HACKTEX VIRTUAL TRAINING MATERIALS

[MOOC NAME]
Learning unit 4. Standards and characterization of functional and smart textiles
Lesson 3

Characteristic properties of smart textiles and their characterisation

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Innovative smart textiles & entrepreneurship

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Content

1. Introduction

As mentioned in the previous lesson (LU4_1), there is a huge need for standardization in the domain of smart textiles, a significant part of the existing standards being adopted in the last 2 years. Other standards are in progress and will be adopted in the following couple of years. Therefore, when developing smart textiles or evaluating their performance, durability and reliability, the standards to be used must be identified and brought up-to-date.

The lesson will present the currently existing standards used to characterise the processability and performance of smart textile products and materials with integrated functionalities and will also discuss future standards to be considered. The standards will be succinctly presented in terms of applicability and content.

1.1. General standards for smart textiles – terms and definitions

The need to develop a common language in the field of smart textiles was recognized by the organizations for standardization, researchers and manufacturing community. Considering the multidisciplinary character of smart textiles, the use of a common language, accepted terms and classifications avoids the risk of misunderstandings

For the moment, there are several standards that define the basic notions related to smart textiles.

1. **CEN ISO/TR 23383:2020 Textiles and textile products - Smart (Intelligent) textiles - Definitions, categorisation, applications and standardization needs** (adopted from ISO/TR 23383:2020)

The standard addresses directly the fundamental notions regarding smart textiles, classifies them and provides definitions for:

- Functional textile products - electrically conductive textile products; thermally conductive textile products, thermally radiative (emissive) textile products; optically conductive textile products; fluorescent textile products; phosphorescent textile products; textile products releasing substances.
- Smart (intelligent) textile products - chromic textile products; phase change textile products; textile products with active ingredients inside the microcapsules; shape change (shape memory) textile products; super-absorbing polymers and gels; auxetic textile products; dilating and shear-thickening textile products; piezoelectric textile products; electroluminescent textile products; thermo-electric textile products; photovoltaic textile products; electrolytic textile products; capacitive textile products.
- Smart textile systems - systems without energy or communication function (NoE-NoCom); systems with energy function, but without communication function (E-NoCom); systems with communication function but without energy function (noE-Com); systems with energy and communication function (E-Com).

These smart textile systems are exemplified based on different possible applications. The standard also discusses aspects regarding standardization, as related to performance evaluation, innocuousness, durability, sustainability and required product information.

2. IEC 63203-101-1:2021 Wearable electronic devices and technologies - Part 101-1: Terminology

This standard considers only wearables and provides terminology related to wearable electronic devices and technologies, near-body wearable electronics, on-body wearable electronics, in-body wearable electronics, and electronic textiles.

3. ASTM D8248-20 Standard Terminology for Smart Textiles

This standard adopted by the ASTM organization (USA) presents terminology and definitions related to smart textiles, such as electrical textiles and wearable electronics, fiber, yarn, and fabric that compose them, and final end products.

4. CEN/TR 17512:2020 Smart garments - Terms and definitions

This technical report created at European level provides terms and definitions related to smart garments used as PPE for protection against heat and flame. The definitions refer to textile and clothing in general, personal protective equipment (PPE), smart textiles, electronics, ergonomics of such PPE with integrated smart textiles and non-textile elements, smart PPE.

1.2. Standards for design and manufacturing smart textiles

In many applications, smart textiles are subjected to specific requirements that must be considered when designing and/or manufacturing such products. Domains like PPE and medicine are regulated in the EU in general and producers must certify their products accordingly.

As smart textiles tend to become relevant for such domains, there is a concentrated effort to adopt standards that offer guidelines for design and manufacturing to companies.

1.2.1. Standards for design and manufacturing of e-textiles

Such standards are extremely important for companies developing and producing smart textiles, as they offer a basis for product conformity to adopted norms and regulations (in general or between partners), quality and uniformity.

1. IPC-8921-2019 Requirements for Woven, Knitted and Braided Electronic Textiles (E-Textiles) Integrated with Conductive Yarns and/or Wires

The standard intends to create a common base for the entire smart textiles value chain, so that electrical, thermal, mechanical and chemical exposure characteristics are non-ambiguously determined and accepted. The standard also provides the conformance requirements for the

electrical/electronic performance of textile fabrics (woven, knitted, braided) with integrated conductive yarns/wires.

2. IPC-8952 Design Standard for Printed Electronics on Coated or Treated Textiles and E-Textiles

The standard states specific design details, materials, material processing (coating of the textile substrate), evaluation of mechanical properties, electrical properties, thermal management, interconnections and quality assurance for printed electronics on coated or treated textile substrates.

3. IEC TR 63203-250-1:2021 Wearable electronic devices and technologies - Part 250-1: Electronic textile - Snap fastener connectors between e-textiles and detachable electronic devices

This technical report reviews the use cases of conductive snap fasteners applied as electrical connectors for e-textile products available on the market and provides guidance on future standardization works.

1.2.2. Standards for design and manufacturing of PPE

Due to inherent risks, the field of PPE is heavily regulated. There are standards with general requirements for the design of PPE, standards that address a particular type of protection, in this case protection against heat and flame and standards that discuss PPE with integrated smart textiles.

1. ISO 13688:2013 Protective clothing — General requirements

The standard specifies general performance requirements for ergonomics, innocuousness, size designation, aging, compatibility, and marking of protective clothing and the information to be provided by the manufacturer with the protective clothing.

2. EN ISO 11612:2015 Protective clothing. Clothing to protect against heat and flame. Minimum performance requirements (replacing EN 531)

EN ISO 11612 is a standard that uses various tests to determine the extent to which clothing is capable of enduring industrial heat. The standard defines the requirements for

- General heat performance - resistance to heat, flame spread, dimensional changes and mechanical strength (materials, seams)
- Heat transmission - convective heat, radiant heat, molten aluminium/iron splash, contact heat

The standard also includes annexes for test pre-treatments, rating of results, guidelines for clothing design, risk assessment.

3. CEN/TR 17620:2021 Guidelines for Selection, Use, Care and Maintenance of Smart Garments Protecting against Heat and Flame

This technical report is the basis for design and manufacturing of PPE for thermal protection (heat and flame), with integrated smart textiles. It defines the framework for:

- Selection - risk assessment, required level of protection, product optimization, testing, compatibility
- Use - training, introducing protective clothing into service, record keeping, routine examination, in service evaluation and monitoring, frequency of cleaning on type of smart garment
- Care - label, marking and instruction for use/manufacturer's instructions/user instructions, cleaning, drying, decontamination, storage
- Maintenance - inspection, repairs and alterations, disposal

1.3. Standards for performance evaluation of smart textiles

Performance evaluation can refer to functional/smart yarns, fabrics and/or products. These standards describe test methods and procedures for the evaluation of properties determinant for the application. Methods for performance evaluation of smart textiles are also referred to in the standards presented in the previous chapter for the design of smart products.

For this lesson, the performance evaluation regards only conductive and electronic textiles, PCMs and SMMs. Most standards adopted until now refer to conductive and electronic textiles, but work has yet to be done to cover more properties and extend the domains of interest.

However, when considering determining the characteristics that define the level of performance of smart textile product/material, it is important to see what to other standards the testing method is based on and respect their requirements. Such example are the standard atmosphere and conditions for the testing which are generally regulated.

1.3.1. Performance evaluation of conductive textiles, smart textiles/e-textiles/wearables, with electronic components

The characteristics specific to the domain of e-textiles are mostly referring to electrical properties, considered at yarn and fabric level: resistance, resistivity, conductivity.

As different standardization organizations adopted standards, some of them discuss the same properties, therefore the use of the one commonly used in a region or accepted by the community is recommended, unless otherwise agreed upon. This section offers information on all currently existing standards. The standards address the properties of different types of e-textiles, considering textiles with integrated conductive elements (woven, knitted, braided, embroidered) and conductive tracks printed on textiles substrates.

1. CEN EN 16812: 2016 Textiles and textile products - Electrically conductive textiles - Determination of the linear electrical resistance of conductive tracks

The standard describes the measurement of the linear electrical resistance of conductive tracks, defined as the "electrically conductive part of the textile having a length to width ratio of minimum 10 to 1" (EN 16812 - Textiles and textile products - Electrically conductive, 2016). This definition applies to yarns, printed or coated tracks, ropes, ribbons and webbing with conductive properties that will be processed into textile materials.

The preferred test method is the four electrode – four wire method, but the two electrode – four wire method is considered when the first method cannot be applied. Samples should be tensioned before measurements. The advantage of the four electrodes method is that it compensates the contact resistance between the electrodes and the sample. Figure 1 illustrates the principle of the four electrode – four wire method (four-terminal sensing).

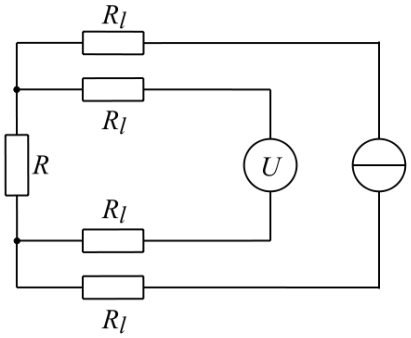


Figure 1. Electric diagram for the four electrode – four wire method
(Source: https://commons.wikimedia.org/wiki/File:Vierleitermessung.svg, author CaZeRillo)

The linear electrical resistance is calculated as

$$R_l = \frac{R}{d} = \frac{\frac{U}{I}}{d} \qquad (1)$$

Where: R_l is the linear resistance [Ω/m]; R = U/I is the resistance [Ω] and d is the distance between the electrodes for the voltage measurements.

2. EN IEC 63203-201-1:2022 Wearable electronic devices and technologies - Part 201-1: Electronic textile - Measurement methods for basic properties of conductive yarns

The standard defines the types and structure of conductive yarns, as

1) Conductive fibres
   a) Fibres made of conductive polymers or metals (called monolithic)
   b) Fibres coated with conductive layers (on non-conductive fibres) or coated with non-conductive layers (on conductive fibres)
   c) Bicomponent fibres with conductive and non-conductive polymers
   d) Fibres with conductive fillers

It presents the methods to determine the characteristics of the conductive yarns, namely:

1) electrical properties

a) resistance of conductive yarns - electrical resistance per unit length of the conductive yarn (Ω/m), according to EN 16812:2016
b) fusing current – the level of current that can melt or ignite a conductive yarn

2) perspiration resistance – variation of the linear resistance when the yarn samples are exposed to artificial perspiration
3) detergent resistance - variation of the linear resistance after the yarn samples are washed, rinsed, dried

3. EN ISO 24584:2022 Textiles – Smart textiles – Test method for sheet resistance of conductive textiles using non-contact type

Eddy current is a non-destructive method of testing that is based on the signal variation of an electric current induced in a sample by an oscillating magnetic field produced by coils. Apart from determining sheet resistance, the method is mostly used to detect defaults in textile reinforced composite materials. Sheet resistance is defined as:

$$\rho_s = R \times t = \frac{V}{I} \times t \qquad (2)$$

Where: ρ_s is sheet resistivity [Ω cm]; R is resistivity [Ω] and t is material thickness [cm]. V is the voltage and I the intensity of the current.

The standard describes the apparatus for eddy current measurements (the instrument, sensor probe and the software for the calculation of the sheet resistance from the variation of the eddy current signal), sampling, test procedures and result interpretation.

4. EN IEC 63203-201-2:2022 Wearable electronic devices and technologies - Part 201-2: Electronic textile - Measurement methods for basic properties of conductive fabrics and insulation materials

The standard classifies conducting and insulating materials used for e-textiles (polymer films, coating with polymers and non-conductive fabrics) and defines the testing methods for these materials:

1) Electrical properties
   a) sheet resistance (according to IEC 60468:1974 and EN 16812:2016) – the samples are pre-tensioned and the sheet resistance is calculated using the following relation

$$R_s = R \times \frac{W}{L} \qquad (3)$$

Where Rs = sheet resistance; R = R measured in the longitudinal direction, using the four wires-four electrodes method (according to IEC 60468:1974 and EN 16812:2016) and W and L are the dimensions of the samples.

   b) fusing current – the level of current that can melt or ignite a conductive fabric
   c) electric insulation properties - insulation resistance of cover and insulation cover side; electric strength of insulation cover side; insulation resistance and electric strength of substrate side
2) Chemical and biological resistance

a) perspiration resistance – variation of the sheet resistance when the fabric is exposed to artificial perspiration
a) detergent resistance - variation of the sheet resistance after the fabric is washed, rinsed, dried

5. IEC 63203-201-3:2021 Wearable electronic devices and technologies - Part 201-3: Electronic textile - Determination of electrical resistance of conductive textiles under simulated microclimate

IEC 63203-201-3:2021 specifies a test method for determination of the electrical resistance of conductive fabrics under simulated microclimate within clothing. The microclimate is created using a sweating guarded hotplate, as defined by ISO 11092:2014 Textiles — Physiological effects — Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test).

The electrical resistance is determined based on the four electrodes-four wire method. The testing procedure includes the preparation of the conductive tracks, specimen placement on the measuring device, the determination of the water vapour resistance for multiple textile layers comprising air and the determination of the electrical resistance.

5. AATCC EP13, Evaluation Procedure for Electrical Resistance of Electronically-Integrated Textiles

The standard presents the determination of electrical resistance for textile fabrics woven, knitted, printed, or stitched conductive elements or smart products in normal conditions or after simulating use conditions, like stretching and washing.

6. AATCC 210 Test Method for Electrical Resistance Before and After Various Exposure Conditions

The standard creates the framework to evaluate the effect of exposure to different conditions (laundering, drycleaning, water, perspiration, acids and alkalis, ultraviolet (UV) radiation, and/or microbes) has on the electrical behaviour of e-textiles fabrics and products.

7. IPC-8971 Requirements for Electrical Testing of Printed Electronics E-Textiles

The standard presents what is needed in terms of procedure and equipment to test electrical characteristics of printed electronics on e-textiles. The textile materials are coated or functionalized.

8. IEC 62899-201:2016+AMD1:2018 (Consolidated version) Printed electronics - Part 201: Materials - Substrates

The standard discusses materials and evaluation methods for substrates used in the printing process to form electronic components/devices, including polymeric substrates. For this type of materials, the following categories of characteristics are presented: surface properties, mechanical properties, chemical properties, electrical properties, thermal properties, optical properties and flammability.

9. IEC 62899-201-2:2021 Printed electronics - Part 201-2: Materials - Substrates - Measurement methods for properties of stretchable substrates

The standard refers to fabrics with structural stretchability, composite structures (fibre reinforced elastic polymer film or sheet), and elastic resin-coated fabrics. It provides testing methods and defines the following characteristics of stretchable substrates used for printed circuits: width and length of stretchable substrates; thickness of stretchable substrates; mass per unit area of stretchable fabrics; elongation at break of stretchable fabrics; volume resistance of stretchable polymer films and sheets; surface resistance of stretchable polymer films and sheets; electric strength of stretchable polymer films and sheets.

1.3.2. Performance evaluation of smart textiles with phase change materials (PCMs)

CEN/EN 16806-1:2016 Textiles and textile products - Textiles containing phase change materials (PCM) - Part 1: Determination of the heat storage and release capacity

The first part of standard 16806 presents the evaluation of the heat storage and heat release capacity and the phase change temperatures of textile fibers, yarns and fabrics (woven and knitted fabrics, nonwovens) containing phase change materials (PCM). The test method can also be applied for pure or micro-encapsulated PCM.

1.3.3. Performance evaluation of smart textiles with shape memory materials

In the case of smart textiles with shape memory materials, testing is carried out to evaluate wrinkle recovery, angle, switch temperature, crease retention, flat appearance (surface smoothness after washing).

1. AATCC TM 66:2017 Test Method for Wrinkle Recovery of Woven Fabrics: Recovery Angle

The test requires measuring the angle formed by a suspended wrinkled fabric (which was folded and compressed) after a certain period of recovery.

2. ISO 9867:2022 Textiles — Evaluation of the wrinkle recovery of fabrics — Appearance method

The standard establishes the procedure for the evaluation of a wrinkled fabric after a period of recovery.

3. AATCC 88:2018 Test Method for Crease Retention in Fabrics after Home Laundering

The standard describes the subjective evaluation of the retention of pressed creases, after the fabric samples were subjected to several cycles of washing and drying.

1.3.4. Performance evaluation of smart textiles for protective garments (PPE)

EN 17673:2022 Protective clothing - Protection against heat and flame - Requirements and test methods for garments with integrated smart textiles and non-textile elements

The standard presents the requirements of EN ISO 13688 and EN ISO 11612 applied to PPE in general and specific requirements concerning protection against heat and flame:

- Implementation of the requirements in EN ISO 13688 for smart textiles and nontextile devices
- Implementation of the requirements in EN ISO 11612 for smart textiles and nontextile devices - evaluation of the integrated smart textiles and non-textile elements; penetration of hardware; heat resistance; limited flame spread; whole garment test against fire exposure on thermal manikin (optional)
- Electrical safety and functionality of smart electronic components/devices - use under variable temperatures; slow and fast change in temperatures; manufacturer's specifications; thermal safety; electrical safety; water and humidity resistance of smart textiles and non-textile devices; batteries; sinusoidal vibrations; safety towards electromagnetic fields; explosive zones
- Evaluation of smart textiles and smart non-textile devices and elements after heat and flame testing

1.4. Standards for evaluating the durability of smart textiles

The problem of durability is extremely important for smart textiles, especially e-textiles, for which the integration of conductive yarns, electronic components, conductive inks present major failure risks during processing and use. Durability of smart textiles refer to the way that induced functionalities are maintained during the product's life cycle, when that product is subjected to stress factors of mechanical, thermal, chemical, environmental nature, as well as washing.

1.4.1. Washability of e-textiles

One of the main requirements for e-textile products and a reason why they have yet to succeed in entering the markets is washability, the capacity to withstand washing cycles without damage to the electronic circuits, the electrical characteristics, maintain full functionality of the products, integrity and appearance (Rotzler, 2021).

The effect of the washing process on the smart products depends on four factors:

1. Duration of the washing process
2. Mechanical strains
3. Water temperature
4. Chemistry/biology

Washability is assessed by subjecting the e-textile products to washing cycles and then the electrical properties are determined and compared to the initial ones. This is a problem that

needs comprehensive regulatory standards, as the experimental procedure and therefore the results depend on a lot of factors, like the type of washing machine used, washing program, minimum and maximum load, temperature, type of detergent, spin cycle characteristics, etc.

Such tests conclude after how many washes an e-textile product loses its integrity and functions, helping to evaluate its durability.

Most common standard for the washing procedure is ISO 6330 Textiles — Domestic washing and drying procedures for textile testing. The document defines:

- 3 types of washing machines, namely horizontal axis, front-loading machine; vertical axis, top-loading agitator machine and vertical axis, top-loading pulsator machine.
- 6 types of drying procedures - line dry, drip line dry, flat dry, drip flat dry, flat press, tumble dry
- 6 reference detergents
- Water characteristics – water hardness, pressure and cold-water inlet temperature
- Washing and drying procedures

The experimental data currently available are not following a common testing protocol, therefore their conclusions are not comparable. This demonstrates the need for standardization for the evaluation of the washability of smart textiles. There are standards already approved and others that are still in development.

IEC 63203-204-1:2021 Wearable electronic devices and technologies - Part 204-1: Electronic textile - Test method for assessing washing durability of leisurewear and sportswear e-textile systems

The standard specifies a household washing durability test method for leisurewear and sportswear e-textile systems. This document includes testing procedures for leisurewear and sportswear products with electrically conductive components and sensors to collect the data of the user. It describes the pre-treatment, washing and testing after washing methods. The washing test must comply to ISO 6330.

1.5. Standards in development

This part refers to standards currently in development, and as such published only as drafts. They have yet to be approved and will be published in the near future, so they are of interest and will have to be considered for the design and manufacturing and performance evaluation of smart textiles.

Standards to be released by CEN/CENELEC

FprCEN/TR 17945 Textiles and textile products - Textiles with integrated electronics and ICT - Definitions, categorisation, applications and standardisation needs

Standards to be released by IEC

The IEC 63203 series dedicated to e-textiles will include

- IEC 63203-202: Passive electric parts for e-textiles

IEC 63203-202-1: Passive e-textile parts – Connectors for e-textile applications

- IEC 63203-203: E-textile functional elements
- IEC 63203-204: E-textile systems (evaluation method for garment-type wearable systems)

IEC 63203-201-4 Wearable electronic devices and technologies - Part 201-4: Electronic textile - Test method for determining sheet resistance of conductive fabrics after abrasion

Standards to be released by IPC

IPC plans to develop a set of standards in the IPC 8981 series, referring to:

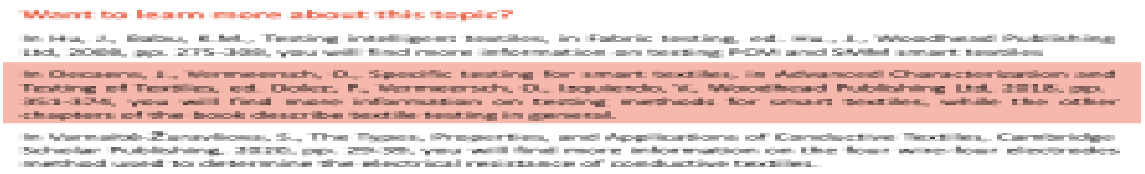
A. General principles, textile motherboard, sensors, electronic modules, power supply
B. Mechanical performance – abrasion, tensile, shearing
C. Mechanical performance – flexing, bending, stretching, torsion
D. Performance under exposure to salt water, acids and alkalis, sweat and perspiration, microbes
E. Performance under exposure to water (water repellence, hydrostatics), UV radiation, temperature
F. Cleaning procedures – washing, drying and dry cleaning

The following standards are expected to be released in the near future.

IPC/JPCA-8911 Requirements for Conductive Yarns for E-Textiles Applications

IPC-8953 Design Standard for Embroidered E-Textiles

IPC-8922 Qualification and Performance Specification for Printed Electronics on Coated or Treated Textiles and E-Textiles



Summary

This lesson discusses the current standards for the design, manufacturing and performance evaluation of smart textiles. The lesson presents short descriptions of the standards and technical reports that are published by standardization organizations: ISO, IEC, CEN/CENELEC, ASTM, AATCC, IPC.

The lesson considers first the standards for terminology, as establishing a common language is of utmost importance in this field.

The standards for design and manufacturing are discussing guidelines for smart textile materials and products in terms of type of materials, structures, functionalization (integration of smart functions) and what characteristics should be considered when evaluating material/product performance. Also, the domain of application influences design and manufacturing criteria, so there are fields where guidelines (in general and for smart textiles in particular) are created, like PPE.

The standards for performance evaluation discuss one or more specific characteristics that are significant for the use of smart textiles, describing the testing method (sampling, equipment, test procedure) and the processing and presentation of test results. These standards are very important in R&D, for certification of products and as conformity criteria. Most of these standards refer to the performance of e-textiles/wearables.

Standards referring to durability discuss the evaluation of external factors (mechanical, chemical, thermal and washing) have on the functionality of a smart product. This section presents the influence of washing on e-textiles.

The last section lists standards to be released in the near future.

References

EN 16812 - Textiles and textile products - Electrically conductive. (2016). CEN/CENELEC.

ISO's committee on consumer policy (COPOLCO). (n.d.). (ISO) Retrieved January 10, 2023, from https://www.iso.org/sites/ConsumersStandards/1_standards.html

Rotzler, S. v.-R. (2021). Washability of e-textiles: current testing practices and the need for standardization. *Textile Research Journal*, 2401-2417.

Partnership

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