STELLA Newsletter VI

STretchable ELectronics for Large Area applications

Welcome to the sixth issue of the STELLA Newsletter.
STELLA is an EC funded project within FP6 (IST-028026), started in February 2006; see: www.cordis.lu. In this project a new technology platform for electric circuit boards being stretchable and breathing will be developed as a consequence of the ambient intelligent vision where the citizen carries along more and more electronic systems near the body.
In this issue we would like to present the final status of the project at the end of Year 4 related to the actual results in technology development and final application demonstrators.

Content Issue No. 6:

I The STELLA Project

Time to say good-bye

Four years are a short time after all – at least that is what I feel. Honestly speaking I shed some tears, because it is over now. Why? Because this was the best project, I have ever participated in. This is not the Jacques Rogge type of speaking, who always tells that the latest Olympic games have been the best ones. I mean it and I would like to tell you why.
I have been part of many cooperation and many projects – both purely industrial and publicly funded. And I have never before experienced this style of cooperation. It is extremely rewarding and satisfying to know, that one can rely on each other. This will be my key memory of the STELLA project and I hope that you feel the same.
Maybe I should stop the sentimental part here and focus again on the project. This is a success story and we can be proud of it. The demonstrators are ready and the first products are already visible at the horizon. Please enjoy reading about the latest status of the demonstrators and the exploitation of the project results in products and technologies.

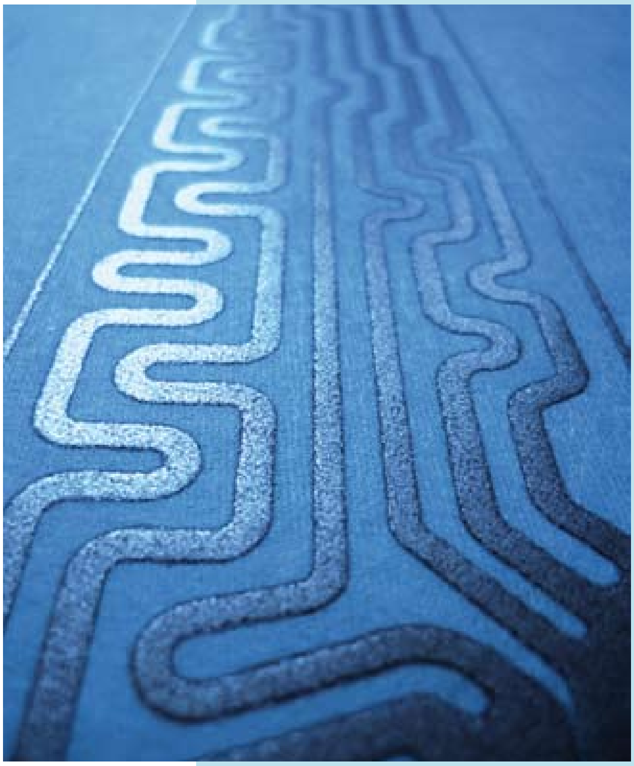

Figure 1: Conductive Paste on Nonwoven

What's next .....

Beside bringing the demonstrators ready for the market the idea of developing, discussing and learning about stretchable electronics will be continued with:

- the **Flex-Stretch-Workshop III in November 2011**
- the Dissemination day **18.10.2010** at **Plastic Electronics 2010**
- new EC funded projects **PLACE-it** and **PASTA**

Follow-up project PLACE-it

At 1 February 2010, the European PLACE-it project has started. PLACE-it stands for "Platform for Large Area Conformable Electronics by InTegration", and aims to realize an industry platform for thin, lightweight and flexible optoelectronics systems. These will not only open new dimensions in product design, but will also create unique opportunities for on-body applications in healthcare and wellness.
PLACE-it looks beyond the bulb for lighting applications. The project will optimally exploit the energy efficient and small form-factor characteristics of the new lighting technologies like LEDs and OLEDs (organic LEDs), while at the same time making use of the tremendous developments in flexible substrate technologies such as foils, stretchables and fabrics. Imagine a lamp that is not fixed to the ceiling, but that can be designed into any shape, or even blended into the surroundings. Or curtains that emit light to mimic the natural, daytime situation. Illuminating jackets for children to safeguard them as they cycle home from school and even bandages that shine light on the body to treat skin diseases are just some examples of scenarios that could become reality in the near future.

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www.stella-project.eu

II Applications and Market

Figure 2: Urgo band aid demonstrator for pressure measurement under compression garments.

Final Status of the URGO band aid demonstrator

BACKGROUND OF THE APPLICATION
Chronic wounds are a major health problem worldwide. The compression of the lower leg is an effective treatment in preventing venous and lymphatic disease, with results that depend strongly on the gradient of compression applied upward along the leg. A tool for laying tape and control the maintenance of pressure levels over time would be very useful to improve the effectiveness of treatment.

DEMONSTRATOR
The objective of these 4 years of study was therefore to develop a „embedded measurement system“ able to detect interfacial pressures and automatically record their values over time with wireless transmission. This need to develop a pressure sensor attached on a stretchable substrate and a miniaturized electronic system that communicates the values measured at a recording station. This work has been performed in this European research project involving industrial and academic partners with whom collaboration was very fruitful and rewarding (TUB, NXP, Freudenberg, etc.).

The optimization of the pressure represented the breakthrough work of Urgo. Indeed, the addition of elements of a certain hardness at the interface between the sensor and the skin has improved metrological characteristics related to the measurement of pressure in compression therapy. This achievement has been the subject of an application for a patent (FR0950147).

NEXT
The marketing aspect should be worked regarding a product dedicated to phlebology specialists to control not only the laying of bands but also to record the data of pressure during treatment and during clinical trials of long duration. This device include a reusable portion and a disposable part (see figure). It would be done with Stretchable Copper Board of our partners of TUB (IZM). The electronics utilize the technology developed during the European project with our partner NXP.

The manufacturing process of this demonstrator will be studied with the help of our partner QPI in the months following the project with the launch of a pre-series of a hundred prototypes.

For more information, contact:
Julien Steinbrunn, URGO
j.steinbrunn@fr.urgo.com

The „Fourth“ Dimension
Freudenberg NOK Mechatronics enters new markets

The STELLA project has now come to an end and we are all looking back on some quite busy years. These years were full of intensive development work, product and market analysis and first tentative attempts to place the product in the market. Substantial amounts of money have been spent, both, at the expense of the companies involved as well as governmental funding. Was it worth it? Do we have a product which meets market demands?

The answer to these questions is simple, as far as we, Freudenberg NOK Mechatronics, are concerned. It is a straightforward “yes!”.
The originally wide spectrum of possible product applications where STELLA technology could be employed, ranging from toys to smart clothing, has now been narrowed down to realistic medical and automotive applications.
Extensive development work has been carried out at our plants in Berlin and Pécel, Hungary, and also at some of our potential customers for STELLA products. So is one of the leading European automotive seat heating system manufacturers testing our STELLA material during an extensive endurance test program - up to-date without any problems. Seat heating is one alternative, however, the flexible STELLA heating material can be employed for ambient heating virtually anywhere in the car. This will become more and more important especially with the introduction of electric vehicles, where the engine does not provide sufficient heat to warm the car interior.
Freudenberg NOK Mechatronics is looking at sensor applications in automotive vehicles but in addition at sensor applications in the medical field.

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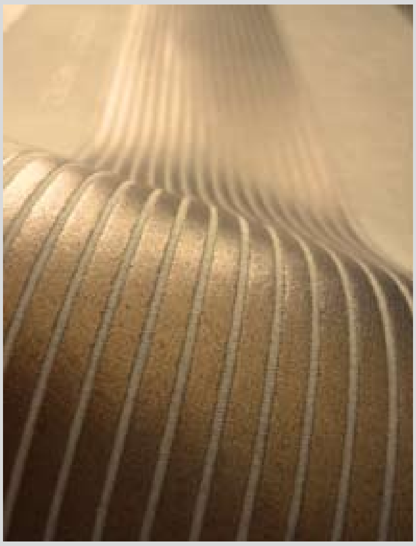

Figure 3: Printed heating circuit in STELLA-SPB-Technology by FNM

SPB=Stretchable Polymer Board

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One of the requirements in the medical area is the reliable flexibility of the material. Patients move and breathe and the material must be able to follow these movements. Therefore, internationally recognized substantial bending tests have been carried out and completed without any problems. Various sensor applications have been investigated and on the basis of these results medical companies have analysed the Stella material and are extremely interested to have the first products in the market as quickly as possible.

The development work, however, did not only include the production of numerous samples for various tests and applications and the analysis of test results, it also included the analysis of how to realize the STELLA material under mass production conditions. Here the tests have shown that there are no obstacles to put production into place and we are really looking forward to the first production of a new generation of products.

All in all we can say is that STELLA has brought a new dimension to our product world!

For more information, contact:
Gunter Bobzin,
Freudenberg NOK Mechatronics
gunter.bobzin@freudenberg.de

Reliability of the SMI/SCB technology

Reliability is defined as “the ability of a product to perform according to specifications, under specified conditions, during a specified period of time”. In that sense quality describes the intended functionality, and reliability is maintaining that quality over time.

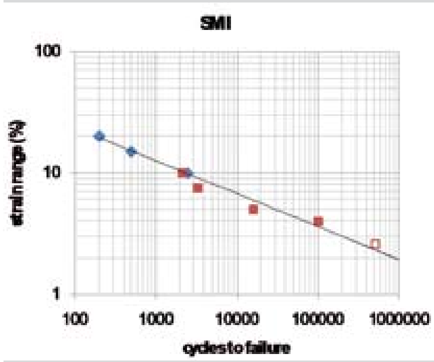

Figure 4: Cycles to failure of the SMI technology for different stretch rates

SMI=Stretchable Mold Interconnect
SCB=Stretchable Copper Board

The stretchable substrate technologies that are developed in the STELLA-project will probably be accompanied by other failure mechanisms in addition to those we already know from rigid and flexible substrate technologies. Of course, reliability involves many aspects, but in this research and development project the focus was on stretchability and electrical connectivity (of the conducting traces on the substrates). For the actual demonstrators additional tests were carried out, such as storage at various temperatures, the effect of moisture, bending of the substrates et cetera.

Consider any electronic product – either consumer or professional, lighting or medical – as a system. Failure of a component will often lead to failure of the entire system. Sometimes its unreliability or failure is just inconvenient (TV-set, hair dryer), but failure may also cause hazardous situations (vehicles, aircraft, medical equipment). Knowledge about the behavior of products under various conditions is thus important. This requires knowledge about the loading or use conditions (the so-called mission profile), the design of the product and the response of the materials to the stress loads. As assessing product reliability involves testing all parts of that particular product this is a tedious, time consuming and expensive work. Therefore the (electronics) industry seeks means to speed up such test procedures, for instance by designing accelerated tests and developing predictive models. This Physics-of-Failure approach has proven to be very successful. It is of the greatest importance to address these issues as early as possible in the product development process. In the end, one strives to be able to build in reliability of the products.

In the STELLA-project the reliability was addressed using these ingredients – mission profiles, geometry, and materials properties – in a sequential approach. In the first step test samples were stretched until failure to find the maximal amount of strain they could withstand, and to identify the possible failure modes.

The second step concerned endurance tests by repeated stretching of the samples from zero strain to well below the maximum allowed strain that was determined in the first step. In practice the samples were thus stretched from 0 to 2–15%. Depending on the technology and the design, the number of stretching cycles until failure varied from many hundred thousand at small strain values to a few thousands at larger strain values. The third step in the reliability assessment was to define the mission profiles for the various application areas, and then to compare these with the test results. The outcome was that there are good prospects for the technologies to comply with the requirements.

In parallel, model simulations were done to study the stress and strain evolution in the samples, in particular in the region were the stretchable substrates are connected to the necessary rigid interposers, but also at other parts of the substrates. In this way we were able to make substantial progress in constructing the damage model for these technologies.
The combination of experiments and simulations has led to various improved designs for the conducting structures on the substrates.

For more information, contact:
Hans de Vries,
Philips Applied Technologies
j.w.c.de.vries@philips.com

II Applications and Market

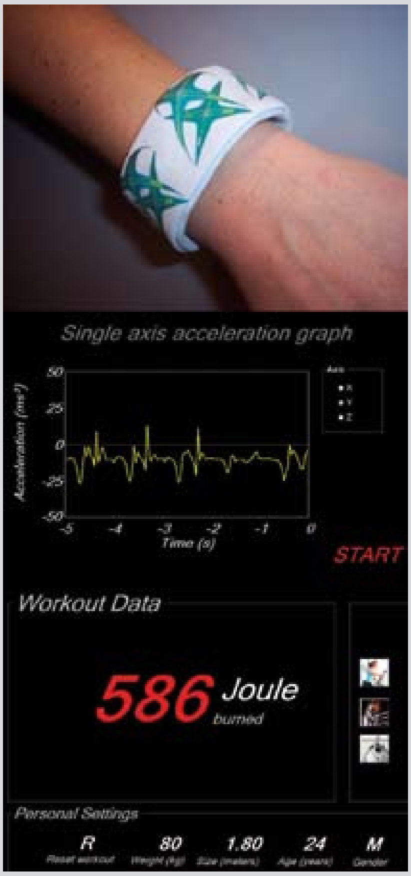

Figure 5: Stella activity monitor and application software: acceleration graph and calorimeter

Final Status of the Philips - STELLA Activity monitor

In the STELLA project demonstrators of a stretchable wireless activity monitor, designed by Philips, have been manufactured. The demonstrator device, put in a soft, flexible and stretchable textile package can be attached to stretchable (Velcro) straps of different lengths. In this way it can easily be attached to the body at different locations. The wireless activity monitor transmits rough 3-axial acceleration data, which can be converted locally in e.g. acceleration graphs or energy consumption. A picture of the demonstrator, acceleration data and output screen are shown in figure 5 and figure 6.

In this demonstrator the SCB (Stretchable Copper Board) technology developed in STELLA by TUB has been applied. QPI produced industrial substrates and Philips assembled the devices on an industrial line.
In SCB technology, conductive copper tracks have been patterned on a poly-urethane substrate. The electronic design has been partitioned into 5 interposer boards, which have been soldered onto the SCB substrate with low temperature solder and ruggedized using under fill (figure 6). The robustness of the interface was verified through elaborative stress testing. As a result, in STELLA distributed electronics on stretchable substrates has been successfully demonstrated.

The activity monitor is an example of a wireless body sensor, which is part of a smart wearable system architecture as shown in figure 5.
Using the technology developed in the STELLA project and the wireless Philips sensor platform, sensor functions can easily be exchanged or added to the system. Such a system will be used for sports, wellness or healthcare. The combination of sensors integrated in a body area network, embedded in stretchable soft touch materials provides options for enhanced capabilities in monitoring and early warning/detection combined with improved wearing comfort.

Figure 6: Activity monitor hardware in SCB technology partitioning (from left to right): Battery (1), power management (2), sensor board with 3D accelerometer and 2D magnetometer (3), microprocessor (4) and 2.4 GHz radio with antenna on top (5)

For more information, contact:
Ric van Doremalen,
Philips Applied Technologies
Ric.van.doremalen@philips.com

Final Status of the shoe insole demonstrator

The shoe insole demonstrator is a demonstrator with a very clear product vision – condition monitoring of diabetes shoe insoles. Due to this market pull the development status is much closer to a product than the status of e.g. the car compartment demonstrator. It was outlined in the last issue of this newsletter that a larger set of samples has been produced. In this issue we will focus on the testing and on the advances in software.

The shoe insole demonstrator measures the pressure of the foot on the shoe insole at 3 different positions using a magnetic principle. The signals are evaluated to determine whether the compression set of the insole has changed so much that a replacement of the insole is compulsory. Besides the cyclic walking stretch of the circuit board which connects the sensors with the microcontroller, aggressive media like sweat are an issue for the lifetime of the electronics.

Figure 7: Shoe insole demonstrator in SCB technology

The necessity to develop a graphical user interface (GUI) to program the microcontroller on the demonstrator became apparent, as the complexity of the signal processing and the calibration routines increased. The new GUI – as shown in figure 8 – improved the efficiency and reliability of the calibration process and the signal analysis.

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Histograms are shown, that visualize the frequency of occurrence of different pressure values at the foot pad at three different positions, e.g. behind the little toe. Furthermore it is possible continuously monitor the pressure using the online function. For this reason the GUI has quickly become the most important tool for evaluation of the status of the shoe insole demonstrators.

The focus of the lifetime tests has been put on mechanical stress for two reasons

1. the materials selected are considered to be stable against sweat.

2. Mechanical stress currently remains the most important cause of failure. To a life-time tests are carried out.

The shoe insole is exposed to static stretch during manufacture and to dynamic stretch during usage of the insole. The static stretch during manufacture may be combined with either high temperature or media attack by solvents. The shoe insole samples did perform very well in both static and dynamic stress tests and no difficulty in first patient tests are expected.

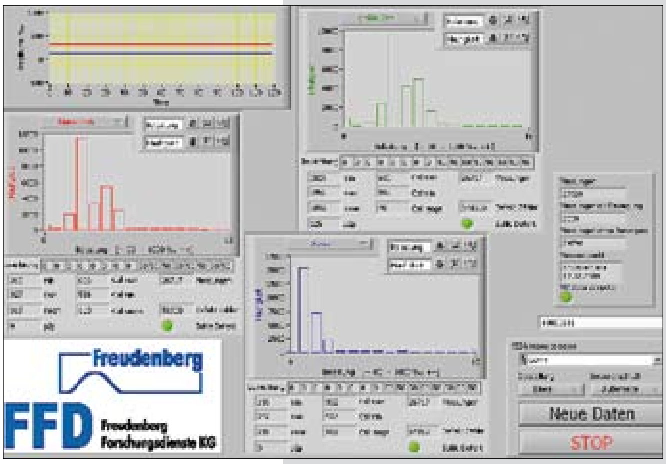

Figure 8: Graphical user interface (GUI)

For more information, contact:
Dr. Gregor Grun,
nora systems
gregor.grun@nora.com

Status of the Verhaert infant respiratory monitor

The infant respiratory monitor measures the chest and abdominal elongation of the breast. Therefore, we have to measure the change in elongation, on two fixed locations of the breast. The system is encapsulated in a cloth that can be clipped onto a pajama. The pajamas are thus exchangeable and washable. The cloth with electronics is self-contained and apart from clipping the cloth onto the pajamas, no other setup is required. In case of an alarm an optical and a noise signal are given.

The use of a Rubbery Ruler to measure elongation of the breast, a strain of more than 10% is required. (a Rubbery Ruler is a type of transducer with slim sensors, an elastomeric body and double helix conductive core, by the university of Melbourne). For a breathing monitor, 5 million breathings in one year is the goal to be achieved. Tests on stretchable substrates at an elongation strain of 10% indicate a lifetime of 300-1500 cycles which will not suffice.

To reuse the experience of elongation measurement based on capacitive change of the double helix of the "Rubbery Ruler", a similar concept of small parallel capacitor plates has been introduced on the SCB (stretchable copper board by TU Berlin) technology. This integrated version on stretchable technology does not only give an answer on lifetime of the sensor but also on the production price which will be almost reduced by a factor 2. With the integrated sensor, we only need a strain of 2% compared to 10%. This means that the resolution of the measuring system is higher and it requires less effort from the baby. The Next picture gives an impression of the proposed design in SCB technology.

Figure 9: Baby dummy with sensor pad clipped on.

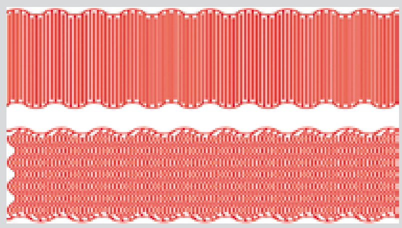

Figure 10: One side meandered capacitor plates & two directional meandered capacitor plates.

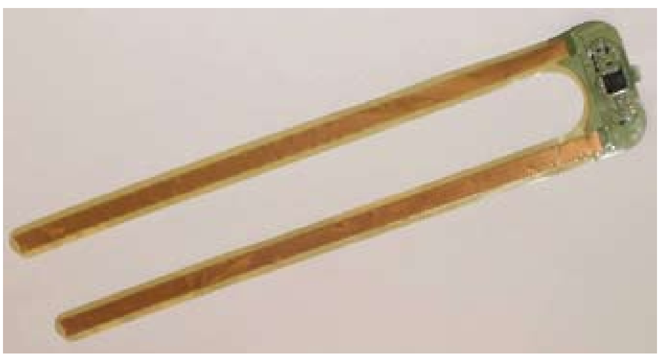

Figure 11: Integrated stretchable Ruler in SCB design

One can see clearly the two "integrated" sensors together with the onboard processing electronics. This demonstrator can easily be integrated onto fabrics. Different shapes (one and two side meandered plates) of capacitor plates have been produced. Due to the stretchable substrate the distance between the different lines (capacitor plates) will be changed in function of the stretch. Using this capacitor in a oscillator gives a linear relationship between the frequency and the stretch of the sensor.

For more information, contact:
Peter VandenBergh, Verhaert
Pieter.VandenBergh@verhaert.com

II Applications and Market

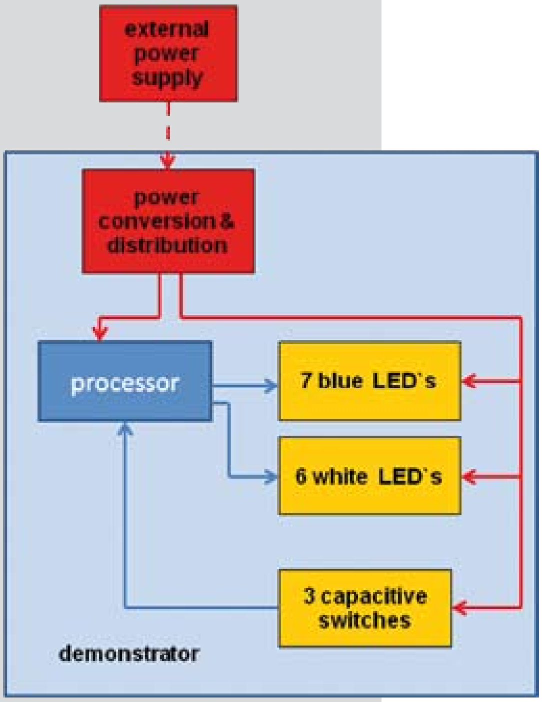

Figure 12: New sensor node architecture

Figure 13: Final design of the car compartment demonstrator

Final status of the Car Compartment Demonstrator

The car compartment demonstrator is in many respects an exceptional demonstrator.

- It is the only demonstrator built in SPB technology
- It is the only demonstrator built on non-woven
- It is the only demonstrator where a on-time static instead of a dynamic stretch is applied.
- It is the only demonstrator where the stretch is applied as a part of the manufacturing process and not during application.

The car compartment demonstrator is to prove that it is possible to manufacture 3D-shaped electronic circuits without the necessity to place electronic components on this 3D shape. The basic idea is to manufacture a flat (2D) but stretchable printed circuit board (SPB), then place the electronic components and in a final step transform the printed circuit board in its 3D shape with neither destroying the circuit nor the components.
As this demonstrator aims to prove the technological concepts and the feasibility of the manufacturing processes, a relatively easy electronics' design, as shown on figure 12, has been chosen for the car compartment demonstrator.

The car compartment demonstrator could be seen as part of the car interior lighting. The white LEDs represent a reading light and the blue LEDs an alarm light. In the demonstrator all switches are used to turn the LEDs on and off, whereas in a real car application some LEDs might be turned on and off by external switches and some switches might be used to turn external applications on and off.

The switches are implemented as printed capacities which are controlled by a specific slave controller. The unit and peripherals of this controller are installed on a flex of polyimide. As the distance and wiring of the capacitive switches to the slave controller must be short the flex is installed next to the printed capacitive keypad. The communication of the switches commands are transferred via I²C Bus to a PIC-µcontroller. Dependent on the desired keypad commands the PIC-µcontroller switches the LED arrays on or off.

The manufacturing of the demonstrator can be divided in 3 main steps:

- At first the SPB is manufactured. This step is divided in several subprocesses, as different layers of PU printing paste – some for insulation, some as conductors – are printed consecutively on the nonwoven backbone. Between the printing steps curing steps have to be applied.
- The second step is the placement of the electronic components on the SPB. Then a cover layer typically made of the same material as the nonwoven backbone is placed and laminated on the SPB.
- Finally the SPB is deep-drawn into its final 3D shape and the stretchable part of the electronics is connected to flex or rigid circuit.
  This first aim to prove that we have a reproducible process to manufacture a functional car compartment demonstrator has been achieved.

The car compartment demonstrator has a lead application with several specifications beyond reproducible functionality after manufacturing. Henceforth, several tests have been performed to test the reliability of the conductors and the circuit:

- The abrasion of the switches by sweaty fingers has been tested in the Veslic test. It was found that the demonstrator has a very good resistance against acid sweat, for alkaline sweat the requirements of the lifetime test are not yet met.
- The colour fastness of the samples has been tested using EN ISO 105. Here the samples are 5 times 70 hours exposed to a UV power of 60 W/m2. It was found that the samples exhibit an almost perfect colour fastness after the first 2 cycles. The degradation of the colour in the following cycles indicates that more UV stabilisator is needed in the formulation of the PU printing paste.

The concept to manufacture 3D shaped circuits using well established 2D processes for flat circuit boards is very attractive for many applications – not only car interior. The inquiries coming from the market give us more than hope that SPB technology will be used in a lot of marketable products.

For more information, contact:
Dr. Jürgen Günther,
Freudenberg Forschungsdienste KG
juergen.guenther@freudenberg.de

2nd International Workshop on Flexible & Stretchable Electronics

Figure 14: Participants of the 2nd International Workshop

The STELLA consortium organized again a three-day International Workshop and Tutorials event on the subject of Flexible & Stretchable Electronics. The event took place in Ghent, Belgium, November 16 to 18, and was the second edition after the first one, which took place in Leuven, Belgium, September 2007. First a day of tutorials on flexible and stretchable electronic circuits was organized on November 16 at the Centre for Microsystems Technology (CMST) of IMEC/University of Ghent. During this day authorities in the field have shared their knowledge and views. The Workshop Organisation Committee, led by Dr. C. Klatt, co-ordinator of STELLA, and Dr. W. Christiaens of IMEC/CMST, was able to attract distinguished speakers such as Mr. Joe Fjelstad, who is a well-known personality and authority from the USA in the world of flexible electronic circuits and who gave a broad overview about the history, the current status and the bright future for flexible circuit applications.

Also Dr. Stéphanie Lacour from Cambridge University, who is one of the pioneers in stretchable electronics technologies, contributed to the tutorials and teached the basics and peculiarities for making stretchable thin film devices. Finally UGent/IMEC together with TUBerlin STELLA partners went more into detail on their large area stretchable circuit technologies, covering also modelling and reliability issues. In total 41 participants attended the tutorial day.
The 2-day Workshop (November 17-18) was organized in the city centre of Ghent at the beautiful Aula, which is the Assembly Hall of the Ghent University, a neo-classical style building, finshed in 1862. This workshop was organized as a dissemination activity, mainly of STELLA, but also of various other EC and nationally funded projects in the field of flexible and stretchable electronic circuits. Moreover external leading experts in the field, both from industry and from academia, delivered key-note talks on the subject. It can be stated that all leading groups world-wide, active in the field of stretchable electronics, were present at the workshop. Keynote talks included contributions from Nokia (T. Ryhänen), Nippon Mektron (H. Schenk), University of Illinois (J. Rogers), University of Tokyo (T. Sekitani), Harvard University (J. Vlassak), Daimler AG (H. Meinel), Philips Research (L. Van Pieterson), Princeton and Arizona State University (O. Graudejus) and Innovation Lab (N. Gretz). STELLA strongly contributed to the technical programme with 8 presentations in total. The Workshop was successfully concluded with 31 speakers and 122 participants in total. It is therefore intended to organise a third edition in fall 2011, where again the core and other contributors worldwide in the expanding field of stretchable electronic and sensor circuits will meet.

Stretchable Circuits

stretchable circuits

Stretchable circuits (SC) is a spin-off founded by scientists and engineers at Fraunhofer IZM, Berlin. Its aim is the realization of innovative product concepts using stretchable and textile circuit technologies. The competency of stretchable circuits covers the field of material science, system and technology development, medical technology, electronic in textiles and project management.

The members of SC have played a very active role in the EU-project STELLA and many other research projects at Fraunhofer IZM and TU Berlin.

Stretchable Circuits closely cooperates with Fraunhofer IZM and offers the full range from conceptualization to realization of custom-made stretchable and textile electronic systems.

More information www.stretchable-circuits.com

For more information, contact:
Manuel Seckel,
Stretchable Circuits
manuel.seckel@stretchable-circuits.com

Good-Bye of the STELLA Newsletter team

May we introduce ourselves? Us, that is Andrea and Christoph. We are the editorial team of the STELLA newsletter.
Most of the newsletter authors are already quite familiar with us. We enjoyed the cooperation with you. Many thanks for your contributions, they were the essence of the newsletter. Hope we did not torture you to much with our deadlines.
We wish all our readers good-bye. Sincere thanks to those who read the newsletter regularly. We hope that you enjoyed the newsletter. Please send complaints to Chris and gifts to us. See you soon … in the PLACE-it newsletter.

Sincerely yours

III The STELLA Partners

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In the PLACE-it project, developments in stretchable electronics as in STELLA will be continued with a focus on optical systems, reliability and manufacturability. However, this is only a part of the story; at the same time the unique possibilities of electronic textiles (drapeable, breathable) and foil-based systems (organic or dense electronics) are being explored. The common goal is heterogeneous integration so that strengths of each technology are combined to offer a manufacturable and low-cost solution with yet unique properties.
Supported by the EU seventh framework program, PLACE-It aims to realize the industry platform for lightweight, thin and flexible optoelectronics systems within three and a half years and will:

- Develop an integration platform of foil, elastic and fabric optoelectronic technologies.
- Create foil, elastic and fabric-based devices for light emission, electronics and sensing.
- Formulate industry design guidelines for light-emitting flexible surfaces and textiles.
- Build demonstrators of compelling beyond-the-bulb applications.

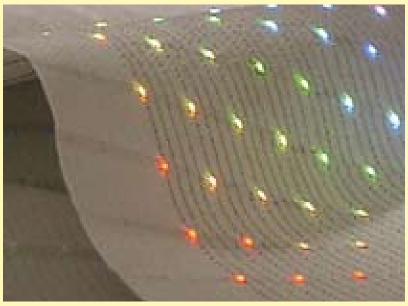

Figure 15: Light-emitting textiles (Philips)

PLACE-it aims to integrate lighting into people's daily surroundings. The point of departure is that technology should be bendable and stretchable – not flat, square and fragile. The aim is to combine technical performance with elasticity, comfort and light in light-emitting flexible surfaces and textiles. PLACE-it works with 12 partners in the project: Philips Research, Netherlands Organisation for Applied Scientific Research, Technische Universität Berlin, Freudenberg Forschungsdienste KG, Interuniversity Microelectronics Centre, Centexbel, TITV Greiz, Philips Lighting, Grupo Antolin, Universität Heidelberg, RWTH Aachen and Ohmatex.

For more information, contact:
Dr. Liesbeth van Pieterson,
Philips Research
liesbeth.van.pieterson@philips.com

More information www.place-it-project.eu.

Meet us:

- **Hannover Industrial Trade Fair** 19.-23. April 2010, Hannover/Germany
  http://www.hannovermesse.de/
- **pHealth,** 26.-28. May 2010, Berlin/Germany
  http://www.phealth2010.com
- **Advanced Textiles,** 16.-17. June 2010, Paris/France
  http://www.ifai.com/AdvancedTextiles10.cfm
- **Plastic Electronics,** 19.-21. Oct 2010, Dresden/Germany
  http://www.plastic-electronics2010.com

Impressum:

9.4.2010
Freudenberg Forschungsdienste KG
Dr. Ch. Klatt
Höhnerweg 2-4
D-69465 Weinheim