



BSI Standards Publication

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

National foreword

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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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Contents

Page

Foreword.....	3
Introduction	4
1 Scope	6
2 Terms and definitions	6
3 Functional and smart textile materials	7
3.1 Functional textile materials	7
3.2 Intelligent (smart) textile materials	9
4 Smart textile systems.....	14
4.1 Categories	15
4.2 Examples of “intelligent textile systems” and their functional analysis	16
5 Recommendations for standardization	21
5.1 General.....	21
5.2 Verification of claimed performances	22
5.3 Innocuousness.....	22
5.4 Durability of properties	22
5.5 Product information.....	22
5.6 Environmental aspects	23
5.7 Examples of possible standardization of intelligent textile materials and systems	24
Annex A (informative) Regulations, standards and conformity assessment	28
Bibliography	32

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 $> 10^{-2} \text{ S/m}$ ($< 10^4 \text{ } \Omega \cdot \text{cm}$). A material is considered to have a 'metallic conductivity' if it has a specific resistivity of $> 10^2 \text{ S/m}$ ($< 10 \text{ } \Omega \cdot \text{cm}$). 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 , $(\text{Cd}, \text{Zn})\text{S}$, $(\text{Ca}, \text{Sr})\text{S}$) 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 magnetostriction			

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.

The most common method today to produce phase change textile materials is by coating or impregnating fibres or fabrics with a polymeric binder containing micro-encapsulated PCMs. Alternatively, micro-encapsulated PCMs may be incorporated into fibres during the fibre spinning or filling of hollow fibres. They may also be laminated as a PCM containing polymeric film onto a textile structure.

Space suits and gloves were the first application of phase change materials (PCM), but nowadays PCMs are also used for consumer products to improve the thermal comfort of active-wear garments and clothing textiles. During a sports activity, the thermal stress is mainly due the disequilibrium between the heat produced by the human body during an effort, and the heat released into the environment. When PCMs are encapsulated on underwear, during the same activity a larger amount of the human heat will be released to the environment.

3.2.4 Shape change (shape memory) textile materials

These materials change in shape, size or internal structure upon an external stimulus, e.g. temperature, UV light, moisture, magnetic field, pH value. The shape change can have a one-way or a two-way effect.

A one-way material has a preformed structure, which returns in a non-reversible way to its original, not-preformed state after receiving an external stimulus.

A two-way material or composite can be cycled between two different preformed states by receiving opposing external stimuli, e.g. a higher and lower temperature.

Shape memory materials can be:

- polymers with a combination of permanent physical or chemical cross-links, integrated into a mobile matrix, which is able to store mechanical deformation energy until recovery is activated by an external stimulus;
- metal alloys switching between two different crystal structures upon a thermal impulse, e.g. Nitinol, or
- composites of shape-memory-materials and materials providing an elastically restoring force in one unit (e.g. artificial muscles).

Shape memory materials can be implemented in textile systems in the form of yarns, i.e. in the bulk of the textile structure or as a coating on a fabric, e.g. creating a membrane. Applications can be textile systems adjusting their shape, e.g. a garments reducing its length when exposed to heat; or a membrane adjusting its porosity, e.g. to adjust the water vapour transmission rate.

3.2.5 Super-absorbing polymers and gels

Super-absorbing polymers and gels absorb and retain extremely large amounts of liquid relative to their own mass resulting in strong swelling and gel formation. Water absorbing polymers (hydrogels) absorb aqueous solutions through hydrogen bonding with water molecules. The ability to absorb water depends on the presence of ions in the water, being 500 times its weight (30 to 60 times its volume) for distilled or deionised water, but only 50 times its weight for a 0.9 % saline solution.

The total absorbency and swelling capacity are controlled by the type and degree of cross-linking in the polymer. A low-density cross-linked polymer has a higher absorbent capacity and a softer and more cohesive gel is formed. High cross-link density polymers exhibit lower absorption capacity but the gel strength is firmer, maintaining its shape under low pressure.

Examples of the use of super-absorbing polymers are hygiene products, blockage of water penetration in underground power communication cables, horticultural water retention agents, spill and waste control, artificial snow for motion picture and stage production and filtration.

3.2.6 Auxetic textile materials

Auxetic materials or composites harden and laterally expand upon elongation. This phenomenon is caused by the macro-structure or micro-structure of the material and not by its chemical composition. Such materials have a so-called negative Poisson ratio.

Some auxetic textile materials contain on a micro-scale both temporary, relatively weak bonds (e.g. hydrogen bonds), which can be broken and restored (slipping from one to the other) under a low shear force and stable bonds, which, under a high shear force, will counter the full load of the force, resulting in a 'stiff' behaviour.

Other auxetic textile materials are based on the use of materials with diverging properties, e.g. a textile yarn comprising a thicker, elastic cord entwined with a thinner, stiffer cord. When tensioned the system will change to the thin, stiff cord being entwined by the thicker, elastic cord and the total diameter will be increased as compared to the relaxed state.

Auxetic textile materials are intended for improved energy absorption and fracture resistance. Examples of auxetic textile applications are blast resistance, window covering, military tents, and hurricane defence. Examples of auxetic foam materials are found in sound and shock absorption, medical engineering, filtration of biological fluids and process engineering.

3.2.7 Dilating and shear-thickening textile material

These materials show an increase in viscosity with increasing shear rate, i.e. they will become hard upon impact and remain soft under low force movement.

A dilatant effect occurs when closely packed particles are combined with enough liquid to fill the gaps between them. At low flow velocities, the liquid acts as a lubricant, and the dilatant flows easily. At higher flow velocities, the liquid is unable to fill the gaps created between particles, friction strongly increases, resulting in a sudden increase in viscosity.

Applications in textiles are found in protective clothing against mechanical impact, e.g. body armour, and in traction control. An example is a soft silicone coating on a fabric, which hardens under impact, thus damping the force of the blow.

3.2.8 Piezoelectric textile material

The piezo-electric effect consists of a separation of electrical charges across a material in response to an applied mechanical deformation. This effect can also be inverted, i.e. a mechanical deformation is generated in response to an applied electric field.

Applications of the piezo-electric effect are found in insulating materials having a non-centrosymmetric crystal lattice (e.g. quartz, PZT, PVDF). In order to utilize the charge separation by mechanical deformation or to realize the mechanical deformation by applying an electric field, the piezo-electric material needs to be positioned between two electrodes. For polycrystalline materials to exhibit the piezoelectric or inverse piezoelectric effect, the individual crystallites need to be aligned, which is done by applying a high electric field at elevated temperatures.

Piezoelectric materials can be used to develop textile materials for strain or acceleration sensing as well as for energy production utilizing mechanical deformation (e.g. in shoes).

3.2.9 Electroluminescent textile materials

This refers to textile materials emitting light in response to an electric current passing through them or to a strong electric field being applied to them. In these structures the electroluminescent layer needs to be sandwiched between two electrodes, the top one being transparent for transmission of the emitted light.

For the electroluminescent layer most commonly inorganic or organic semiconductors (thin film or powder) are used, together with a dopant (additive) to define the colour, or inorganic materials such as ZnS, doped with Cu, Ag, or Mn.

Electroluminescent textile materials can operate at low voltage and low current. They can be used to provide lighted displays on apparel or canvasses for leisure or advertising purposes.

3.2.10 Thermo-electric textile materials

These materials will generate an electric field when a thermal gradient is applied. The material needs to show a good electrical conductivity but a poor thermal conductivity in the direction of the thermal gradient.

In these structures the thermo-electric material needs to be sandwiched between textile electrodes and a good heat transfer needs to be ensured at the external surfaces.

Thermo-electric textile materials applications are power generation and refrigeration.

3.2.11 Photovoltaic textile materials

In photovoltaic (photoelectric) materials the impact of a photon results in the transition of an electron from the valence band to the conduction band of a semiconductor.

Photovoltaic materials, as used in photovoltaic cells, consist of a top electrode, a p-type semiconductor/ n-type semiconductor junction and a bottom electrode. Illumination of a photovoltaic cell results in the generation of charges, i.e. building up of a voltage between the two electrodes. Hence, the device can act as a power supply.

Examples of photovoltaic materials are doped Si and dye sensitised oxide semiconductors (TiO₂, ZnO). Their major application field is in solar cells (absorption of sunlight), as grid independent power supply.

3.2.12 Electrolytic textile materials

An electrolyte is a substance containing free ions that behaves as an electrically conductive medium (based on ion conduction). Electrolytes are used as a part of a battery. Placing a metal into an electrolyte will result in the deposition of ions on the electrode or dissolution of ions from the electrode into the electrolyte, i.e. the formation of a galvanic half cell. Two galvanic half cells are combined to form a battery.

Fully textile based batteries have not been developed yet, but are anticipated as they will be much lighter weight and retain textile properties as compared to current battery technology. The latter is usually a major drawback in textile systems requiring an input of electrical energy.

3.2.13 Capacitive textile materials

Capacitive textile materials have the ability to store electrical charges. A typical capacitor consists of an insulating material placed between two conductive materials (electrodes). When an electrical field is applied to the insulating material, negative and positive charges will be separated and stored at the opposite surfaces of the material.

Capacitive textile materials can be created by multilayer weaving or embroidering, laminating multilayer structures or printing multi-layers of conductive ink.

4 Smart textile systems

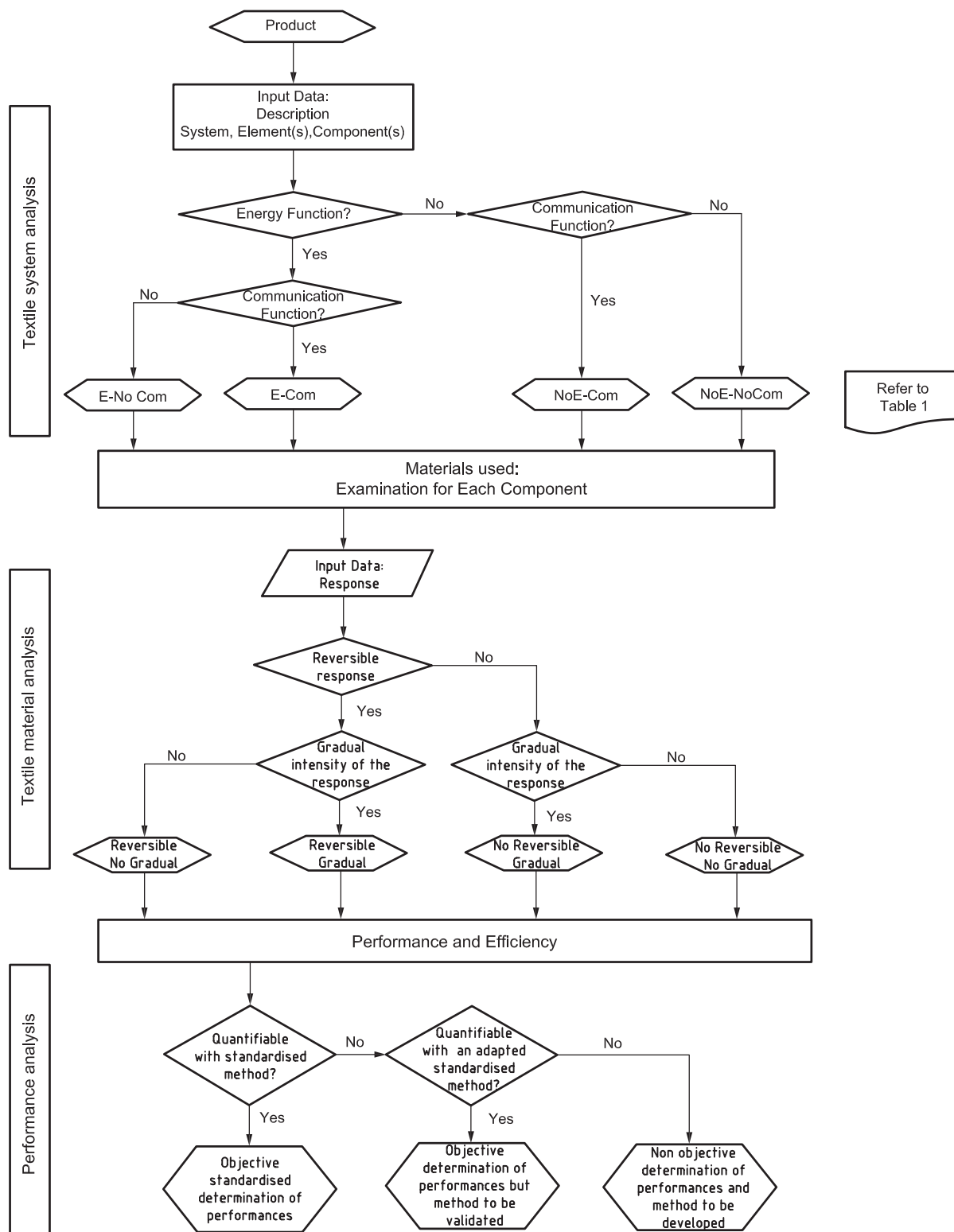


Figure 1 — Flow chart for characterizing an intelligent textile system, also giving guidelines for later standardization efforts

4.1 Categories

4.1.1 General

An intelligent textile system is basically composed of:

- Actuator(s), completed by possible sensor(s)
- Information management device

The information within the intelligent textile system can be controlled and/or managed by electronic device(s) (such as a processor). Such textile systems are also called "e-textiles" or "textronics".

An intelligent textile system can be characterised by two functions: the energy function and the external communication function. External communication can be unidirectional or bidirectional, and implies a possible interaction with human intelligence.

Based on these two functions, depending on whether they are present or not, four different categories can be determined (see Table 2 and Figure 1).

Table 2 — Categories of intelligent textile systems

	Without energy function	With energy function
Without communication function	"NoE-NoCom"	"E-NoCom"
With communication function	"NoE-Com"	"E-Com"

Intelligent textile systems **"with energy function"** are based on the presence of an internal power supply device fed by elements of the system capable of producing and supplying energy to it. Energy sources outside the textile system are usually needed for ensuring the continuity of the energy function.

Intelligent textile systems **"without energy function"** are not equipped with an internal energy supply device, but may require an external supply of energy, usually in form of the stimulus.

Intelligent textile systems **"with communication function"** include the presence of mono- or bidirectional means of communication with their environment. The communication may be intended for direct perception by humans, e.g. visual information, sound, odours, etc., or for detection by electronic devices (emission of phonic, electromagnetic, photonic waves) relaying the information towards man.

Intelligent textile systems **"without communication function"** are characterized by the absence of external communication with their environment/ surroundings. This does not exclude internal communication, e.g. in a self-regulating system.

4.1.2 Systems without energy or communication function (NoE-NoCom)

Examples of this category are:

- Garments equipped with shape memory or phase change material: the thermal energy is externally supplied from the temperature of the environment. A temperature rise or drop will be the stimulus leading to the modification of the material's behaviour.
- A LED Curtain: the energy is supplied by the external electrical power grid. The electric current is the stimulus that leads to the emission of photons (lamp)

In both examples there is no internal energy supply source or communication with the external environment.

4.1.3 Systems with energy function, but without communication function (E-NoCom)

Examples of this category are:

- A backpack with a battery connected to a photovoltaic device. The battery needs to be replaced when it runs empty, but this replacement is delayed thanks to the photovoltaic device transforming photonic energy (light) into electricity.
- A shoe with a battery connected to an electro-mechanical transducer. The battery needs to be replaced when it runs empty, but this replacement is delayed thanks to the electric energy produced by the electro-mechanical device.

Both examples show systems, which comprise an internal energy source (battery), completed by an external energy source. Neither of them is designed for communication with the external environment.

4.1.4 Systems with communication function but without energy function (noE-Com)

Examples of this category are:

- Breathing sensor on a hospital patient. The mechanical stimulus (deformation of material) acts on a sensor which transmits an electric signal to the system, leading to the emission of radio waves towards the environment, received by a detector used by a physician.
- A baby pyjama dyed with a thermochromic pigment for indicating a raise in body temperature of the baby (development of a fever). When the temperature of the baby rises above a certain threshold the dye changes colour, giving a visual warning signal to the observer, e.g. a parent.

Both examples do not include an internal energy supply source, although an external source is present. These systems include a means of communication with the external environment.

4.1.5 With energy and communication function (E-Com)

Examples of this category are:

- Sensing and warning system for chemical plant workers. The chemical stimulus (molecule) acts on a sensor, which will transmit the chemical information internally to the system. The information is then transmitted towards the outside environment as a change of colour or as a sound, perceived by the human eye or ear.
- Thermal Detector in a fire fighter's jacket. The thermal stimulus (temperature) acts on the thermal sensor which transmits the internal information to the system (electric signal), leading to the emission of a light signal, perceived by the human eye.

Both systems make use of an internal energy supply (battery) and include a means of communication with the external environment.

4.2 Examples of “intelligent textile systems” and their functional analysis

4.2.1 Medical application: monitoring of health situation

Medicine is expected to clearly benefit from intelligent textile technologies. These applications cover a broad and complementary range of explorations (i.e. a diagnosis of heart disease), prevention (i.e. biofeedback) and treatment/healing (i.e. wearable orthoses, drug delivery). Future medical applications may include sensors, that will non-invasively measure blood gases (CO, SO₂, CO₂) and vital signs.

Wearable monitoring systems with integrated sensors can be separated into two categories:

- Systems with conventional sensors integrated by textile technologies in a textile-based material
- Systems with textile-based structures used as sensors to measure vital parameters of the human body.

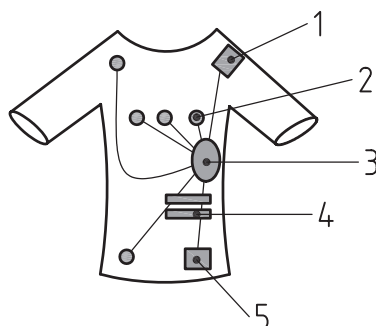
The vital parameters can be separated in electrical, mechanical and other parameters. For monitoring the EMG, ECG, or EEG the electric stimulus acts on the conductive textile by a galvanic skin-contact or by a non-contact capacitive principle, which will transmit internal (electric) information to the system leading to the emission of electromagnetic waves (radio waves) towards a detector device used by a physician.

Mechanical signals like breathing rate can be measured by elastic conductive ribbons which change their resistance under strain. The mechanical stimulus (deformation of material) acts on the deformation sensor (elastic conductive ribbon) which will transmit internal information (electric) to the system leading to the emission of electromagnetic waves (radio waves) towards the environment, detected by a detector device (used by a physician).

Beside the sensor, the wearable monitoring system has to contain at least a storage device. Devices for data analysis, data transport and actuator devices for warning or defibrillation functions can complete the monitoring system.

Considering that in this example the system is autonomous, this "intelligent textile system" belongs to the "E-Com" category:

- "with energy function" because the concept is based on the presence of an electric battery as power source. The replacement of the battery is necessary when the reserve is depleted.
- "with communication function" because the concept is based on communication with the environment, in the form of emission of an electromagnetic wave suitable for electronic monitoring devices.



Key

- 1 Communication
- 2 Sensors
- 3 Processors
- 4 Actuator
- 5 Energy supply

Figure 2 — Example of a wearable textile system

4.2.2 Occupational safety application: work wear and protective clothing

These systems bring together features such as sensors, connections, transmission systems, power management etc. The integration of intelligent textile technologies into work-wear or protective clothing can result in such systems being able to gather, present and transmit information about the wearer and his or her immediate environment.

For example, protective clothing incorporating such textile systems could potentially gather information on:

- wearer position, either globally by GPS or locally by reference to one or more base-stations;
- wearer activity, monitored by accelerometers integrated into various parts of a garment;
- physiological data including the wearer's body temperature, pulse, blood oxygen level and breathing rate (see also 4.2.1, medical monitoring application);
- environmental temperature measured using textile sensors. In the case of fire-fighters' PPE this might include information on the direction of sources of radiant heat relative to the wearer;
- chemical hazards in the environment including monitoring of toxic chemicals and detection of explosive atmospheres;
- electromagnetic hazards in the environment, including monitoring of various forms of electromagnetic radiation;
- the status of the smart system itself. For example this might include data on the state of charge of an incorporated flexible lithium-ion polymer battery or confirmation that sensors are operating correctly and mutually consistently.

Such information can then either be transmitted to a command/control station, e.g. via a low power consumption "Bluetooth" module integrated with a textile antenna, or be presented to the wearer in the form of audible or visible warning signals or smart textile display devices. The wearer might also interrogate the system via a textile keypad incorporated into the garment. Data may also be stored intermittently.

Considering that this textile system is autonomous with respect to energy, this intelligent textile system can be categorised "E-Com":

- with energy function: although some parts of this textile system could be based on sensors not requiring an internal energy input, e.g. chromic sensors, the system as a whole relies on an internal energy supply source.
- with communication function: communication with the wearer and with external observers is an essential feature of the system.

4.2.3 Leisure and fashion application

The emergence of intelligent textiles will leave its mark on the fashion industry. Adding a dynamic aspect to the ever so static garments is a very challenging issue that attracts many designers. This may include location of the wearer (GPS), listening to music, use of mobile phone and internet, or showing one's mood through changing colours.

An example is an interactive dress with stretchable circuit board technology. The concept of the interactive dress is to translate the pattern of the dynamic body movements into a changing light pattern on the dress. The body movements are detected by an acceleration sensor and processed by a microcontroller, which is used to control the illumination pattern of light emitting diodes (LEDs) that are integrated onto the dress. To show the lightweight character of the system, a very light dress was chosen as a carrier. To create the visual aspect, 32 LEDs are integrated into the dress. To improve the spreading of the light, these LEDs are placed under different layers of transparent and freely draped cotton cambric fabrics. The interconnections between the different components of the system are based on stretchable circuit board (SCB). The base of this technology is an elastic thermoplastic polyurethane substrate material with specially shaped copper conductor lines. The dedicated meander shaped lines allow stretching of the interconnections of up to 300 %.

This "intelligent textile system" can be categorized as "E-Com"

- “with energy function” because the dress has to operate autonomously. The LEDs and the microcontroller require energy provided by a small battery, hidden in the belt of the dress. It allows running the system for about eight hours.
- “with communication function” because the dress establishes a communication function with the environment through the dynamic illuminating pattern. The changing of the lights tells the neighbouring people something about the body movements of the wearer.

4.2.4 Underwear based on thermal control by phase change materials (PCM)

The example considered is underwear containing PCM microcapsules. The thermal properties of PCM are linked to their phase change process: During the phase changing processes the temperature of the material remains constant. During melting (heating) the heat is absorbed and stored in the liquid phase. During the solidifying process (cooling) stored energy is again released. Hence, the stimulus is a change in the temperature of the environment (increasing or decreasing). The response is the melting or solidification of the PCM with an absorption or emission of energy (cooling effect or heating effect).

This is a "NoE-NoCom" system:

- without energy function because the concept is based on the absence of an internal energy supply; external energy is required as a stimulus.
- without communication function because the concept doesn't include communication with the environment.

4.2.5 Heated blankets, car seats etc. for comfort or protection

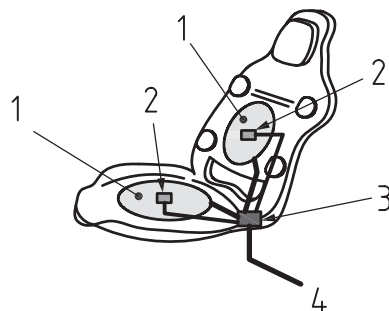
Heating features are present in many applications such as home or automotive textiles. Textile-based heating elements can be found in garments, seats or carpets. Protection of technical installations, e.g. de-icing of water pipes, or improved comfort to a car driver by a heated car seat are only two examples. The combination of conductive fibres and non-conductive fibres can be used to create textile structures with heating capacities.

The combination of these textile heating structures with an electric power supply, a control unit or a temperature sensor creates an intelligent textile system, which acts as a self-regulating heated unit. The complexity of such systems depends on the application requirements. For example, the system can include several heating zones, which can be individually regulated.

In the case of a heated seat cover with integrated temperature control, the seat cover textile is equipped with two heating elements, one in the seat area and one in the back area of the seat. The power is supplied through a cable connected to the car power network. The power of each heater can be adjusted through an integrated power controller. This controller receives temperature information from two embedded temperature sensors and regulates the temperature of each heating structure individually.

The intelligent textile system includes sensors, active heating and a power controller to form a self-regulated system, i.e. a "E-NoCom" system. However, the textile in itself is a "noE-noCom" system:

- Without energy function because the energy is not provided by the textile itself. The power is supplied by an external power supply through a power cable.
- Without communication function because no information is transmitted to or received from the outside. The temperature information is given by the embedded sensors to the embedded controller integrated in the textile.



Key

- 1 Heating elements
- 2 Sensors
- 3 Power controller
- 4 Power cable

Figure 3 — Example of a heated car seat

4.2.6 Irradiation system for medical therapeutics

Treatment and healing applications will be of interest due to the desire of patients to have more autonomy when receiving treatment. Smart textile products take advantage of the fact that people wear textiles most of the time and sometimes even 24 hours a day. That permits to use a smart textile system for therapies where longer periods of continuous treatment are needed, e.g. skin diseases that need to be treated with light irradiation. Textiles with embedded active light emitting components can be used to perform this task. Such textiles may also be equipped with optical sensor elements to measure the degree of skin healing in order to inform the doctor of the healing status of the skin.

Such a smart textile system for light therapy includes sensors, active light emitting components, a communication unit and an embedded power pack for energy supply to allow for the mobility of the patient. It is an "E-Com" system,

- with energy function because the system includes the power supply in form of an electric battery. Replacement or recharging of the battery is necessary when the reserve is depleted;
- with communication function because collected and processed information from the sensor can be transmitted by a wireless standard to a fixed communication module connected to the web. By this way a link over IP can be established to the medical doctor.

NOTE This smart textile system is a medical device and should be checked for compliance with the existing regulations for medical devices.

4.2.7 Geotextiles

Intelligent geotextile systems are used to provide early warning of deformations in soil structures. It consists of a geotextile that incorporates optical glass fibres, linked to special instrumentation equipment and software outside the system. Slight settlements and temperature and strain changes in e.g. embankments and dykes can thus be registered at an early stage. This makes it possible to take any necessary measures and to avoid breaches. The system is built into dyke bodies during the construction of seawalls, roads and railways and the building of retaining walls, tunnels, underground structures and pipelines.

Fibre Bragg gratings (FBG), stimulated Brillouin scattering and Raman scattering are all proven fibre optic technologies that can be built into these systems. These technologies measure strain or temperature changes or both in soil structures. All have in common that an incoming optical signal is changed along the length of

the optical fibre, with the changes being determined by the stimulus to be measured at the sensor points in the optical fibre.

This is a "noE-noCom" system,

- without energy function since the power input (light source) is external,
- without communication function since the signal processing unit is located outside the intelligent textile system.

5 Recommendations for standardization

5.1 General

Product specifications and test methods for the different textile materials and textile systems described in clauses 3 and 4 will be very specific, since they will depend on the intended conditions of use. Intelligent textile materials and textile systems should meet the requirements of similar "non-intelligent" materials and systems, plus specific requirements linked to their particular properties. Existing specifications and test methods may be used as such or with modifications in some cases, but new specifications and test methods should also be developed (see Figure 1).

The standardization work related to intelligent textile materials and textile systems will not necessarily be allocated to CEN Technical Committee 248 "Textiles and textile products". There are specific technical committees dealing with for example, textile floor coverings (CEN/TC 134), protective clothing (CEN/TC 162), geosynthetics (CEN/TC 189) or medical devices (CEN/TC 205). These specialised committees should address standardization items – both product standards and test standards – related to intelligent textile materials or systems in their specific field of application. CEN/TC 248 could then address standardization items of a more horizontal nature or in the domain of leisure and fashion clothing, curtains, upholstery fabrics etc. In many cases, it will not be possible to draft satisfactory standards with textile or clothing expertise only and a multidisciplinary approach will be necessary. This may require co-operation with other technical committees or even with other standardization bodies, such as CENELEC or ETSI.

Large groups of textiles products are subject to regulations. Besides the General Product Safety Directive (2001/95/EEC), which aims at banning unsafe products from the European market in general, several specific European Directives contain legal provisions pertaining to textile products. This is for example, the case for floor coverings (Construction Products Directive 89/106/EEC), for protective clothing (Personal Protective Equipment Directive 89/686/EEC), for geosynthetics (Construction Products Directive 89/106/EEC) or for medical clothing (Medical Devices Directive 2007/47/EEC). Standards pertaining to these products should take into account the basic health and safety requirements specified in the respective EU Directives and needed for putting them on the market in accordance with legal provisions. Other EU legislation such as the Cosmetic Products Directive (76/768/EEC), the Biocidal Products Directive (98/8/EC) or the REACH regulation (1907/2006/EC) may also be envisaged. More information can be found in the respective directives.

Product standards for intelligent textile materials or systems should always cover at least the following aspects:

- a verification of the claimed performances both as a textile product and as an intelligent textile material or system;
- the innocuousness of the product in its interaction with the human body or with the environment of the product;
- the durability of product properties, in particular with relation to repeated cleansing;
- product information needed for safe use and maintenance of the product;
- environmental aspects

5.2 Verification of claimed performances

Manufacturers of intelligent textile materials or systems should be able to substantiate the claims they make for their products. Since claims and the techniques to prove them are constantly evolving, it is not possible to provide compulsory or binding methodologies. State-of-the art techniques, codes of good practice and/or generally accepted and available methods should be taken into account.

The performance claimed for an intelligent textile material or system concerns the performance of the product as such and the performance of the features that make the product "intelligent".

A fire fighter's jacket should comply with the harmonised European Standard EN 469. An "intelligent" fire fighter's jacket still should comply with this standard, but additionally the performance of the "intelligent" features, e.g. body temperature or heart rate monitoring, chemical sensing, wearer location, etc. should be assessed. This assessment should be done under conditions representative for the intended use and the methods used should be relevant, repeatable, reproducible and available on the market.

5.3 Innocuousness

Intelligent textile materials and systems should be designed and manufactured in a way as to preclude risks and other nuisance factors under foreseeable conditions of use. The provisions of the relevant European and national regulations and their supporting standards should be observed.

The constituent materials and parts of intelligent textile systems, including their decomposition products, should not adversely affect user hygiene or health. Textile materials should not contain or release substances known as irritating, allergenic or otherwise hazardous to health. The surface of any part of the system in contact or in potential contact with the user should be free of roughness, sharp edges, etc. which could cause excessive irritation or injuries.

Any impediment caused to movements, postures or sensory perception should be minimized and not endanger the user or other persons.

Constituent materials and system parts should not create additional risks for the user, other persons or goods. They should for instance, not constitute increased fire risks or a risk of electroshock or explosion in their interaction with the environment.

5.4 Durability of properties

The performance of intelligent textile materials and systems may be significantly affected by ageing, due to exposure to weathering elements (sunlight, temperature, precipitation, etc.), wear and periodic cleaning, e.g. washing. It may even be possible that a product loses its properties when stored under appropriate conditions. In such cases, the date of obsolescence should be indicated on every item or interchangeable component and/or on the packaging.

The manufacturer should provide information on procedures and conditions of storage, use, cleaning, maintenance, servicing and disinfection in order to ensure a maximum life-time of the product and good conservation of its properties. Manufacturers should indicate which precautions should be taken before, during and after the cleaning process to achieve this goal.

The cleaning, maintenance or disinfectant products and instructions recommended by manufacturers should have no adverse effect on materials, systems or users when properly applied. However, where appreciable and where rapid performance deterioration from periodic cleaning is likely to occur, the manufacturer should give an indication, on the product, the packaging or in an informative note, on the maximum number of cleaning operations that may be carried out before the product needs to be inspected or discarded.

5.5 Product information

If applicable, the marking and product information provisions of European and national regulations and their supporting standards should be observed in addition to the general principles contained in this clause.

Every individual "intelligent textile product" should be marketed with a product label to provide the necessary information to the consumer. The label should be firmly attached to the product itself or, if this is not possible, the same information should appear on the smallest packaging. In addition, a marketing label, hang tag or accompanying notice may be used. All information on both product label and marketing label or hangtag should be written in the national language(s) of the country where the product is marketed.

The information should contain the following:

- The name, brand name or logo and the address of the manufacturer or any other person responsible for putting the product on the European market. If this information is abbreviated, it still should make identification and location of the manufacturer/importer possible.
- An unambiguous identification of the product (commercial name, code, serial number, etc.).
- A recommendation to keep the information provided with the product during its entire life.
- Information on storage, transportation, use, cleaning, maintenance, servicing and disinfection. This should also inform on how the product should not be used or serviced. Product markings expressed as symbols, pictograms or codes should be explained in the information label unless they are self-explanatory.
- The performance claims made for the product, including its limitations. These performance claims should be expressed as results from quantitative testing in accordance with standardized test methods; were appropriate, the performance may be expressed as classes or levels, corresponding to specific conditions of use.
- If applicable, a list of suitable accessories and spare parts used with the product, and how and when they should be applied.
- The limit date until when the product retains its function and does not cause any damage to human health, if stored under appropriate conditions and used under normal or reasonably foreseeable conditions in accordance with the manufacturer's instructions. The date should be provided alongside the words: "Best used before ..." followed by the limit date or details where the date appears on the packaging.
- Particular precautions to be observed in use, especially with regard to active substances or components integrated in the product;

More user information can be found in:

- ISO Guide 14:2003 Purchase information on goods and services intended for consumers
- ISO/ IEC Guide 37:1995 Instructions for use of products of consumer interest
- ISO 6347:2004 Floor coverings – consumer information

5.6 Environmental aspects

The provisions on environmental aspects stipulated in national and European regulations, e.g. REACH, should be observed.

Guidance for addressing environmental issues in product standards can be found in:

- CEN Guide 4:2008 *Guide for addressing environmental issues in product standards*

This Guide is intended for use by all those involved in the drafting of product standards, to draw attention to environmental issues in support of sustainable international trade, and is not intended to be used to create

non-tariff barriers to trade. Standards writers are not expected to become environmental experts but, by using this Guide, they are encouraged to:

- identify and understand basic environmental aspects and impacts related to the product under consideration, and
- determine when it is possible and when it is not possible to deal with an environmental issue through a product standard.

During the life-cycle of a given product, different environmental aspects can be determined. However, the identification of these aspects and the prediction of their impacts is a complex process. When writing a product standard, it is important to ensure that an evaluation as to how products can affect the environment at different stages of their life-cycle is carried out as early as possible in the process of developing the standard. The results of this evaluation are important for specifying provisions in standards. It is anticipated that product standards writers actively consider compliance with any applicable national, regional or local product related regulation.

The checklist gives examples of possible environmental provisions in standards for each stage of the life-cycle. It is recommended to use the checklist while drafting standards as this will ensure that relevant environmental aspects are addressed at each stage of the life cycle of the product/process. Once completed, the checklist provides an overview of the clauses that address environmental aspects for each stage of the life cycle of the product. The checklist may be published as an informative annex to the standard.

5.7 Examples of possible standardization of intelligent textile materials and systems

5.7.1 Intelligent textile materials

5.7.1.1 Shape memory materials

A product standard for a textile material that makes use of shape memory materials should contain the following elements.

- determination of mechanical strength;
- sensitivity to temperature: a change of shape should occur near room temperature or body temperature;
- reversibility of shape change (if relevant);
- durability of properties after repeated cleaning cycles and – in general – resistance against ageing and degradation;
- water vapour transmission (moisture management);
- water repellence;
- colour fastness;
- crease recovery.

For the assessment of some of these properties, well established test methods are available. Others should be developed and the list of relevant requirements should be completed through further discussion.

Further research and product development of shape memory materials could comprise the tailoring of material properties (shape memory functionality, hand feel, etc.) and a better understanding about the mechanical and thermo-mechanical effects of shape memory polymer additives and antibacterial finishing agents. Textile research should also take more advantage of shape change effects, e.g. the increase in shape recovery forces, development of triple- and multiple-shape polymers, which may allow multi-directional shape changes,

optimization of programming techniques, reversibility of shape changes through heating/cooling, Joule heating, UV light, moisture etc. The establishment of a database with documented material properties is also considered to be useful

5.7.1.2 Phase change materials (PCM)

This Technical Report was established with the aim to clarify some issues about the emerging area of smart textiles and to make standardization in this new area possible. It is the view of the working group that the field of PCM treated textiles is one of the more mature areas, where standardization can start in the near future.

A product standard for a textile material that makes use of phase change materials should contain the following elements:

- the relevant product properties should be clearly stated and their effectiveness should be proven;
- the intrinsic safety of the material and of the end product should be demonstrated;
- proof should be given about the durability of product properties;
- sufficient information should be provided for a correct and safe use and maintenance of the product.

Possible applications of PCM can be found in leisure clothing (sportswear, outdoor leisure wear, shoes, gloves) and professional clothing (surgical gowns, patient gowns, cooling vests for people working in hot environments) but also in textiles for indoor use (mattress ticking, seat covers). The amount and type of PCM needed and the transition temperature range will depend on the application and the conditions of use (single or multiple use, environment, activity to be performed).

PCM that can be used in clothing are often paraffin based, but hydrated salt based PCM are also considered. PCM materials are used for thermoregulation, i.e. buffering the temperature in a certain desired range, often also referred to as comfort zone.

A thin film of paraffin will not be suitable and the PCM needs to be encapsulated or otherwise integrated into the polymeric network structure or the fibre in order to remain firmly attached to the textile. PCM are always added onto the textile or integrated into textile fibres. Different processes are available and they can influence the behaviour of the PCM (see also the chapter on "Intelligent Textiles with PCM" by W. Bendkowska, in "Intelligent Textiles and Clothing", see Bibliography [3]).

A phase change material (PCM) is a substance which is capable of storing or releasing large amounts of energy when the material undergoes a phase transition. Hence it is of utmost importance to determine the energy storage capability of the textile as part of its thermal insulation and thermoregulation capacity. It is also important that this phase change is reversible and that overcooling in the liquid phase does not occur. Other issues to be considered are a low vapour pressure in the liquid state, good thermal conductivity, good thermal and chemical stability and limited volume changes during the phase transition.

The thermal storage capacity (energy), absorption/release of heat and transition temperature (range) could be determined by using differential scanning calorimetry (DSC). The measurement procedure should be clearly defined in order to obtain reproducible and reliable data. Furthermore, the necessary conditioning before testing (e.g. number and type of washing and drying cycles) should be specified.

Other techniques could be used as alternatives or to obtain supplementary information. The Kawabata technique can give an indication of the thermal feeling, which is proportional to the heat flux. Monitoring a hot/cold plate with an IR camera is a more qualitative technique to assess the dynamic behaviour when the temperature changes and gives indications where the textile can be used. The use of scanning electron microscopy (SEM) can be a tool to check the distribution density of the microcapsules and damage to them after application.

Possible test methods of interest are:

- ASTM D7024-04 Standard Test Method for Steady State and Dynamic Thermal Performance of Textile Materials;
- ISO 5085-1:1989 Textiles -- Determination of thermal resistance -- Part 1: Low thermal resistance.

The effectiveness of the thermo-regulation effect can be assessed by wearer trials or by the use of instrumented thermal manikins or parts thereof (hand, foot, etc.) that simulates how the PCM treated textile will behave in actual use under a temperature gradient between the body and the external environment.

It will also be necessary to consider other textile related issues such as innocuousness, durability after cleaning, etc. The use of PCM should not have an adverse effect on these properties

5.7.2 Intelligent textile systems – Heating textile with temperature control

In the first place an electrically heated textile should be safe for the user, i.e. it should not present burning and/or electrocution risks. This means that such product should be considered as an electric device, which should meet the requirements of the European low voltage directive (2006/95/EC) and the applicable standards that support this directive. Standards, which could be applicable, are EN 60335 (Safety of household and similar electrical appliances) and EN 61000-4-2, given the specificity of a textile system, e.g. the fact that it is deformable and/or cleanable.

The functional performance of the product should also be proven, preferably by standardized test methods.

In this field a close cooperation with CENELEC will be necessary. At present electronic textile systems are still electronic devices put on textile but in future stretchable, textile based electronics will be available. This will also have an influence on the position and type of the power supply.

The following aspects should be subject to standardization:

- thermal flux;
- maximal surface temperature (worst case scenario) Even though maximum reached temperature should not harm human body, avoid wearing heating element against bare skin;
- influence of (repeated) mechanical stress on performance, e.g. folding and packaging;
- influence of repeated cleaning: heated textile should be washable in the same way as everyday clothing. The heating element, including connections, should be able to resist multiple machine washing cycles;
- electrical insulation: the system should e.g. be short circuit proof in a moist or wet environment, e.g. caused by spilled beverages;
- temperature regulation performance of the system;
- fire behaviour (resistance to ignition, flame propagation, toxicity of fumes, melting);
- degradation of performance by thermal cycles (minimal lifetime) Long time use will not degrade the performance of the heating element itself, the performance of the battery may degrade after long time use;
- durability and robustness of connectors: the heating element itself and the connections should be sufficiently robust and not be subject to chemical or electrochemical corrosion, when exposed to liquids that can come into contact with the heated textile (food liquids, perspiration, detergents);
- the connection needs to be properly connected with the heating element in order to avoid fracture during use. Given the weakness of a connection, the contacting area between heating element and connection needs to be as localized as possible. The minimum strength of the connection with the heating element is preferably higher than 100 N..

Although some test method standards already exist, e.g. for fire behaviour or for electrical insulation, amendments to existing standards or the development of specific standards will be needed to take textile specificities into account.

Intelligent textile systems are composed of several integrated parts and hence the compatibility and interoperability of these parts will be an important aspect. Where parts from various sources can be used, standardization of mechanical attachments or of the electrical connections of such parts is of interest, to allow for the use of parts coming from several independent suppliers, e.g. flat and waterproof electrical connectors.

Annex A (informative)

Regulations, standards and conformity assessment

A.1 EU regulations of potential relevance

The following EU legislation may have an impact on the standardization of intelligent textile materials and systems and should be taken into account when relevant:

- General product safety directive (2001/95/EC);
- European Directive on textile names (2008/121/EC);
- Consolidated directive on the quantitative analysis of ternary fibre mixtures (73/44/EC);
- Directive on the classification, packaging and labelling of dangerous substances (67/548/EC);
- Directive on the classification, packaging and labelling of dangerous preparations (1999/45/EC);
- REACH regulation (which contains e.g. provisions on azo-dyestuffs, PCP, nickel, cadmium, mercury, asbestos, flame retardants, phthalates, PFOS, etc.) (1907/2006/EC);
- Construction Products Directive (89/106/EEC);
- Personal protective equipment directive (89/686/EEC);
- Medical device directive (2007/47/EEC);
- Toys directive (2009/48/EEC);
- Directive on the protection of individuals with regard to the processing of personal data and on the free movement of such data (95/46/EC).

Some of these regulatory documents provide for CE marking and allocate some conformity assessment tasks to notified conformity assessment bodies. The new EU legislative framework (EU Regulation 765/2008 and Commission Decision 768/2008) describes the conformity assessment tasks as a modular system. The specific modules to be used are defined in the specific EU directives.

Some products may have to comply with the requirements of several EU directives. In the case of such multiple purpose products the EU Commission will decide on the conformity assessment route to be followed.

A.2 Standardization bodies of potential interest

A.2.1 Standardization organisations

European standards are developed by CEN, CENELEC (electro-technical domain) and ETSI (telecommunication). Although these standardization organisations have many common procedures, some of their rules and formats are specific, which may lead to diverging approaches.

On the level of international standardization ISO is the counterpart of CEN, IEC corresponds to CENELEC and ITU to ETSI.

More detailed information on the rules and procedures of these organisations can be found on their web sites:

- www.cen.eu
- www.cenelec.eu
- www.etsi.org
- www.iso.org
- www.iec.ch
- www.itu.int

A.2.2 Technical standardization bodies

A.2.2.1 General

The scope of the CEN, CENELEC, IEC and ISO standardization committees and their working groups in A.2.2.2 to A.2.2.5 may have an impact on the standardization of intelligent textile materials and systems and liaisons should be established when relevant (non-exhaustive list). More information on the work programmes of these technical bodies can be found on the web sites of their respective standards organisations.

A.2.2.2 CEN committees

- CEN/TC 52 – Safety of toys
- CEN/TC 122 – Ergonomics
- CEN/TC 161 – Foot and leg protectors
- CEN/TC 162 – Protective clothing (including gloves and life jackets)
- CEN/TC 205 – Non-active medical devices
- CEN/TC 224 – Personal identification
- CEN/TC 248 – Textiles and textile products
- CEN/TC 249 – Plastics
- CEN/TC 251 – Health informatics
- CEN/TC 252 – Child use and care articles
- CEN/TC 309 – Footwear

A.2.2.3 CENELEC committees

- CLC/TC 210 Electromagnetic compatibility (EMC)
- CLC/TC 82 Solar photovoltaic energy systems

- CLC/TC 86A Optical fibres and optical fibre cables
- CLC/TC 86BXA Fibre optic interconnect, passive and connectorised components
- CLC/TC 106X Electromagnetic fields in the human environment

A.2.2.4 ISO committees

- ISO/TC 38 – Textiles
- ISO/TC 94 - Personal safety -- Protective clothing and equipment
- ISO/TC 180 – Solar energy
- ISO/TC 181 – Safety of toys
- ISO/TC 216 – Footwear
- ISO/TC 229 – Nanotechnologies
- ISO/TC 243 - Project Committee: Consumer product safety
- ISO/TC 246 - Project committee: Anti-counterfeiting tools

A.2.2.5 IEC committees

- TC 21 Secondary cells and batteries
- TC 23 Electrical accessories
- TC 35 Primary cells and batteries
- TC 40 Capacitors and resistors for electronic equipment
- TC 47 Semiconductor devices
- TC 48 Electromechanical components and mechanical structures for electronic equipment
- TC 49 Piezoelectric and dielectric devices for frequency control and selection
- TC 56 Dependability
- TC 77 Electromagnetic compatibility
- TC 82 Solar photovoltaic energy systems
- TC 86 Fibre optics
- TC 101 Electrostatics
- TC 103 Transmitting equipment for radio communication
- TC 106 Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure
- TC 113 Nanotechnology standardization for electrical and electronic products and systems

A.3 Standardization and certification of intelligent textile materials and systems

European "new approach" Directives use the principle of "presumption of conformity". This means that a product is presumed to comply with the applicable legal provisions when compliance is demonstrated with the requirements of the relevant harmonised European standard.

Such harmonised European standards are developed under a mandate of the European Commission to CEN or CENELEC. The titles and references of the harmonised standards are published in the Official Journal of the European Union.

The correlation between the provisions of the European directive(s) and the corresponding clauses of the harmonised standard is given in the Annex ZA to the standard. Candidate harmonised standards are screened by a specialised CEN consultant to verify that the clauses of the standard actually allow to perform a check of their compliance with the essential health and safety requirements of the directive(s).

Some products may have to comply with the provisions of several directives. In such cases the Annex ZA will contain more than one correlation table and the product should comply with all of the applicable criteria.

European directives usually contain provisions on the procedures to be used for product conformity assessment, both at the development and the production stage. Some of the tasks defined in these procedures are allocated to conformity assessment bodies (notified bodies). A complete assessment of more complex products, which comply with more than one directive, may require the competence of more than one notified body.

Bibliography

The bibliography is not meant to give exhaustive references on the specialized literature of smart materials or textiles. The aim is rather to provide some references which can provide the reader of this text with some general background information. Herein the reader can find references to the specialized literature concerning a specific subject of interest.

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