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Textiles and textile products - Smart textiles - Definitions, categorisation, applications and standardization needs

Textilien und textile Produkte - Intelligente Textilien - Definitionen, Klassifizierung, Anwendungen und Normungsbedarf

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Textiles and textile products - Smart textiles - Definitions, categorisation, applications and standardization needs

Textiles et produits textiles - Textiles intelligents - Définitions, catégorisation, applications et besoins de normalisation

Textilien und textile Produkte - Intelligente Textilien - Definitionen, Klassifizierung, Anwendungen und Normungsbedarf

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (CEN/TR 16298:2011) has been prepared by Technical Committee CEN/TC 248 “Textiles and textile products”, the secretariat of which is held by BSI.

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Introduction

Terms like “smart textile” and “intelligent textile” mean different things to different people. However, there is some common agreement that these are textiles or textile products that possess additional intrinsic and functional properties not normally associated with traditional textiles.

Although adjectives such as "smart" or "intelligent" are mainly intended for marketing purposes, more technically correct definitions will not prevent the use of this terminology by textile manufacturers or by the general public. Nor will the unintended inclusion of “non-smart” products make products any less safe or fit for purpose.

The standardization of smart textiles or smart textile products or systems is not straightforward because it involves an overlap between the standardization of the "traditional" textile product, e.g. a fire fighter's jacket, and the standardization of the additional intrinsic functional properties of the "smart product", whatever they may be. This overlap can manifest itself in a number of areas that may include:

— Legislation: all textile products should comply with the requirements of the general product safety directive, which stipulates that only safe products should be put on the European market. Certain textile product groups, e.g. protective clothing, geotextiles or textile floor coverings, are in addition subject to specific national and European legislation and it may even be necessary to simultaneously address the requirements of more than one EU Directive. A "classic" fire fighter's suit should comply with the requirements of the PPE Directive, usually supported by EN 469, whereas a "smart" fire fighter's suit with built-in electronic features should e.g. also comply with the applicable provisions of ICT and ATEX regulations. Conformity assessment will also need to follow the conformity assessment schemes for both regulations.

— Expertise: the knowledge and experience of standardization for the textile properties and for the additional properties (temperature sensing, variable thermal insulation properties) may come from different unrelated standardization groups. To take the above example, there will need to be input from standardization groups working in the areas of textiles, medical devices and electric or electronic devices.

— Testing: there will be a need to test the additional functional properties to specific textile test standards and vice versa. Again, with the same example, the electronic elements might have to be assessed for their resistance to cleaning and the textile elements may need to be tested for electrical safety.

— Unexpected and/or unintended synergies: these might result from the combination of technologies in smart textiles and should be recognised and addressed by standardization, wherever possible. For example, the presence of conductive fibres to incorporate a personal stereo into a smart raincoat might increase the risk of the wearer suffering a lightning-strike in a thunderstorm. This is despite the fact that neither rainwear nor personal stereos, when separate, need to be assessed against this risk.

The purpose of this technical report is to give advice and information on the considerations that need to be addressed when writing standards for smart textiles, or applying existing standards to them. This information may be of use to:

— end-users, in determining whether a product has indeed been fully assessed;

— conformity assessment bodies, as a guide towards assessing products according to the appropriate standards;

— specification writers, as a guide to writing new specific standards for smart textiles;

— manufacturers of smart textiles, to advise them on appropriate product testing and on suitable ways to substantiate product claims;

— market surveillance authorities, to help in the assessment of product claims, product safety and fitness for purpose.

The factual information in this report is available elsewhere in a more comprehensive form and each individual item will inevitably be common knowledge to at least one group of readers. The aim of this technical report is to guide readers through those areas, with which they are not familiar, and to direct them towards further, more specialised reading. In accordance with CEN rules, this Technical Report will be reviewed regularly to keep it in line with technical and market evolutions.

1 Scope

This Technical Report provides definitions in the field of "smart" textiles and textile products as well as a categorisation of different types of smart textiles. It describes briefly the current stage of development of these products and their application potential and gives indications on preferential standardization needs.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

In literature, both the terms ‘smart’ and ‘intelligent’ are used. In this text the two terms are considered equivalent and hence exchangeable.

NOTE European Directive 2008/121-EC provides definitions of "textile products" and "textile fibres", but these definitions are not suitable for the purpose of this Technical Report, since they do not distinguish between "textile products" and "textile materials".

According to the Directive "textile products" are "raw, semi-worked, worked, semi-manufactured, manufactured, semi-made-up or made-up products which are exclusively composed of textile fibres, regardless of the mixing or assembly process employed" or

— (a) products containing at least 80 % by weight of textile fibres;

— (b) furniture, umbrella and sunshade coverings containing at least 80 % by weight of textile components; similarly, the textile components of multi-layer floor coverings, of mattresses and of camping goods, and warm linings of footwear, gloves, mittens and mitts, provided such parts or linings constitute at least 80 % by weight of the complete article;

— (c) textiles incorporated in other products and forming an integral part thereof, where their composition is specified.

2.1
textile material
material made of textile fibres and intended to be used, as such or in conjunction with other textile or non-textile items, for the production of textile products

2.2
functional textile material
textile material to which a specific function is added by means of material, composition, construction and/or finishing (applying additives, etc.)

2.3
smart textile material (intelligent textile material)
functional textile material, which interacts actively with its environment, i.e. it responds or adapts to changes in the environment

NOTE The term "smart textile" may refer to either a "smart textile material" or a "smart textile system". Only the context, in which the term is used, will determine which one of the two is intended.

2.4
environment (surroundings)
the circumstances, objects, or conditions, which surround a textile material or textile product or the user of that material or product

2.5
textile system
an assemblage of textile and non-textile components integrated into a product that still retains textile properties, e.g. a garment, a carpet or a mattress

NOTE The terms "textile system" and "textile product" may be interchangeable in many cases.

2.6
smart textile system
a textile system which exhibits an intended and exploitable response as a reaction either to changes in its surroundings/environment or to an external signal/input

3 Functional and smart textile materials

3.1 Functional textile materials

3.1.1 General

Functional textile materials can be components of intelligent textile systems and hence functional textile materials, which are relevant for these intelligent textile systems, will be discussed here. This is illustrated by the following examples:

Example 1: A textile resistance heater

— Functional textile material: a conductive material forming the basis of a resistance heater in a textile system.

— Smart textile system: a textile resistance heater as (part of) a textile system, connected to an electrical power supply which can only be switched on and off manually or a resistance heater as part of a textile system, connected to an electrical power supply with a regulated power output and equipped with a temperature sensor as to maintain a constant temperature around the heater.

Example 2: Optical fibres

— Functional textile material: optical fibres used as part of a textile system

— Smart textile system: optical fibres as (part of) a textile system, connected to a light source which can only be switched on and off manually or optical fibres as part of a textile system, connected to a light source with a regulated power output and equipped with a sensor to adjust the illumination level to the amount of light present due to other light sources in the surroundings of the textile system.

3.1.2 Electrically conductive textile materials

Electrically conductive textile materials conduct an electrical current or supply an electric field to a device. Electrical conduction is the movement of electrically charged particles through an electrical conductor, called an electric current. The charge transport may result as a response to an electric field or as a result of a concentration gradient in carrier density, i.e. by diffusion.

A material is considered 'electrically conductive' if it has a specific conductivity (resistivity) of > 10^{-2} S/m (<10^{4} Ω·cm). A material is considered to have a 'metallic conductivity' if it has a specific resistivity of > 10^{2} S/m (<10 Ω·cm). The materials with the highest specific conductivity are metals. Some polymers and ceramics can also have metallic conductivity, e.g. intrinsically conductive polymers (e.g. doped polyaniline) or indium tin oxide (ITO).

3.1.3 Thermally conductive textile materials

Thermally conductive textile materials conduct heat. The transfer of thermal energy in a substance is due to a temperature gradient, i.e. from a region of higher temperature to a region of lower temperature, acting to equalize temperature differences.

Metals have thermal conductivities above approximately 20 W/(m·K) and are considered to be very good thermal conductors. Their thermal conductivity increases with their electrical conductivity. There are also non-metallic elements and compounds that are (very) good thermal conductors (e.g. carbon and boron nitride).

Applications in intelligent textile systems can be as a heat sink, e.g. for cooling electronic components.

3.1.4 Thermally radiative (emissive) textile materials

Thermally radiative (emissive) textile materials radiate heat, i.e. they emit electromagnetic radiation in the infra-red range of 750 nm to 100 µm from their surface due to their temperature.

Thermal radiation (emission) can be utilized in the form of a resistance heater, where the resistance of a conductor is used to heat the conductor to a sufficiently high temperature to generate heat radiation or as a heat exchanger, e.g. a pipe with hot air or hot water flowing through it.

Applications in intelligent textile materials are as thermal heaters, as described in 3.1.1.

3.1.5 Optically conductive textile materials

Optically conductive textile materials transport (visible) light, i.e. electromagnetic radiation in the range of 400 nm to 750 nm.

Optical fibres from glass or plastic keep the light in their core by total internal reflection, i.e. the fibre acts as a waveguide. Optical fibres are widely used in fibre-optic communications, which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communications. Fibres are used instead of metal wires because signals travel along them with less loss, and they are also immune to electromagnetic interference.

Fibres are also used for illumination, and are wrapped in bundles so they can be used to carry images, thus allowing viewing in tight spaces. Specially designed fibres are used for a variety of other applications, including sensors and fibre lasers.

3.1.6 Fluorescent textile materials

Fluorescence is the molecular absorption of a photon, followed almost instantaneously by the emission of a less energetic photon. As the emitted photon is of lower energy than the absorbed photon, the emitted light will be of longer wavelength than the absorbed light, which allows e.g. to turn UV radiation into visible light.

Fluorescence is used in high visibility clothing for safety purposes. Fluorescent textile materials are available in a variety of colours from red to blue-violet. A variety of organic and inorganic materials show fluorescence.

3.1.7 Phosphorescent textile materials

Phosphorescence is the molecular absorption of a photon, resulting in the formation of an excited state, followed by the emission of a less energetic photon. Since the emitted photon is of lower energy than the absorbed photon the emitted light will be of longer wavelength. The lifetime of the excited state in phosphorescent materials can be very long, in the order of hours. This means that once activated, phosphorescent materials will continue to emit light for hours without any external power supply. This makes them suitable for emergency lighting in the case of power interruptions or for watches, toys, apparel, giving a 'glow in the dark' effect.

Examples of phosphorescent materials are e.g. doped (mixed) sulphides (ZnS, (Cd, Zn)S, (Ca, Sr)S) or doped (mixed) oxides ($SrAl_2O_4$) but can also be organic molecules.

3.1.8 Textile materials releasing substances

These textile materials release substances at a molecular level under the influence of an external stimulus. The substances used for this purpose are pharmaceuticals, cosmetics, fragrances, etc. They are bonded to the textile structure by micro-encapsulation or by surface bonding.

The micro-encapsulation technique makes use of small capsules, in which the substance to be released is enclosed. When the shell of these capsules is pierced due to an external stimulus, the substance is released. The different stimuli that can cause piercing of the shell include mechanical force, heat, pH and contact with water.

The surface bonding technique makes use of substances (loosely) bonded to the surface of the textile material and released during the use of this material. The nature of the bonding and the surroundings of the material will determine the release rate.

3.2 Intelligent (smart) textile materials

3.2.1 General

In this subclause, different intelligent (smart) textile materials will be described. Some of the textile materials may already be composite systems. The described textile materials may be used on their own or in combination with other (non)smart textile materials or used in textile systems. The latter is described in clause 4.

NOTE Some of the smart functionalities may also be achieved by non-textile materials. Therefore, we will be referring to textile materials to clearly make the distinction.

Table 1 provides an overview of the most common stimulus-response pairs and the corresponding effect materials or structures can exhibit.

Table 1 — Overview of stimulus-response effects (adapted from [1])

Stimulus	Response				
	Optical	**Mechanical**	**Chemical**	**Electrical**	**Thermal**
Optical	Photochromism			Photovoltaic/ photoelectric effect	
Mechanical	Piezochromic	Dilatant, Thixotropic, Auxetic	Controlled release	Piezo-electricity	Friction
Chemical	Chemiluminescence, Solvatochromism, Halochromisms	Shape memory, Super-absorbing polymers, Sol/hydrogel	Controlled release		Exo/endotherm reactions
Electrical	Electrochromism, Electroluminescence, Electro-optic	Inverse piezo-electricity, electrostriction Electro-osmosis shape memory	Electrolysis		Joule/coulombic heating Peltier effect
Thermal	Thermochromism, Thermo-opacity	Shape memory		Seebeck effect, Pyroelectric	Phase change
Magnetic		Shape memory magnetrostriction			

3.2.2 Chromic textile material

Chromic materials is the general term referring to materials whose absorption, transmission and/or reflection of light changes due to an external stimulus. The result is a different colour impression.

Chromic materials can be classified depending on the external induction stimulus, e.g. light (photochromic), heat (thermochromic), pressure (piezochromic), enzymes (biochromic). It goes beyond the scope of this report to list all possible chromic effects or to discuss them in detail.

One commercial application of a thermochromic textile material is baby clothing which shows a change in colour when the baby has developed a fever. Other applications envisioned for safety clothing are the use of chromic textile materials for indicating exposure to chemicals or radiation.

3.2.3 Phase change textile material

A phase change material (PCM) is a substance which is capable of storing and releasing large amounts of energy in the form of latent heat, at a specified temperature range (range of phase transformation) during which the material changes phase or state (from solid to liquid or from liquid to solid). This energy (heat) is absorbed or released when the material changes from solid to liquid (or the other way around), thus buffering any external temperature change by evoking a phase transition in the material.

Classic PCMs are water, hydrated salt complexes and saturated hydrocarbons (where the length of the chain will determine the melting point). Depending on the nature of the phase change, e.g. when formation of a liquid phase is involved, micro-encapsulation will be required. The choice of material or composite will depend on the temperature to be buffered.