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Edited by

Jinlian Hu

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Introduction to active coatings for smart textiles

1

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1.1 Introduction

The coating, finishing, and lamination of textiles are old arts and traditional technologies and are used in almost every area of industry and our lives. Laminating combines a fabric and a prepared film by adhesive, heat, and mechanical bonding, which replaces or supplements sewing to obtain laminated fabrics with enhanced function and more consistent qualities. However, it is easy to confuse the definitions of coating and finishing. The term "finishing" is usually used in a broad sense to refer to operations for improving the appearance or usefulness of a textile after it leaves the loom or knitting machine (Tomasino, 1992). These operations include washing, bleaching, coloring, and all kinds of chemical and mechanical steps that may comprise coating. In this book, "finishing" is used in its narrow definition (Schindler and Hauser, 2004), which is the final step in the textile manufacturing process (Fig. 1.1), which distinguishes it from a coating according to film continuity or morphology in processing technologies. Under this definition, finishing and coating both create the characteristics of textiles and endow them with special performance such as the final hand feeling. The coating also can complete yarn preparation such as warp sizing. In coating, a thick liquid chemical or paste is used that forms a continuous film on the yarn or textile surface, formed in situ. Gaps between fibers and yarns may disappear or narrow to varying degrees. In finishing, the light liquid chemical paste is applied and penetrates into the fibers and yarns to make up the textile, after which the gaps cannot be altered between the yarns and fibers (Fung, 2002).

Traditional textile coatings are commonly passive protections or decorations for the substrate for which they are designed and are applied by providing a barrier on the surface. Some advanced coatings include functional materials that enable the textiles to exhibit increased functionalities such as wrinkle free, flame retardant, etc. Furthermore, an active coating is to be considered smart. It is able to sense a change in conditions and respond to it in a predictable and conspicuous manner. Generally speaking, an active coating gives textiles intelligent properties more than just functional performance (Smith, 2010). The active coating senses the environment changing, responds to it, and does something by itself.

Active coatings can be categorized in many different ways based on the smart ingredients, fabrication technologies, and applications. For intelligent textiles or

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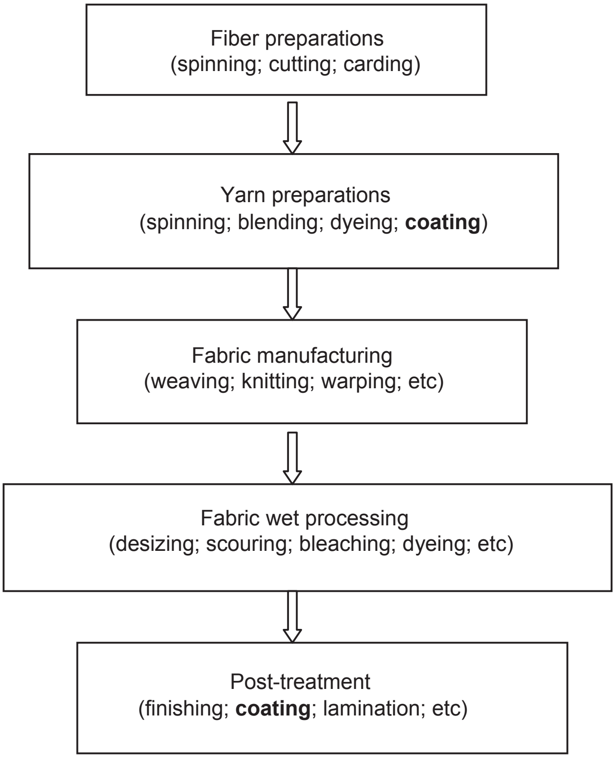

Figure 1.1 Coating positions in textile processing.

systems, there are normally three parts: a sensor, a processor, and an actuator (Tao, 2001; Mattila, 2006). Therefore, besides response, active coatings can consciously trace performance, for instance by remotely monitoring.

Intelligent materials contained in the coating layer can sense and respond to the environment, such as phase-change materials (Ghosh, 2006; Jyothi Sris et al., 2012), memory materials, and chromic materials. Active coatings by these intelligent materials acting as sensors can respond to changes in heat, light, chemicals, electronics, liquid, humidity, pressure, or bioactivity. Response may involve color change, shape adaptation, surface cleaning and healing, energy harvest and release, textile structure dimensional variance or drug release, and so on.

The smart ingredient within the active coating can be the polymer or resin itself, such as a memory polymer or a variety of additives consisting of nanoparticles for self-cleaning, pigments for color changing, microcapsules of phase-change materials for thermal regulation, microelectromechanical devices for wearable electronics, or antimicrobial agents for biomedical textiles. The successful combination of smart material science with advanced processing technology makes the active coating possible.

1.2 Functions and applications of active coating

Functions of textile coating are usually summarized according to their applied chemical properties, such as antibacterial, water resistance, etc. In this chapter, however, their functions are classified into three major categories; examples are listed in Table 1.1 based on the type of common or active coating.

Applications of textile coating are listed only partially based on industrial and civilian uses. This is a good place to begin understanding common coatings and discuss potential applications for active coatings, which also have occurred or been applied in these areas and products: for example, in breathable garments with a water-responsive, variable-sized opening fabric structure; in antibacterial bedding; and in impact-active protection (Table 1.2).

Table 1.1 Functions of common and active textile coating

Categories	Common coating	Active coating
Aesthetic	Wrinkle free; flat appearance; dimensional stability; antistain; water or oil repellent; leather; color resistance	Color change; appearance retention; self-cleaning;
Comfort	Windproof; thermal resistance; water resistance; moisture management	Thermal adjustability; breathability
Protection	Humidity resistance; flame retardant; antiimpact; ultraviolet protection; antistatic; reflective; chemical resistance; blood resistance; anticorrosion; safety airbag; thermal insulating; aging resistance	Antibacterial; wearable electronics for biomedical use; self-healing; chemical odor absorbing and decomposing
Others	Filtration; stiffness	

Table 1.2 Applications of textile coatings

Areas	Examples
Clothing	Garments; footwear; accessories
Home furnishings	Upholstery; bedding; carpet
Medicals	Implants; barrier materials; bandages; hygiene products; health monitor
Industrial	Belts; hoses; filtration; screens; covers; liners; barriers; tents; separation; building reinforcement layer

1.3 Development of smart materials for active coating

Smart materials for active coating are mostly active materials which transport the sensing and responding properties to textiles by traditional coating technologies (Singha, 2012). Adaptive polymers can exhibit distinct and great changes when responding to a small stimulus. Accordingly, adaptive coating textiles have preprogrammed responses to small environmental changes. Different stimulations of active materials are listed; these have been applied in active coating textiles:

- heat and temperature
- pH value
- chemical and ionic strength
- electromagnetic radiation (ultraviolet, visible light)
- electrical and magnetic fields
- mechanical stress, strain, and pressure
- water and humidity

A number of active materials exist for textile coating, such as smart and polymeric hydrogels, memory polymers, phase-change materials, color-change materials, and functional nanomaterials.

Smart or polymeric hydrogels as a special classification of hydrogels display different changes under specific stimuli such as temperature, pH sensitivity, light, salt, and stress. Responses include swelling/collapsing and hydrophilic/hydrophobic changes in shape. The most commonly used hydrogels in active coating are temperature-active hydrogels with a transition temperature adjusted by additives, a modifying monomer structure, or copolymerization. The widely applied and known hydrogel active coating application is temperature-dependent water vapor permeability textiles, based on their swelling and integrity characteristics below and above the switch temperature.

Memory polymers can sense thermal, mechanical, electric, and magnetic stimuli and respond by changing shape, position, stiffness, and other static and dynamical characteristics. Memory polymers have found wide applications in textiles and other fields. Their low cost, good processing ability, and controllable responses make them more suitable for industrial production than memory alloy (Maria Rosa Aguilar, 2014; Hu, 2010). The functions of memory polymers can be achieved in many systems such as a molecular structure with covalent and noncovalent bonding or a supramolecular structure with novel quadruple hydrogen bonding. As a group of the most applicable smart materials, memory polymers have developed rapidly in both academics and industry areas in past decades.

Adaptive polymeric particles include nanoparticles and microcapsules. The benefits of smart materials combined with particle materials give an integrated and unique property to textile coating owing to their tiny forms and responsive characteristics, which are different from normal particles. The morphology, shape, size, light reflection/diffraction, and solvent ability are the important chemical and physical parameters of adaptive polymeric particles. The surface properties of nanoparticles are more essential than those of microcapsules. The surface energy, surface structure, and reaction ability can be modified to serve the active requirements of coating textiles. There are different methods for obtaining adaptive polymer particles, such as the core—shell structure microencapsulation technique and surface modification. Applications of active coating of these particles include self-cleaning textiles, phase-change microencapsulation textiles, and hydrophilic/hydrophobic textiles.

1.4 Development of processing technologies for active coating

Many traditional coating techniques have been applied in the active textiles industry (Sen, 2007). These may include, but not limited to:

- yarn coating
- spread coating
- dipping
- calendaring
- extrusion coating
- foam coating
- rotary screen coating

Coating processes vary, but the objective of all of the technologies is to produce stable films with desired adhesion and designed functions on the substrate surface. Some new technologies such as microencapsulation, plasma technology, nanotechnology, and sol—gel technology have been applied in the coating process to achieve functional and active textiles.

Plasma offers a uniquely effective surface treatment effects because of its physical and chemical range and low temperature, low energy cost, and environmentally friendly nature (Shishoo, 2007). The study or potential use of the plasma finishing of textiles may achieve futuristic results such as the hydrophilic/hydrophobic enhancement of water and oil-repellent textiles, antibacterial textiles by coating functional particles in the plasma, a flame-retardant coating using monomer vapor, and the electroconductivity of textiles by surface plasma coating.

Nanotechnology-based coating is different from traditional coating methods such as dipping and soaking. The thickness of nanocoating film is less than 100 nm and is formed and processed by atomistic or molecular deposition technology such as chemical vapor deposition, physical vapor deposition, electroplating, and self-assembly (Schindler and Hauser, 2004; Hyde, 2008). The most commonly used ones are nanoparticles and nanocomposites. Nanotechnology-based coatings not only achieve the active properties of textiles but ensure that the fabrics have the ability to breath and drape and have hand characteristics comparable to untreated fabric (Chow et al., 2000). Because of the higher surface energy between the nanocoating layer and the fabric surface, the durability of these textiles is better than traditional finishes.

Sol—gel coating is also an effective technology to obtain active textiles. The sol—gel technique offers a low-temperature method for material synthesis with totally inorganic or both inorganic and organic results. Several methods can be applied to obtain sol−gel coatings with the sol−gel process (Huang et al., 2001). Spin coating, dip coating, and roll coating are basic techniques used to deposit sol−gel coatings.

Microencapsulation has been proven as a successful technology in the pharmaceutical and agrochemical industries. The technology allows combinations to be made of the properties of different materials that will achieve various active performances from the smart textiles.

1.5 Outline of the book

This edited book is intended to provide an overview and review of the latest developments in active coating materials and the technologies of textiles for smart clothing, protective clothing, and equipment, and biomedical and industrial applications. It targets readers including researchers in materials science textile processing; engineers in the area of smart textiles product developments; architects, medical scientists, equipment developers, and students in colleges and universities.

The book has been contributed to by a panel of international researchers and experts in the field and covers various aspects of active coating research and development. It is composed of 18 chapters, which can be divided into three parts except this chapter, the introduction, which provides background information on active coating technology for textiles including a brief overview of active and smart materials, coating technologies, and the book's structure. The first part involves a classification of main active coatings from Chapters 2 to 8. Chapter 2 is concerned with memory polymers and their smart coating for appearance and structure retention, and hydrophobic/hydrophilic textiles. Chapter 3 deals with active coating by nanoparticles for self-cleaning textiles. Chapter 4 presents self-healing and durable textile coatings using a specific memory material. Chapter 5 involves smart breathable textiles coated with a water vapor permeability-controlled material. Chapter 6 presents protein coatings for smart textiles, and Chapter 7 discusses natural photonic materials for textile coatings.

The second part contains six chapters from Chapters 8 to 13, with a focus on coating processes and techniques for active textiles. Chapter 8 provides an overview of the developments and key issues in coating techniques and processes which integrate smart materials and textiles. Chapters 9−13 describe advanced technologies and principles for active coating, which consist of microencapsulation technology, plasma surface treatment, nanotechnology, biomimetic coating technology, and sol−gel technology.

The third part focuses on applications of active coating textiles. Chapter 14 outlines various smart coatings for comfort clothing and Chapter 15 concentrates on smart coatings for sportswear. Chapter 16 describes the applications of smart coatings for protective clothing and equipment. Chapter 17 introduces medical applications of smart coating textiles for patient care and wound dressings. Chapter 18 describes applications in architecture textiles.

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