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# Functional Textile Materials: Intelligent Textiles

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# Chapter 1. Introduction

# 1 *Definition of Smart Textiles.*

The term ‘smart textiles’ is derived from intelligent or smart materials. The concept ‘Smart Material’ was for the first time defined in Japan in 1989.

The first textile material that, in retroaction, was labelled as a ‘smart textile’ was silk thread having a shape memory (by analogy with the better known ‘shape memory alloys’ which will be discussed later in this paper). The discovery of shape memory materials in the 60’s and intelligent polymeric gels in the 70’s were however generally accepted as the birth of real smart materials. It was not before the late 90’s that intelligent materials were introduced in textiles. It is a new type of products that offers the same potential and interest as technical textiles.

**What does it mean exactly, ‘smart textiles’?**

Smart textiles can be described as textiles that are able *to sense* stimuli from the environment, *to react* to them and *adapt* to them by integration of functionalities in the textile structure.
The stimulus as well as the response can have an electrical, thermal, chemical, magnetic or other origin.

Advanced materials, such as breathing, fire-resistant or ultra-strong fabrics, are according to this definition not considered as intelligent, no matter how high-technological they might be.
The extent of intelligence can be divided in three subgroups [1]:

- passive smart textiles can only sense the environment, they are *sensors*;
- active smart textiles can sense the stimuli from the environment and also react to them, besides the sensor function, they also have an *actuator* function;
- finally, very smart textiles take a step further, having the gift to adapt their behaviour to the circumstances.

So two components need to be present in the textile structure in order to bear the full mark of smart textiles: a sensor and an actuator, possibly completed with a processing unit which drives the actuator on the basis of the signals from the sensor.
Sometimes, the change in the material is clearly visible, but sometimes it takes place on a molecular level, completely invisible to the human eye. The


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application possibilities offered by these materials are only limited by human imagination.

Processing these intelligent materials (in the form of fibres, threads, gels, liquids, …) into textiles or producing textiles from these intelligent materials results into an **intelligent textile**. The resulting textile will have self-regulating properties on the basis of changes that occur in the surroundings.

Although smart textiles find and will find applications in numerous fields, most of the attention is focused on medical applications. These kind of textiles include for example wearable smart textiles (biomedical clothing), designed to fulfil certain functions, but apart from that without any fringes. More casual applications are possible as well, which are expected to be functional as well as fashionable. It also can go as far as daily skin care, where the comfort factor is even more critical. But also smart wound dresses, bandages and hygiene applications are envisaged.

Initially, smart clothing will find applications in fields where the need for monitoring and actuation can be of vital importance, such as a medical environment, and with vulnerable population groups (newborns, elderly). The main factors to be overcome in the initial phase of the development will be the communication between textile engineers and medical people, in order to be able to define and demonstrate the benefits of new applications. However, as experience and familiarity will increase and hence breaking down barriers, the field of application will in the long term definitely widen to more daily applications such as sports and leisure, the work environment and so on.

A study about *intelligent textiles* is in a first stage reduced to a study about *intelligent materials*.

In a second phase, it is to be considered in which way these intelligent materials can be processed in the textile or into a textile material.

A textile material is traditionally a woven fabric, a knitted fabric, a braided fabric or a non-woven. The building stones of the textile material are *fibres*, which can or cannot be further developed in the form of yarns, or *filaments*. Innumerable combinations of these source materials result into a whole range of textile materials. Each of these materials already have a number of properties, such as :

- dimensions : length – width – thickness
- transformability
- permeability
- absorptive power
- stiffness
- tensile strength


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It is clear that the intelligent character of the textile material can be introduced at different levels. It can occur at fibre level, a coating can be applied, other threads can be added to the textile material, it is even possible to closely connect completely independent appliances with the textile.

**What is not smart textile?**
One of the first examples presented as an intelligent textile is undoubtedly GORETEX[2]. It was developed about twenty years ago. The fabric is a breathing membrane exuding sweat without admitting the rain to get in. In a strict sense, this is not an intelligent material as its properties do not change under the influence of the surroundings. It can better be classified as a functional textile, its function being the breathability.

## 2 *Why textiles?*

Textiles show several advantages. Clothes are unique in several aspects.
They are extremely versatile in products as well as processes. The building stones of the textile material are *fibres* or *filaments*. Innumerable combinations of these source materials result into a whole range of textile materials. Fibres are available in a very broad range of materials, single or combined: natural or synthetic, strong, elastic, biocompatible, biodegradable, solid or porous, optical or electro-conductive. They can have varying lengths, fineness, cross-sectional shape, surface roughness, etc.. Fibres of various can be arranged at random or in a strictly organized way in yarns or fabric structures. From this, even 3-dimensional structures can be constructed. After treatments allow the creation of very special properties such as hydrophilic/hydrophobic nature, antimicrobial, selective permeability etc.. Textile materials are able to combine advanced multi-functionality with traditional textile properties.

Clothes are our own personal house. They can be made to measure, with a perfect fit and high level of comfort. Clothes make contact with a considerable part of the body. They are a common material to all of us, in nearly all of our activities. They look nice and attractive, the design and look being adapted to the actual consumer group. We all know how to use them. Maintaining textile is a daily practice: house as well as industrial laundry are well developed.
And last but not least: textiles and clothes can be produced on fast and productive machinery at reasonable cost.
These characteristics open up a number of applications that were not possible before, especially in the area of monitoring and treatment, such as:

- Long term or permanent contact without skin irritation,
- Home applications,
- Applications for children: in a discrete and careless way,


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- Applications for the elderly: discretion, comfort and aesthetics are important.

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Full success however will only be achieved when the sensors and all related components are entirely converted into 100% textile materials. This is a big challenge because, apart from technical considerations, concepts, materials, structures and treatments must be focusing on the appropriateness for use in or as a textile material. This includes criteria like flexibility, water (laundry) resistance, durability against deformation, radiation etc.

As for real devices, ultimately most signals are being transformed into electric ones. Electro conductive materials are consequently of utmost importance with respect to intelligent textiles.

## 3 *The evolution of smart textiles.*

The first generation of intelligent clothing uses conventional materials and components and tries to adapt the *textile design* in order to fit in the external elements. They can be considered as e-apparel, where electronics are added to the textile. A first successful step towards wearability was the ICD+ line at the end of the 90ies, which was the result of co-operation between Levi's and Philips. This line's coat architecture was adapted in such a way that existing apparatuses could be put away in the coat: a microphone, an earphone, a remote control, a mobile phone and an MP3 player. The coat construction at that time did require that all these components, including the wiring, were carefully removed from the coat before it went into the washing machine. The limitation as to maintenance caused a high need for further integration.

The Wearable Motherboard [3] is probably the first intelligent suit that can be used for medical purposes. The basic shirt includes an optical wiring structure that can detect penetration of the shirt and an electrical wiring system that can be equipped with conventional sensors to measure different body parameters. More details will be given later on.

Alternatively, conductive textile materials are appealed to. Infineon [4] has developed a miniaturised MP3 player, which can easily be incorporated into a garment. The complete concept consists of a central microchip, an earphone, a battery, a download card for the music and an interconnection of all these

components through woven conductive textiles. Robust and wash-proof packing protects the different components.

No matter how strongly integrated, the functional components remain non-textile elements, meaning that maintenance and durability are still important problems.

In the second generation, the components themselves are transformed into full textile materials.

## 4 *The functions of smart textiles*

Basically, 5 functions can be distinguished in an smart suit, namely:

- Sensors
- Data processing
- Actuators
- Storage
- Communication

The different components all have a clear role, although not all smart suits will contain all functions. The functions may be quite apparent, or may be an intrinsic property of the material or structure. They all require appropriate materials and structures, and they must be compatible with the function of clothing: comfortable, durable, resistant to regular textile maintenance processes and so on.

### References

[1] X ZHANG and X TAO, *Smart textiles: Passive smart*, June 2001 p 45-49, *Smart textiles: Active smart*, July 2001 p 49-52, *Smart textiles: Very smart*, August 2001, p 35-37, Textile Asia

[2] GORE-TEX is a membrane from polytetrafluoroethylene (PTFE) with a very small pore size. This prevents water droplets, which are 20.000 times bigger than the pores, from penetrating into the membrane whereas vapor molecules exuded by a transpiring body can migrate through the pores.

[3] S PARK, S JAYARAMAN, *The wearable motherboard: the new class of adaptive and responsive textile structures*, International Interactive Textiles for the Warrior Conference, 9-11 July 2002

[4] http://www.wearable-electronics.de/intl/fotos_vorbereitungen.asp