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Murat Bengisu
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Materials that Move

Smart Materials, Intelligent Design

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Preface

Contemporary technological and productive transformations with the emergence of smart materials and technologies are changing the way of thinking and designing objects. Because technology is one of the major drivers of the transformation of our life and society, here and now—in the computational era—designers must deal with the transition from conventional materials to smart materials in order to improve the qualities of the next generation of products, implementing user experiences.

This is the main objective of *Materials that Move* which follows our first book published by Springer, Materials that Change Color (ISBN 978-3-319-00290-3). These two books present a design-driven investigation into two different families of smart materials defined according to “what they do” as Ezio Manzini suggested in his well-known book *The Material of Invention* (1986), emphasizing that new materials are characterized by their performance rather than simple functionality. In fact, the concept of performance is complex. It refers to the capability of a product (or a material), i.e., its contribution to bring actions or processes to the achievement of goals and objectives, affecting users and giving rise to unique user experiences. Performance is often a function of two components: efficiency and effectiveness. So, defining smart materials that act according to what they do is very relevant with respect the conventional ones, because their reaction to stimuli will result in an action that at the macroscopic level shows a first evident result in the change of their appearance on which their performance and personality depends.

Smart materials are radically different from traditional ones. They are sensitive, can be active, kinetic and responsive to various stimuli, such as external conditions around them (temperature, electricity, magnetism, humidity, light, pressure, chemical substances, etc.) to which they respond to with no need of human intervention, within a predefined reaction pattern, as long as the stimulus persists. Due to their ability to perform both sensing and actuating functions, they are inherently interactive. Just like living organisms, their interactions are autonomous. However, they can also be controlled and programmed according to the desired type of interaction. Thus, objects made of them will become interactive, showing similarities to living systems.

The performance of smart materials is a powerful stimulus for design, promising much more in relation to current paradigms based on sustainability, communication, interaction, and human experience. Smart materials are great tools to design radically innovative products that respond to new customer needs. On this account, a considerable amount of design research has been dedicated to potential applications of smart materials. While they represent "a turning point in the methods of design", they pose new opportunities in all aspects of design and perception. The intrinsic dynamics of smart materials provide the capacity of continuous, harmonious adaptation, and unusual experiences.

These two books are useful for all who need a deep knowledge of the potentiality of these novel materials to better deal with designing with them in the perspective of the relationship between people and technology. Presenting what smart materials do and how they respond to a certain stimulus, these two books are useful tools for literacy on smart materials for designers, architects, engineers, creative enterprises, and educators active in related fields.

Smart materials have many advantages like reduced dimensions, lightness, and not requiring any energy supply to function (apart from few cases, e.g., where they need a small electric stimulus for activation). Furthermore, they can be programmed and integrated into computerized systems to function in a controlled manner according to the needs of a project. Thanks to such characteristics, smart materials are appropriate and closely linked to the truly great issues of our time—environment, energy, mobility, and health. They are good tools to foster innovation for increased product quality while combining sustainable profitability with responsibility. Therefore, the appropriation of smart materials by designers is very important nowadays, and the knowledge about these materials, their potentiality, limits, and application in different design or production sectors is the key to increase their acceptance as well as the capability to exploit these new materials wisely.

The subtitle *Smart Materials, Intelligent Design* used in the two books underlines the need to use these new media available today for complex functions that they are capable of, augmenting the intelligence of objects. Designing with them, one can operate with a perspective of innovation with minimized environmental impact while helping to improve the performance of products instead of reducing the use of new technologies, which, according to many environmental extremists, is the only possibility to guarantee the sustainability of products.

Taking advantage of the smartness of these materials, namely their ability to feel and react to stimuli in a fast, automatic, reversible, controllable, and predictable manner and the possibility of embedding digital intelligence, designers have the opportunity to create radically new products. Such products will have new and better levels of quality of use: communicative, interactive, connective, and behavioral, affecting the established human–object relationship patterns.

Design has the opportunity to expand the experiential levels of the relationship between the user and the object, the interpersonal and social relationships through the object, or the relationship with the spaces and the nature through the object. It is up to the project to be able to use these materials to achieve a rich, effective, intuitive interaction that is engaging on many levels. This is what we mean by intelligent design.

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Chapter 1
Introduction

The book *Materials that Move* introduces a particular category of smart materials able to react to a stimulus acting with a kinetic effect. The general characteristic of these materials is their ability to move. As the movement that characterizes them produces a change of physical form, we could also name them *materials that change shape* or *kinetic materials*. Their shape changes can be free and casual yet also programmed and controlled. So one realizes the complex functions these materials perform. Therefore, this new essence of material introduces elements of radical changes in the material design culture (Bengisu and Ferrara 2015).

Various categories of these materials are presented along with their behavior related to stimuli to which they react (thermo-, photo-, magneto-, electro-, pH-responsive and piezoelectric) and their composition (prevalent materiality), responding to the questions "what is it?" and "how does it work?" The categories presented are shape memory materials (alloys, polymers, elastomers, gels, ceramics, and composites), bimetals, electrorheological fluids, magnetorheological fluids, gels, and elastomers, electroactive polymers, and piezoelectric materials. Furthermore, kinetic materials are often made up of different components working together hierarchically down from the nanometer scale up to visibly macroscopic scales to produce responsive or functional behavior.

Materials that move are presented with their properties, behavior, and other basic information, like characteristics, potentialities, advantages, production processes, and challenges for applications. This way to transmit material information was acknowledged as one of the powerful strategies to shorten the time of a materials innovation, according to the words of Gottfried Semper (1989, 2004) that emphasized the need for designers to appropriate new materials and techniques in order to master them and freely express their purposes.

Therefore, the book contains various chapters discussing how kinetic materials are produced and applied in systems to work, how they have been applied and put to use until today, and how they impart new performances to products in order to explain how to make such materials work, how to engage consumers, and how to take advantage of their multi-faceted nature.

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Addressing the creative professions, one of the main objectives of this book is to instill a mindset for applying these materials and related technologies, trusting in the cross-fertilization of design methodologies (product, interaction, and experience design) by orchestrating functions, forms, sensory experiences in different time-frames and contexts, and by designing "smart experiences" (Russo and Ferrara 2017).

Chapters 5–8 discuss the rise of investigation on and applications using kinetic materials, demonstrating that they are great tools to design innovative products that respond to new businesses, customer needs, and desires in the context of current global problems and opportunities (Carmagnola 2009). On this account, a considerable amount of research has been dedicated to applications of kinetic materials to increase the functionality and sustainability of products. Research is also thriving in arts and design fields, i.e. creative spaces where people are experimenting with the expressive, symbolic, and aesthetic potentials of shape changing materials, questioning about interactive experience. This research provides a scenario for looking out of the box of current industrial production. Most of experimental practices, even though conducted at level of crafts and do-it-yourself, are developing new ideas and reflections in order to understand how to realize technology- and experience-inspired innovation that require a better comprehension of human perception of objects and spaces. With a material thinking approach, operating with simple methods and collaborative practices, these investigations move from a material vision to concept design and prototyping.

Case studies were chosen to represent the state of the art in creative practices in different fields of design and art, including architecture, product, fashion, exhibition, and communication design. Unlike industrial patents, this broad review of emerging and widespread creative practices focus on experimentation with materials characterized by a kinetic response to stimulus. This is useful to understand a whole perspective of design with regard to user experience, functionality, interactive performance, and the expressive nature of these materials (Ferrara and Bengisu 2014).

Many case studies reported in this book show the intrinsic dynamics of kinetic materials providing the capability of continuous and harmonious adaptation to spaces, conditions, and human presence. The case studies show how designers interpret material capabilities, giving meaning to their application and motion. Meanings change in relation to how new products are designed and to which emotional experience the user gets during the interaction with shape-changing objects (Bengisu and Ferrara 2015).

Changing surfaces are adaptable to different conditions to guarantee better comfort in interiors to safeguard energy and material resources. The dynamism can influence the behavior of people in a certain space. Jewelry can be reshaped by customers according to their own taste. Art projects show the power of attracting and holding the audience using kinetic effects. Interactive products use kinetic effects to communicate with the user in a more intuitive and understandable manner. Active responses can materialize intangible information which cannot been perceived with the human senses in daily life. Other projects exploit shape changes to encourage user interaction (through touch or gestures). These possess the playful characteristics needed for learning by contributing to a pleasurable user experience. Others grab the attention of the consumer enticing and seducing them. Many unusual user experiences are described in the case studies.

The selection of case histories that traverse various fields of creative work has the intention of promoting a better understanding of opportunities offered by these material technologies for designers. This approach derives from the typical mode of operation of Italian design, which utilizes approaches such as design-driven innovation, cross-fertilization, and technology transfer, in order to develop creativity and facilitate innovation in products deriving from sectors with low capital investment (Cardillo and Ferrara 2008; Ferrara 2017a, b).

The observation and critical analysis of emerging practices make it possible to consider the expansion of ideas and skills of design, in its being an artistic and technical approach, towards these new materials, their processes and uses. Therefore, the analysis proposed by the book is not exclusively technical but concerns the cultural dimension of design in technological innovation, which takes into consideration the updating of design methods and tools capable of producing knowledge, visions, and quality criteria, as suggested by Manzini (2016).

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Chapter 2
Materials that Move

Various terms have been used to describe the phenomenon of shape change caused by a certain stimulus. The most common of these terms is *shape memory*. Shape memory materials (SMMs) are smart materials that have the capacity to “remember” a certain shape they were “trained” to adopt. SMMs are part of a larger group of materials that change shape, namely *kinetic materials*. Various types of external stimuli can trigger the shape change of a kinetic material. Most commonly, a temperature change is used as the stimulus but many kinetic materials have been developed that react to other stimuli such as light intensity, stress, pH, electric fields, or magnetic fields.

A clear distinction is necessary between a shape memory material and a material that has the capacity to return to its former shape when the applied force is removed. The latter effect is nothing new and many materials have this capacity in one form or another. It is the elastic deformation capability of any material which makes it act like a spring. In the elastic region of a stress-strain curve of a metal part, when tensile stress is applied, the length increases and when the stress is released, the part returns to its original dimensions. Springs are made from materials that have the capacity of large elastic deformations. Spring steels, stainless steel, piano wire, brass, phosphorus bronze, and copper beryllium alloys are such materials (Yamada and Kuwabara 2007).

Recoverable deformations can also be achieved in piezoelectric ceramics and electroactive polymers. Piezoelectric ceramics such as lead zirconate titanate (PZT), ZnO, $PbTiO_3$, and quartz have the capacity to undergo a small strain ($\sim 0.1\%$) under an electric field due to the inverse piezoelectric effect (Bengisu 2001). Much larger strains (up to 200%) have been achieved in electroactive polymers, thanks to research since the 1990s (Bar-Cohen 2002). Recognizing the great variety of materials that can be included in the naming of materials that move, we propose the classification below.

Electronic supplementary material The online version of this chapter (https://doi.org/10.1007/978-3-319-76889-2_2) contains supplementary material, which is available to authorized users.

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