Intelligent Textiles, Soft Products

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ABSTRACT

The first section deals with the vast field of material alternatives and properties designers have today. We are faced with thousands of materials that completely lack reference. Material gain intelligence, and it is predicted that all our surroundings soon will be controlled by invisible, intelligent devices. The second section demonstrates the advantages of integrating intelligent systems in our clothing. Here the link is made between human skin qualities and intelligent textile. Section three provides an overview of the different types of intelligent textiles and some of its application areas. What could be considered intelligent is discussed in the beginning of this section.

The paper wishes to focus on electronic and interactive textiles, therefore the whole of section four is dedicated to this. Definitions, alternatives, advantages and things you need to make a fully flexible interactive textile, are included here. The whole article focuses much on wearable computing, but in section five, other areas of applications are looked upon.

The paper wishes to give knowledge of where these research technologies are today and also give a good overview of the intelligent textiles that exist. The viewpoint is technical, leaving e.g. social changes, cultural references, economy and ergonomic aspects to other papers.

KEYWORDS

Wearable Computing, Ambient Intelligence, Intelligence, Phase Change, Shape Memory, Chromic, Electronic textile, Flexible Interactive Products.

1. INTRODUCTION

Technology is getting smaller and faster and we all know the speed of this development is increasing. We see an ongoing miniaturization and production of materials equipped with special properties. It is possible to integrate properties of sensitivity, information and intelligence into single materials.

1.1 Intellectualization of materials

The materials of our surroundings are being “intellectualized”. Whereas, in the past, we needed several components to satisfy a certain function, technology today has allowed us to satisfy the same function with less components. “The new generation of objects, rather than being solidly located in space, tend to flow through time.” [1]. These materials can interact, communicate and sense. Miniaturization not only means the production of smaller components, but the elimination of components. Mechanisms, that previously had to be manufactured by different materials and as separate objects, can now be made of one single material. Examples of this reduction of components and matter are; a light bulb where the separate materials are replaced by a single electroluminescent surface, a complex sensor system replaced by a piezoelectric film and the mechanical keyboard replaced by the membrane keyboard.
Formerly people had a traditional relationship with materials, but new materials do not have a known image of themselves. People have had to change from perceiving with cultural and physical depth to perceiving appearances. Therefore materials and objects today are not what they actually are, but what they seem to be and the performance they offer. Their true form (the image that they impress in our minds) does not correspond to their actual physical form, but rather the form of relations to which they imply [1].

Materials have moved from being a specific piece (to a craftsman) to a set of controlled properties (to a machine or a designer), an abstract model characterized by parameters and their relationships with each other. When selecting material, there is no single, obvious choice. This “hyper-selection” is not even the end of it. We are moving into an era where you can just order an appropriate material from your set of demands. These ”made-to-order materials” can not exist independently of the object and the manufacturing process. Often the material is even established at the moment in which the finished product is produced.

The question remains: Is this liberating the designer or just making things far too complex? The totality of a process is essential. Manufacturers, product developers and specialized professionals have to work very close. While some have the deep vertical knowledge, designers should have a wide horizontal one.

Manzini [1] compares the designer with a surfer; the wave of material transformation can be experienced as a heavy and uncontrollable force. However, the high wave also provides vast opportunities for those who dare to ride it correctly. You cannot influence the wave too much, but rather maintain your individual control. One should not underestimate the knowledge of the technology’s internal currents; it is the base of creativity.

1.2 Ambient Intelligence

Our everyday life is being more and more regulated by intelligent devices. Is slowly changing the way we live. Making a system of intelligent objects is one of the most important trends in contemporary engineering and design. Not only is it the priority area of many companies, many even claim that it is the very goal of our knowledge based society to integrate smart technology into our surroundings. "Society in the next 10 to 15 years will involve people being surrounded by electronic gadgets with ambient intelligence," says Werner Weber, senior director of corporate research and emerging technologies at Infineon Technologies AG of Munich, Germany. Most people agree with him - that technology will continue to become less and less visible to us.

We have seen this intelligence in commercials and movies (Minority report, Blade Runner). We also have seen attempts been made in realized projects (Philips, Telenor). A typical thing is voice commands. This technology can enable you to control your house appliances, such as saying “Open the windows”, “Turn on the oven, 200 degrees”_. Your surroundings will know the situation. And your clothes can also be context aware. As we will see in the next sections, wearable computers can contribute to the vision of an ambient intelligence.

2. WEARABLE COMPUTING

The mobility aspect of wearables is what makes it unique as a medium for communication. Today, mobility is a fundamental aspect of many services and devices. There is an almost unlimited number of application ideas, e.g. in the fields of health, knowledge and entertainment. Health applications include the monitoring of ill or high-risk persons, people exposed to extreme conditions or people doing sports. This also applies to therapy and improvement of physical abilities. A wearable computer is always on, should not hinder the user’s activities, can be aware of the user’s situation and can display relevant information, augmenting ones view of reality. The vision for wearable computing is to be an integrated part of our everyday clothing serving us as intelligent personal assistants.

In all sections, links are more or less made to clothing because it is a natural and obvious starting point for textiles. Smart garments are intelligent products that provide platforms for the development of new innovative applications (more in section 5). The first wearable computers were developed for navigation and maintenance tasks. There are also military applications as body-worn computational resources for soldiers. They need
intelligent textiles for uniforms to protect soldiers in extreme weather; constantly monitoring of the soldiers’ physical conditions. Some even claim automatic healing of wounds. Other outfits have the ability to adapt their colour to the surroundings for camouflage purposes. The tendency is and has always been that innovations are made in the military- or aerospace industry. They have a lot of money and are considered the most important areas of research and progress. However, they have also come to realize the advantages of sharing knowledge and cooperating with other companies/industries. Wearable computing is predicted to have a future in daily life acting as a more general-purpose system.

As we will see, various efforts have been made. The biggest challenge for the designer is to make them comfortable for the user.

But it is even more interesting when electronics and textile are one material. We will get back to this in section 4.1, after comparing fabrics with human skin qualities. This includes discussing intelligence and examining some categories of smart textiles.

2.2 Why clothing

Clothing is personal, comfortable, close to the body and used almost anywhere and anytime. Most of us do not walk around dressed like Adam or Eve, we wear clothes or cover in other textiles from day one. Everybody knows how to use clothing and integrated smart systems can serve us in a very unobtrusive and natural way. Our capabilities can be enhanced without any conscious thought or effort required. Clothing is an extension to our physiological characteristics and is very close to the body, enabling an intimate man-machine interaction. Your suit, dress or jacket can be a communication medium, an information platform. They can also promote safety or provide working aid. We surround ourselves with textiles. So much of our environment is already made of textiles; we have a natural relationship with it. There already exists huge amount of information about the body and clothing, like e.g. ‘body maps’ of stress, wear and tear [2] and where to place non-textile devices on the body [20].

Mann [3] regards wearable computers as a ‘second brain’ and their sensory modalities as additional senses augmenting human intellect.

2.3 Skin

Clothes are worn almost all the time, but skin is ever-present. I want to mention the qualities of skin, to illustrate how and to what extent we try to imitate nature (complex and perfect) with the products we create. Skin is a flexible multilayered, multipurpose organ. It is heterogeneous, shifting from thick to thin, tight to loose, lubricated to dry, across the landscape of the body. The thick parts (under our feet) are built up with dead cells as a reaction to mechanical stress. The skin also has elastic parts (elbow) and parts packed with nerves (inside the nose).

It is knowledge-gathering, responds to heat and cold, pleasure and pain. It is both living and dead, self-repairing (the amazing ability of scar tissue to pull together the edges of a wound), self-replacing and full of nerves and capillaries [4]. It is important as a barrier, a container and biochemical manufacturer. Skin protects the body from infection, harmful radiation and mechanical and electrical forces. It maintains body temperature and fluid balance, absorbing vitamins and cleaning cells. It is our largest organ. It contains nerve endings, which provides the sense of touch. It communicates emotional, physical states (blush, blanch, goose pimples, sweat, blue with cold, red with anger) and communicates through hormonal signals. Water-repellant and inflammatory response, are other intelligent qualities. Yes, skin is definitely intelligent.

Human beings tend to have an image of things as content with a shell around, because we ourselves are containers. We see, think and speak about objects from our human viewpoint. Another thing is that we try to make clothing fabrics that has the extensional qualities of our skin. Many clothing manufacturers claim that their product breathe, sense and lives, like it is “your second skin”. Or like Eleksen, producer of a sensatory fabric [5] says it in their product catalogue: “Elektex is like skin; the fabric can sense the location as well as pressure from human touch. The skin is soft and also flexible. The skin is itself intelligent.” In a fashion technology school, a whole course is even named “The Epidermis as Metaphor” [27]. Epidermis is the layer of skin which we see and touch. They continue saying that “textile technologies enrich the cognitive characteristics of our epidermis”.

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Intelligent textiles, soft products
Living skin is also grown in laboratories; it is a medical product (e.g. Apligraf). But artificial (not living) skin also exists, as temporary substitutes, often as barriers, with chemically engineered materials that mimic real skin. In a specific two-layer artificial skin, the synthetic outer layer prevents infection and regulates fluid loss. The inner layer arranges for the new natural skin cells to grow. There actually are quite a few alternatives in the wound closure business.

The outer layer of our skin consists of dead cells. Death is not a sudden happening, it is an ongoing process (Taylor M C, *Hiding*, 1997) and to prevent these changes and other threats, the first protective shelters and garments were made of animal skins. We use animal skin today as well, but it is still not our second skin. But of course: “One can imagine clothing that senses and adapts to our surroundings much like a second skin.” [9]

### 3. INTELLIGENT TEXTILES

Materials are considered to be textile when they consist of drapeable structures that can be processed on textile machinery. Usually textiles are made of fine and flexible fibres and threads that have a high length/diameter ratio. The hierarchical structure are made of bundles of fibres are twisted to create yarns, which again are e.g. woven or knitted into fabrics. However, textiles can also contain non-woven structures as membranes and foils. Ready-made textile products include ropes, ribbons, fabrics and also three-dimensional products like clothing [3].

#### 3.1 Intelligence. What is considered intelligent

What does it mean when we say that skin is truly intelligent? It does not have a brain. Intelligence is described in the Encyclopaedia Britannica as “the ability to adapt effectively to the environment, either by making a change in oneself or by changing the environment or finding a new one. (...) Effective adaptation draws upon a number of cognitive processes, such as perception, learning, memory, reasoning, and problem solving. This definition is from the psychologist’s viewpoint, but still holds up for human skin.

There are no definite laws about what is considered intelligent. In addition, things have varying degrees of intelligence. People tend to use the terms way too much, especially for marketing purposes. Here are four quite similar explanations of intelligent textiles:

- They are materials that react to impulses without the need for us to control them [7].
- They are able to respond to its environment [8].
- In garment they react to impulses coming from outside or inside [9].
- They react automatically to some kind of stimuli [10].

Intelligent textiles are fibres and fabrics with a significant and reproducible automatic change of properties due to defined environmental influences.

Other textiles that are more passive can be called high performance textiles. Microfibres are very passive, but waterproof, but at the same time permeable to water vapour.
Wearable Computing is different from smart clothing. Wearable computing is used for everything you wear that has some element of electronics. Smart can be interpreted as either clever or as fashionable/chic. Some say that smart clothing can be a combination of both meanings. The most typical way is to put electronic devices, like mobiles and MD players, into pockets. This should be called an intelligent solution, but never intelligent textiles when it is not including textile which themselves are defined as intelligent. But it is still wearable computing.

Intelligent textiles can be divided into these groups [9]:

- Phase Change Material
- Shape Memory Materials
- Chromic Materials
- Other intelligent fabrics
- Electronic/Conductive textiles

### 3.2 Phase Change Material (PCM)

When you warm a material, it absorbs heat while its temperature is rising continuously. When cooling it, the heat stored inside, is released into its environment through a reverse cooling process, where the temperature decreases [9]. A normal textile absorbs 1 kJ/kg with the increase of 1 degree Celsius. Due to a melting process during heat absorption and crystallisation during release of heat, the temperature of a PCM and its surroundings remains constant all the time. Therefore a PCM can absorb much more heat than a normal one. It functions as heat storage. When absorbing e.g. 200 kJ, a normal textile would increase its temperature by 200 degree Celsius, whilst the temperature of a PCM will not change. Because of its solid/liquid state, the PCM in textiles is “enclosed into small plastic spheres with diameters of only a few macro meters”, called PCM-microcapsules.

Think of a typical jacket for sporting activities. It should keep a balance in temperature at any moment and intensity in activity, but many fail to do so. PCM is therefore used as thermo regulating in active-wear. When you get dressed for some sporting activity on a cold winter night, the layers of air between the garment layers keeps the heat inside. However, it can suddenly get too hot and sweaty. Then the jacket will breathe due to active thermal insulation of PCM. When the body produces more heat than the jacket can release (heavy activity), heat is absorbed and stored in the PCM. And when too much body heat disappears through the jacket (light activities), the PCM will emit stored heat. It is constantly recharging and releasing heat during varying activity.

When designing this, one has to take into consideration the generated human body heat, heat flux, level of activity, way of use, duration, quantity of PCM and the relationships between these factors. Considerations for the characteristics of a PCM:

- Heat storage capacity and quantity
- Textile substrate/carrier construction (apart from breath ability and flexibility; thickness and density of microcapsules)
- PCM temperature range should match the application temperature range
- Suitable location in the garment

The designers at Norrøna [11] have tested some of the most known PCMs, like Outlast [12] and Frisby [13]. Their experience is that it is expensive, and not able to come close to their claims. “Lots of money is being pumped into the marketing. The phase change does occur, but not as controlled as they claim”, says Brad Boren at Norrøna, still keeping his optimistic view of the future.

### 3.3 Shape Memory Materials (SMM)

SMMs can deform from the current shape to a previously set shape, usually due to the action of heat. You may have seen this on TV; that a strip of metal is heated with a lighter and finds its original shape. In garments the scale is smaller. When these SSMs are activated (at a certain activation temperature), the air gaps between close layers of clothing are increased. This is to give better insulation and protection against extremes of heat or cold. In clothing, the temperatures for the shape memory effect to be activated should be near body temperature.

SM Polymers are more flexible than the alloys. Thermoplastic polyurethane films have been made
which can be put in between layers of clothing. When the temperature of the outer layer of clothing has fallen sufficiently, the film responds so that the air gap between the layers of clothing becomes broader. This out-of-plane deformation must be strong enough to resist the weight of the clothing and the movements of the wearer. If the outer layer of clothing becomes warmer, the deformation must be reversed. Some alloys are capable of a two-way activation, triggered by changeable weather and varying physical activity.

Shape memory alloys are also used in various domestic appliances, such as shower mixer valves and valves for the safety shut of fuel lines in case of fire. Like other intelligent materials, the shape memory alloys can also contribute to the miniaturization of equipment and systems. This decreases the number of parts required and extend the life expectancy.

Both PCMs and SMMs in clothing depend on the physical activity and surrounding conditions (temperature, humidity). The human body produces a span from 100 W of heat (rest) to 1000 W (maximum physical performance). Our body temperature increases with the heat production. The textile reacts through perspiration in order to withdraw energy by evaporation and thus cooling. Reduced thermal insulation in clothing during hard activities makes it possible for some of the heat to escape. The thicker the fabric, the better insulation, but the weight and freedom of movement have to be taken into account. After all, comfort is the most important user demand in the clothing industry [11].

Diaplex [15] names itself as “the intelligent material” and claims that thermal vibration/movement occurs within the molecule structure when temperature rises over a predetermined activation point. This creates micro pores and membrane permeability that allow vapour and body heat to escape.

3.4 Chromic Materials

Chromic Materials are also called chameleon fibres, because they can change their colour according to external conditions. These materials have mostly been used in fashion, to create funny colour changing designs. Because of this, some people fear that the chromic materials will be a short boom. But the accuracy and endurance of the materials are all the time being improved. The different types are classified by the stimuli affecting them:

![Figure 1; External stimuli energies and their corresponding chromic name.](image)

Number one is not much used in textile. And its characteristics depend highly on a liquid which has to be melted into the fabric. When exposed to ultraviolet light, some fibres emit fluorescent colour in the dark. The threads are supplied with a mix of liquid with fluorescent paint. The dyes are entrapped in microcapsules, applied to fabric like a pigment in a resin binder [9]. The selected wavelength of light reflected depends on the arrangement of molecules or liquid crystals, which again varies with temperature.

Solvate chromism is normally used for swimsuits. Other materials have paint which can store light. Applications for this are e.g. working clothes in bad light circumstances or as guiding arrows during a power failure. Research has been done to change the optical transparency of materials by application of an electrical or magnetic field.

Application examples [4]:

Karim Rashid designed a table where the surface changes colour in response to heat. This serves as a visual index of the activities on it (hands, elbows, cups)

A bicycle frame created by Marc Newson is coated with tritium, a photo luminescent paint that provides a beautiful and traffic-safe glow in the dark.

An interactive wood surface/table is made of electric plywood: Ultra-thin polymers are layered...
between the laminations. The film conducts electricity, information and electroluminescent light. The light charges a Memory Blotter with a phosphor that absorbs and recycles the light. When the EL light is off, the MB glows. Digital tools can be plugged into the wood surface and some are even embedded into the desk, activated by touch through a springy, resilient wood veneer.

“Increasingly, the digital realm penetrates and manifests itself through the physical realm of materials – unlike initial predictions, where the virtual was seen to be different from the physical.” (Sheila Kennedy). She made the Chameleon cloth, a curtain with photo luminescent pigments in fibres. Light is stored and the emission is designed as a light pattern.

Instead of having a complex mechanical roller blind for the windows, it could be replaced by an electro- or photochromic plate glued directly on the window. This is another example of performance integration in materials.

4. ELECTRONIC TEXTILE SYSTEMS

“Electronic” means that a system is able to exchange and process information. If textiles had the ability to record, analyse, store, send and display data, a new dimension of intelligent high-tech clothing could be reached [2].

The wearability totally depends on the way of integration into clothing:

- miniaturization of electronic components
- and attachment to textiles
- development of textiles with electronic functions

Most of the wearable computers on the market up until today still consist of bulky and rigid boxes and are portable machines rather than a comfortable part of the clothing. The textiles just serve as a carrier of conventional cables, special connectors and miniaturized electronic devices. Recently, examples which include both points above have been commercialized. A typical example of this is the Philips and Levi’s collaboration [16]. It is a jacket with fully integrated communications and entertainment system (earphones, microphone, remote control, mobile phone, mp3 player). Other projects are a collaboration between Mac and Burton [17], IBM Research with MIT [18] and a concrete example from Finland; Clothing for the arctic environment [19]. It seems like all big companies have done research and product concepts for this kind of wearable computing. Gemperle [20] describes how the shape and placement of such devices can be improved in terms of wearability.

4.1 Electronic Textiles

But humans prefer to wear textiles, as they are flexible, soft, lightweight, breathable, robust and washable. So the idea emerged to develop fibres and fabrics that can be used for electronic functions. A suitable definition considers electronic textiles as materials with electronic functionality and at the same time textile characteristic. This makes a versatile combination of physical and electrical properties. Electrically conductive fibres can be made by filling synthetic fibres with carbon or metal particles, coating fibres with conductive polymers or metal or using continuous short fibres that are completely made of conductive material. These fibres can be woven, knitted or embroidered into fabrics.

There are several companies and trademarks offering these materials. But all textiles have the same basic properties: Lightweight, durable, flexible, cost competitive with ability to be crimped, soldered and subjected to textile processing.

Electronic textiles have already found their applications in EMI shielding. If the fabric is covering from most sides, it offers an excellent protection against this electromagnetic interference. It is also highly accurate, because of the constant improving of fine fibres. It is light, which makes it attractive for aerospace. And it offers capability with standard braiding equipment. (Competing alternatives with similar characteristics, like printed membrane, conductive or pressure sensitive ink or piezo films, have limitations when it comes to flexibility and they are still on an experimental level.)

However, there are some requirements for embedding electrical functions in clothing (as mentioned earlier); flexibility and comfort are the most important. In addition to conductivity, fabrics
have to have good process ability and wear ability: The fibres have to:

- **maintain their functionality** despite of repeated typical textile handling, like weaving, wearing, washing and wrinkling (the four Ws). Wearing includes constant motion and stress from body movement, perspiration, body heat etc.

- **be fine and to some extent elastic** in order to be comfortable to wear.

- **have a low mechanical resistance** to bending and shearing so that they can be easily deformed and draped. The more the textiles are close to the body the more they have to be flexible and lightweight.

As we have seen, these demands are not fulfilled by all the other data- and power-devices that are needed to construct a fully flexible electronic garment.

Conductivity can be electrical or optical. Optical fibres have the advantages of no shorts, no corrosion and no parasitic field effects. The cost is high due to expensive light sources and transceivers. Most plastic optical fibres are stiff and allow a limited bending radius and are difficult to weave or knit. People are working on overcoming these challenges.

Electrical conductors are easier to handle in textile fabrication processes. But metal, carbon and conductive polymers are also quite rigid and brittle materials. They are heavier than most textile fibres, making homogeneous blends difficult to produce.

According to ETH Zurich [2] these are the components of a wearable system. These functions are combined to form services:

- **Network unit**: transmission of data within the wearable computer and to external networks
- **Sensor unit**: registration of biometric and environmental data and of user commands
- **Processing unit**: calculating, analysing and storing data
- **Power unit**: supplying energy
- **Action unit**: adapting to situations, creating an effect on the user, displaying data

### 4.2 Textile networks

On-body data and power transfer in wearable systems can be wired or wireless. ETH Zurich explains that textile network means that fabrics are used to replace conventional wires, whole circuit boards or antennas [2]. Extensive studies were carried out to measure and model the high frequency properties of conductive fabrics for optimising communication networks in textiles. Their aim is to “replace conventional wires and even high performance circuit boards with textile fabrics”.

**MIT Media Lab, E-broidery project** [18]: Conductor lines were realized by emboidering metal fibres or weaving silk threads that were wrapped in thin copper foil. The main drawback was the need for protection against shorting and corrosion, as the conductive fibres are not insulated.

**E-broidery project, Courtesy of MIT**

**The Wearable Motherboard** [21] had a garment including electrically conductive fibres and plastic optic fibres for transferring information from sensors to processing units. Each electrical fibre (e.g. stainless steel, copper or doped nylon fibre) is insulated with a PVC or polyethylene coating.
Other projects include in-woven mobile antennas on the large fabric surface, and wireless communication infrastructure between various pieces of clothing (which can be used to communicate with chips that are embedded e.g. in personal items).

### 4.3 Sensors and actuators

One can use textiles to transform signals in two ways:

**Sensor**: Transformation of physical phenomena into processable electrical signals.

**Actuator**: Transformation of electrical signals into physical phenomena.

Sensors can be used to measure biometric or environmental data but also to act as an input interface. Actuators can adapt themselves to a situation, affect the human body or serve as a display.

**SOFTswitch** [22] is one example of a textile pressure sensor. It is made of conductive fabrics with a thin layer of elasto resistive composite that reduces its electric resistance (resistive change) when it is compressed.

Another solution has two conductive fabric layers separated by a nonconductive layer, where pressure can create a contact in the holes of the mesh in the middle layer.

In the Wearable Motherboard [21], plastic optical fibres detect damage (broken paths) in the fabric and can give information about the location of e.g. bullet penetration. These sensors can also be made to detect chemical, biological and thermal hazards.

So-called ‘electro active polymers’ (e.g. electro chromic material, section 3.4) and can be used as sensors or actuators.

**France Telecom** [23] developed a display made of optical fibres woven into a fabric. The pixel number was just 64 and the fibre diameter 0.5 mm due to the mechanical limitations of the optical fibres. Textile displays also can be realized with conductive fibres covered with a fine layer of an electroluminescent material.

### 4.4 Textile processor

Processing includes arithmetic operations and storage of data. Challenges such as stability, short lifetime, slow switching speed have recently been overwon, to create organic devices like electro active polymer transistors and batteries. (They are actually threads with transistor functionality.) Flexible chips (e.g. silicon) can be attached to textiles but they are not textile themselves.

### 4.5 Power supply

The power supply is the heaviest part the biggest problem, says Brad Boren at Norrona [11]. Two of the most known approaches to develop new power supply technologies, are lithium polymer battery and micro fuel cells.

Sunlight, body temperature and body motion are alternative energy sources on the body that can be transformed into electrical energy. Also in this case, one should differ between flexible and textile, because there are more efforts to mount flexible energy supplies onto textiles than inventing pure textile power supply.

**Infineon** [24] uses the temperature difference between the outside and the inside of clothing, which produce a power of a few microwatts per cm².

Thin film solar cells can be made on flexible surfaces such as plastics. The flexible solar cell technology has also been adapted to fibre form. The efficiency of these alternative energy sources needs to be improved. Creating components that are wirelessly powered by an electric field in the environment is another interesting approach.

**Lunar Design** [25] has with its BLU jackets predicted a near future with thin, cheap and flexible digital displays. Another object designed by Murray and Allen “seeks to merge the softness of skin with the hard lines of consumer electronics” [4].
5. FROM CLOTHING TO OTHER SOFT PRODUCTS

Ellen Lupton says in her book Skin [4], that “in the 1920s/30s, the pioneers of industrial design created hard shells around the mechanical guts of appliances. Today, designers construct skins for objects that are warmer, more responsive to touch. Mario Bellini expanded the paradigm of industrial design with his calculator for Olivetti in 1972. The mechanical keys were wrapped in soft, elastic rubber membrane (figure 2).

Elektex [5] is an active skin which translates electronic impulses into digital data. It recognizes the contact point and sends signals to e.g. a CPU. It is less than 1 mm thick and can sense location on three axes (X,Y,Z). It recognizes the contact point of touch and can use this digital information. They predict that “eventually, the material touches the lives of people that don’t even know it’s there”.

“This product landscape intentionally avoids the obvious and over-theorised applications for soft technology: wearables. (...) Elektex has the potential to make a bigger impact on all areas of design, not just clothing.” Elektex [5]. First of all, it is important to take advantage of the experience obtained in wearables to use it on other applications. But it is also about time to challenge what has become the standard construction/design of interactive products with electronics. Most products bury technology inside a hard shell, which in most cases consist of many materials. Now products can be made of the same material as the interface. This also offers many advantages for sustainability and economy; by reduce the number of materials and using less matter. We remember Manzini talking about these single materials that can perform many tasks.

5.1 Interaction and interfaces

The role of human interaction is in a way diminishing. Humans are becoming less of a part of the functioning technology.

Both our skin and the skin of products are interfaces between body and product. The skin is the body’s largest sense organ, registering temperatures, pleasure and pain and an infinite
range of textures. It is the plane of contact between things and people. The skin of mechanical and electronic devices is the point of interface with users, where the surface also has the aesthetical identity of the object and contains its controls.

Some fabrics are coated with a thin conducting polymer layer that possess strain and temperature sensing properties and also actuating properties. These fabrics contain fibre bundles that contract and relax under electrical control and can be used e.g. in a sensor glove as a tactile output interface.

The ability to dispense with fixed castings, rigid mountings and inflexible substrates facilitates new radical possibilities in flexible, user-friendly interfacing.

To use this material today is not easy. According to the administration of Eleksen on the phone, the material has to be customized to the product. And they prefer collaboration with the biggest companies, rather than selling material samples to other interested people without knowing what they will do with it. It is quite common in this industry, that companies keep a lot of information to themselves. Amongst racing competition and copycats, control is better kept like this. Their advertising is meant for other large industries. Their collaboration with IDEO, Fabrications [5], resulted in different soft telephones, qwerty-keyboards and remote controls. They were meant to provoke the next evolution of products.

5.2 Other non-clothing textile applications

Zapper cushion [26]: A pillow made of touch sensitive fabric, replacing traditional remote controls (for children and people with motor-skill problems).

Hospital beds with linens that detect your position, and can e.g. prevent bedsores.

Smart upholstery in cars that ensures proper inflation of airbags. Textiles can also sense and remember your movements to automatically regulate the seating position.

Sensory textiles built into airplanes, roads, bridges and buildings to give early warning of potential catastrophic failures. Use of fibre optic sensors inside fabric-reinforced structures that monitor mechanical, acoustic, electric, magnetic and thermal perturbations. This is done by detecting the wavelength-shift induced by strain or temperature change.

Elek tex/IDEO flexible mobile phone
6. FLEXIBLE ELECTRONIC TEXTILE FUTURE / CONCLUSION

A shift in consumer values has occurred; instead of wanting the finest natural materials, people look at the engineered beauty, innovative design and the intelligent aspects of products.

We are still far from taking full advantage of the potential of information technology services, but the future for fully soft electronic products is very attractive. And it requires a different, but interesting design approach. The geometric and mechanical properties of textiles (large flexible area) differ strongly from conventional electronics and can create new computer designs and architectures.

Firms that understand how to incorporate emerging IET technologies into their new product strategies will establish and sustain financial and competitive advantages.

To take the next step towards electronic clothing (made of electronic textiles) research has to be carried out in the following areas:

- clothing technology for manufacturing
- testing under wearing conditions and washing/cleaning treatments
- investigation of reliability

We have seen that electronics can not only be attached to textiles but also realized in form of textile structures. Today, some performances cannot be compared with conventional computer technology. There are also some limitations concerning mass production and reliability.

In the future it could become quite difficult to clearly separate electronic textiles from the aforementioned method of miniaturization plus attachment, because computers could be miniaturized until they are molecule-sized. In this case ‘attachment’ to fibres or fabrics would also lead to what we define as electronic textiles.

Plastic was a revolution, and nano-technology will probably be the next big change. There are a lot of thoughts about what could be done if we were able to manipulate, rearrange and build from molecules and atoms. Having a machine that changes a bicycle tire into meat, self-cleaning carpets, changing state from rigid to flexible and visa versa.

1 nanometer is equal to 1 billionth of a meter. A human hair diameter would have space for 12,000 such particles. It has unlimited potential and is called the key technology of the 21st century.

The focus of nanotechnology is now in California’s Silicon Valley. “There is no doubt it will be taking what we wear to the next level in terms of durability, comfort and safety. They have already approved the first textiles that permanently repel fleas, ticks and other insects which have been known to contribute to the spread of disease.” (Brad Boren, Norrona)
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