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Special Edition: Smart textiles

The Editors

Smart Textiles

The Smart Textiles initiative has in the past year changed from an initiation phase to a development phase, addressing three main areas:

- development of innovative collaboration and clusters;
- experimental research,
- business innovation

Smart Textiles has strengthened its role as a national and international cluster in the textile field. The results range from being involved in European projects such as Crosstexnet (an ERA-NET project where the Västra Götaland region is a ”lead partner”), collaboration in other initiatives, such as research and development in cellulosic fibres for textile and fashion purposes, ”Pulp Fashion”, the organization of seminars to strengthen links between institutes and universities, formation of centres (PPE-Personal Protective Equipment, together with the SP, the Swedish Technical Research Institute) and business-driven projects.

Smart Textiles Design

Smart Textiles design items have become highly sought-after, although they are not yet finished products. Examples are the interactive pillows and the Energy Curtain project. Here we together with a textile producer (Ludvig Svensson AB) presented a prototype of a textile with integrated lighting elements that form a self-sufficient energy system through solar cells applied to the textile design. This prototype was developed in 2004-2005 – now an architect proposes to purchase about 2500 sq.m. of energy curtain fabric. This can be seen as a first example of how research can proceed into product development and production.

Thus, there is high expectation that the experimental design research will generate ideas that can be quickly translated into products. Therefore a ”smart textile sample collection” has been developed to show how the textile material or expression can be developed in parallel with the application and need. It facilitates collaboration with textile producers, textile designers and product developers, where enterprises and local designers will be able to use the new textile materials. It is intended as a collection to use in workshops, product development, etc.

At the same time it is important that we maintain the height of the experimental design research group, to continue a long-term development and support. ”New” pillows and energy curtains are ready for product development during the next decade.

Smart Textiles Technology

One main focus is on experimental research in melt spinning of conductive and piezoelectric fibres. Conductivity is achieved by mixing in conductive particles, where both novel carbon nanotubes and traditional carbon black particles are used in the experiments. The ability of the materials to be drawn into fibres was tested as well as the conductivity level after drawing to fibres. The results showed that increased levels of filler were detrimental to the spinning properties, and, in addition, conductivity decreased at drawing. With the new nanotubes conductance disappeared completely.

By using bi-component technology in melt spinning fibres could still be made of the material with high filler content. Heat treatment of the bi-component fibres made it possible to recover the lost conductivity. The result was a thin fibre with a core of electrically conductive material and with good strength, just slightly less than an ordinary nylon fibre. The intended use of the new fibres is inter alia as small heaters that can be woven into textiles, but there is also an opportunity to use the fibres as temperature sensors.

Research has also focused on the development of conductive fibres by melt spinning and coating. Here polymers with intrinsic conductive properties are used, predominantly polyaniline. Melt spinning was carried out of polypropylene which had been modified with polyaniline or carbon nanotubes. The aim was to determine the critical process parameters to achieve both high electrical conductivity, and good fibre properties. The results show that about 10 S/cm conductivity can be achieved, which is comparable with results from other research groups. The addition of the conductive components, however, impairs other fibre properties. With the help of compatibilizers features can be improved and a relatively good conductive fibre obtained. By steam polymerisation reactive monomers are absorbed on the surface of a fibre or yarn, and then polymerized to PEDOT (poly(3,4-ethylenedioxythiophene)). This method gives yarn with conductivities of about 10 - 20 S/cm, with the advantage of having good textile properties. So far only short fibre lengths can be coated. A continuous coating method will be developed, which should provide a commercially viable process.

Another theme has been the so-called shape memory polymers, polymers that can change the shape from the stimulation of temperature, light, electro-magnetic fields, pH, etc. The focus was initially on textile aspects, such as textile structure and appropriate conditions for industrial production of textiles with memory polymers. However, the availability of these materials is very limited, and own solutions were then developed. Switching is achieved by temperature stimuli, in what we call thermally activated textile actuators, TATA. The big advantage is the reversibility. Many memory polymers are one-way; they switch into a shape and stay there.

In a new project the focus is to create electrically conductive coated fabrics, where the choice of materials (a textile substrate and a polymer blend for an optimal coating paste) in combination with process parameters (conditions of the coating) was the theme. Conductive textile is a technology platform for several varieties of smart textiles, which in most cases are based on being able to transmit or process electrical signals.

In the medical field, concentrated in the platform MT3 (Medical Texttronics), research is made on textile structures for the measurement of ECG. Especially, the development of new knitted electrode structures, development of a new model for the integration of electrodes with increasing pressure and the generation of strain- and pressure-sensitive structures.

Metrology and measurement technology for electrical measurements in textile materials responds to a great need. Equipment has been designed and theoretical modelling of the correct measurement procedure for the fibre, with its special geometry, has been performed. A project about sound-absorbing fabrics aims to investigate how a textile should be designed in the best way to act as sound absorber and how materials can best be used to create sound control in common types of rooms, such as schools and nurseries. Initial measurements of acoustic properties in different classrooms have been carried out.

Business Innovation

Smart Textiles Business Innovation consists of two parts, Company Driven Projects and Prototype Factory. The foundation of Company Driven Projects was laid at the initiative's start in 2006, and in subsequent years, this programme is increasingly taking shape. Initially a number of enterprises announced their interest and during the first two years 13 company-driven projects were started. Three ongoing projects per month was an average to compare with the last two years, where we have an average of 15 projects per month and a total of 25 projects started. The reason for this large increase is greater emphasis on activation of companies and enticing them to cooperate with researchers. The distribution of both active and formerly non-active firms is larger and project results improve.

In some instances the Smart Textiles programme initiates projects. Preferably these are thematically oriented projects with enterprises working together. One example is the project Qanuk on the cold climate theme, which started in September 2010.

An example of a successful project and a new company, Y-Graft AB Project "Y-graft in human-adapted textiles". Two authors, a mathematician and a vascular surgeon joined Smart Textiles and opportunities around collaboration were discussed. Bypass surgery on legs and hearts is a common form of treatment in symptomatic atherosclerosis. Unfortunately, there is often a severe scarring of the tissues into which vascular bypass grafts are sewn. This leads to narrowing and about 30% of all such implants cease working after a year. The idea then was to develop an artificial blood vessel of a textile that was adapted for human use. Such blood vessels have a design that mimics nature and has the potential to improve function. Together with Smart Textiles a patented flexible graft in textiles has now been developed.

A further example of a project that turned out well, the company TST Sweden AB with the project "Smart fabrics impact on the human body". The project has resulted in a new business with the brand name TEMPTECH. In addition to the TEMPTECH product, a refrigeration and heating element of PCM (Phase Change Material), also business knowledge and advice are provided. The project was laid out to develop PCM materials and clothing for various user situations and analyze the needs in different contexts.

Prototype Factory, which is the second part of the Business Innovation programme in the Smart Textiles initiative, is a resource for prototyping and testing and verification of ideas. A textile library, described in another article in this journal, has been inaugurated in the spring and is now under implementation in the Prototype Factory. It will be a support and a platform for various stakeholders to stimulate innovation and creative development.

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Adjusting daylight and solar heating in offices

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Abstract

There is a need to adjust daylight and temperature in office buildings according to changes of the type of work, the day and the seasons. This project seeks to merge aesthetical, functional and theoretical reflections into indoor decorative textiles for the regulation of daylight. Diverse techniques for obtaining different levels of diffusion and transparency were applied in decorative patterns and the resulting textiles investigated in two series of experiments. The first experiments were conducted in a model, the second in full scale. Temperature measurements, digital photography and infra-red photography were used for the evaluation of results.

Key words: Daylight regulation, light diffusion, printed textiles, devoré, woven textiles.

Introduction

In both old and new office buildings there is a need to regulate daylight and temperature according to changes of the type of work, the day and the seasons. For the employees direct sunlight often cause problems when working on computer screens, and increase of temperature in the office space can be most impeding. But it is also important to have sufficient and changing daylight in our working environment, as it is vital to our health and state of mood. Several research projects have documented the problematic (Christoffersen et al. 1999, Figueiro et al. 2002, Traberg-Borup, Grau & Johnsen 2005, Osterhaus 2009). However, these investigations are mainly concerned with measurements of sufficient daylight, health issues, building regulations and architectural problems. They do not consider the aesthetic aspects of the working environment or suggest new interior design solutions.

This project seeks to merge aesthetical, functional and theoretical reflections into indoor decorative shadings, which can adjust daylight and solar heating in offices. The objective is also to explore new solutions that will take maximum advantage of daylight in order to save energy. We see decoration as an active functional element, which can provide both a means for light adjustment and a pleasurable experience to users. Our research is practice based and carried out through a series of experimental investigations of ornament, textile materials and – techniques in combination with polarizing, UV- and IR-filtrating foils.

Existing Solutions

We did a survey of existing shadings on the market, and made a small qualitative study of daylight adjustment in six office buildings – five of them taken into use between year the 2000 and 2005, and one in 1984 – facade renovated in the year 2000 to prevent overheating.
Our study showed that there is a relatively small range of products, which have been mounted on the facade or inside the buildings. In all six cases there were two sets of shadings, either one outside and one inside or two inside. The shadings on the market are generally roller blinds and Venetian blinds or flat panels – the majority is without decoration and in white or neutral grey tones. Although there is a choice of solutions on the market with color or decorative surfaces those chosen all have an anonymous appearance, which does not seek to give the user any tactile or visual pleasure. Most of the outside screenings were centrally controlled and outside the influence of the individual. These are the points we are aiming to challenge in our research.

The conclusion of the study is that problems with light and heat are still not solved in office buildings. Because the blinds have to be down in order to get enough screening, artificial light is often turned on all day even during the summer – adding to the energy consumption of the building.

Decoration

The basis of our research is a conviction that decoration is more than just frippery. We believe that ornament can bring about more pleasure to the users of a working environment, and also become an integrated functional element in the shading.

According to the design historian David Brett, decoration is an expression of a deep human need for visual pleasure: "… a disposition not unlike the faculty of language and counting, immanent in our nature without which we would not be complete human beings. Just as there are no societies that do not speak or count so there are none that do not decorate, embellish or make patterns".
This he defines as a group of values, which include social recognition, perceptual satisfaction, psychological reward and erotic delight (Brett 2005).

Textiles

Textiles are both flexible and strong and possess specific properties in regard to light diffusion. These can be influenced through the choice of fibers and constructions such as yarn twist and weave density. When the light passes through the yarn, it is diffused due to the differences in refraction index between fiber material and air. Furthermore, the finishing techniques and the layout of the decoration can play an active role in the distribution of daylight in a room. Fabrics and also foils can be manipulated and decorated in various printing techniques and laser cutting to obtain different levels of transparency and diffusion.

Apart from its functional properties, textiles also have specific tactile, poetic and aesthetic qualities, which are linked to our early subjective emotions and bodily experiences. These experiences are at the same time collective and included in our common cultural references (Attfield 2000, Collet 2010). This aesthetic, technical, functional and cultural knowledge is the vocabulary of the textile design profession, and it is applied in our practice-based experiments.

New technology and materials

A literature study of new technologies and materials was carried out, including different types of window glass. Among other things we looked at Photo Chrome and Photo Luminescense pigments, which are activated by UV light, but found that these pigments were not suited for indoor screening, because most window glass have an integrated UV filter. Thermo Chrome pigments that react to heat were also investigated, but not found relevant, because at present they are only available in colors that change from darker to lighter – for our purpose the opposite was needed.

Also more sophisticated high tech products were evaluated eg. phase changing materials that can store and release heat. Used in a thin fabric this material needs to be close to the body in order to work, and to regulate room temperature it must be added in a large amount. Thus it makes good sense to use phase changing materials in walls, but not as threads in a thin curtain fabric. Another high tech material - photovoltaic foil - which transforms light into energy was studied, but abandoned, owing to the fact that two layers of window glass would lower energy harvesting considerably. We looked at several other high tech materials, which for various reasons did not suit our purpose – some also had an unacceptable impact on the environment if applied to mass production.

On this background it was decided to base the experiments on traditional textile techniques, new loom technology, new fibres, foils and 3D structures.

First experiments

The first series of experiments were carried out as flat horizontal sliding panels. This offered the opportunity to work with combinations of ornamentations and materials on different levels. The point of departure was the hypothesis that:

- It is possible to unite decoration and function in a new type of interior screen
- The optimal regulation can be obtained by combinations of materials with different properties regarding light diffusion, light transmittance and heat reflection
- It is possible to do this using two or more adjustable layers with patterns creating new visual impressions by combination

In order to limit the experiments, we used only white, grey and silver tones. Nine different materials were selected and printed or cut with five geometric patterns – all constructed from the same hexagon grid. The patterning consisted of different levels of transparency obtained by the use of different cutting and printing techniques. The patterns were designed to form an open and closed position in two or three layers – allowing more or less light in the room.
From the first 32 samples 14 were selected and tested in a 1:4 scale model of an office at Kolding School of Design. These first experiments mainly had the purpose of testing different materials and their patterning properties. The actual patterns were chosen as representative, with the intention to be perceived as relatively neutral and of no narrative connotation. The light was measured in the model at different positions and places in order to get a picture of the general distribution of light and glare. All combinations were documented with a digital camera during the process. The aesthetic appearance of each combination was discussed between the members of the team with reference to what was percieved as an overall pleasant distribution of light, relation of the patterns, proportions and materials.

Preliminary findings

There was a clear correlation between the visual impressions of the light distribution and the measurements. The decorative aspect clearly has to be further developed and structured into user surveys in connection with the further development of patterns.
The aesthetic results of some combinations could be described as poetic, delicate and fragile, both visually and in the fabric tactility. This was particularly linked to the devoré samples. Others were perceived as disagreeable, with hard pointed forms and too harsh contrasts when exposed to backlight. This effect was due to the pattern layout in combination with pigment or foil transfer printing, which shut out the light completely in the printed parts.
The experiments made it clear that the design of pattern, the choice of material and technique as well as the variation of backlight in daytime and artificial light in the evening poses a huge challenge, which is further complicated by the need for functional performance to distribute daylight and moderate the solar heating.
But the experiments confirmed the idea that textiles and other fiber based materials are diffusing the light and removing the glare, while the IR-reflecting foils reduce the amount of light considerably, but have no positive effect on the glare. The preliminary findings show that a combination of materials and several layers will be necessary for an effective screening.

The second series of experiments

On the basis of the first findings a new series of experiments were planned and carried out in 1:1 scale. The results were later tested in the office on which the 1:4 model had been based. Two or three layers can be combined in the commercial panel system which was applied. In this system the panels can slide horizontally and overlap.
As a point of departure for developing the new ornamentation, we chose three distinctly different pattern categories: *floral, textural and geometric* – all well known within the textile vocabulary (Meller & Elffers1999). The reason for this choice was partly a wish to establish a common frame of reference, which could be recognized by a wide group of users, partly to further investigate the visual and functional effect of combining two different materials with three different patterns in two or three layers.

Before selecting designs for printing the 1:1 panels, a relatively long sketching phase took place. Based on a visual analysis of historical documents a great number of different means of expressions were explored and brought into new designs. An on-going evaluation took place in the group, until finally three motifs were selected: One big flower with no repetition, one texture – opening gradually towards the top and resembling the surface of a melon, and one geometric repeat pattern with oval shapes in different sizes.

The three patterns were printed as devoré on a 'silver fabric' (woven with aluminized foil yarn) - and on a cotton/polyester fabric. Devoré is a printing technique that locally removes some fibers or aluminum from the fabric. In the finished fabric the printed pattern will show as more open areas with enhanced transparency and translucency.

On three sunny days in July we registered 14 combinations with a digital camera. And in order to find out to what extend the screening could reduce the solar heating, we also used a thermal camera. To measure the room temperature two digital thermometers were placed in the window and next to the computer on the working desk. The illumination was measured at five different places in the room in order to evaluate the distribution of light.
At this point, we have not yet had the opportunity to compare and analyze all the measurements and the variation of aesthetic expressions in the 14 combinations, but some preliminary conclusions can be drawn.

Results from the second series of experiments

The measurements show that a gradation of the pattern, from more closed in the lower part to more open in the upper part, clearly helps to get more daylight into the inner parts of the room, while screening the space near the window.
The pictures taken by the thermal camera show that the number of layers and the distance between them is more important than the type of material, although it was expected that the metallic fabric would have a higher level of heat protection than the white cotton/polyester fabric. The influence of the densities in the fabrics was also visible on these photos – e.g. the devoré patterns were clearly discernable as hotter parts.

One immediate observation also was that the exclusion of color seemed to make it difficult to remember the various combinations, even though they were in fact very different. This suggests a wider focus in future research experiments, raising the question on the role of color and memory. This observation along with a hypothesis on textile genre identification will be tested in the future on a group of potential users.

Woven fabrics

While the first two series of experiments were based on commercial fabrics with a limited choice of densities we have also initiated investigations into design of new woven qualities based on the experiences and results from those. This implies working with different weave constructions, density and yarns. These experiments were made by hand weaving on a computerized 24 shaft loom and on the new EasyLeno machine loom at Lindauer Dornier in Germany.
The hand woven samples tested different yarns and densities concentrating on flame retardant polyester and newly developed fibers with special light diffusing properties from the companies Trevira, Torcitura Padana and Teijin. The filament yarns of polyester were without pigmentation, allowing a maximum of light transmission but with a high degree of diffusion due to the new shape of the cross section. Fibers of PLA (Linnemann, Harwoko & Gries 2003) and viscose FR were also included.

These investigations are strongly linked to a topic, not touched upon in this article, namely the legislation on flame retarding materials in public buildings, and our goal to create more environmentally friendly and sustainable solutions for interior screens. The devoré technique demands two different kinds of fibers, and it is not possible to combine flame retardant polyester with other types of flame retardant fibers in order to make a fabric suited for devoré without loosing the flame retardancy. In order to obtain different levels of transparencies imitating devoré, most of the hand woven samples were aimed at decoupure patterns, where the differences in density are obtained by cutting away floats on the surface.
The hand woven samples were generally too small for any practical tests and have mainly been used for visual and aesthetic evaluation, particulary of the new PLA fiber Biofront from Teijin, these samples will serve as inspirational material for later developments on a machine loom.
The machine woven samples were on a larger scale and could be tested. The EasyLeno was chosen because of its ability to control the density of the fabric from very open to very dense without loss of stability. The changes in density could however only be achieved in horizontal stripes mimicking the Venetian blinds. Recently the EasyLeno® MultiPattern loom has been developed, this combines EasyLeno® technology with Jacquard technology thus allowing many more pattern variants.

Parallel experiments

Parallel to the experiments with the adjustable flat panels, we have explored designs in deployable structures and tilted honeycombs, made of woven and non-woven materials. The tilting of the honeycomb or the folding makes it possible to screen for oblique and low sunlight, which is prevalent in the Northern hemisphere. Daylight is conducted towards the ceiling and a view to the outside is at the same time possible.
This has widened the perspectives and some of the 3-D structures have shown promising potentials in screening for heat and glare. The first full size prototypes have been made in a flexible and diffusing non-woven material, decorated with a heat reflecting printed pattern. Next step is to test the prototype in an office and to measure if it brings about the desired heat-reduction and fulfill the theoretical calculation in relation to diffusing and directing the light.

Discussion

In this project technology and materials have been considered the means to solve a problem mainly with mass production in mind. Pleasant light diffusion, minimizing heat, functionality and sustainability has been the core issues. Developing acceptable aesthetic expressions for a large group of office users with different taste have also played a central role in our aesthetic considerations, allthough this aspect still remains to be tested.

We have chosen this approch from an environmental point of view, because we believe it is important to create simple solutions that can help cut down energy consumption in office buildings as soon as possible. Other designers and architects are also working with sustainability in mind e.g. including solar cells in curtains (Astrid Krogh 2009, Sheila Kennedy 2008 and Carolin Müller 2005). These projects are concerned with harvesting energy from daylight to power electrical appliances or to make the curtain an artificial light source, which is a different approach than ours.

This type of research is important in order to investigate upcoming technology, challenge the way we think and push textile innovation. A challenge to which Textile Future Research Group, University of the Arts, London and Smart Textiles Innovation Center, University of Borås, are also making important contributions.

References

Attfield, J. (2000). *Wild Things – The material culture of everyday life*. Oxford: Berg.

Brett, D. (2005). *Rethinking Decoration – Pleasure & Ideology in the Visual Arts*. New York: Cambridge University Press.

Christoffersen, J., Petersen E., Johnsen K., Valbjørn O & Hygge S. (1999). *Vinduer og dagslys – en feltundersøgelse i kontorbygninger*. Hørsholm: Statens Byggeforsknings-institut (SBI-Rapport, 318).

Collet, C. (2010). *Poetic Textiles for Smart Homes* [Online]. Available at: http://www.carolecollet.com/portfolio/ carole_collet.html [Accessed 7 May 2010].

Fermoso, J. (2008). *MIT Lecturer Develops Solar Textiles, Redefines Curtain Function* [Online]. Available at: http://www.wired.com/gadgetlab/2008/06/mit-lecturer-de [Accessed 7 May 2010].

Figueiro, M. G., Rea, M, S., Stevens, R. G. & Rea, A. C. (2004). Daylight and productivity - A possible link to circadian regulation. *Light and Human Health, EPRI/LRO 5th International Lighting Research Symposium* pp. 185–193. Orlando Florida November 3-5, 2002. Palo Alto, CA: The Lighting Research Office of the Electric Power Research Institute.

Krogh, A. (2009). *Suntiles* [Online]. Available at: http://www.astridkrogh.com/html/suntiles.html [Accessed 7 May 2010].

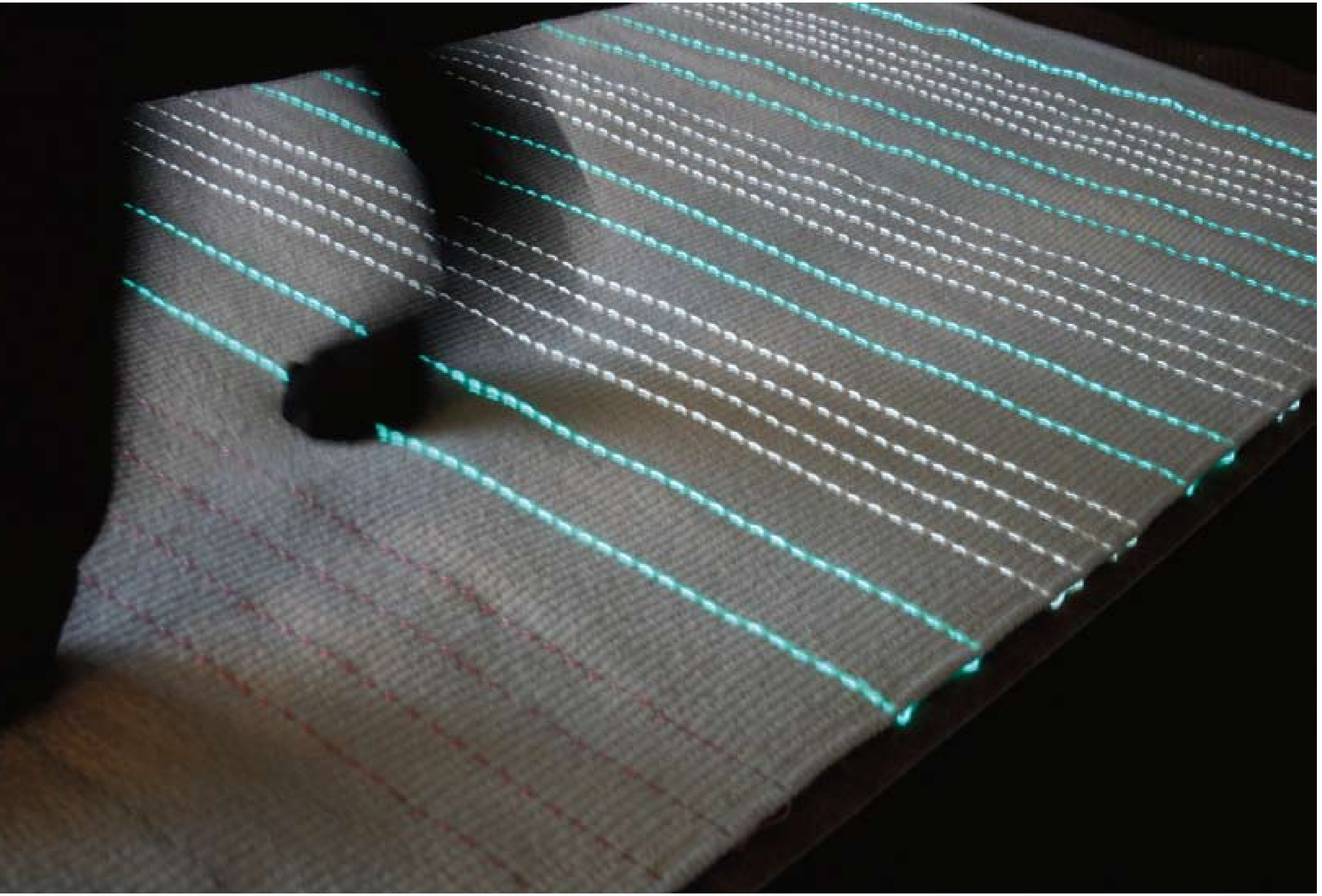
Linnemann, B., Harwoko, M. S. & Gries, T. Polylactide fibers (PLA). *Chemical Fibers International*, vol. 53, December pp. 426-433.

Meller, S. & Elffers, J. (1991). T*extile Designs, Two Hundred Years of European and American Patterns for Printed Fabrics*. New York: Harry N. Abrams.

Müller, C. (2005). *Energy Curtain - a self-sustaining curtain using photovoltaic technology to light up optical fibres*. Master Thesis, The Swedish School of Textiles, University College of Borås. [Online]. Available at: http://www.tii.se/static/papers/The Energy Curtain_Master Thesis by Carolin Mueller 1.pdf [Accessed 7 May 2010].

Osterhaus W.(2009). *Design Guidelines for Glare-free Daylit Work Environments*. 11th European Lighting Conference LUX Europa 2009. [Online]. Available at: http://www.thedaylightsite.com/filebank/W_Osterhaus_LUX_Europa_2009_Design_Guide_Glarefree_Work_Environments_Final.pdf [Accessed 7 May 2010].

Traberg-Borup, S., Grau, K. & Johnsen, K. (2005). *Effektiv belysning i kontor og erhvervsbyggeri - En undersøgelse i ni kontorbygninger*. Hørsholm: Statens Byggeforsknings-institut.



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In the making - designing with smart textiles

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Abstract

The past decade has seen an increasing interest in our small-scale experimental textiles at the design lab at the Swedish School of Textiles. Representatives from various industries and professions have visited to find out more about our so called smart textiles and to collect product samples. We want to encourage designers to work directly with the textile material in the design process to enlarge the understanding for how to design with smart textile materials. Weand we are currently working to develop a collection of samples of smart textile sample collection´s for designers to use and work with, enabling them to better understand the great potential of smart textiles. This article also describes some new design variables regarding dynamic textile patterns; a result from the thesis *Designing Dynamic Textile Patterns* (Worbin 2010).

Key words: Textile design, smart textiles, dynamic textile patterns, design variables

During the industrial era, modern society turned craftsmen into designers and specialists on different segments in the process of making an object. In comparison to the craftsman, a modern day designer may grasp the process from fibre to yarn, but a designer typically has no first hand experience with the material itself. In 1947, the textile designer and artist Annie Albers saw a justification for craftmanship in textile design and through that emphasis on craftmanship a bringing back of the contact with the material to strengthen textile expressions both aesthetically and functionally. She said that "the material itself is full of suggestions for its use if we approach it unagressively, receptively. It is a source of unending stimulations and advises us in a most unexpected manner" (Albers 2000).

In the autumn of 2010 I met the head of a German electronics company that produces electronic components for wearables, e.g. an integration of light and energy supply for clothing. He told me that a well known fashion house wanted to order a "test kit" and use it in their new collection. The fashion designer did not come up with a new design from the test kit (that merely showed a few possibilities) but they wanted the kit just the way it was because they did not know how to design with and for the new possibilities.

Just like Albers suggested more than 50 years ago there is still an urgent need to work directly with a material to be able to develop it. A need that has grown even more pressing today, as there is a fundamental shift in what textiles may express and how they may function with the introduction of electronic and information technology into the textile field. A few introductory examples of experimental prototypes merging new materials, textiles and electronics can be found in project E-broidery: Design and fabrication of textile based computing (Post et al. 2000).

The design lab at The Swedish School of Textiles have been hosting a variety of projects looking into smart textile structures with qualities such as color change, conductivity and light emittance. Textiles have been used for example to produce or design with heat, show information, light up when dark and to leave traces from someone's steps etc. (Worbin 2006, Dumitrescu & Persson 2008).

Materials that can sense and react on the environment has been described as smart due to their "smartness" and are classified in three categories; passive smart, active smart and very smart materials by Tao (2001). Ever since, the smartness in smart textiles has been a matter of the materiality united within a textile construction. A textile pattern that shows different aesthetic expressions over time is called a dynamic textile pattern (Worbin 2010). One example is a pattern that initially appears to be striped changes a moment later to appear chequered instead. This exemplifies a kind of textile pattern that needs to be designed differently compared to traditional "static" textile patterns that are designed to keep a given expression over its planned life span.

From a textile designer´s perspective, there is a big difference to designing a textile using materials that may change their expressions over time compared to designing a static textile pattern. That is why personal experience of the material is preferred. Aside from the design possibilities, another challenge is the eventual connection to and integration of electronic components. Textile designers and electronic engineers suddenly developesdevelops a need for collaboration, however not regarding the creation of the machinery. Instead, they need to collaborate on how to program a textile to sense and react upon different situations and applications. A personal experience could be described as the need for a "new modern craft" that can merge textiles, electronics and information technology. However, the conditions within the fields of textiles and electronics contradict at the moment: e.g. the products of one needs a washing instruction while products from the other should not even be exposed to moisture. It is hard to bring electronic wire/yarn into industrial production for several reasons, one of which is a global economy where industrial production mainly supports standardization, low prices, production capacity, etc. which has forced industrially produced textiles into what seems to be a dead end.

In hand looms the weft creates a textile by turning the yarn at the edges and continuing to build up a woven structure in an unbroken manner. Industrial weaving machines most often cut the yarn at the edges, creating a textile that resembles several single straws creating a textile structure, resulting in one cut length for each inlaid. With regard to the intregration of an electronic or lightning system this fact limits the potential use of industrial weaving techniques. Thus it would make sense to work with these smart materials in a hand loom when beginning the search for new smart textile materials and production facilities.

There are of course other techniques than weaving that are suited for merging electronics with textiles, but as was mentioned before, there are strong limitations which are related to our present textile industry and its current manner of production. We need to see textiles from a new perspective and here a new modern craft will play a crucial role for a possible new field of textiles that may eventually merge electronics and information technology.

Even the imprint of time is changing when it comes to smart textiles. It is no longer only a question of when and where something is made and for how long it will stay trendy. Today time is a central design variable regarding dynamic textile patterns. A designer needs to handle traditional form and color variables in relation to the design variable time.

The time variable relates to temporal and spatial conditions and can be identified and developed by answering these questions:

What initiates change?
When does change appear?
Where does change appear?
Why does change appear?

Answering these questions should be done with respect paid to design methodology, design techniques and material choices. Also whether the change should be considered a reaction to manual or digital stimuli is an important factor for the final expression and use.

Aesthetics and function

In a dynamic textile pattern the aesthetic expression and the function can be bound together in a way that is not possible in more traditional "static" textile expressions. The merging of textiles and information technology (Redström, Redström & Maze 2005) opens up for new scenarios and uses where information are the building blocks for aesthetic expression and the other way around, i.e. in a way having the aesthetic expression function as a textile interface, "displaying" information. Today, technology supports textiles that can be handled as soft hardware and we may subscribe to new aesthetic expressions, instead of changing the actual textile object.

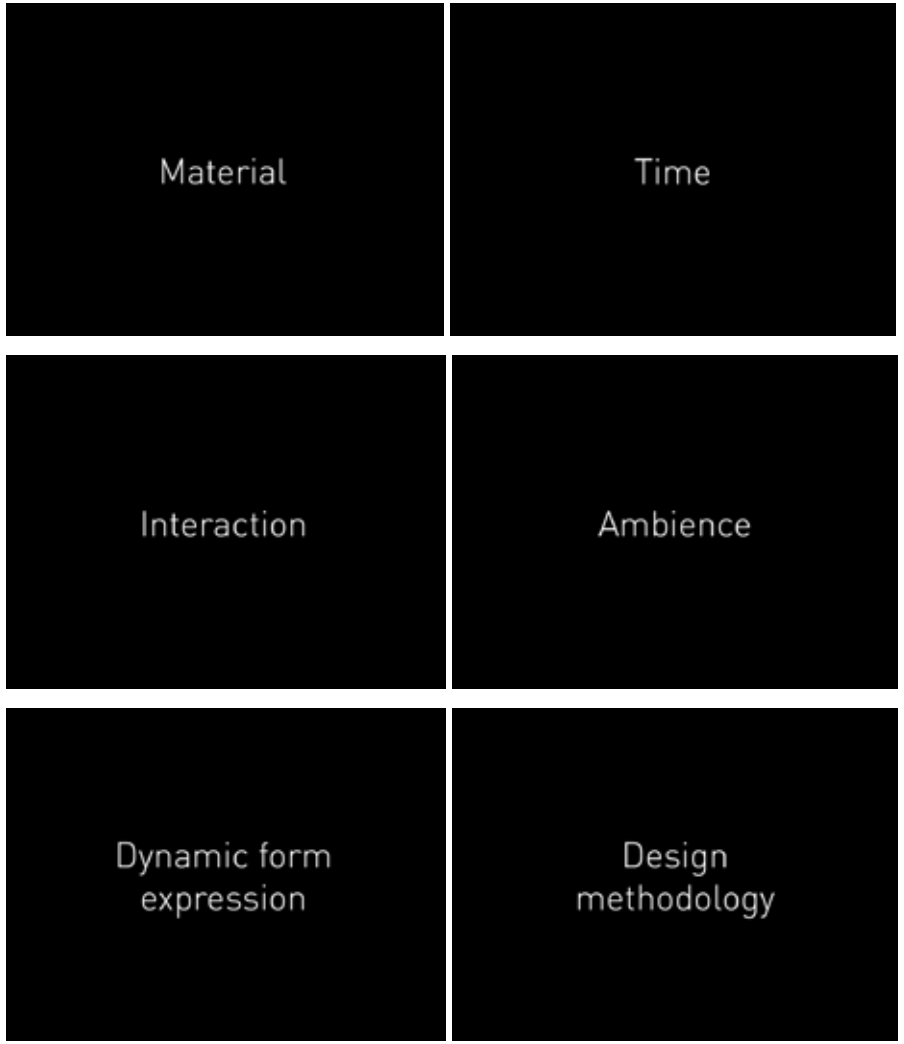
Collection of smart textile samples

Today it is quite hard and expensive to acquire a small quantity of smart textile materials. Also, one may succeed in acquiring the material/yarn/wire/chemicals and find oneself devoid of the facilities required to make a textile out of it.

In the collection we are creating qualities such as;

- color changing textiles (due to temperature or light conditions)
- lighting textiles (light transporting and emitting textiles, etc.)
- conductive textiles (for example to be used as sensors, heat emittors or for transporting electricity).

To begin with the collection will be made to meet industrial requirements and limitations, to spark a discussion and to make users see the actual textile material more as a design tool. By creating a collection of smart textile samples a possibility will arise for other disciplines to work with the smart textile materials. The goal is to collect feedback on how these new textile qualities can be used. The aim is to further developed the textiles for different areas and for a variety of applications. We want to know if smart textile materials will gain from being developed from a more craft based perspective in the next phase.



Example of dynamic design variables regarding dynamic textile patterns

References

Albers, A. (2000). *Anni Albers. Selected Writings on Design.* Middletown, CT: Wesleyan University Press.

Dumitrescu, D. & Persson, A. (2008). Touching loops. Interactive Tactility in Textiles. *Proceedings of Futuro Textiel*, pp. 95-100. Kortrijk, Belgium 13-15 November 2008.

Post, E. R., Orth, M., Russo, P. R. & Gershenfeldt, N. (2000). E-Broidery: Design and fabrication of textile based computing. *IBM Systems Journal*, vol. 39:3/4, pp. 840-860.

Redström, M., Redström, J. & Maze, R. (eds.) (2005). *IT+Textiles*. Helsinki: IT Press.

Tao, X. (ed.) (2001). *Smart fibres, fabrics and clothing*. Cambridge: Woodhead.

Worbin, L. (2006). *Dynamic textile patterns, designing with smart textiles*. Lic. thesis. Department of Computer Science and Engineering, Chalmers University of Technology and The Swedish School of Textiles, University of Borås.

Worbin, L. (2010). *Designing Dynamic Textile Patterns*. Ph.D. Thesis. The Swedish School of Textiles, University of Borås.

Exhibitions Review

Since 1992, Annie Andréasson works as a journalist at the Communications Office at the University of Borås, specializing in covering the areas of textiles and design.

Integrity Nature-Creature-Culture

June 5th 2010 – September 5th 2010 at the Museum of Textile History, Borås

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Museum of Textiles, Borås, Sweden

Additional images from students personal archives

Smart design for integrity. Clothes to hide away in, garments that protect from extreme cold or textiles purifying water. The exhibition Integrity is the result of a project by twelve Master students in Design, Textile Technology and Textile Management. They have travelled to widely varying places in the world to develop their ideas and find new areas of application for smart textiles.

According to the Swedish National Encyclopedia (Nationalencyklopedin), the word Integrity is synonym to inviolability, i.e. the right of any individual to have his personal character and inner sanctum respected by others. The students' objectiv was to develop smart textiles that would strengthen integrity in places where it is not self-evident and include artistic and scientific perspectives in the results. The students were divided into three groups, who went to the shanty towns of Kampala, the cold and barren Svalbard, and crowded down-town Tokyo.

Culture: city environment and integrity

- We began by thoroughly reading up on Japan, anything from culture, philosophy, lifestyle, traditions, technology, and fashion. Then we compared Western/European culture with Asian/Japanese, says Marta Kisand, who belonged to the group who went to Tokyo.

Marta is a Master student in Textile Design and has worked together with Anna Lidström (Master in Fashion Design), Eleonor Johansson, and Katja Schmitz (both master students in Applied Textile Management). Working from the ideas they came up with they developed a collection of innovative garments on the concept "hiding and seeking – creating or sharing space/communicate".
- We chose to focus on how we could help people acquire their "own space", since Tokyo is one of the most densely populated cities in the world. It was the most interesting topic to work on, especially because Scandinavia, where we all are studying at the moment, is one of the least crowded areas in the world. I find it very exciting to work on extreme topics, says Marta Kisand and continues:
- Westerners define themselves as "I" but Japanese define themselves as "my share of the shared space between us". Also belonging to a social group (family, friends, etc.) is very important in Japan, in contrast to Western people, who are very individualistic.
She says that the collection mainly is a tool to investigate social relations in a crowded city environment. Despite the earnestness behind the garments, they have the feel of having been drawn with a humorous twinkle in the artist's eye – and sure, we all need that joy to feel good and appreciate personal integrity.

The Black Air Dress

For the Black Air Dress and its white counterpart White Air Dress the group was inspired by inflatable life-jackets. Inevitably, I am also reminded of Yin and Yang. Anyway, by the release of gaseous carbon dioxide, the collar or back of the dress is inflated to form a pillow. This allows the wearer to lean against a wall or another person to rest while waiting for the train or the arrival of a friend. The white dress also lights up to invite other people to use the pillow.

– We did several garments with inflatable parts. The idea behind inflatables is philosophical but also very practical. In the Western world space between objects or air is so called "nothing". But in Japanese culture the space between objects is perceived and also named. We did garments which are made of "nothing" for the Western world, but are made of "something" for Japanese culture. Some people get very stressed in a crowded space. The concept of our inflatable garments helps create instant private space around you, says Marta Kisand.
Black Air Pants share the same concept but here it is the hind section that inflates, allowing you to sit comfortably wherever you are, even on the hardest of surfaces. The Red Thermo-Chromic Dress is made for anyone who loves company as it has room for two. Another fun detail is that the love-red dress is printed with a pattern that is thermo-chromic, i.e. it changes color when it comes in contact with the body. Strips of textile from the dress are displayed in the exhibition, allowing visitors to try out the various color combinations available.


Culture
PLEASE
SLOW
DOWN

Bookshelf

Marta Kisand's personal favourite is the bookshelf dress.
– It is a bit absurd to dress oneself up as a bookshelf, but then again it actually worked out well. We had fun testing it in Tokyo.
Marta Kisand is grateful to have been a part of the project and for her group being allowed to develop their concepts all the way through.

Their Bookshelf Dress is made for anyone who wants to hide away in their surroundings. Using a sound sensor the dress can even tell when there is too much invasive noise around it, at which time some of the books light up, displaying the words "Please", "Slow", "Down". The words are placed in various places in the bookshelf so as not to provoke the surrounding world too much but simply ask for something that should be obvious to one and all. A row of image sequences shows the visitor how Japanese people reacted to the garments in Tokyo: on the subway, in the streets, in alleyways and stores. The Bookshelf dress can be said to have been well received. When it leans against a post a man in a suit hurries past it without even noticing it and the same happens when it is squeezed in an alleyway.

– It is of immense value to have been able try to our prototypes in extreme conditions. Most school design projects are very theoretical and very rarely tested. We also had several discussions with Japanese people about our collection and the theme crowdedness in general.
At the exhibition in Tokyo we had questionnaires, where we asked people how they feel about crowdedness and how they deal with it. We ask the same questions in the Swedish exhibition. We hope to get opinions about crowdedness from the one of the most and from one of the least crowded areas in the world. It will be interesting to compare the opinions of those different areas.
The five garments are displayed to the public at the exhibition.

Nature: pollution and integrity

Water is the single most important factor of our survival. It is something we take for granted, while many developing countries such as Uganda are faced with increasing shortages of usable water. They need the water for their personal integrity but also that of for their countries. Producing drinking water became the mantra of the group, who went to the polluted shanty towns of Kampala. Their solution to the problem was to focus on the use of an unlimited natural resource, such as sunlight or rain water. In the exhibition, two screens display onsite interviews with different people shedding light on the drinking water problem. For example, a man who explains how the people of Kampala is supplied water today and a woman showing her outside tank collecting rain water.
Between the interviews are sequences showing large garbage heaps beside a brownish stream of muddy water, from which the local population draws their drinking water. On the other screen, the group displays their solution to the problem: a fabric that purifies water.
It is a smart textile made up of three processes: water collection, storing, and cleaning. The waterproof fabric collects rain water from an adjacent roof and drains it into a tank. The water is then stored in the tank, which has a textile that acts as a germicide when it is exposed to sunlight, i.e. UVrays and heat. The textiles used by the group are made by F.O.V. Fabrics AB and were developed by the group on site in Uganda. The group consisted of Sarah Torkelsson, Marina Rehbein, Jeannine Han, and Shufei Wang.

Human being: living conditions and integrity

In sharp contrast with the heat in Uganda is the arctic cold of Svalbard, which was the destination for Laura Clausen, Cecilia Elf, Emma Jönsson, and Anna Madella. The point of departure of their work was the extreme weather conditions and the great variations between periods of light and dark. Other important notions were safety and function, which are evident in the exhibited prototypes. Their focus is on practical products that save lives. Safety Shelter is a mobile home where everything is combined in one product: coat, mattress, sleeping bag, and wind shelter. The idea is for everyone to have an inflatable "home" that is easy to use for homeless people and victims of natural disasters. The material is windproof and waterproof ripstop coated in aluminum. The fabric protects the user from cold, while keeping the body heat in. The outside of the tent has a thermo-chromic exclamation mark that glows in the dark. It makes the pigment change color when temperatures drop below 8°C (46°F). The group also developed both a mobile home for expeditions that combines a sledge with a tent and a portable wind shelter. In all modesty, the undergarments made to look like a traditional Icelandic wool sweater may however be the most important. Using electrically conductive yarns on the body parts, where heat is most needed when the body is being cooled down, makes it easier staying warm. It also contains sensors registering body temperature and blood pressure. The group explains that their goal is to have the sensor send SOS signals if e.g. the wearer's registered blood pressure is too low.

In perspective it is clear that all three student groups have adopted the keyword integrity into their ideas of the future of smart textiles. They display widely differing solutions to widely varying problems with a common denominator: integrity. The audience visiting the exhibition at the Museum of Textile History during the summer months received it very well and it is considered a success, much owing to some parts of the exhibition inviting the audience to pause and think again. In defiance of a complex topic the students', often unusual, approaches show that it is possible to penetrate and make sense of it. Smart textiles can do good and help change. All we have to do is dare to leave our traditional trains of thought and think outside the box.

A book about the project Integrity, can be ordered by Proteko. CTF Publishing € 15 ex vat & shipping.
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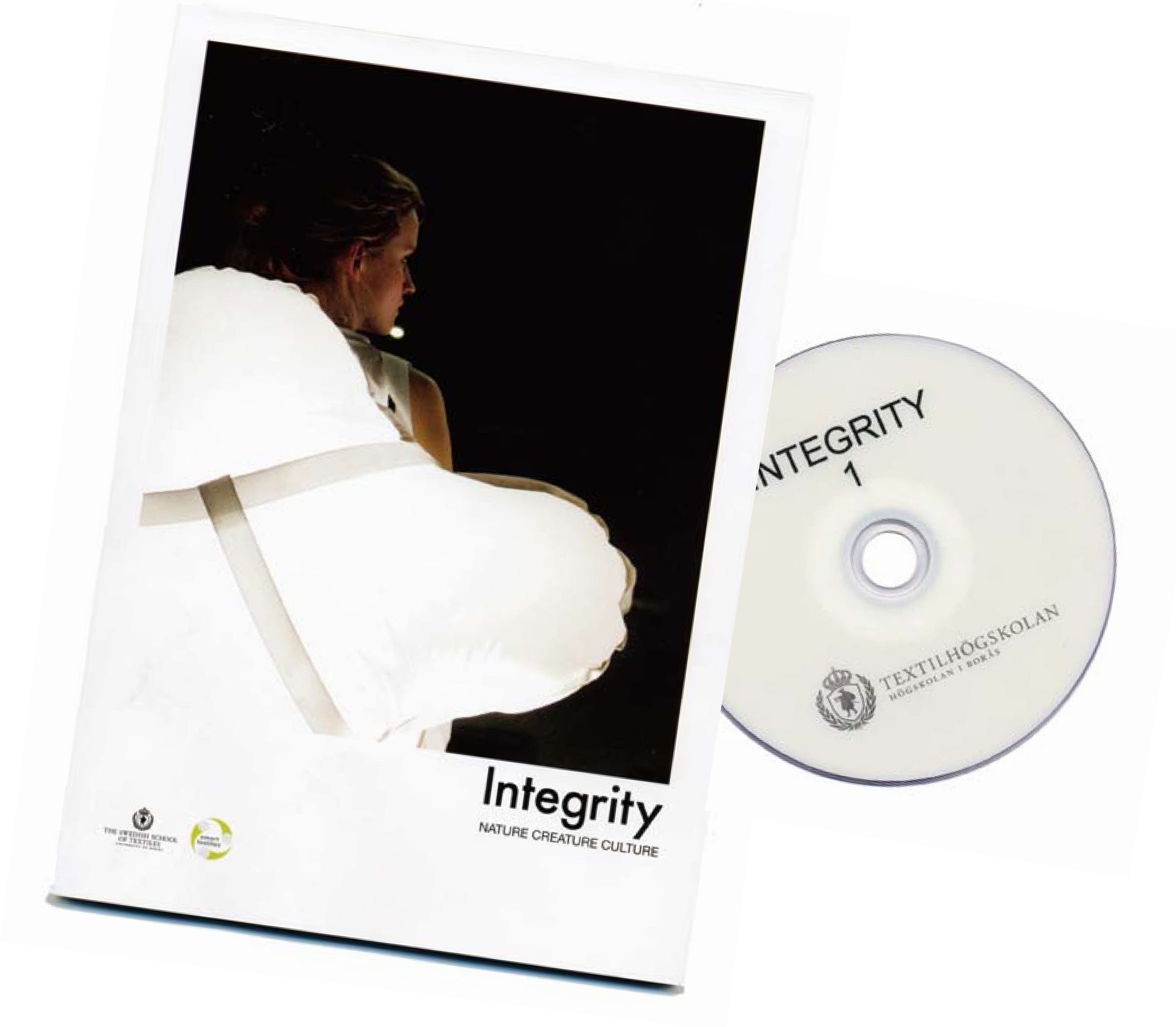

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Electroactive textile fibers produced by coating commercially available textile fibers with conductive polymer

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Abstract

The development of electrically conductive fibers, exhibiting higher mechanical properties and their integration in smart and interactive textiles, has become a prominent research area throughout the world. Smart textiles have increasingly been used in medical, sports and military applications. In other words, we can say, smart textiles are going to shape our future. This paper describes our ongoing research in which, we have produced relatively highly conductive fibers by coating commercially available textile fibers (viscose, polyester) with conductive polymer, poly(3,4-ethylenedioxythiophene) (PEDOT). A novel coating technique, called oxidative chemical vapor deposition (OCVD), was used for this purpose. Different testing and characterization techniques were then employed to investigate electrical, mechanical, thermal, and surface properties of PEDOT coated fibers. The surface modification of electrically conductive textile fibers with silicone resins is also discussed and an analysis is given to show how silicone coating enhances the mechanical as well as hydrophobic properties of coated textile fibers.

The obtained PEDOT coated textile fibers showed good electrical as well as mechanical properties. From this research, we can easily select the most appropriate type of fiber according to the specific electronic application, exhibiting the required end-used properties. These conductive fibers could also be used as substrates for heat generation devices, such as solar cells, and organic fuel cells.

Keywords: Electroactive textile fibers, conductive polymers, OCVD coating technique, fibrous solar cells

1. Introduction

Electroactive textile fibers and fabrics will be the key component of the smart and interactive textiles that will be used in the future, and they feature widely as power and signal transmitters in many potential applications such as sensors (Bowmaker et al. 2005), sports and military garments, motion capture devices (Lorussi et al. 2004), electrotherapy (Oh et al. 2003), ECG measurements (Rattfält et al. 2007), pressure sensors (Rothmaier et al. 2008), and photovoltaic devices (Bedeloglu et al. 2009). Different kinds of wearable computing devices have been developed to date by integrating metallic wires and carrying electronic devices that make these garments heaver and uncomfortable for daily uses (Meoli & May-Plumlee 2002). Electrically conductive fibers having good electrical properties could be an alternative of metallic wires in wearable textiles, which can transmit the signals as well as maintain the comfort level same as that of common textiles. Also the woven structure of these conductive fibers could be used for different applications such as pressure and stretch sensors.

Electrically conductive fibers could be produced by different techniques such as by incorporating metallic fibers in commercially available textile yarns, by melt spinning and wet spinning of conducting polymer with thermoplastic polymers, by coating textile and polymer fibers with carbon powder, metallic powder or conjugated polymers (Okuzaki et al. 2009, Pomfret et al. 2000). In order to enhance the adaptability and processability of conductive fibers in different applications, they should have good electrical properties, mechanical properties, enough flexibility, better hydrophobicity, and resistance to different acids. The fibers produced by above mentioned techniques have some problems concerning mechanical and electrical properties. It is quite difficult to introduce both of these properties in conductive fibers by conventionally used techniques.

During the last decade, several research groups have tried to produce highly conductive fibers without integrating any metallic content. For this, intrinsic conductive polymers (ICPs) are good choice because they have been used in several useful electronic applications (Otero and Cantero 1999, Bouzek et al. 2001, Gerard et al., 2002, Dall'Acqua et al., 2004, Breslin et al. 2005). Commercially available textile fibers, such as, viscose, polyester (PET), nylon, have very good mechanical properties and conductive fibers based on these textile fibers should also have good mechanical properties. So, very interesting approach to transform commercially available textile fibers into electroactive fibers is to coat them with conjugated polymers by the oxidative chemical vapor deposition (OCVD) technique. It is a solvent-less technique which has been used to form thin layers of conjugated polymers on a variety of substrates (Hong et al. 2005, Lock et al. 2006, Xia and Yun 2008). Among the large number of ICPs, PEDOT has received considerable attention by scientists because of its good environmental stability and its application in different fields such as EMI shielding, heat generation, light emitting diodes, and chemical sensors.

In this article, we have summarized our ongoing research in which, we are trying to produce textile based electroactive fibers having good mechanical, thermal, and hydrophobic properties. We have produced electrically conductive fibers by coating commonly used viscose and polyester (PET) fibers with highly conductive conjugated polymer, poly(3,4-ethylenedioxythiophene) (PEDOT). The technique, which we have used for this purpose, is oxidative chemical vapor deposition (OCVD). We will give short explanation of all steps which we have covered to date. We aim to use these obtained fibers in different medical and energy generation applications (fibrous solar cells).

2. Experimental

2.1. Materials

We selected two types of yarn fibers, (a) viscose (1220 dtex 720, No. of filaments, Z100 twist/meter) purchased from CORDENKA®, (b) polyester (2200 dtex, No. of filaments 210, without twist) purchased from Performance Fibers. In the OCVD polymerization, we used 3,4-ethylenedioxythiophene (EDOT) monomer (CLEVIOUS® M V2), ferric (III) chloride ($FeCl_3$) (Sigma-Aldrich, 98%), and butanol (C_4H_9OH) (Aldrich, 99%) solvent. For surface modification, we used thermoplastic silicone elastomer (GENIOMER® 80) purchased from WACKER and methyl ethyl ketone (MEK) ($C_2H_5COCH_3$) from Fisher Scientific. All of these materials were used without of any further modification.

2.2. Production of PEDOT coated viscose fibers

Initially, we had selected viscose yarn fibers for our experiments because viscose has supportive chemistry (excess number of –OH groups) to make strong bonding with conjugated polymers. The schematic diagram of setup, which we had developed for our experiments, is shown in Fig. 1 (Bashir et al. 2010c). The detailed process description has been explained in our previous publication (Bashir et al. 2010d). In short, viscose fibers cut into 150 mm length, first pretreated with oxidant ($FeCl_3$) solution. Oxidant solutions were prepared with variable concentrations (3 wt. % to 15 wt. %) in butanol solvent. The oxidant treated viscose fibers were dried at room temperature and were then introduced in tubular reactor, shown in Fig. 1. In tubular reactor, EDOT (3,4-ethylenedioxythiophene) monomer vapors were introduced from separate flask along with nitrogen gas. During the passage of EDOT monomer vapors from tubular reactor, the polymerization reaction was started immediately at the surface of viscose fibers and a smooth, thin, and darkish blue layer of PEDOT was deposited on the surface of viscose fibers. PEDOT in un-doped form shows relatively lower or no conductivity, so PEDOT coated viscose fibers were again treated with a dopant solution. We used $FeCl_3$ solution again as dopant. The polymerization and doping mechanisms of PEDOT on surface of viscose fiber, is shown in Fig. 2 (Bashir et al. 2010b).

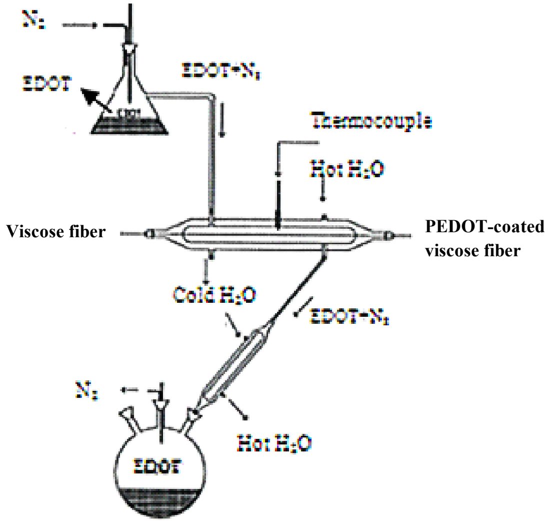

Figure 1. Schematic diagram of setup used for OCVD polymerization of PEDOT

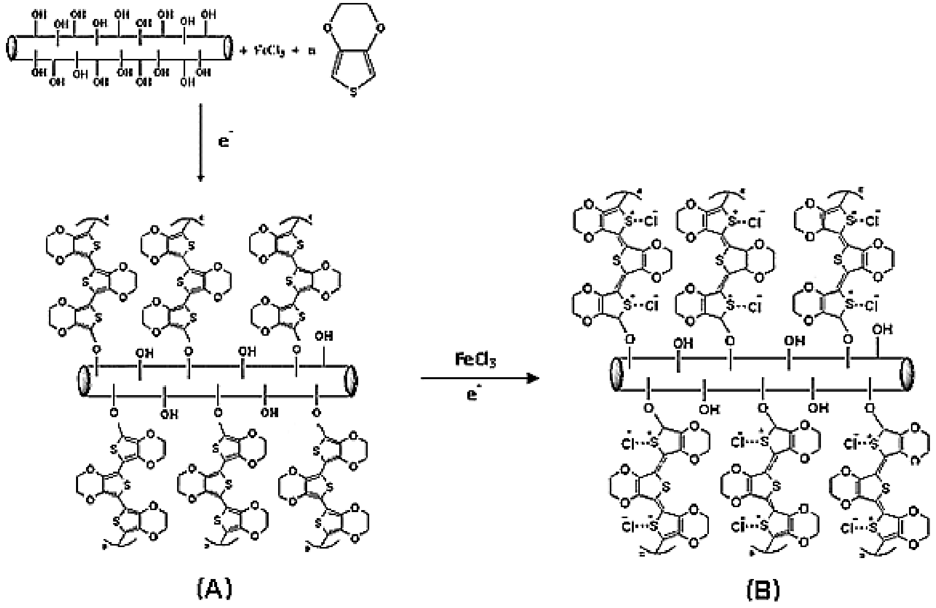

Figure 2. OCVD polymerization mechanism on viscose fiber, (A) Oxidation of EDOT to PEDOT, (B) Doping of PEDOT with FeCl3 dopant solution

In this study, we investigated the effects of different reaction conditions, such as, oxidant concentration, dipping time of viscose fibers in oxidant (FeCl3) solution, drying time of oxidant enriched viscose fibers, and reaction time, on electrical, mechanical and thermal properties of PEDOT-coated viscose fibers. The effect of these variables on surface resistance of PEDOT-coated viscose fibers is shown in Fig. 3 (Bashir et al. 2010d). The polymerization of PEDOT layer on viscose fibers was justified by scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FT-IR), and thermogravimetric analysis (TGA), which is shown in Fig. 4 (Bashir et al. 2010d). The effect of oxidant concentration on electrical and mechanical properties of viscose fibers is given in Table. 1. It was concluded that maximum conductivity can be produced at 15 wt. % oxidant concentration i.e. 14.2 S/cm but mechanical properties were reduced a lot at this concentration.

Figure 3. Effect of reaction conditions on surface resistance values of PEDOT coated viscose fibers

Figure 4. SEM micrographs at [(A) 0 wt. %, (B) 3 wt. %, (C) 5 wt. %, and (D) 9 wt. %], FT-IR analysis [(a) 3 wt. %, (b) 5 wt. %, (c) 9 wt. %, and (d) 15 wt. %)], and TGA analysis of PEDOT coated viscose fibers

Table.1. Effect of oxidant concentration on electrical and mechanical properties

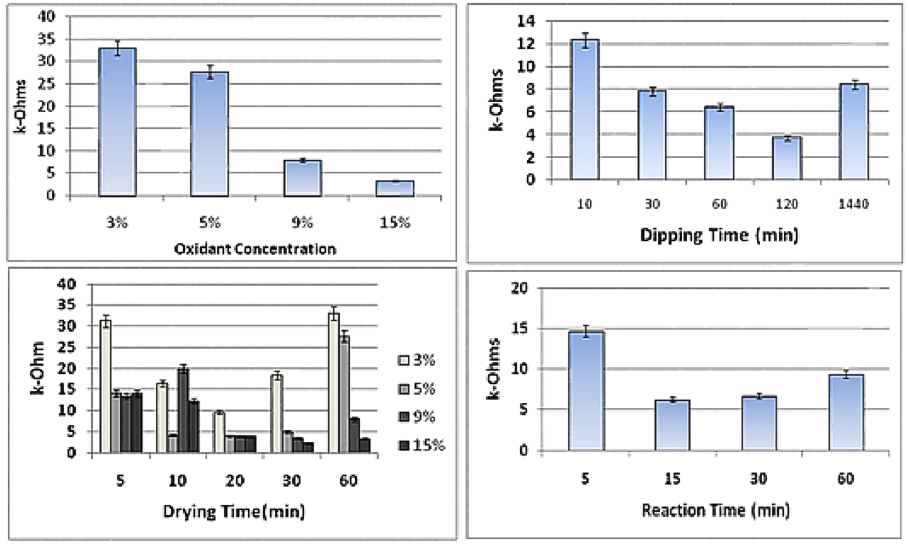

Fig.3

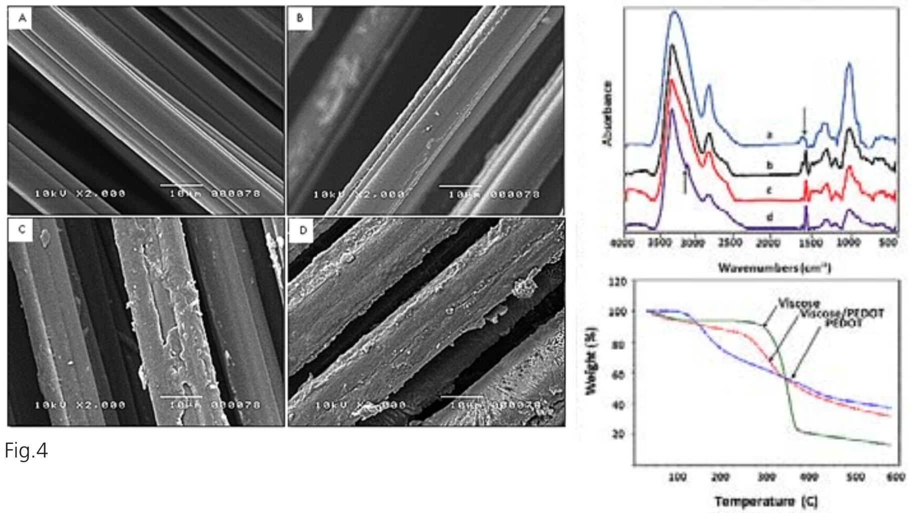

Fig.4

Table. 1

Oxidant Concentration (wt.%)	Surface Resistance (kΩ)	Conductivity (S/cm)	Max. force at break (N)	Tenacity (N/tex)
0	…….	……..	65 (±3.3)	0.351
3	18.4	1.85	41 (±1.4)	0.21
5	5	6.81	34 (±1.3)	0.18
9	3.5	9.74	32 (±1.9)	0.16
15	2.4	14.2	26 (±2.1)	0.13

2.3. Production of high performance PEDOT coated PET fibers

From our initial experiments, we found the most suitable reaction conditions at which we can achieve at least maximum electrical properties. But for integrating these electroactive fibers in smart and interactive textile applications, mechanical properties should also be required along with good electrical properties. So, we selected polyester (PET) fibers having higher mechanical properties and different chemistry than viscose fibers. We used same reaction conditions at which we had achieved maximum electrical properties and same experimental setup while using viscose fibers. From experiments, we concluded that PEDOT coated PET fibers exhibit higher electrical as well as mechanical properties as compared to PEDOT coated viscose fibers at same reaction conditions.

In Fig. 5 and Fig. 6, the comparison of electrical and mechanical properties of PEDOT coated viscose and PEDOT coated PET fibers is shown (Bashir et al. 2010b). We found that PET fibers almost retained their original mechanical properties even at higher oxidant concentration (15 wt. %) at which viscose fibers reduced their original mechanical properties up to 60%.

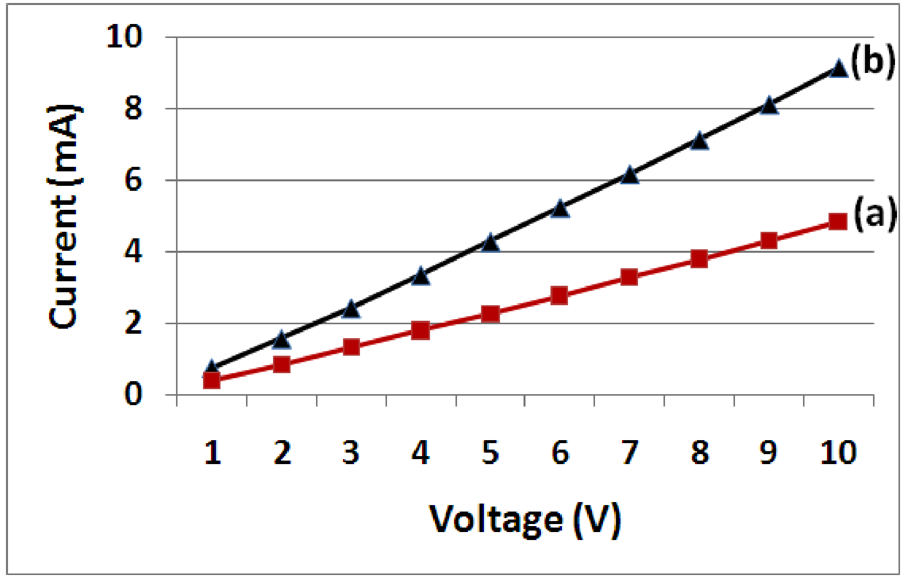

Figure 5. Voltage-current (V-I) characteristic curves of, (a) PEDOT-coated viscose fibers, (b) PEDOT-coated PET fibers

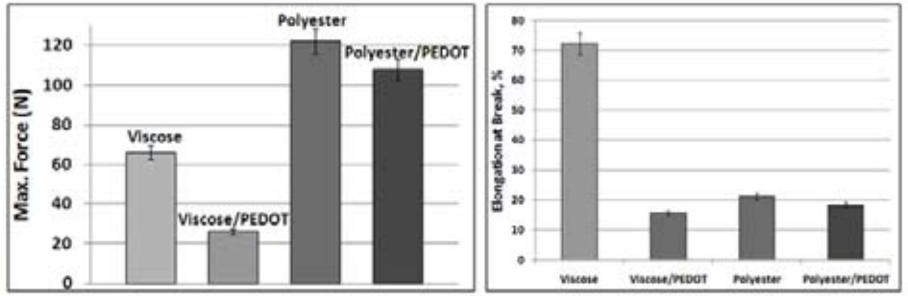

Figure 6. Comparison of mechanical properties between PEDOT coated viscose and PEDOT coated PET fibers

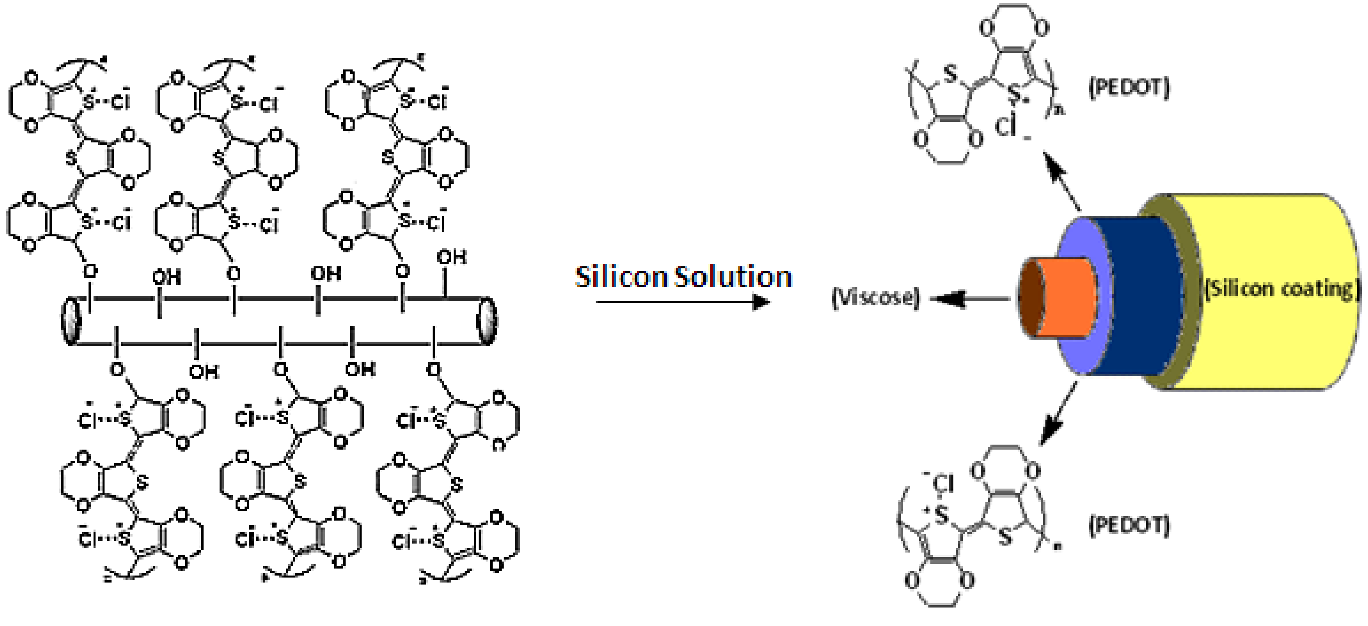

Figure 7. Schematic diagram of conductive viscose yarn after silicone modification

2.4. Surface modification of PEDOT coated conductive fibers

Although, viscose and PET fibers were successfully coated with PEDOT and also PEDOT was partially impregnated inside the fibers, the PEDOT coating was easily be removed by scratching or un-twisting yarn fibers. As a result electrical properties were considerably reduced. It was necessary to modify the surface of PEDOT coated conductive fibers with some surface modifiers, which can enhance scratch resistance and improve mechanical and hydrophobic properties. So, we selected thermoplastic silicone elastomer resin (GENIOMER® 80 from WACKER) solution in methyl ethyl ketone (MEK). We used PEDOT coated viscose fibers for surface modification, because viscose is hydrophilic in nature and we wanted to enhance its hydrophobic properties. We treated PEDOT coated viscose fibers with silicone solution for 10 minutes and then dried at room temperature. A very smooth and thin layer of silicone resin was deposited on surface of PEDOT coated viscose fibers; the schematic diagram is shown in Fig. 7 (Bashir et al. 2010a).

It was also justified by FT-IR analysis that PEDOT coated viscose fibers were completely covered by silicone layer and IR spectra are illustrated in Fig. 8 (Bashir et al. 2010a). The characteristic absorption bands of PEDOT coated viscose fibers, pure silicone resin, and silicone treated coated fibers, are shown in Fig. 8 (A), Fig. 8 (B), and Fig. 8 (C), respectively.
It is clear that all absorption bands of PEDOT coated viscose fibers after silicone treatment are exactly same as that of absorption bands of pure silicone resin. The absence of characteristic peaks of PEDOT coated viscose fibers in silicone treated coated fibers is the strong evidence that fibers were completely covered with thin layer of silicone resin.

It was expected that silicone coated conductive fibers would not show any conductivity but these surface modified fibers were still conductive, due to a very thin layer of silicone on the surface of the PEDOT coated fibers. The change in surface resistance of the PEDOT coated fibers after silicone coating is shown in Fig. 9.

In order to find out the effect of water treatment on surface resistance values of PEDOT coated viscose fibers before and after silicone coating; modified and un-modified conductive fibers were dipped in water for 10 minutes and washed them without any detergent.

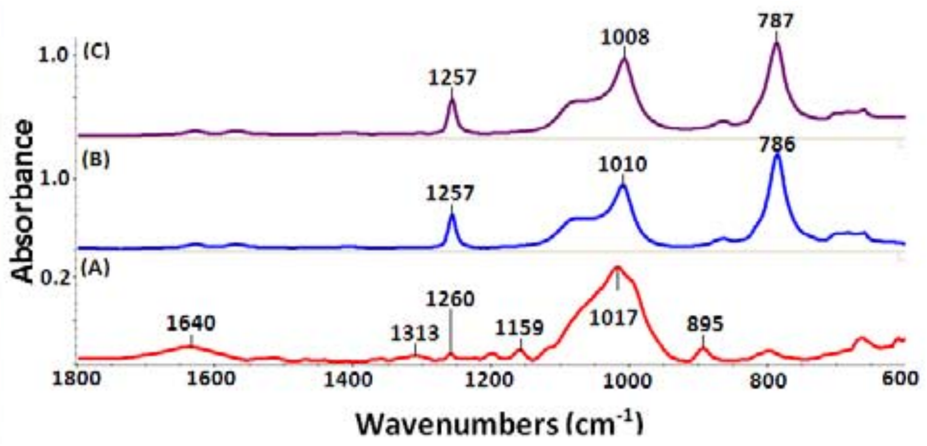

Figure 8. FT-IR spectra of, (A) PEDOT coated viscose fiber, (B) pure silicone resin, and (C) silicone treated conductive fiber

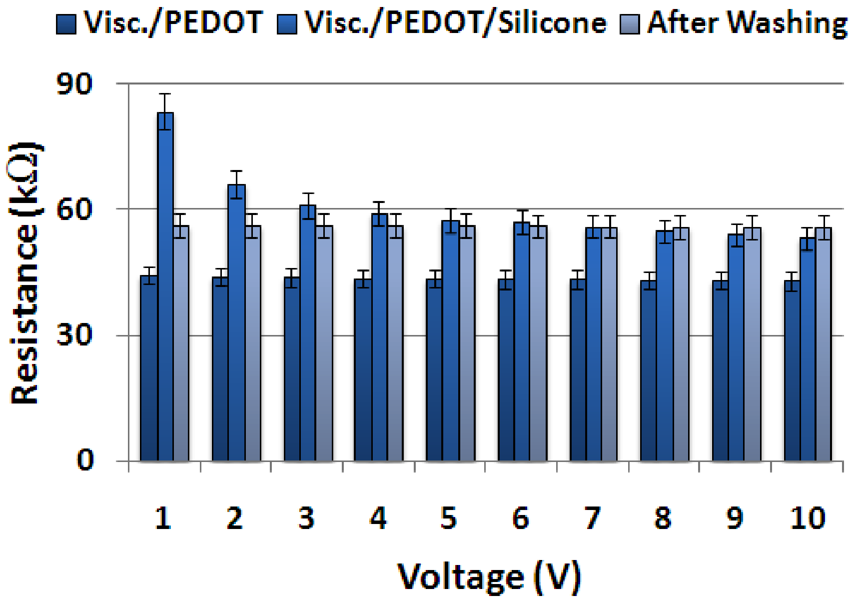

Figure 9. Effect of silicone coating on electrical properties of PEDOT coated viscose fibers before and after washing (From left to right, PEDOT coated viscose fibers, silicone treated coated fibers before washing, and silicone treated coated fibers after washing)

The change in electrical properties of PEDOT coated viscose fibers without silicone modification after washing is shown in Fig. 10.
The effect of silicone coating on electrical properties of PEDOT coated viscose fiber before washing and after washing is shown in Fig. 9.

It is clear from Fig. 9 and Fig. 10 that without silicone coating surface resistance values of PEDOT coated viscose fibers increased a lot after washing as compared to silicone treated PEDOT coated viscose fibers. So, the hydrophobicity of PEDOT coated viscose fibers enhanced with surface modification. The effect of silicone coating on mechanical properties of PEDOT coated viscose fibers is illustrated in Fig. 11 (Bashir et al., 2010a).

It is clear that maximum force at break is almost same for treated and un-treated fibers but flexibility of PEDOT coated viscose fibers have been increased after surface modification. These silicone treated conductive fibers could be used as pressure and stretch sensors in medical and sports applications.

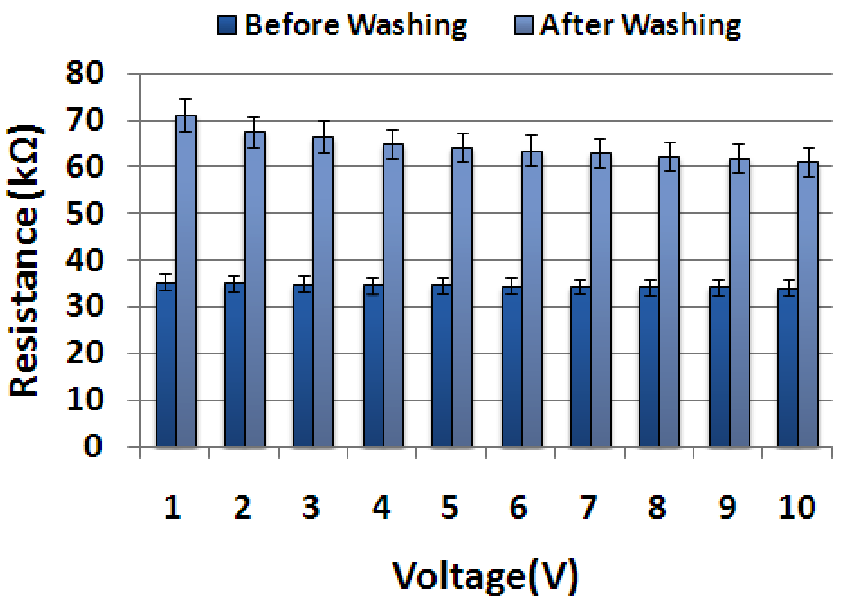

Figure 10. Effect of washing on electrical properties of PEDOT coated viscose fibers before surface treatment with silicone

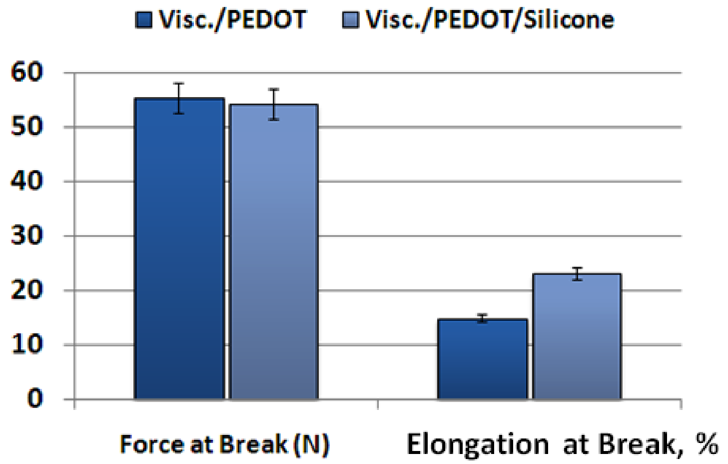

Figure 11. Effect of silicone coating on mechanical properties of PEDOT coated viscose fibers

2.5. Production of coated fibers in longer length

The oxidative chemical vapor deposition (OCVD) technique is being used throughout the world to produce thin, smooth coating on different substrates. But the major drawback of OCVD technique is that the samples cannot be coated in longer length. For this reason; we selected 150 mm long viscose fibers for our initial experiments even though this length could not be used for any textile application. Now we can produce PEDOT coated fibers in longer length i.e. from 5 meter to 10 meters by using specific fiber holding setup, shown in Fig. 12. The fibers of 5-10 meters in length can easily be winded over fiber holding setup and then inserted into tubular reactor having larger a diameter. By using this setup, we can coat longer lengths of fibers in one batch. The setup could also be modified to a semi-continuous process by increasing the length of the fiber holding setup and diameter of tubular reactor.

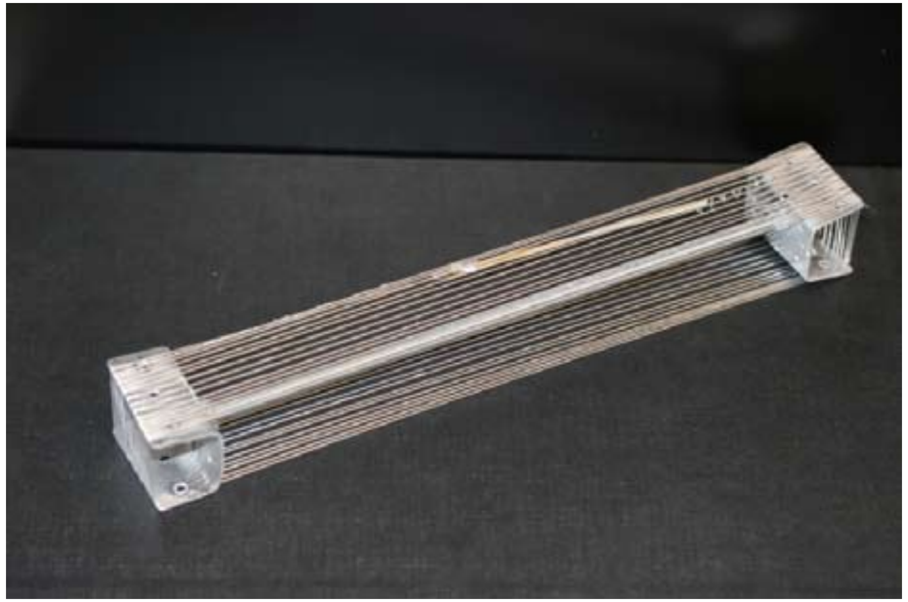

Figure 12. Fiber holding setup used to produce longer lengths of PEDOT coated conductive fibers

3. Future prospects

These PEDOT coated electroactive textile fibers in longer length could be transformed into woven structure that will give higher mechanical as well as electrical properties. That woven structure could be used to form different sensors for medical applications such as ECG, pressure, and stretch sensors. We are trying to find out different electrical applications of these fibers in smart and interactive textile clothing. These coated fibers having good electrical properties could also be used as solar cell and organic fuel cells demonstrators, which could be used to produce flexible and wearable energy harvesting devices. The schematic diagram of fibrous solar cell based on PEDOT coated viscose fibers is shown in Fig. 13.

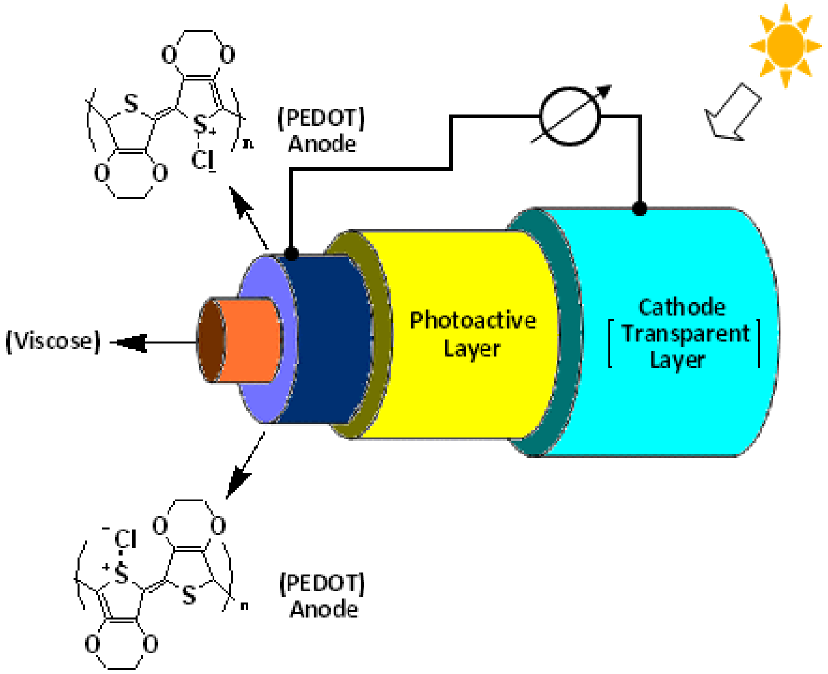

Figure 13. Schematic diagram of fibrous solar cell based on PEDOT coated viscose fibers

4. Conclusions

We have concluded that commercially available textile fibers exhibiting higher mechanical properties could be converted into electroactive textile fibers by coating them with intrinsically conductive polymers (ICPs). OCVD is the most suitable and economical technique to get smooth and uniform polymer layers on the surface of textile fibers. The coated fibers exhibit good electrical as well as mechanical properties, which could not be achieved with conventionally used melt and wet spinning processes. The surface properties of PEDOT coated fibers could be enhanced by modifying with silicone resins. This surface modification can improve scratch resistance, flexibility, hydrophobicity, and the service life of coated fibers. We have produced PEDOT coated fibers in longer length i.e. 5-10 meters, which is, according to our knowledge, maximum length ever achieved with OCVD technique to the date. The obtained electrically conductive fibers could be transformed into three dimensional woven structure according to the end used required applications. Also, these fibers could be used to produce energy harvesting wearable devices such as wearable solar cells and flexible organic fuel cells.

5. Acknowledgement

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6. References

Bashir, T., Skrifvars, M. & Persson, N.-K. (2010a) Surface Modification of Conductive PEDOT coated Textile Yarns with Silicone Resin. Submitted in *Materials Technology Journal*.

Bashir, T., Skrifvars, M. & Persson, N.-K. (2010b) Synthesis of High Performance, Conductive PEDOT-coated Polyester Yarns by OCVD Technique. Submitted in *Polymers for Advanced Technologies*.

Bashir, T., Skrifvars, M. & Persson, N.-K. (2010c) Conductive Textile Fibers for Medical Applications Produced by oCVD of PEDOT: Structural, Morphological and Electrical Characterizations. Submitted in *Journal of Applied Polymer Science*.

Bashir, T., Skrifvars, M. & Persson, N.-K. (2010d) Production of Highly Conductive Textile Viscose Yarns by Chemical Vapor Deposition Technique: A Route to Conitnuous Process. Submitted in *Polymers for Advanced Technologies*.

Bedeloglu, A. C., Demir, A., Bozkurt, Y. & Sariciftci, N. S. (2009) A Photovoltaic Fiber Design for Smart Textiles. *Textile Research Journal*, vol. 80:11, pp. 1065-1074.

Bouzek, K., Mangold, K.-M. & Juttner, K. (2001) Platinum distribution and electrocatalytic properties of modified polypyrrole films. *Electrochimica Acta*, vol. 46:5, pp. 661-670.

Bowmaker, G. A., Chiu, W. W., Travas-Sejdic, J. & Cooney, R. P. (2005) Spectroscopic and conductivity studies of doping in chemically synthesized poly (3,4-ethylenedioxythiophene). *Synthetic Metals*, vol. 155:1, pp. 80-88.

Breslin, C. B., Fenelon, A. M. & Conroy, K. G. (2005) Surface engineering: corrosion protection using conducting polymers. *Materials & Design*, vol. 26:3, pp. 233-237.

Dall'acqua, L., Tonin, C., Peila, R., Ferrero, F. & Catellani, M. (2004) Performances and properties of intrinsic conductive cellulose-polypyrrole textiles. *Synthetic Metals*, 146:2, pp. 213-221.

Gerard, M., Chaubey, A. & Malhotra, B. D. (2002) Application of conducting polymers to biosensors. *Biosensors & Bioelectronics*, vol. 17:5, pp. 345-359.

Hong, K. H., Oh, K. W. & Kang, T. J. (2005) Preparation and properties of electrically conducting textiles by in situe polymerization of poly(3,4-ethylenedioxythiophene). *Journal of Applied Polymer Science*, vol. 97:3, pp. 1326-1332.

Lock, J. P., Im, S. G. & Gleason, K. K. (2006) Oxidative Chemical Vapor Deposition of Electrically Conducting Poly(3,4-ethylenedioxythiophene) Films. *Macromolecules*, vol. 39:16, pp. 5326-5329.

Lorussi, F., Rocchia, W., Scilingo, E. P., Tognetti, A. & Rossi, D. D. (2004) Wearable, Redundant Fabric-Based Sensor Arrays for Reconstruction of Body Segment Posture. *IEEE Sensors Journal*, vol. 4:6, pp. 807-818.

Meoli, D. & May-Plumlee, T. (2002) Interactive Electronic Textile Development: A Review of Technologies. *Journal of Textile and Apparel, Technology and Management*, vol. 2:2, pp. 1-12.

Oh, K. W., Park, H. J. & Kim, S. H. (2003) Stretchable Conductive Fabric for Electrotherapy. *Journal of Applied Polymer Science*, vol. 88:5, pp. 1225-1229.

Okuzaki, H., Harashina, Y. & Yan, H. (2009) Highly conductive PEDOT/PSS microfibers fabricated by wet-spinning and dip-treatment in ethylene glycol. *European Polymer Journal*, vol. 45;1, pp. 256-261.

Otero, T. F. & Cantero, I. (1999) Conducting polymers as positive electrodes in rechargeable lithium-ion batteries. *Journal of Power Source*, vol. 81-82, pp. 838-841.

Pomfret, S. J., Adams, P. N., Comfort, N. P. & Monkman, A. P. (2000) Electrical and mechanical properties of polyaniline fibers produced by a one-step wet spinning process. *Polymer*, vol. 41:6, pp. 2265-2269.

Rattfält, L., Linden, M., Hult, P. & Berglin, L. (2007) Electrical characteristics of conductive yarns and textile electrodes for medical applications. *Medical and Biological Engineering Computing*, vol. 45:12, pp. 1251-1257.

Rothmaier, M., Luong, M. P. & Clemens, F. (2008) Textile Pressure Sensor Made of Flexible Plastic Optical Fibers. *Sensors*, vol. 8:7, pp. 4318-4329.

Xia, Y. & Yun, L. (2008) Fabrication and properties of conductive conjugated polymers/silk fibroin composite fibers. *Composites Science and Technology*, vol. 68:6, pp. 1471-1479.

Textile strain sensors characterization - Sensitivity, linearity, stability and hysteresis

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Abstract In this paper 4 different textile based strain sensors for measuring different level of strains were presented. Sensor consist a conductive part formed by coating or weaving technique. Both elastic and inelastic textile substrates were selected to achieve the required stains in applications. Sensor configuration was characterized using a tensile tester and measuring the resistance parallel by microprocessor. A linear working range with working function of each sensor was found. Coated sensor gives a good stability, while woven sensor was relative less stable. Inelastic textile substrate reduces the hysteresis error caused by refraction and construction of materials. The sensitivities were between 2.5 to 9 vary with different sensors. This paper finished by a discussion of how to choose sensors with different applications, among which sensor function and processability are most important aspects to be considering.

Key words: Smart textile, strain sensor, textile integration, conductive yarn, measurement

1. Introduction

Smart Textiles represent the next generation of textiles anticipated for use in many applications. Fibres, yarns and fabric structures with added-value functionality, such as conductivity, sensing and actuating abilities, have been developed for a range of applications, especially in sport and heath care areas. Integration of intrinsic sensing function into textile structures is an elegant way to monitor the human body and/or environment changes. The integration of sensors is not only a concern in clothing industry, but also has a potential in technical textiles applications, for example in the automotive area where the share of textile components is constantly increasing (Drean et al. 2007). The possibility of using textile strain sensors has been presented in several research projects. This new generation of strain measurement devices have been made for applications, where conventional sensors are not suitable due to their rigid mechanical properties (Cedric et al. 2008).

Strain sensors may be based on several types of principles, most commonly on piezoresistive, and optical. The piezoresistive effect, successfully employed in sensors, can indicate the stress or strain change during time by recording intrinsic resistance change of the material. Optical fibres use another phenomenon, by measuring the path and strength of an optical signal. The advantage with optical fibre sensors is that optical signals effectively eliminate the electrical noises. Many previous approaches have integrated strain sensing properties into the textile structure based on different textile processes. Knitted sensors manufactured from yarns based on carbon (Bickerton 2003) or metal (Van Langenhove 2004) have been used for measuring cyclic forces such as breathing rate. Coating or chemical vapour deposition is another method to apply conductivity into textile structure. Conducive elastomeric composites coatings have been shown to have highly sensitive pizeoresistive properties when deformation, such as stretch (Tognetti et al. 2004) or press (Softswitch) is applied. Conductive polymers, such as polyaniline, polypyrolle or polythiophene, are polymers that are inherently able to conduct charge through their polymeric structure, and they have been used as strain sensors in several projects as well (Li et al. 2005; Munro et al., 2008; Tsang et all, 2005 & Dunne et al. 2006). The integration of piezoelectric PVDF films by means of lamination has also been shown as a potential flexible strain sensor (Edmison et al. 2002). D.W.Lloyd, D.G.Neilly and D.B.Brook (Lloyd et al. 2001) have succeeded to measure small strain as the normal engineering strain, but the sensor was limited for large strain up from 10%. In this paper, we present four different textile strain sensors based on different textile manufacturing processes. First, the sensor materials and the textile integration are described. Thereafter the experimental procedure is described, followed by the result. Finally the results are analysed and future efforts are suggested.

2. Sample preparation

The sensors presented in this paper are based on conductive materials which have been applied to the textile substrate by means of coating or integrated into the textile substrate directly in the weaving process, figure 1.

The textile substrates were both elastic and inelastic woven fabrics. Four types of samples were developed, each of them described below.

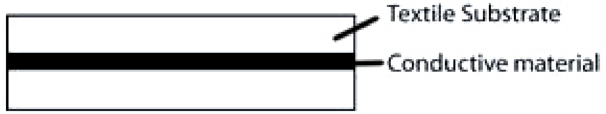

Fig. 1.Construction of textile strain sensor

2.1 Sample 1, S1 (Fig. 2.)

Textile substrate: Polyamide/Lycra
Conductive material: Silicon rubber filled with carbon-black particles, Elastosil LR 3162 A/B. Supplier Wacker Ltd.
Manufacturing method: Textile substrate: plain weave.
Conductive material: knife-over-roll coating.
Sample Size: 200mm x 50 mm, coated area: (150mm x 10mm)

Fig. 2. Elastic coated sensor, sample 1(S1)

2.2 Sample 2, S2 (Fig.3.)

Textile Substrate: Cotton (95%) & lycra(5%)
Conductive material: Bekintex 50/2, Staple fibre 80% polyester, 20% stainless steel. Supplier Bekaert
Manufacturing method: plain weave
Sample size: 200mm x 50 mm.

Fig. 3. Elastic woven sensor, sample 2(S2)

2.3 Sample 3, S3 (Fig. 4.)

Textile substrate: Polyester (cargo security strap).
Conductive material: silicon rubber filled with carbon-black particles, Elastosil LR 3162 A/B. Supplier Wacker Ltd.
Manufacturing method: Textile substrate: plain weave.
Conductive material: Knife over roll coating.
Sample Size: 200mm x 50 mm, coated area: 150mm x 50mm

Fig. 4. Inelastic coated sensor, sample 3 (S3)

2.4 Sample 4, S4 (Fig.5.)

Textile Substrate: Cotton
Conductive material: Bekintex 50/2, Staple fibre 80% polyester, 20% stainless steel. Supplier Bekaert
Manufacturing method: Plain weave
Sample size: 200mm x 50 mm.

Fig. 5. Inelastic woven sensor, sample 4 (S4)

3. Experimental procedure

The samples were measured to determine the relationship between mechanical properties (strain-stress) and electrical properties (resistance) of sensors.

3.1. Measurement setup

The mechanical properties were measured by a tensile tester and by a specific cargo strap testing machine. Sample 1, 2 and 4 were tested in the tensile tester presented in figure 6, and the measurements were done at a speed of 50mm/min. The maximum elongation variance with different sensors refers to the sensor span. Sample 3 was tested by a specific cargo strap testing machine, where a regular force from 100N to 2500N was applied. Each sample was measured five times and the relaxation between measurements was 10 sec.

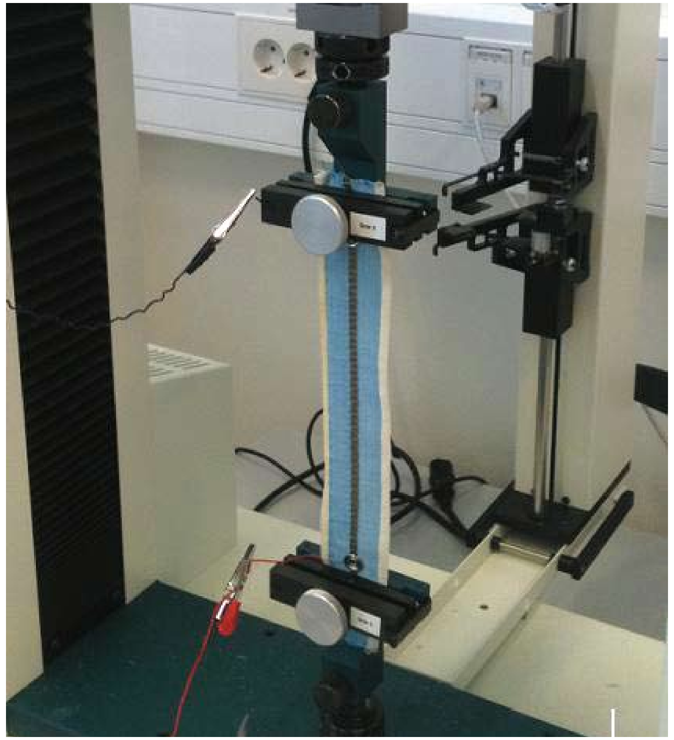

Fig. 6. Mechanical measurement setup

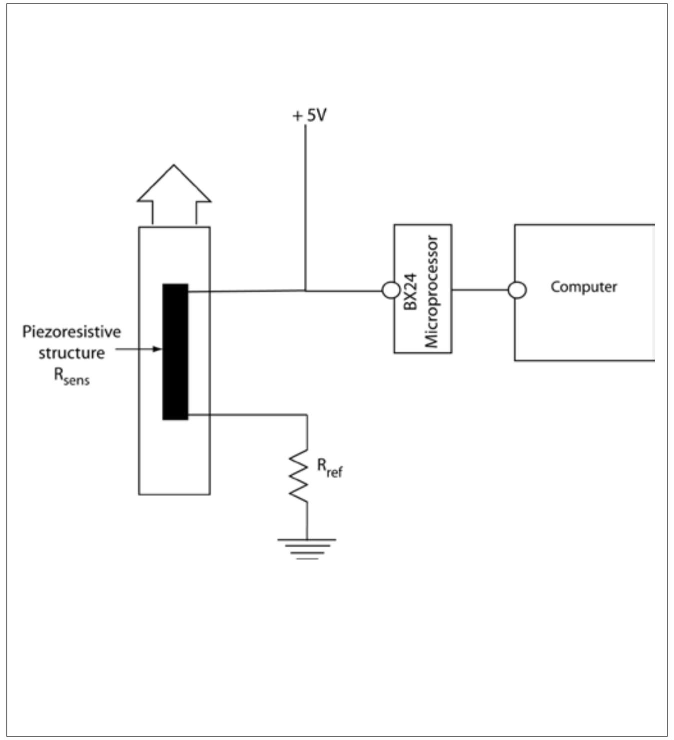

Fig. 7. Electrical measurement setup

In order to determine the electrical and mechanical properties simultaneously, the sensor resistance was recorded by a pre-programmed microprocessor and a computer. The circuit is explained in figure 7. The sampling rate for resistance measurement was 9 samples/ sec, which corresponds to 9Hz in frequency. Snap buttons were used as the interface between textile sensors and electrical wires.

The output voltage measured from the microprocessor was in digital form (D_{out}). It can be calculated into analog output voltage (V_{out}) by the equation:

$$V_{out} = \frac{5\,Volts}{2^{10}} * D_{out}$$

The output voltage (V_{out}) over the reference resistor (R_{ref}) was measured according to Ohm's Law in series circuit. The sensor resistance (R_{sens}) was calculated by:

$$\frac{V_{out}}{R_{ref}} = \frac{5 - V_{out}}{R_{sens}} \Rightarrow R_{sens} = \frac{R_{ref}(5 - V_{out})}{V_{out}}$$

The reference resistance (R_{ref}) was determined in advance, similar to the resistance of the textile sensor.

3.2 Measurement method

Using the described measurement set-up the sensor linear working range (span), working function, sensitivity, stability and hysteresis error were measured.

3.2.1 Sensor span

The sensor span represents the working range of the sensor, which is the determination of the linear input-output relationship. The sensor working function defines the numerical relationship between input and output of the sensor within the linear working range (span). The sensors span and output-input relationship is determined by simultaneously recording the sensor resistance and elongation.

3.2.2 Sensitivity

The sensitivity of a strain sensor is defined as the resistance change (percentage) divided by the elongation (percentage) during strain. The sensitivity provides the overall sensing property of sensor. The sensitivity of a metal strain sensor is around 2, while the sensitivity of semiconductor strain may be as high as 150.

3.2.3 Stability

The repeatability in short term is called stability, while it is called aging in long term. In this experiment, the sensor performance after 1 hour, 1 day, 5 days and 14 days has been tested, confirming the sensor stability.

3.2.4 Hysteresis

A hysteresis error is a deviation of the sensor's output at a specified point of the input signal when it is approached from the opposite direction (Fraden,J 2007). The hysteresis before stretch and after release is of interested in our experiment. Sensor has been stretched until the maximum working range and released immediately.

4. Result

In this section, the sensor working range, the working function within this working range and the sensor sensitivity are presented. The phenomenon of whether resistance increase or decrease with extension has also been analyzed. Further, the sensor stability and hysteresis errors were illustrated and compared.

4.1 Sensor linear working range (Span)

Linear working range of textile sensors depends on the properties of the textile substrate and how the conductive part has been integrated into textiles. The elastic samples had a larger span than the rigid samples. But the conductive coating increased the span due to the excellent elasticity of the silicon rubber. According to the curves in figure 8, the span of elastic coated sensor ranges between 5% to 40 %(10mm elongation and 80mm elongation to the original length of 200mm). The inelastic coated sensor performed below 6% (12mm). In the woven samples, a linear working range of the elastic sample is 3.5% to 5% (7mm to 10mm), while the inelastic sampled had a working range between 1% and 2.5% (2mm to 5mm).

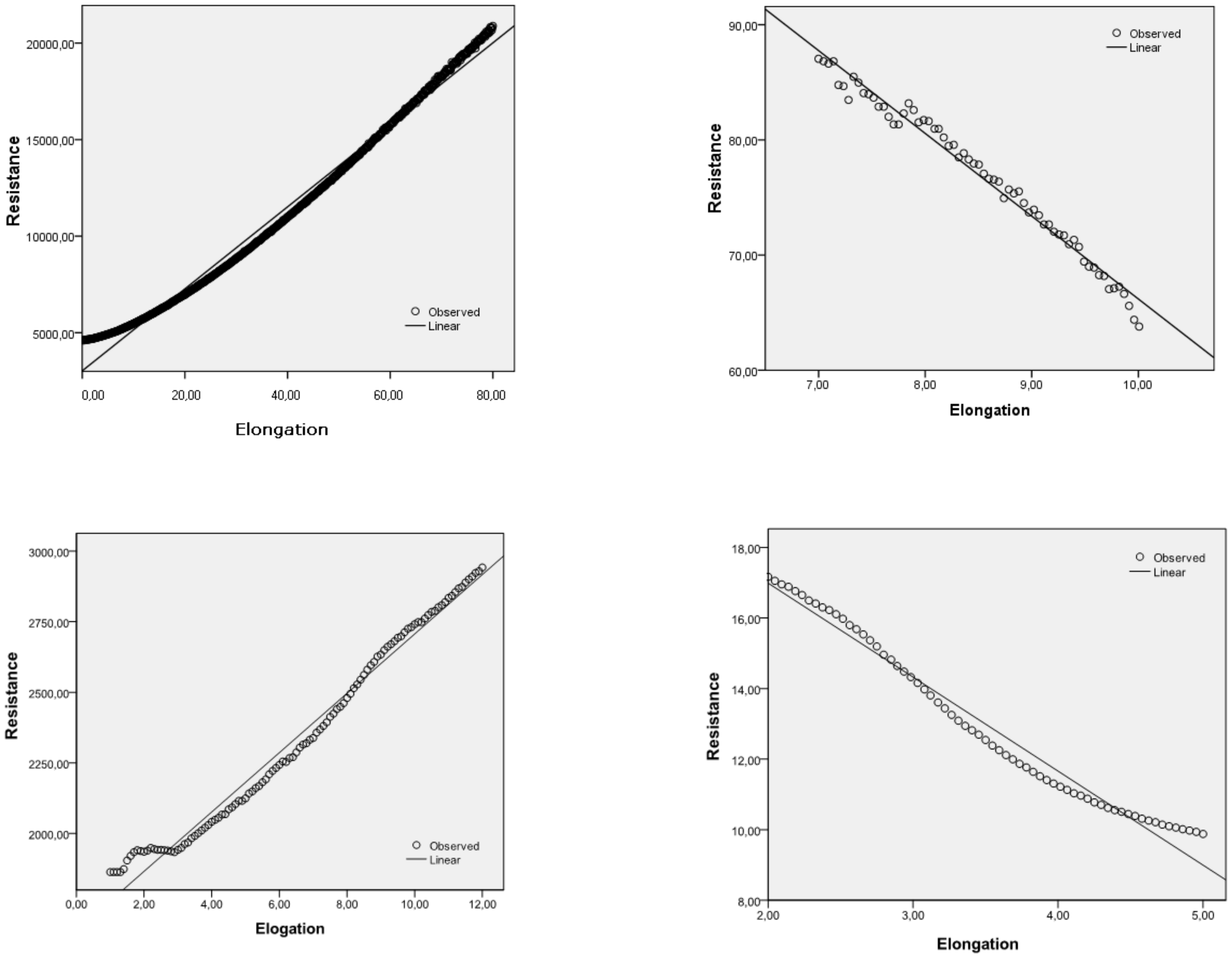

Fig. 8. Linear working range of elastic coated, S1(top left), elastic woven (top right) inelastic coated , S3 (bottom left) and inelastic woven,S4 (bottom right) sensors.

4.2 Sensor working function and sensitivity

As illustrated in table 1, the coated sensors have positive resistance versus elongation change effect, which means that the resistance increases with extension. However, the woven sensors shown opposite phenomenon, the resistance decreases when the elongation is increased.
The reason for that is the construction of different samples. In the coated sensor the conductive effect comes from the presence of carbon black particles. When the sensor is released, the carbon particles are evenly distributed in the silicon rubber and tightly contacted with each other as in figure 9 (left). When the sample is stretched, the carbon particles are pulled apart that some of the carbon black particles contact with nothing. Therefore the conductive path becomes narrow and the resistance will increase.

Table 1: sensor working function and standard error.*: standard error refers to an estimate of standard deviation, derived from a particular sample used to compute the estimate.

Sensor	Name	Parameters		Std. Error*	Working function
1	Elastic Coated	Constant	1700,651	445,518	Y=1700,651+230,382X (+error)
		Elongation	230,382	8,9	
2	Inelastic Coated	Constant	1655,178	9,650	Y=1655,178+105,156X (+error)
		Elongation	105,156	1,332	
3	Elastic woven	Constant	138,078	1,093	Y=138,078-7,189X (+error)
		Elongation	-7,189	0,128	
4	Inelastic woven	Constant	22,842	0,205	Y=22,842-2,776X (+error)
		Elongation	-2,776	0,057	

The woven sensors have different principle to achieve conductivity. As shown in figure 9 (right), the conductive yarns woven in the central part of the sensor form the conductive path. When the sample is stretched, the conductive wefts are tightened to each other. The conductive connections increase and the resistance decreases.

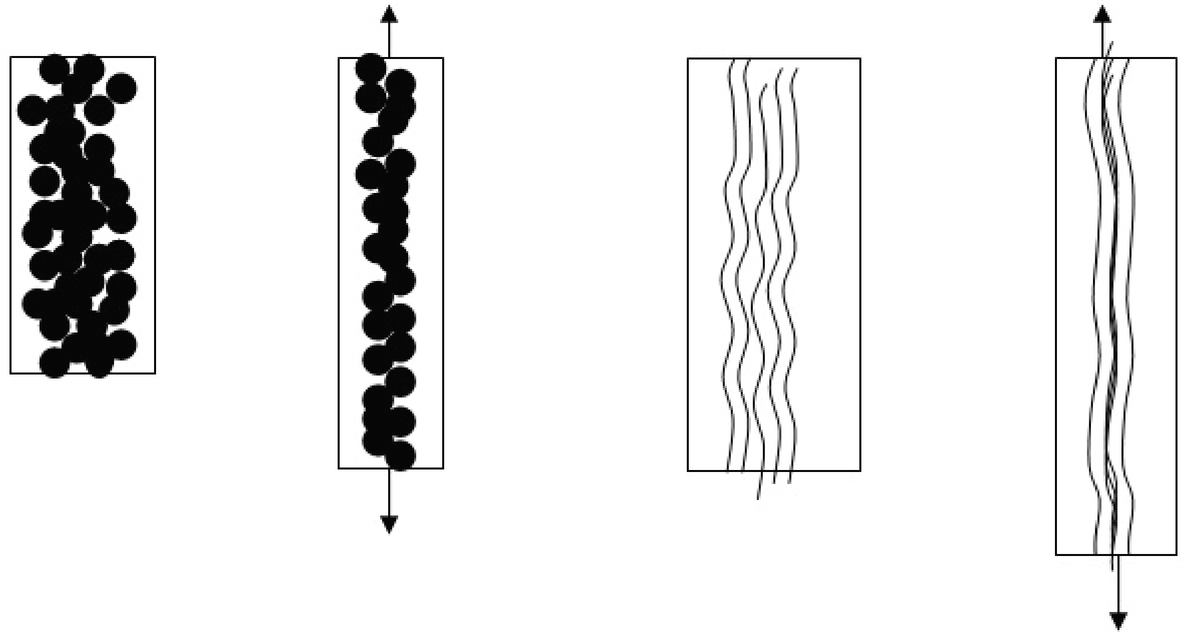

Fig.9. Conductive path of coated sensor (left) and woven sensor (right) before and after stretching.

The sensitivity quantitatively indicates the sensors mechanical-electrical behaviors and the sensitivity usually specified by gauge factor, GF.

Gauge factor can be calculated by $\frac{\Delta R/R}{\Delta L/L}$.

By calculation, the elastic coated sensor had the highest GF equal to 9.2, the inelastic woven sensor had the lowest GF in absolute which was around 2.5. The GF in inelastic coated sensor and elastic woven were 8.5 and 6 respectively.

4.3 Stability

All sensors have acceptable stability after one hour, one day, five days and two weeks repeated measurements. Both elastic and inelastic coated sensors have almost constant performance regardless to the time, confirming the stability of sensor. Concerning the woven sensor, the minimal resistance shows a marginal decreasing along with time of about 10% in elastic woven and 25% in inelastic woven. The result of elastic coated sensor stability change during 2 weeks is shown in fig. 10 (left), while the right one shows the change of in elastic woven sample.

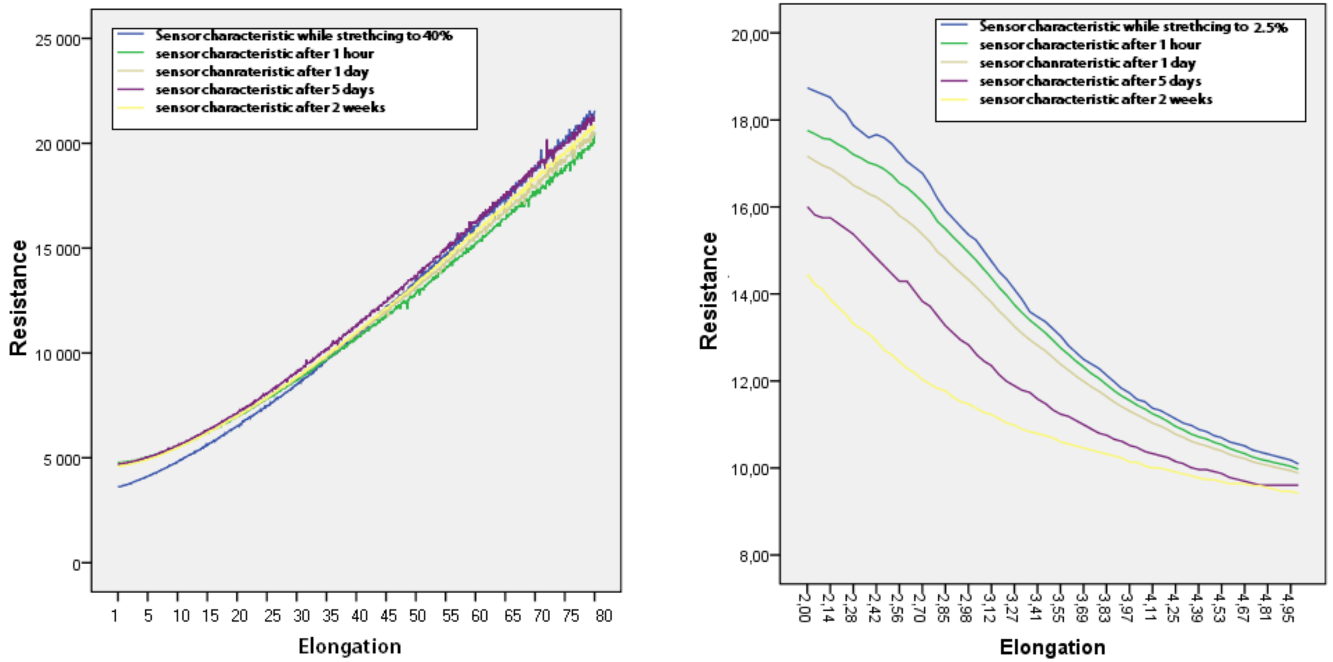

Fig. 10 Stability test during 2 weeks, elastic coated sensor, S1 (top) and inelastic woven sensor,S4 (bottom)

4.4 Hysteresis error

The resistance versus strain under a typical stretch and release cycle plot, figure 11, shows an example of how to calculate the hysteresis error of the sensor. Hysteresis is typically caused by friction and structural change in materials (Fraden, J. 2007). Usually elastic materials have higher hysteresis. This is because elastic materials need longer recovering time, especially when high force is applied.

The hysteresis error for elastic coated sensor (see fig.11.) and elastic woven sensor were rather high, which were around **±10%** (20%) and **±9%** (18%) of the working range. Inelastic woven has smallest hysteresis error; it has only 1.9% deviation. Inelastic coated sensor in our case had large hysteresis around 20%, this caused from the large force (2,5ton) applied on sample. When large force involved in, the textile substrate changed not only in fabric structure, but also in arrangement of yarns. Elongations applied on single yarns were more difficult to recover.

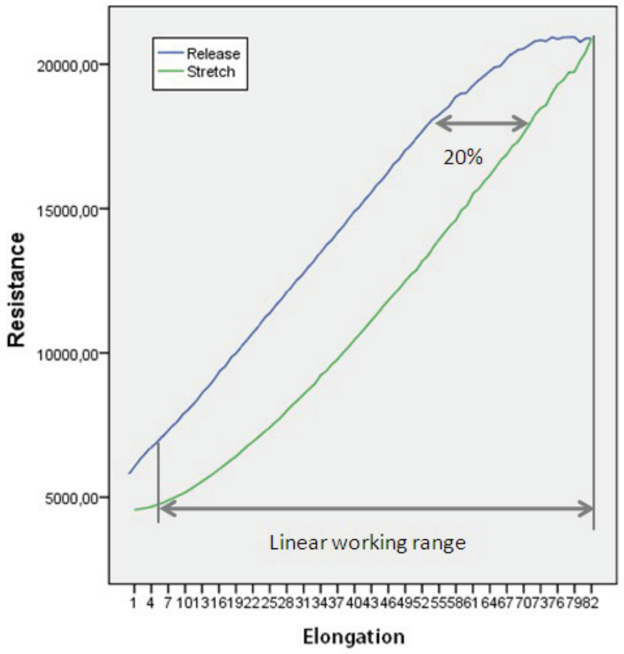

Fig.11.Hysterisis error of elastic coated sensor, S1

5. Discussion and Future work

This project presents four different textile strain sensors and each sensor has been characterised by measuring the mechanical and electrical performance during stretch. Two of the sensors were based on elastic textile structure and the other two sensors were based on rigid textile structure. The result shows that in textile strain sensor development, the requirement of the sensors properties such as the maximum elongation, sensors force, stability and hysteresis depend upon the end application. The quality and the processability are other important issues to consider in the sensor development.

The working range of sensors shows that the different sensors are useful in different applications with different requirements of elongation at maximum. The elastic woven sensor (sample 2) senses strain up to 6% while the other elastic senor, conductive silicon coated on elastic fabric senses strain up to 40%. The rigid sensors on the other hand only sense small strain up to 2%.

The stability of the coated sensors had almost constant performance while the resistance of the woven sensors decreased. The reduction of resistance was quite small and may derive from the influence of the environment. However, the fact that the resistance decreases the initial resistance should be calibrated in advance.

The inelastic samples had less hysteresis error compared with the elastic samples. Therefore, the inelastic textile sensor should be chosen when rapid cyclic force should be monitored.

Besides the mechanical and electrical properties of the sensors, processablility and quality are important issues to consider when designing a textile strain sensor. The silicon rubber used in this project is quite hard to apply by using conventional coating technologies due to its solid state compared to fluid coating materials. However, conductive coating is an economical process when textile substrate is already made. Weaving the sensors by using a strain sensitive yarn or fibre seems to be an easier process and the development of fibres and yarns that could be used as stain sensors in yarn-based processes is of high interest in this area.

The next step of this project is to test the sensors in different climate conditions. Modification of temperature, humidity and UV radiation may influence the performance of the sensors. Besides, it would be interesting to test all the sensors at different elongation rate (elongation/time) in order to be able to evaluate sensors bandwidths. Modeling is another area of interest that could verify the experimental results and eventually push the standardization of textile sensor manufacture and testing methods forward. Accordingly new testing methods and devices need to be introduced in development and evaluation of the smart textile products in order to achieve higher accuracy. An important issue to be considered is that the required characteristics of smart textile products are highly dependent on the end application.

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References

Cochrance, C. , Koncar, C. & Lewandowski, M. (2008) *Development of a flexible strain sensor for textile structures*. In Ambence conference proceeding.

Bickerton, M. (2003). *Effects of Fibre Interactions on Conductivity, within a knitted fabric stretch sensor*. In Proceedings of the IEEE Eurowearable 2003; ISBN: 0-85296-282-7, IEEE Press Birmingham UK, pp 67-72.

Van Langenhove, L., Hertleer, C. (2004). *Smart clothing: a new life*. In International Journal of Clothing Science and Technology, Vol 16, No ½, 2004, pp. 63-72.

Tognetti, A., Lorussi, F., Tesconi, M., De Rossi, D. (2004). *Strain Sensing fabric characterization*. In Proceedings of IEEE Sensors 2004, Vienna University of Technology, Vienna, Austria, 2004.

Softswitch, http://www.eleksen.com/

Li, Y. , Cheng, X.Y., Tsang, J., Tao, X.M. & Yuen, M.C.W. (2005). *A flexible strain sensor from polypyrrole-coated fabrics*. Synthetic Metals, Volume 155, Issue 1, 15 October 2005, Pages 89-94.

Munro, B. J., Campbell, T. E., Wallace, G. G. & Steele, J. R. *The intelligent knee sleeve: A wearable biofeedback device*. Sensors and Actuators B 131 (2008) 541-547

Tsang, H. Y. J., Leung, M. Y., Tao, M. & Yuen, C. W. M. (2005). *Development of textile E-sensor and Instrumented Dancing Garments*. In: Proceedings of 1st Ambience conferene, Tampere, Finland, September 19-20, 2005.

Dunne, L, E., Brady, S., Tynan, R., Lau, K, Smyth, B., Diamond, D. & O'Hare, G. M. (2006). *Garment-Based Body Sensing Using Foam Sensors*. In: Proceedings of the Seventh Australisation User Interface Conference (AUIC2006), Hobart, Australia.

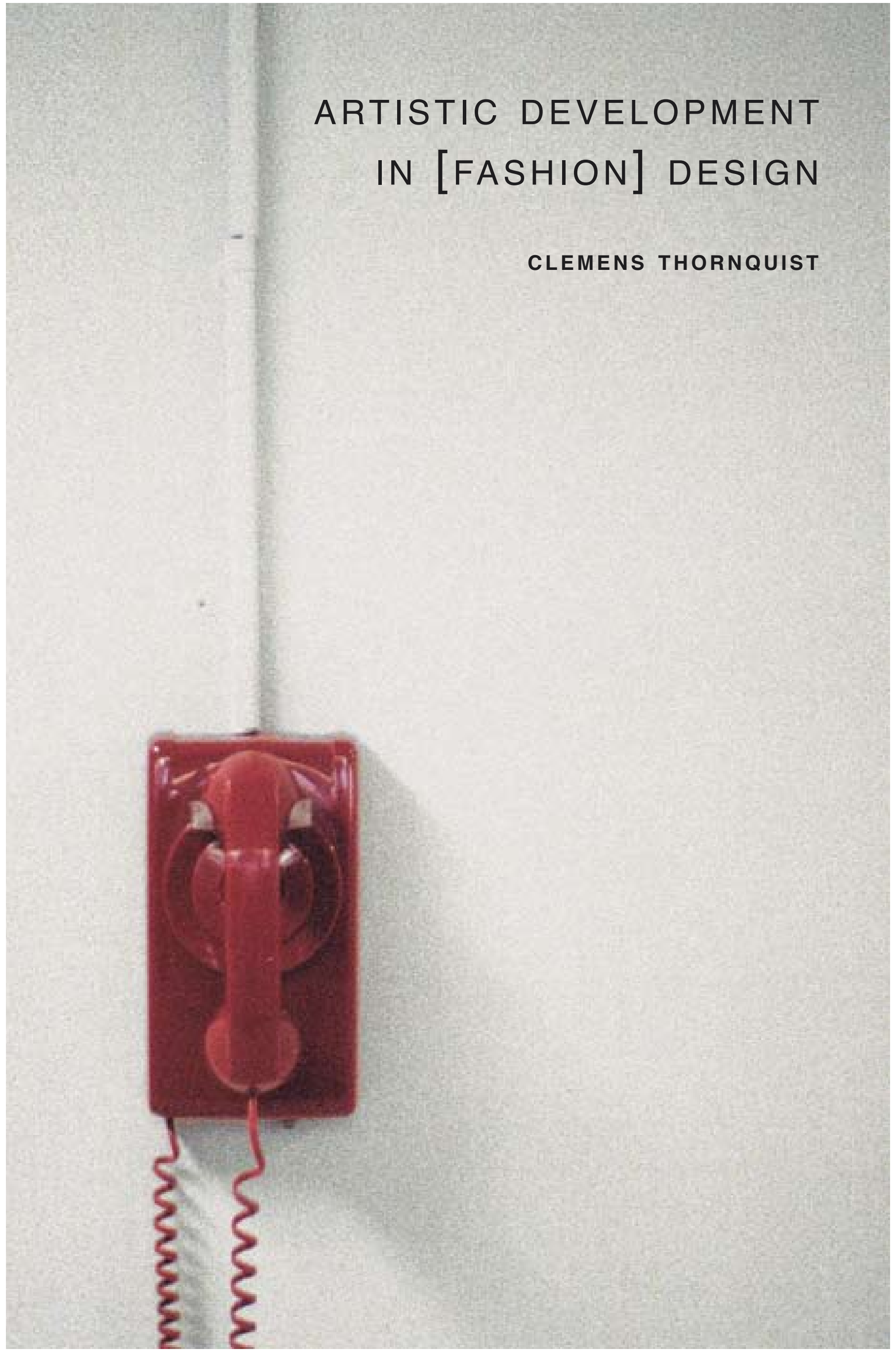
Edmison, J., Jones, M., Nakad, Z. & Martin, T. (2002). *Using piezoelectric Materials for Wearable Electronic Textiles*. In Proceedings of the 6th IEEE International Symposium on Wearable Computers, 7-10 October 2002, Seattle, Washington, USA.

D.W.Lloyd, D.G.Neilly and D.B.Brook, *Strain measurement in fabrics part 1: general considerations and the development of an extensible strain sensor*. In RJTA Vol.5.No.1

Fanden J. page 20, Chap 2. *Hand book of modern sensors*.

Van Putten, AFP. (1996).*Electronic measurement systems*. Second edition. IOP Publishing Ltd, Bristol, 1996.

O'Sullivan, I. (2004). *Physical Computing*. Cengage learning, US.



Book Review

Book Review Artistic Development in (Fashion) Design by Clemens Thornquist

Sass Brown is the Resident Director for the Fashion Institute of Technology's study abroad program in Florence, Italy. Originally from London, England, Sass established herself as a designer with her own signature collection selling in the UK and across Canada. As an academic, her area of research is in community outreach and ethical design practices in fashion businesses. She has published papers and spoken around the world on the topic of sustainable design, has worked and volunteered in women's cooperatives in Latin America, and taught workshops to manufacturers and fashion enterprises in Peru. Her book, Eco Design, for British publishers Laurence King, has been translated into Italian as well as Spanish, with the intent of showcasing some of the best expressions of eco fashion around the world.

The Fashion Institute of Technology, Florence Italy.
Villa Strozzi, Via Pisana 77,
50143 Firenze, Italia.

Clemens Thornquist takes a totally new and modern approach to creativity, not the old paradigm of left versus right brain and logic versus chaos, but instead bridges and compares the similarity of art and science, as a process of immersion and separation. Taking a total departure from the school book format on creativity, Thornquist instead approaches design with an experiential methodology in the form of inspirational projects and conceptual suggestions, very much in the mode and as pivotal as The Artist's Way, only specific to the creative development of fashion designers.

The least understood or appreciated form of fashion design is intellectual design, which in some people's minds is a contradiction of terminology; that of fashion on the one hand considered mere consumerism and vanity, and that of intellect and the inward journey. Thornquist approaches intelligent, intellectual design head on through example, talking of fashion as an "expressive language" that informs our vision and expresses our concepts. Once and for all bridging the gap between "abstract theory and concrete practice."

This book and the projects within it should not only be required reading for all students of design, but required practice.

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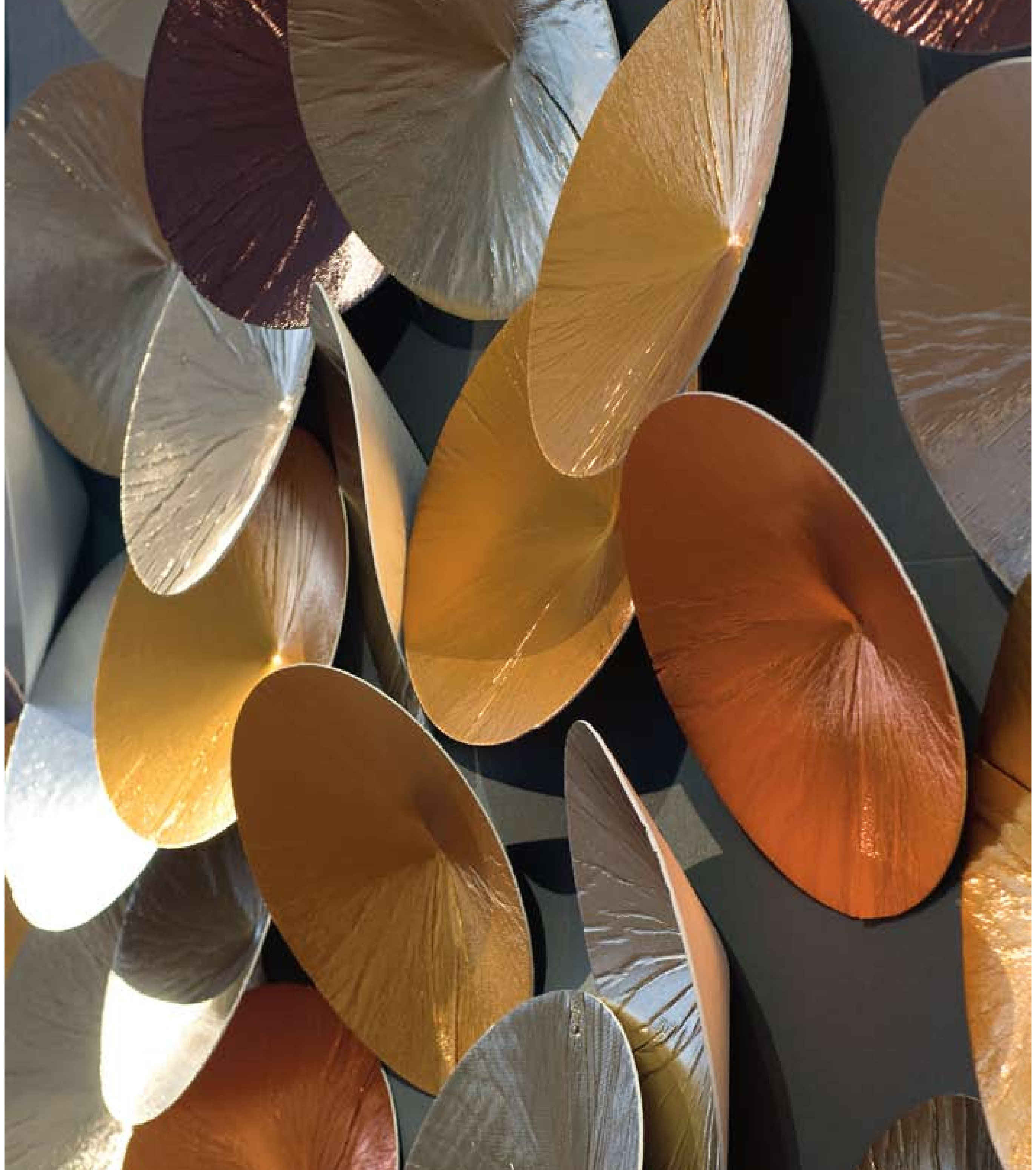
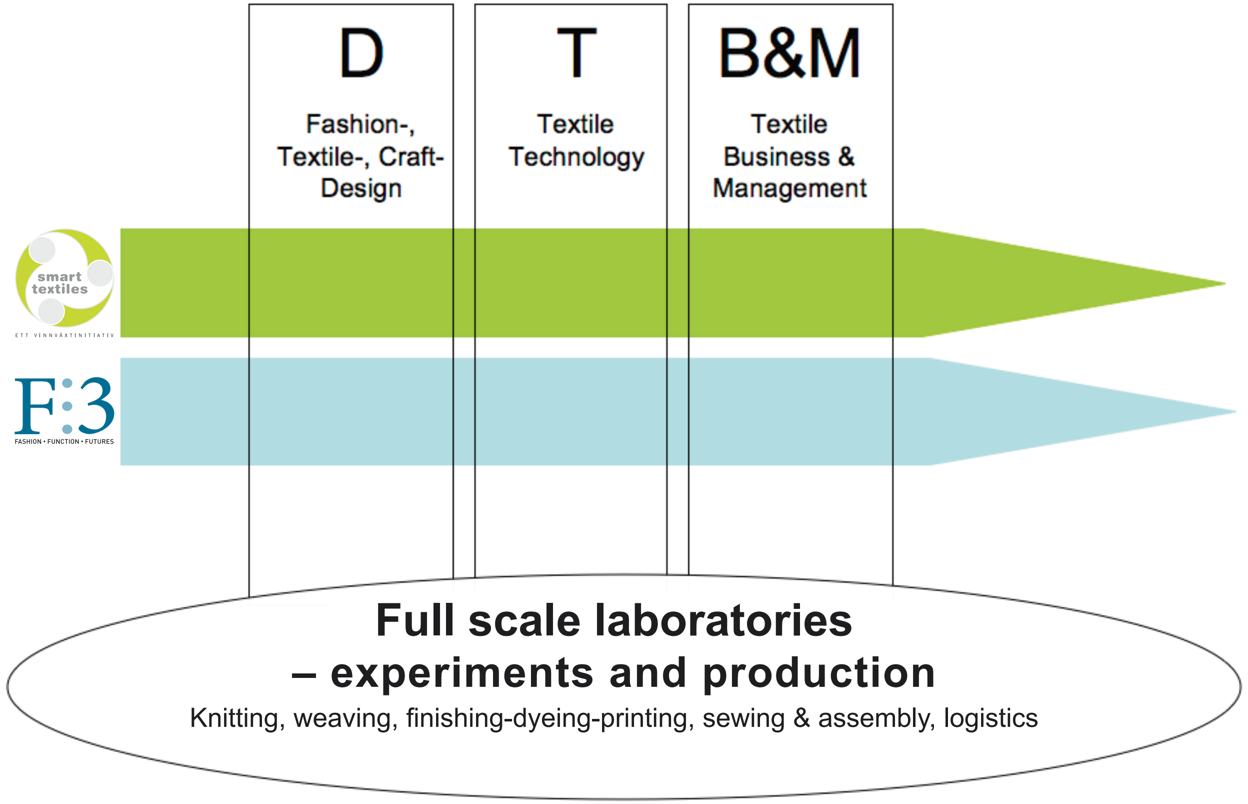


Student exhibition 2010, Photo by Jan Berg, Museum of Textiles, Borås

THE SWEDISH SCHOOL OF TEXTILES

UNIVERSITY OF BORÅS

Research and education at The Swedish School of Textiles



smart textiles

ETT VINNVÄXTINITIATIV

Smart Textiles

More or less all people have a relation to textiles. Textiles can be natural bearer of technology and electronics, so there is an encouragement to further develop textiles.

In Western Sweden, with Borås as the centre, an internationally well-known textile cluster operates with Smart Textiles at its core.

The goal of Smart Textiles is a dynamic innovation system, which promotes growth, strengthens the international competiveness and creates job opportunities in the region.

Smart Textile´s mission is to stimulate and support research and development and facilitate collaboration between end users, researchers and industry.
All this will result in new textile-based products and services on the global market. There is a multitude of innovations and ideas for integrating technology in textiles and finding sustainable solutions to interactive textiles.
Business and development opportunities in the cluster are benefits for all industrial branches with textiles as the common denominator.
More information about Smart Textiles can be found at www.smarttextiles.se.

Student exhibition 2010,
Photo by Jan Berg, Museum of Textiles, Borås

F:3
FASHION • FUNCTION • FUTURES

Fashion Function Futures

In the textile and fashion value chain from ideas to customers and beyond, the decisive stage is the design process, which combines artistic skills and functional considerations in order to make the fashion products logistically manageable, attractive for customers and resourceful from an environmental and sustainability point of view. Other salient elements of the chain are logistics, production, branding and marketing, merchandising and retailing, consumer behavior, and post-consumption management.

F^3 - Fashion Function Futures – is a programme for research and artistic development, addressing these elements from artistic design to distribution logistics and returns management, characterized by a strong professional context and an environment of interaction between theoretical knowledge and applied experience in the field. The programme is based on a ”passion for fashion” and an interdisciplinary environment, which supports the development and balancing of artistic expressions and design methodology with logistics and value chain management skills. Several departments of the University of Borås collaborate to achieve the interdisciplinary approach and knowledge required for identifying and shaping the Fashion Function Futures.

Student exhibition 2010,
Photo by Jan Berg, Museum of Textiles, Borås

The Research Group at The Swedish School of Textiles

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swerea | IVF

Textiles and Plastics department:
Our R&D work covers chemical, physical and mechanical properties of fibrous and polymeric materials, production technologies of, textiles, plastics, nonwovens and rubber products and their waste management.The results of our research work are implemented in a number of industrial applications.

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- Active international collaboration

The Textile Research Board at Swerea IVF, Textiles and Plastics Department

Pernilla Walkenström

Adjunct professor in Textile Technology at The University of Borås, The Swedish School of Textiles. Manager at Textiles and Plastics department, Swerea IVF. Finished her PhD 1996, focusing on "Phase distribution of mixed biopolymer gels in relation to process conditions". Has since then worked with biopolymers, gel formation phenomena, followed by fibre spinning processes.

Bengt Hagström

PhD in Mechanical Engineering. Expert on polymer processing, polymer melt rheology and melt spinning of fibers. Manager Functional fibres group at Swerea IVF.

Anna Thorvaldsson

PhD student at Swerea IVF. Finished her Master of Science in biotechnology in spring 2006. The studies focused on biopolymers (DA-work) and molecular biology. Has thereafter worked with electrospinning of nanofibres for biomedical applications.

Anders Bergner

Senior scientist at Swerea IVF. Polymer materials engineer in 1987, then studied innovation engineering 1989-1992. Long industrial experience in the field of polymeric materials, composites and textiles from automotive, defense and medical technology as design engineer, project manager, R&D manager and technical manger.

Staffan Toll

Senior scientist at Swerea IVF. Professor of Fibrous Materials at Chalmers, since 1995. Research revolves around the micromechanics, rheology and constitutive theory of fibre networks, suspensions and composites.

Martin Strååt

PhD in Mechanical Engineering. Master of Science in polymer engineering materials in 2005. Licentiate in polymer engineering in 2008 on dielectric properties of polyethylene foams. Currently working on developing new conductive fibres for smart textile applications.

Valter Dejke

Licentiate in engineering in 2001 on durability of fibre reinforced polymers in concrete. Has since worked with development and production of chemical type humidity indicators. He was employed 2008 as a researcher at Swerea IVF where he focuses mainly on mechanical and thermophysiological

Erik Perzon

PhD in chemical engineeering. Expert on material science with a specialization in polymer organic chemistry. Focus on solution spinning of cellulose.

Erik Nilsson

PhD-student at Swerea IVF. Focus on development of new, conductive fibers by means of melt spinning for smart textile applications.

Linda Härdelin

PhD-student student at Swerea IVF. Focus on electrospinning nanofibers of celulose in ionic liquids.

The Textile Research Centre

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www.hb.se/ths/ctf

Since its start in 1998 the Textile Research Centre, CTF, gathers international and national actors who work for reinforcing research in the textile and fashion sector. The CTF is linked to The Swedish School of Textiles, THS, at the University of Borås. Through active work the CTF is now of central importance to the research and the artistic development work carried out at The Swedish School of Textiles. Seminars, conferences, publication of journals and other works, and creation of research networks are items from the programme.

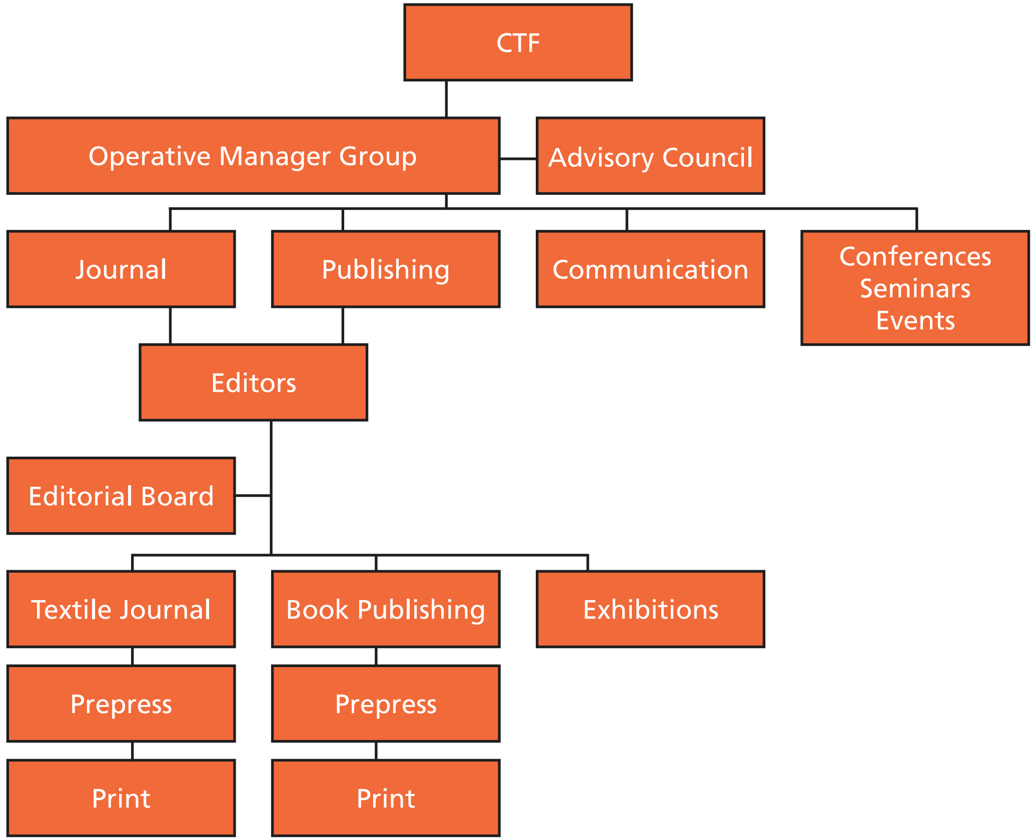
Today (2010), The Swedish School of Textiles has some 10 professors and 25 postgraduate research students. Its intentions are now to develop and strengthen the CTF as an arena and as part of the infrastructure for research and artistic development work. To achieve this, a re-examination of activities, organization, communication, and financing has been carried out.

Purpose

The purpose of the activities of the CTF is to promote Nordic research in textile and fashion by making research results and information available to all professionals in the field. The CTF strives to provide an overall picture of this kind of research by highlighting design and craft as well as technology and management and the unique combination of these subject areas represented by The Swedish School of Textiles and its partners. Thus, CTF activities include hosting lectures, seminars, and conferences along with reflecting current issues and presenting discoveries through publications and media.

Student exhibition 2010
Photo by Jan Berg, Museum of Textiles, Borås

Organisational Scheme of The Textile Research Centre, CTF



CTF, Advisory Council

The aim of the membership of the CTF Advisory Council is to create close links within the field of textiles relevant to the work of the CTF. The first board meeting was held on August 31 1998.

Chairperson:	Håkan Torstensson	Managing Director, CTF, The Swedish School of Textiles, University of Borås Textilhögskolan, Högskolan i Borås hakan.torstensson@hb.se
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	Roger Johansson	Chalmers University of Technology, Chalmers Tekniska Högskola s.roger.johansson@telia.com
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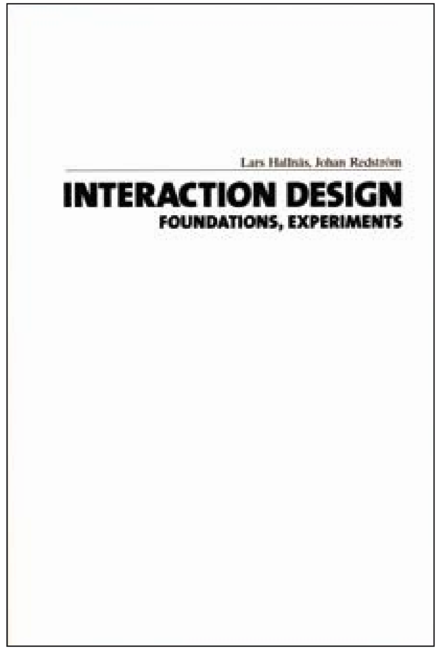
	Karin Rundqvist	Student Representative, The Swedish School of Textiles, University of Borås Textilhögskolan, Högskolan i Borås S082823@utb.hb.se

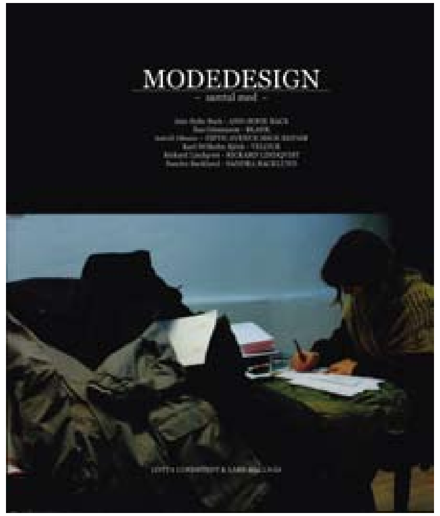
Student exhibition 2010
Photo by Clemens Thornquist

CTF Publishing

Concerning design
Marcus Bergman
Simonetta Carbonaro
Lars Hallnäs
Clemens Thornquist
160x240x7 mm
Colour prints
Paperback
ISBN-91-975576-0-9
Published 2005
Price: € 18



Interaction design Foundations, Experiments
Lars Hallnäs
Johan Redström
150x230x20 mm
310 pages
Paperback
ISBN-91-631-8554-7/
978-91-6318554-0
Published 2006
Price: € 15



Modedesign - samtal med Ann-Sofie Back, Åsa Göransson, Astrid Olsson, Karl-Willhelm Björck, Rickard Lindqvist och Sandra Backlund
Lotta Lundstedt
Lars Hallnäs
220x255x10 mm
Colour prints
120 pages
Paperback
ISBN 978-91-975576-2-7
Published 2006
Price: € 16

Notes on methods
Clemens Thornquist
1 Photographic sketching
Colour prints
60 pages
ISBN 978-91-85659-18-0
2 Experimental fashion design
96 pages
ISBN 978-91-85659-20-3
3 Fashion shoot of me myself and I (sold out)
Colour prints
96 pages
ISBN 978-91-85659-19-7
160x240x4 mm
Paperback
Published 2006
Price: € 18 per unit

Narrations from the Inanimate
Clemens Thornquist
335x230x8 mm
Colour prints
28 pages
Hardcover (cloth)
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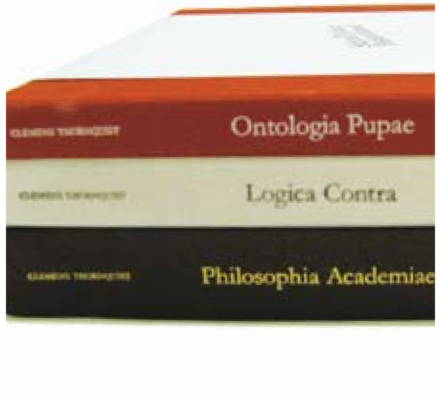
Price: € 37



School Fashion
Fashion School
Clemens Thornquist
Philosophia Academiae
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Three volumes in hardcover (cloth)
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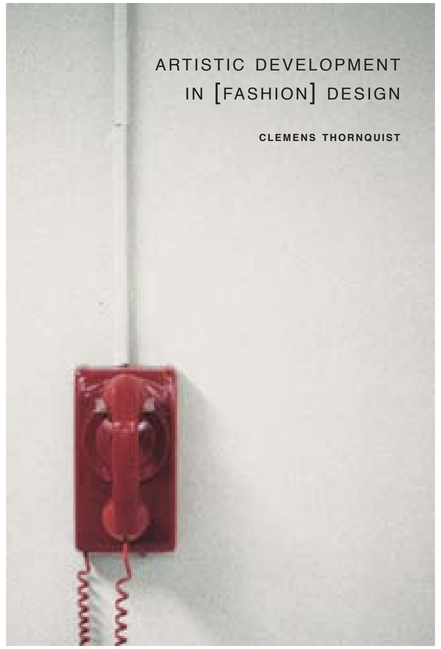
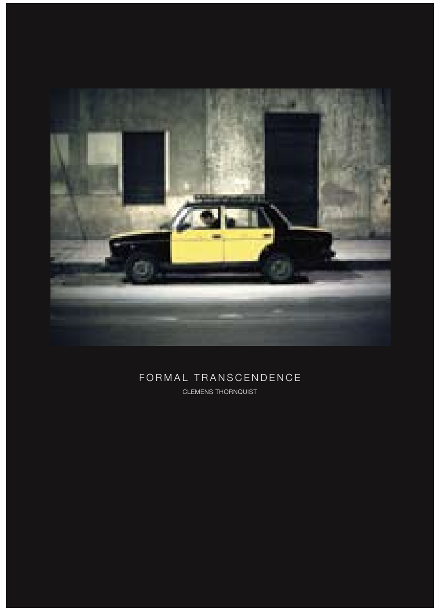


Artistic development in [fashion] design
Clemens Thornquist
132x210x13 mm
160 pages
Paperback
ISBN 978-91-85659-55-5
Published 2010
Price: € 20



Formal Transcendence
Clemens Thornquist
170x240x5 mm
Colour prints
40 pages
Paperback
ISBN 978-91-85659-54-8
Published 2010
Price: € 10

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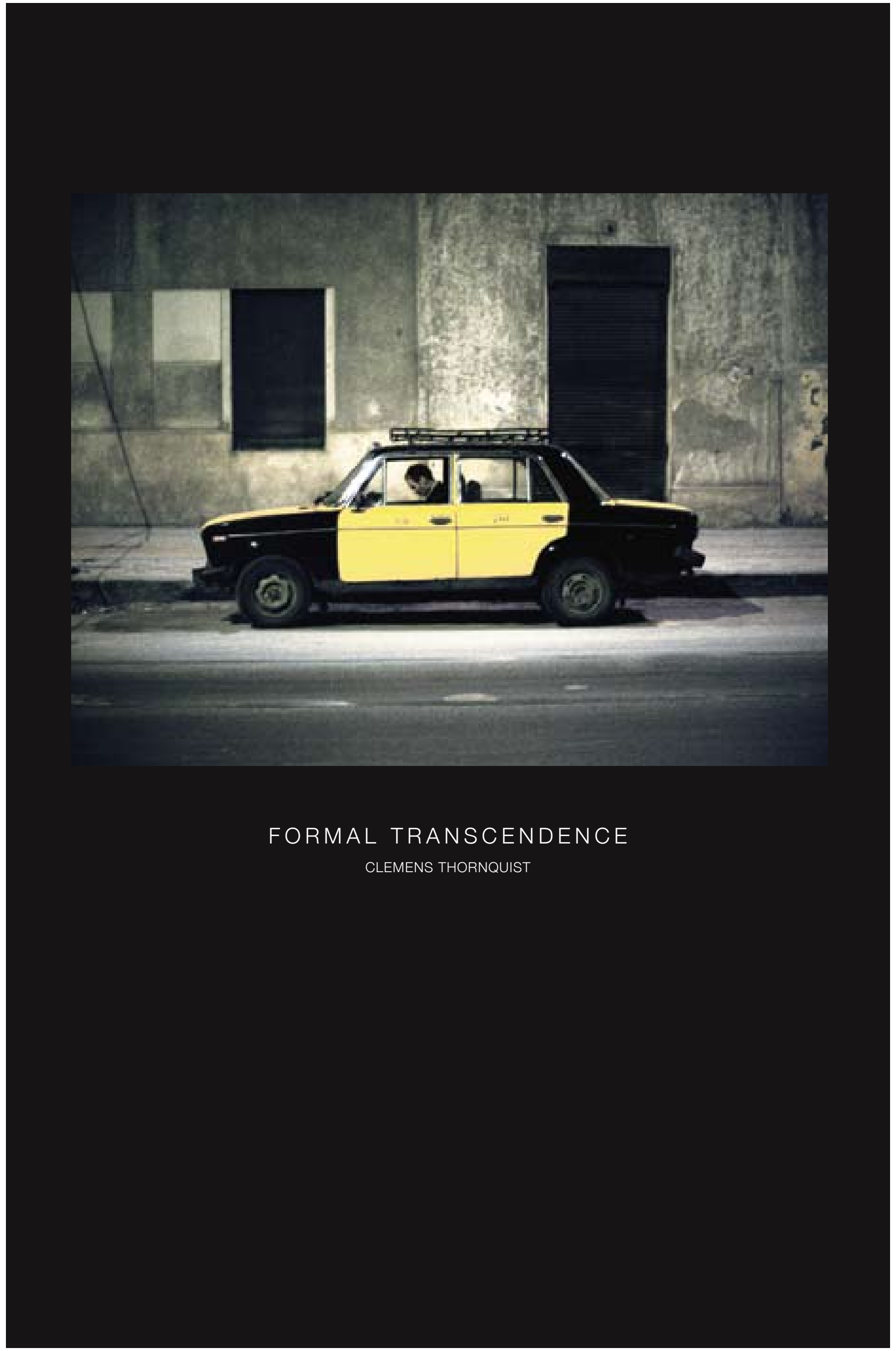

New Book

Formal Transcendence by Clemens Thornquist

Clemens Thornquist is Professor in Fashion Design at the Swedish School of Textiles, University of Borås, Borås, Sweden.
Dr. Thornquist is currently Chairing the Fashion Design Department at The Swedish School of Textiles,Borås, Sweden, and has amongst other things gained professional experience from being arts manager for theatre director and visual artist Robert Wilson and designer at Vivienne Westwood. His action based artistic research in the intersection of art, fashion, philosophy and organisation have resulted in numerous original books and publication and artistic research work in different media exhibited and presented worldwide.

This work aims to explore and present the inevitability of three generally adverse qualities in research methods. The point is to examine these qualities philosophically, without the further aim to disclose anything explicit concerning the content on which they feed. Instead, the work investigates the actualities and possibilities of what together can be noted as a formal transcendence in methods emphasising animated qualites in research.

At the same time, being both a participating subject and an observer from a distance, the voyeur is both present and absent; literally, in-between – inter esse. *Voyeurism* in general, and not only understood in the everyday sense of the word implying sexual arousal by observing people´s intimate situations, is the engaged participating interest where every modality of the body is at work together. At the same time, however, voyeurism involves participating and reflecting from a distance without interfering with the object investigated.

As not so much the opposite of, but rather, the foundation for voyeurism, *immanence* here refers, not to the quality, but instead the ability to remain within, throughout all aspects of the vast and overwhelming spatial world. Through an act of allusion, things do not replace but merely indicate the infinity of nostalgia, and so becomes the long way home. In this gradual direction home, an immanence through all the manifestations of worlds becomes the fundamental movement for actualisation with motives from within.

In order to re-make things into something different, there is first the necessary act of misunderstanding, or simply, an intentional or unintentional *amnesia*. Before things can be re-made into a new meaning, a new direction or a new perspective, the elements to build on must be deprived of their connotations, their contexts, their meanings. From here, as formless, uncategorised and meaningless fragments, things are made into differences.

Textile Notes

Student Exhibition 2010
Photo by Clemens Thornquist

Ballet shoes with shock absorption.
The Capulet Juliet D3o pointe shoe.
Photo Jan Berg.

Textile material library

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Introduction

The collecting and cataloging of knowledge is a human behavior and not even the Library of Alexandria was the first of its kind. The need to collect and make this in a good way has become even more evident since the Western world turned to fierce hard economic competition. The necessity of industrial innovation is pressing. A prerequisite to achieve this is good access to information on material properties. Worldwide there are several material libraries, organized both with commercial structures and achademic ones. Nowadays the textile industry pays particular interest to new functional materials such as "Technical materials" and even "Smart Textiles", i.e. interactive textiles.

Background

The aptly named "Smart Textiles" cluster network in Borås, Sweden, has a need of a Material Library in order to showcase exciting achievements. The Swedish School of Textiles in Borås is home to a multitude of different materials, stored in separate collections. Thus the step is taken to begin coordinating these collections, manifested in May 2010 by the opening of a Textile Material Library. The library is governed by the cluster, and located at the School. Preparations are made to move the library when the School and the Smart Textiles cluster leave the old building for new premises in the Simonsland area in Borås in the fall of 2013. The new school location will be close to the central buildings of the University of Borås. The idea is for the Material Library to become a center of activities at the new location. The benefits are obvious with partners such as the Museum of Textile History, which will move to Simonsland as well, and our new neighbor Swedish School of Library and Information Science. These two partners already work actively with the Textile Material Library in a complementary cluster. Efforts will be made to achieve shortcuts and synergy effects within the disciplines.

Arrangements

At the Textile Material Library in Borås, we have subscriptions of membership in some of the leading international libraries, so we can be sure to assist customers according to normal international level.

We are now collecting interesting materials in different stages of the product development chain. We collect samples from fiber to the ready-made product. The materials are exposed in a gallery with some of the exclusive samples behind glass. Garments are exposed on mannequins. Most of the materials are mounted on walls or listed on hangers.

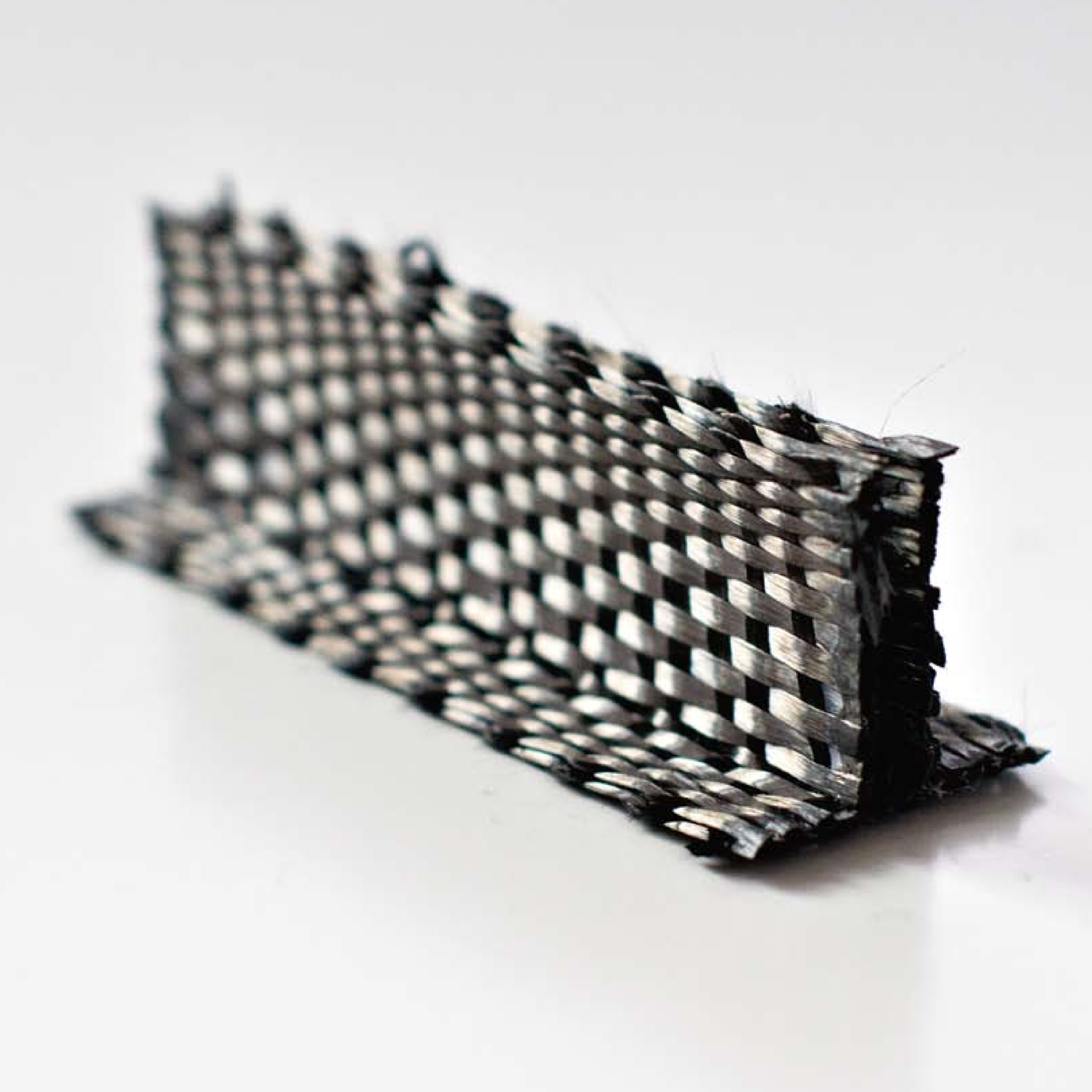
In design circles, the desire is to explore new kinds of venues that represent the combination library – gallery – workshop – courses – conferences in an environment that affirms creativity; a meeting place where students meet producers, trade associations, and project participants such as industrial designers and even artists. Researchers in academia and business entrepreneurs want a database for fact finding, but also a tactile experience - **to touch and feel.**

The Textile Material Library acts as a window between academia, science and industry where different skills, thoughts and ideas can be exchanged – not least for the participants of the Smart Textiles initiative. The library is also a neutral place and part of the Prototype Factory within Smart Textiles and the Swedish School of Textiles.

Two ways of arranging information about textile materials are needed: **one to store materials physically, and one to store information digitally**

Many development processes are complex and depend on various technology components, manufacturing methods and design requirements, where this must be resolved. Visualization, simulation and interaction with digital tools, as well as documentation of the process are even more of interest. Based on this, a pre-study is ongoing to investigate if and how to establish a Visualization Lab within the University of Borås and the Espira development center. The idea is that the Visualization Lab should be another innovation tool within the cluster.

As for the physical arrangement of material samples it would be the Material Library's task to show the potential achievements of each material. All known material libraries have an educational goal. In order to present textile materials, libraries often mount materials on a paper/plastic sheet of approximately 20 × 30 cm, where half of the surface is taken by the material, and the other half by a concise list of data on the material. Reference is then accounted for, typically by a code to a data file. The sheet can then be mounted on walls or stored in boxes, which in turn can be stored on shelves.



3-dimension weaving in carbon fabric by Oxeon
Photo Jan Berg

Relevance

A material library caters mainly to product development related activities. Then again we need it for educational purposes. The pedagogical value in a collection of materials lies in how we use it. American education researcher John Dewey (1859-1952) coined the term "learning by doing" - which is an educational activity where theory, practice, reflection and action are linked. Knowledge must be transformed into something useful and have a real-world training function. According to Dewey, this is done by giving students living knowledge they can transform into practical professional use, as well as personal. The best way to do that is to distance oneself as far as possible from a constructed way of learning. He believed that education should aim to develop the human capacity for problem-solving and critical thinking, rather than focus on memorization.

Work can be done individually or in group, in thematic work and in projects. Here the material library is essential by providing the right materials. The actual gathering of the material in an engaging manner is thus a prerequisite for the process. The student can choose, then create and thereby learn. The Austrian educator Elsa Köhler (1879-1940) in her book Activity Pedagogics argues that the emotional experience is important. Georg Kirchensteiner (1854-1932) points out that manual activities are important. He built laboratories and considered the traditional school as too theoretical. Lev Vygotsky (1896-1934) focused on the processes around the learning man. His vision of human creativity and imagination is important in the understanding of learning.

Heated clothing by WarmX, Germany.
Photo Jan Berg

World perspective

World-wide there are a number of material libraries with different angles in their ambition. Normally they are not limited to fabric, but collect materials in a broader perspective, including materials from the construction industry and handicraft. Such materials are wood, paper, leather, metal, glass, plastics, composites, textiles, stone and concrete.

We are insightful enough to acknowledge the fact that it would be an overwhelming mission to store samples of all materials in the world. We have been commissioned to collect interesting textiles, textiles considered to be state of the art. If we do not have what is needed in physical form, we can always find it digitally. With this mode of work, we are able to work multidisciplinarily.

Curiously, all material libraries were established fairly late – the oldest one a mere 15 years ago.

Material ConneXion holds a front position among the material libraries of the world. It is privately owned and commercial, with headquarters in New York. It has branches in e.g. Milan, Cologne and Bangkok, and is constantly looking for partners around the globe. The business consists of a library of material samples, a gallery that is open to the public, material development software applications, conference rooms, an area for journals/ magazines, and a bookstore. The library stores over 5000 samples of what the library itself brands as new innovative materials and applications at the cutting edge of development. Extra interesting is the New Arrivals Wall, displaying samples of the latest news in materials

Matério, Paris, is the next material library of significance. This library is also privately owned. It has a commercial website allowing access to a database of their entire catalog and search tools. Physically, the library has 400 square meters of showroom shelving exclusively for textiles and some 2500 materials.

Innovathéque in Paris is a commercial material library that is owned and operated by the French wood and furniture industry. It focuses mainly on new materials.

Kuopio Academy of Design, Finland was one of the first material libraries when it was founded in 1994. It is linked to education and has an ambitious approach, both digitally and physically.

Materialbiblioteket in Stockholm is run by University College of Arts Crafts and Design, and is a separate library from the other school library. In order to do everything right from the very start, the founders of this library studied the world market for various material libraries carefully.

Designarkivet in Pukeberg, Nybro. Sweden. The archive premises, 1300 square meters in all, consists of an open plan office, research room, library, archives, photographic studio, conservation studio and an exhibition hall of of 300 square meters.

Material Works based in Frankfurt and Berlin is a very well built material library. Materialbiblioteket in Stockholm acts as a Swedish agent for this German library. The system is very ergonomic with materials on sheets, stored in boxes.

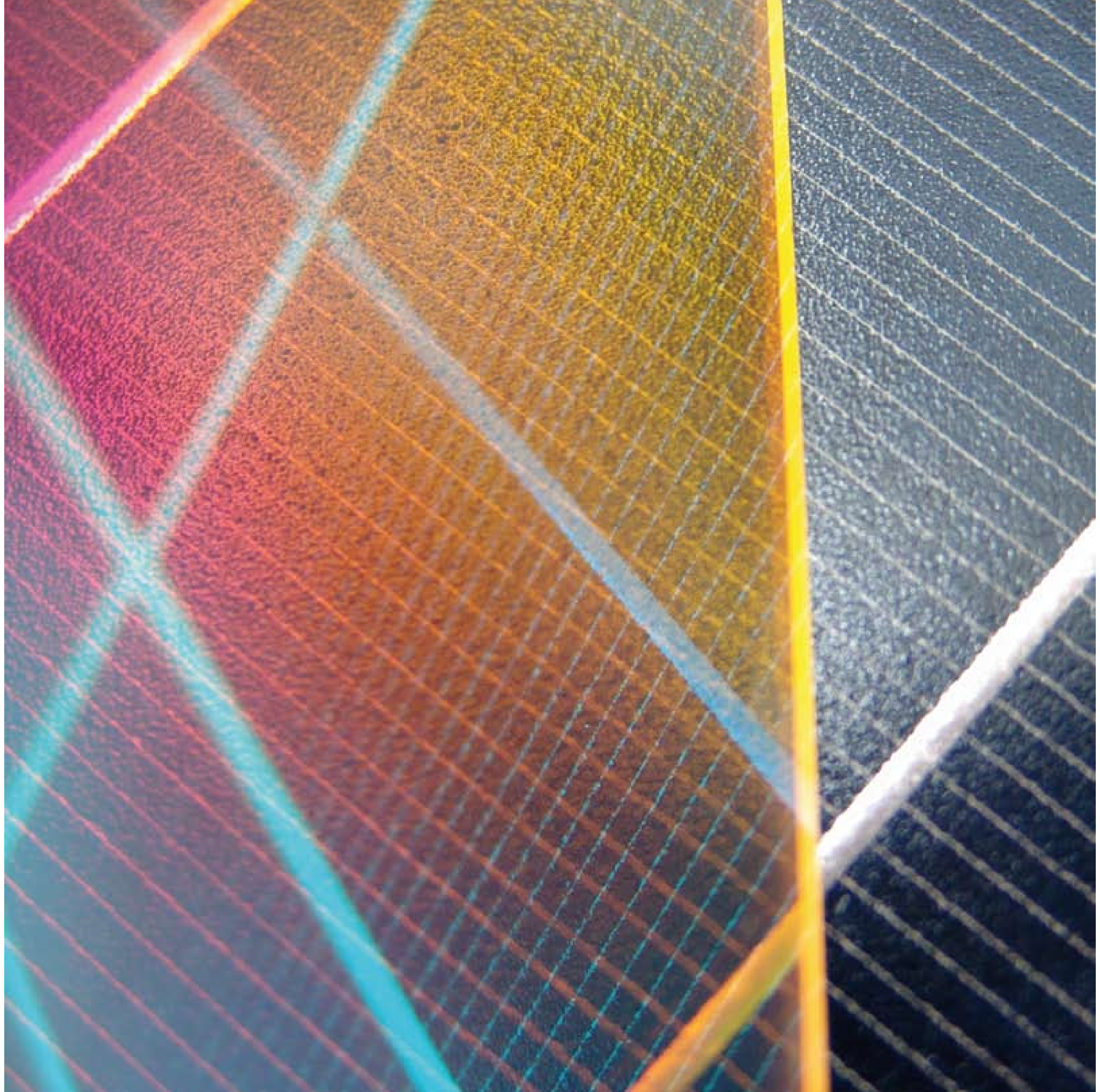
IDEO is a chain of offices over the world with headquarters in San Francisco. IDEO's intranet holds a catalog of materials that is simple, clear and practical. Information given in addition to the neat description of the material is cost, supplier, the size of the sample, instruction how to visualize the material in the best way. If the material / sample is used in the project, the opportunity to comment and link to the manufacturer is a useful and creative feature.

Central Saint Martins College of Art & Design in London has ambitiously collected producer and supplier information with plant samples.

Taking the process one step ahead

A presentation of materials may be good. Visualization of ready-made products is even more exciting. When looking to spark product development processes, a booster that makes the inspiration begin to flow is very useful. We collect interesting products and present them in an exhibition. There we can study developments taking place in different stages, such as **product, finishing, material design, yarn, and fiber.**

The next step is to develop a database that can handle the information at those levels. It should facilitate searching both horizontally and vertically. This is the next step for our Textile Material Library, a never-ending process that has just begun at The Swedish School of Textiles in Borås.



Fluorescent and light emitting plastic held against a solar panel.
Photo Jan Berg

Litterature

Berggren, J. (2006). *Materialbibliotek - vad är det?* Master Thesis. Department of Sociology, Umeå University.

Beylerian, G. M. & Dent, A. (2005). *Material ConneXion. The global resource of new and innovative materials for architects, artists and designers*. London: Thames & Hudson.

Borgman, C. L. (1997). Now that we have digital collections why do we need libraries? In: *Proceedings of the 60th ASIS Annual Meeting*, vol. 34, pp. 27-33. Medford NJ: Information Today.

Kula, D. & Ternaux, É. (2009). *Materiology. The creative´s guide to materials and technologies*. Amsterdam: Frame Publishers.

Martling Palmgren, L., Nordgren, P. & Schmidt, O. (2004). *Materialbibliotek på Konstfack. Rapport, Fas 2: Initiering och integrering*. Stockholm: Konstfack.

Mikkanen, A. (2003). Material libraries in Kuopio. *Arlis Norden Info*, no. 3-4, pp. 23-24.

Bringing active functions to fibres

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Imagine a smart garment where sensors, switches and actuators are no longer push-buttons from the electronics industry but actual textile fibres.

This thought may not be so far fetched. Creating electroactive components in single fibres is now possible by for example using the increasing knowledge of nanocomposites. Plastics mixed with carbon-based fillers, such as carbon nanotubes, graphene and carbon black can conduct electricity. By manipulating the plastic materials and their structures, new materials can be created which can react to its environment, for example by changing its reflective properties or physical shape upon the application of an electrical current. Putting these kinds of functions into fibres and textiles opens up new and exciting challenges.

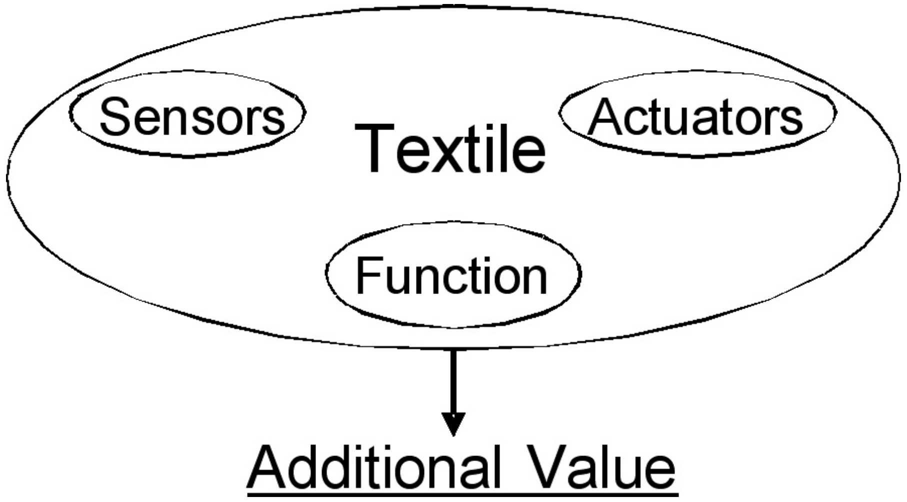

Fig.1 A so-called "smart textile" is a textile which uses sensors and/or actuators for a higher degree of functionality, thereby adding value to the textile.

The Lef-tex project

In the Lef-tex project, further steps are taken towards developing new lightweight and functional fibres, textiles and layers. This new generation of smart fibres will make it possible to create smart functions in textiles which have much more in common with traditional textiles than the previous solutions. Participants from Chalmers University of Technology, Swerea IVF, Imego Institute, Russian Academy of Sciences and University of Borås are joining forces to push the boundaries of the realm of smart textiles. Funding is provided by the Swedish Foundation for Strategic Research.

In its first year, several interesting results have appeared. The prerequisites for producing piezoelectric fibres made from the polymer poly(vinylidene fluoride) (PVDF) has been the outcome of a collaboration between University of Borås, Swerea IVF and Imego institute. The initial trials were made on a small-scale apparatus. Test trials on a larger scale have begun and the preliminary results are promising. One problem with piezoelectric fibres made from PVDF is that a conductive layer is required in order to get the poles. At Swerea IVF, research on melt spinning of conductive nanocomposites has shown the influence of processing on the conductivity when nanocomposites are drawn to fibres. Limitations with this technique as well as possible solutions using bicomponent technology have been described in two scientific publications. The findings together with the articles have also been published in a PhD- thesis presented in June 2010.

Fiberspinning using bi-component technology

The bicomponent technology is a key factor in the chase for fibers which display some kind of electroactivity . It means that two materials with completely different properties can be spun together into the same fibre. Figure 2 shows a sheath-core fibre, cast in an epoxy matrix, with a strong material (polyamide) in the sheath and a conductive material in the core. The fibre feels like a normal nylon fibre but it has certain conductive properties.

Using the conductive material to develop heat or monitoring the conductivity in order to detect changes in the surroundings are typical examples of electroactivity in textiles.

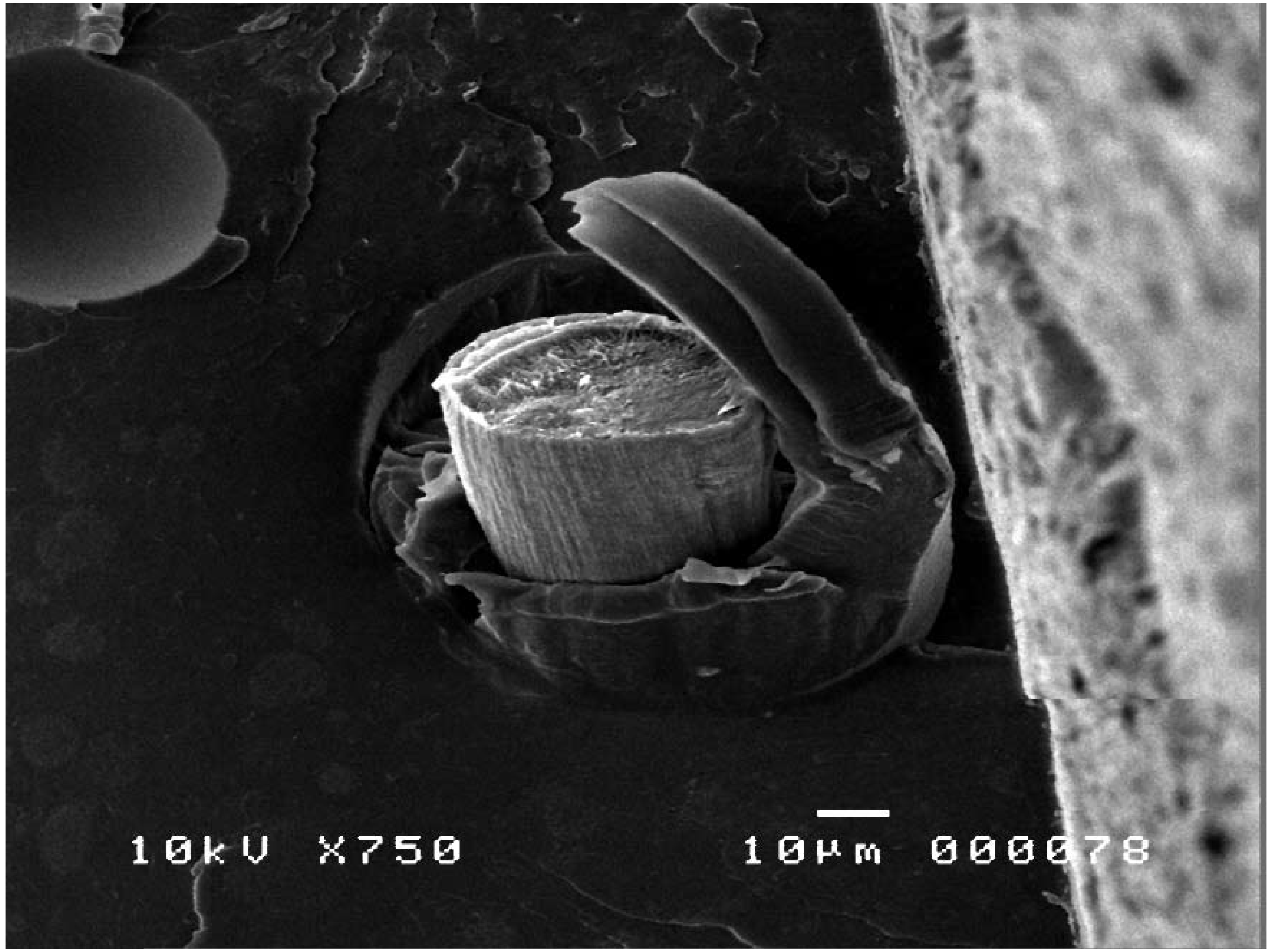

Fig 2. Sheath-core structure of a bicomponent fibre.

A fibre-sensor could be made if the conductive material changes its resistive behaviour due to some stimuli (temperature or a certain targeted chemical). These kinds of fibre sensors would have a faster response time compared with for example film sensors due to their high surface area (high uptake) and small thickness of the active layer (short penetration time).

The bicomponent fibre spinning process is described in Figure 3, where the material is melted and fed from two extruder pumps (1) into a so-called spinneret (2) where the two fluids are combined in a way so that when they exit from the spinneret through a section with small (0.6 mm) holes, called the die, the fibres already have the sheath-core structure. What follows next is the melt drawing (3) which is where the 0.6 mm plastic strands exiting the die are turned into thin fibres. The reduction in thickness is decided by the speed of the godet (4), the rotating wheel which draws down the fibres. By stretching the drawn fibres, in what is called the cold-drawing section (5), the properties of the fibres change radically. Strength for example, can typically increase by a factor of 10 or more if plastics such as polyamide or polyester (PET) are used. Our research shows that cold-drawing unfortunately also reduces the conductivity of this type of fibres as well. Last of all, the fibres are wound up on a bobbin (6).

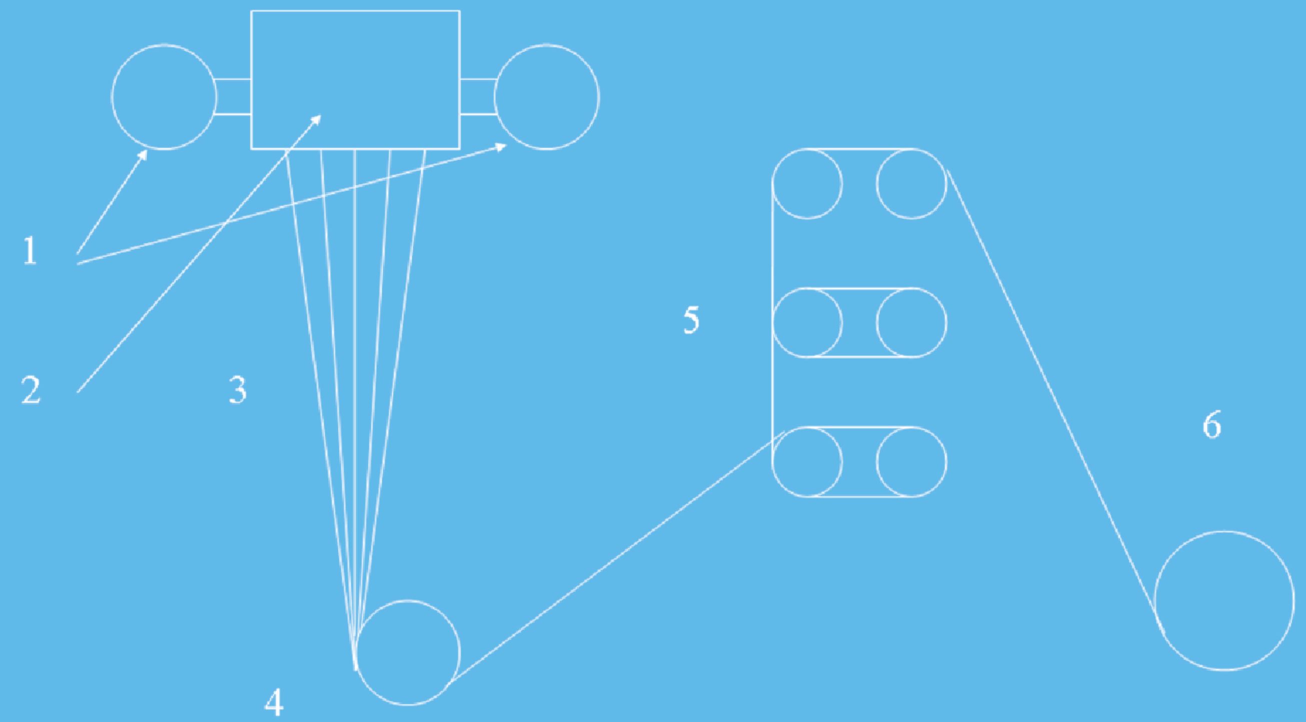

Figure 3. Schematic description of the bicomponent fibre spinning process. The difference between bicomponent versus conventional fibre spinning can be found in steps 1-3.

Call for conference and exhibition participation - First call

An international conference, and exhibition, which welcomes researchers and artists/designers/ architects to the University of Borås 28-30 November 2011.

WELCOME TO AMBIENCE´11
…where art, technology and design meet

The Ambience conference focuses on the intersections and interfaces between technology, art and design. The first international conference in the Ambience series was held in Tampere, Finland in 2005. In Tampere 2005 the basic theme was "Intelligent ambience, including intelligent textiles, smart garments, intelligent home and living environment". In Borås 2008 it was "Smart Textiles – Technology & Design" and in Borås 2011 it will be the new expressional crossroads where art, design, architecture and technology meet; digital architecture, interaction design, new media art and smart textiles.

With a foundation in artistic practice the conference will be organized as a meeting place where art, design, architect and technology communities can come together to discuss and share ideas on the interfaces between art and technology development; a place where art, design, architecture and technology can meet and interact, to inform each other, and to bring new ideas back to their own community.

The conference will include sessions for paper presentations as well as an exhibition for the presentation of art, design and architectural work.
We welcome contributions from the areas of art, design and architecture where new technology plays a key role and also contributions from areas of technology where focus is on applications in contemporary art, design and architecture.

Keynote speakers will introduce discussions about, and critical reflections on, the future development of the intersections between artistic practice and technology. Concerts and performances will also display artistic perspectives on modern technology.

The conference is organized by The University of Borås in cooperation with Tampere University of Technology and is a part of the Smart Textiles Initiative – www.smarttextiles.se

Submitting

Extended abstracts of papers and exhibition proposals should be submitted no later than:
April 1 2011.
Please visit the conference website for more information and detailed instructions:
www.ambience11.se
Be sure to check the website for changes that may appear as the submission deadline approaches.

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Student exhibition 2010
Photo by Clemens Thornquist

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Refereeing

Submitted article manuscripts will be peer reviewed by at least two referees appointed by editorial board. Article manuscripts can be either accepted as submitted, accepted after requested major or minor modifications or rejected by the editorial board. Submitted images of research objects will also be scrutinized by experts appointed by and after the assessment, accepted or rejected by the editorial board.
Submitted exhibition reviews and book reviews will be subjected to an editorial assessment.

Free access publication

The journal will be published electronically, with free access, six months after the publication date of the printed issue. The electronic version will be published in the University of Borås institutional repository BADA (Borås Academic Digital Archive) http://bada.hb.se/ .

Guidelines - articles

- Submitted article manuscripts should be original articles, written in English. They must not be published in the same form earlier or submitted for publication elsewhere.

- The text should be submitted in two copies: one editable copy and one non editable copy in appropriate file formats.

- Photos and other images should be supplied as separate files in an appropriate file format.

- It is the author's responsibility to obtain the required approval from all the parts involved: authors, photographers, artists and others.

- There is no page limit specified for contributions, but it is recommended that the material is presented in a form that is succinct and attractive to read.

- An abstract of not more than 250 words should be supplied as well as 5 essential subject keywords.

- A biography of 3-5 sentences for each author should be supplied as a separate file.

- References should preferably be in Harvard style (the "name-year system").

  Harvard system:

  Example, books
  The reference:
  (Finnane 2008, pp. 44-48)
  In reference list:
  Finnane, A. (2008). *Changing clothes in China. Fashion, history, nation.* New York. Columbia University Press.

  Example, book chapters
  The reference:
  (Breward 2001)
  In reference list:
  Breward, Ch. (2001). Manliness, modernity and the shaping of male clothing. In: Entwistle, J. & Wilson, E. (eds.). *Body dressing.* Oxford. Berg, pp.165-181.

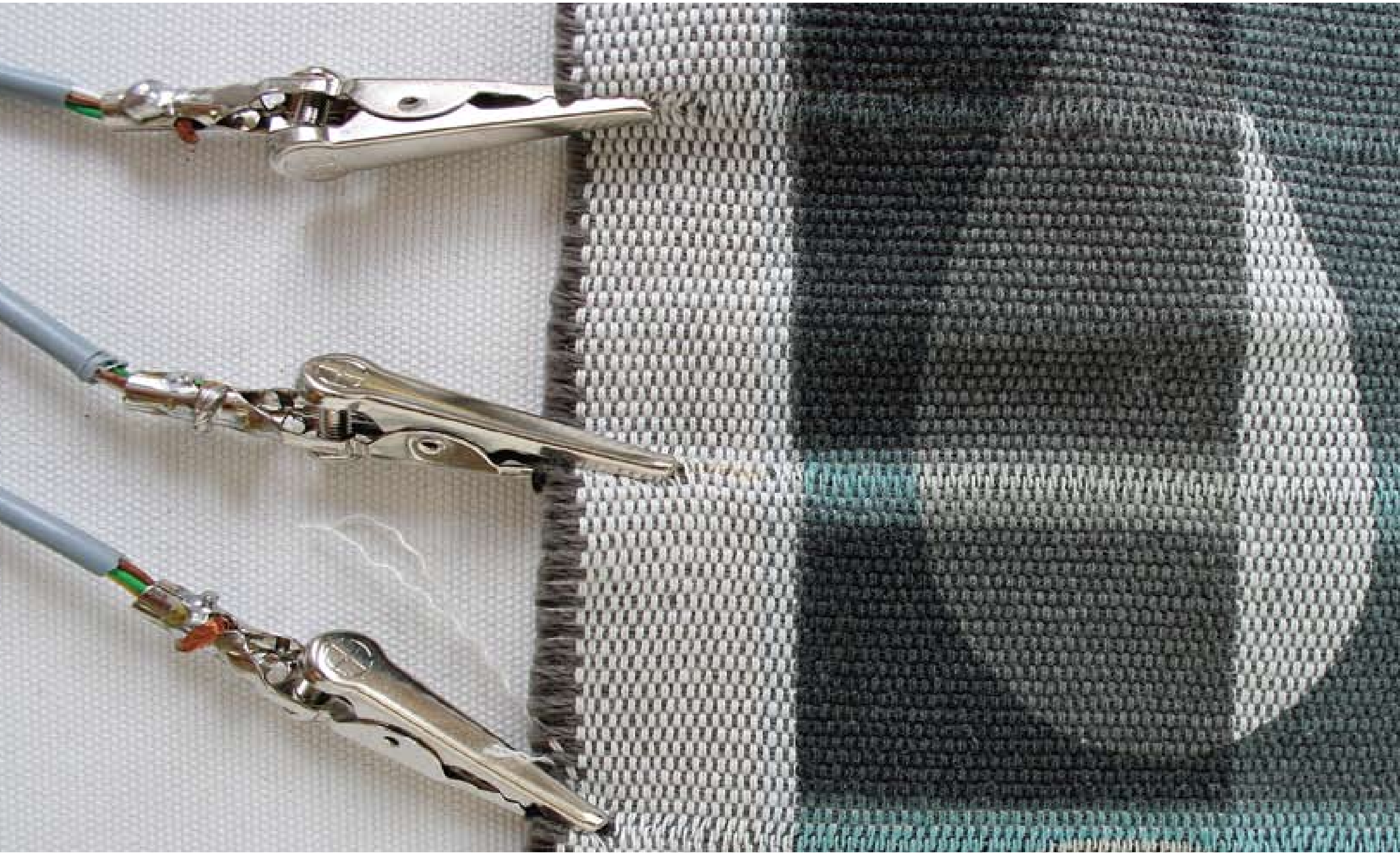
  Example, journal articles
  The reference:
  (Studd 2002)
  In reference list:
  Studd, R. (2002). The textile design process. *The Design Journal,* vol. 5:1, pp. 35-49.

  Example 1, websites
  The reference:
  (Victorian and Albert Museum n.d.)
  In the reference list:
  Victorian and Albert Museum (n.d.). *Fashioning diaspora space.*
  [Online] Available at: http://www.vam.ac.uk / Research & Conservation / Research / Research Project: Fashioning Diaspora Space [Accessed 19 April 2010].

  Example 2, websites
  The reference:
  (Scalway 2009)
  In the reference list:
  Scalway, H. (2009). Essay: *Means and meaning.* [Online] Available at: http://www.vam.ac.uk/collections/fashion/features/diasporas/movingpatterns/essay1/index.html [Accessed 19 April 2010].

Guidelines - exhibition reviews and book reviews

For book reviews, bibliographic information should be supplied: author(s), title, publisher and publication year. For exhibition reviews, name of originator(s), title, location and dates of the exhibition should be supplied.



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