3. Final Remark

The international scientific community agrees that materials are a key element for designing products, interfaces, furniture etc. Indeed materials are, on the one hand, the shape of which every artefact is made up of and, on the other one, a medium between the user and the surrounded by creating innovation that encompasses new languages, meanings and experiences (Karana et al., 2014).

Nowadays, emerging technologies are changing the way the human being lives, thinks, communicates and interacts with each other by imposing researchers, designers and practitioners to investigate the new way the materials will be studied, shaped and consequently experienced.

The rapid spreading and development of Internet of Things (IoT) smart products and interfaces, the responsive environment is adding new dimensions to humans everyday life: smartness, connectivity and interactivity.

This book centres the attention on the way materials are evolving by embracing these three layers focusing on a new class of Materials named ICS Materials.

Authors and contributors of this book explore the role of this new class of materials in the world of always evolving artefacts by reasoning on their unique performance, aesthetic and meaning, sensorial experience and mostly on the latest methods and tools to be used by designers in order to design with and for ICS Materials.

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Authors

Erika Arcari is a product designer and UX/UI junior designer at Sky, graduated with honors at Politecnico di Milano in Design and Engineering. She worked at Politecnico as teaching assistant, then she did an Executive Master in Service Design in collaboration with NTT DATA and PoliDesign. Her work is focused on Interaction Design related to digital and physical products.

Venanzio Arquilla, designer, is associate professor at the Design Department - Politecnico di Milano. He is Secretary of the Bachelor Degree on Product Design and the Master Degree on Integrated Product Design at the POLIMI Design School. His research activities deal with user experience, strategic and service design, smart and connected products. He is founder and coordinator of the Experience Design Academy that comprise the UX Design and the APP Design and Development higher education courses at POLI.design. He is the co-director of the Master of User Experience Psychology held by Università Cattolica del Sacro Cuore and Politecnico di Milano / POLI.design.

Bahareh Barati is a postdoctoral design researcher at Delft University of Technology. She received her MSc (cum laude) in Integrated Product Design from Delft University of Technology and was named Best Graduate of the Faculty of Industrial Design Engineering in 2012. In her PhD work she developed strategies, tools and exemplars to unpack the potentials of smart material composites, specifically focusing on light-emitting materials and their performative qualities. She disseminated her work at design and ACM conferences such as CHI, in international journals, and at exhibitions such as Dutch Design Week. Her current research and educational activities bring into focus the unique qualities of smart and biological materials in designing and prototyping performative and adaptive products.

Arianna Bionda (f), PhD in Design, is a researcher at the Department of Management, Economics and Industrial Engineering, and an adjunct professor at the

School of Design at the Politecnico di Milano. Architect, sailor and yacht designer, since 2014 she is involved in national and international research activity mainly focused on Yacht Design for sustainability and digitalization. She is didactic coordinator and vice director of the Specialized Master in Yacht Design and the Project Manager of the sports&design team 'Polimi Sailing Team', joined in 2009 while she was a bachelor's degree student.

Mauro Ceconello is architect and associate professor. He focused his research activity on tools and apps to enhance cultural heritage and tourism using mobile technology, serious games and interactive systems. He's the scientific coordinator of research projects concerning the valorisation of culture through digital technologies and interaction tools. His latest research interest is AI and virtual assistants in the domestic settings.

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, partici-

pated 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.

FrancoAngeli
La passione per le conoscenze