Chapter 1
Introduction

Textiles have been a prominent interface with our environment and a prime example of innovation-driven developments. Emerging sensing and reacting capabilities are imparted to textiles by means of smart materials and enabling conductive and electronic technologies. Introducing new qualities to textile conventional functions and expressions, smart textiles have been opening up vast potential for the creation of adaptive and reactive surfaces.

Through the perspective of seamless integration of technology into our environment, smart textiles are able to involve physical and immaterial dimensions, promoting added functionality and interaction between people and their surroundings. In interior spaces, variation of artificial light intensity and tone are commonly achieved by acting upon the light source. Smart textile responsive behavior presents the possibility to change the light that passes through them—light transmittance—through the reversible change of their properties, performing as Dynamic Light Filters and allowing the design of dynamic lighting scenarios.

Design and development of smart textiles encompasses competences in diverse domains and presents new challenges: a technical and creative understanding of the materials' properties, behavior and processing possibilities as a materials system are required as well as consideration of their active qualities. In parallel, smart textiles demand a rethinking of conventional design variables and methodologies, given the novelty that dynamic and interactive dimensions introduce.

This book provides interdisciplinary and articulated coverage on smart textiles topics and discusses original research developed on integration of smart materials in textile substrates based on systematic processes, dynamic qualities of color and shape thermo-responsive textiles, and design potential of smart textile behavior to dynamically filter light.

After this chapter introduction to Smart Textiles and Dynamic Light Filters themes, this book examines fundamental concepts and knowledge in each smart material domain and respective research. Part I looks into dynamic color in textiles through Color Change Materials, their thermo-responsive behavior and respective electrical activation. Part II focuses on dynamic form through Shape Memory

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Alloys and textile morphological performances based on origami techniques. Part III presents design research that explores innovative perspectives on smart textiles dynamic qualities, consideration of design variables and possibilities of smart textiles and light interaction to create responsive lighting environments.

1.1 Smart Textiles

Textiles have been a prominent interface with our environment and a prime example of innovation-driven developments. Among diverse possibilities, textiles have been applied for sun shading and transformation of wind into motion energy. They provide enhanced qualities for high-performance applications, such as lighter and stronger architectural structures, protective professional clothing and biocompatible implants. They are at the basis of technological advances, namely materials processing and computing-based technologies and are able to sense and dynamically react to external stimuli (McQuaid 2005; Quinn 2010; Kettley 2016).

Emerging sensing and reacting capabilities are imparted to textiles by means of smart materials and enabling conductive and electronic technologies (Koncar 2016). Smart materials exhibit sensitive-stimulus capability that triggers a reversible response, sensing inputs include thermal, mechanical, electrical and magnetic energy, among others (Tao 2001; Langenhove 2015).

When smart materials are integrated in textile substrates, they embed them with intrinsic dynamic and interactive behavior, thus presenting new qualities to conventional textiles' functions and expressions (Worbin 2010; Kirstein 2013). Dynamic quality refers to the textile ability of property change and interactive quality is due to the changes in response to a sensed stimulus. For example, thermochromic (TC) textiles change color upon temperature variation and, through the same stimulus, shape memory textiles can change shape.

Moreover, smart textiles can also combine data processing, communication and power supply functions, enabled by increased progress of textile-based conductive materials and electronics miniaturization that impart textiles with electronic and computation capabilities. This character is commonly classified as very smart, describing the textile ability of sensing, reacting and adapting (Tao 2001).

Driven by scientific and technological developments, smart materials have been gaining increased attention for textile research and applications, namely in biomedical, protection, fashion and communication fields (Merati 2018). As on-going research into new materials and enabling technologies is moving forward, creative approaches are also exploring and unfolding new textile futures as interactive surfaces of our daily life.

Characterized by interdisciplinary convergence, research and development of smart textiles combine knowledge and competence from materials science, electronics, textile engineering, textile design, interaction design, etc. Towards performance feasibility of textiles, collaborative research seeks to embed and explore functional and interactive dimensions in an unobtrusive way, so that textile intrinsic properties or designed expressions are not significantly compromised, for example stretching, recovery, draping, shearing or handling (Zysset et al. 2013; Stoppa and Chiolerio 2014; Kumar and Vigneswaran 2016; Yilmaz 2019).

The perspective of seamless technology integration is transversal to diverse fields. The ‘ubiquitous computing’ concept, introduced by Marc Weiser in the late 1980s, envisioned that “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it” (Weiser 1991). Whereas technology is embedded into our environment (Ambient Intelligence), occurring through continuous interconnections (Pervasive Computing) or regarding to clothing and accessories (Wearable Electronics), the main aims rely on built-in active performances able to enhance welfare, intellect, creativity and communication, also stimulating sensory and emotional fulfilment (Baurley 2005; Ko et al. 2005; Aarts and Wichert 2009; Schneegass and Amft 2017).

Textiles as a pervasive and soft interface for new technologies and interactive performances, challenge our concept of textiles, commonly associated with passive functionality, as well as the way we may use or interact with them (Frumkin and Weiss 2012; Pailes-Friedman 2016). In addition to encompassing competences in diverse domains, smart textiles also add new parameters to design research and practice. Design reactive and adaptive qualities in textiles requires technical and creative understanding of the materials behavior, process possibilities in respect to smart textiles’ physical materialization and their behavior framework, as well as a rethinking of conventional design variables and methodologies given the novelty that dynamic and interactive dimensions introduce (Worbin 2010; Vallgårda 2014; Mossé 2016). Time and movement as emergent dimensions of textile design entail new perspectives in respect to how the textile changes and what it expresses, as well as how their behavior can be designed.

1.2 Dynamic Light Filters

Through the perspective of seamless integration of technology into our environment, smart textiles are able to involve physical and immaterial dimensions, promoting added functionality and interaction between individuals and their surroundings (Bonnemaison and Macy 2007; Benitez 2016). In interior spaces, variation of artificial light intensity and tone are commonly achieved by acting upon the light source. The emergent sensing and reacting behavior of smart textiles present the potential to change the incident light that passes through them—light transmittance (Yot 2011)—to design dynamic lighting scenarios, performing as *Dynamic Light Filters.*

The interaction between textiles and light is designed through the textile properties and dynamic qualities. The topics and research presented in this book explore smart textiles and light transmittance dynamic variables through textile color and shape changing behavior.

The emergence of Color Change Materials (CCM) allowed the introduction of chromatic dynamic qualities to textiles, a behavior based on the variation of the substances microstructure or electronic state, affecting their optical characteristics—absorptance, reflectance, scattering or transmittance (Addington and Schodek 2005; Bamfield and Hutchings 2010).

TC leuco dyes are a class of CCMs that through thermal stimulus change their visual characteristics reversibly. They perform color change by fading away above an activation temperature and returning to the predefined color below it. Able to be mixed with conventional pigments, instead of a colorless effect, heat variation results in changes from one color to another. As dark colors absorb a greater intensity of the visible light spectrum than lighter colors (Descottes and Ramos 2011), TC textiles can affect the light that pass through them, when they are below or above their activation temperature.

The design concept inherent to the TC materials research presented in this book aimed to transform similar light intensities and tones to heterogeneous, as well as the inverse. In this sense, experimental work with TC pigments concerned with the development of systematic processes to create textiles that change color according to predefined ratios.

Thermo-responsive Shape Memory Alloys (SMAs) are metal compounds capable to change from a temporary to a pre-programmed shape, upon a heat stimulus (Otsuka and Wayman 1998). By displaying interactive motion and force, these materials challenge new perspectives towards innovative and reliable applications, as well as revealing potential to supersede other actuators (Lawson 2016). Their unique properties include stimulus-sensitive with a silent kinetic response and high actuation forces, as well as lightweight and biocompatible options (Bengisu and Ferrara 2018; Mehta and Gupta 2019). As different amounts of textile layers interfere in light transmittance, depending on the light absorbed, it is possible to develop shape memory textiles that perform morphological variations with variable layer numbers. This requirement was studied through geometric structures based on origami techniques, an ancient Japanese art of folding paper.

Defined by the ability to conduct electrical current, conductive materials are a key topic in smart textiles field, as they enable the transfer of energy or data and impart textiles with electronic functionalities (Storey 2009; Eichhoff et al. 2013). Working with thermo-responsive textiles, conductive materials enable the electrical activation of color and shape behavior through resistive heating, according to their properties, integration in the substrate and thermal conductivity of the textile structure. In the research conducted, integration of conductive materials in textiles aimed to produce thermal variation of the TC pigments. SMAs are conductive materials and shape change activation was performed through their resistive heating properties.

Smart textiles design comprises of a synergetic relationship of the textiles tangible and immaterial aspects. Considering time and movement as critical variables that smart textiles introduce, they also entail new perspectives and alternative methods to understand how to work with temporal forms in textiles (Redström 2010; Mossé 2016). With thermo-responsive textiles, heat is a main dynamic variable to explore design possibilities of textile color and shape behavior and, in this research context, the creation of dynamic lighting.

This book provides interdisciplinary and articulated coverage on smart textiles topic and discusses original research developed on integration of smart materials in textile substrates based on systematic processes, dynamic qualities of color and shape thermo-responsive textiles, as well as design potential of smart textile behavior to dynamically filter light.

Part I and Part II look into dynamic color and form in textiles, respectively, and from a material research perspective, Chap. 3 presents the study and development of systematic processes of paste recipe formulation with TC and conventional pigments to screen print textiles with defined color change ratios from similar to different with temperature increase and the inverse; Chap. 4 explain the study of integration processes of metal-based conductive materials in woven substrates and the analysis of their electrical and expressive qualities for resistive heating activation of thermo-responsive textiles; and Chap. 6 discusses the study and development of a workflow setup to design and manufacture shape memory woven textiles in which dynamic behavior achieves predefined geometric morphologies, performing layer number variation.

From a design perspective, Part III presents the practice-based design research developed to explore dynamic qualities of color and shape thermo-responsive textiles and their interaction with light. The research program comprises of two main experimental studies on textile behavior and dynamic light, followed by the development and discussion of three research prototypes. Design and presentation of the prototypes propose to study dynamic qualities of thermo-responsive textiles behavior based on selected design variables and discuss expressive possibilities of color, shape and light performances through different intensity levels of change.

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