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the product is the interface

FINAL REPORT

October 2016

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LEAD PARTNER

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Note for the reader:

The final report of EU FP7 project "Light.Touch.Matters" (grant agreement no. 310 311) is made via a web-based format provided by the EC for that specific purpose. This format is text-only, and therefore cannot accept the visual information that such a report can use. Such visuals can however be included in an attachment (as .pdf file) to that format.

This document is precisely that attachment. Instead of providing imagery only, it contains the same text as put in the EC web-based format, except for the lists of publications and dissemination events (which are complete here, rather than a selection only), and for the report section 4.3 "Report on societal implications", which is NOT included here, as it is of limited relevance.

For additional content – text, visuals, videos – please refer to the project website.

4.1 Final publishable summary report

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4.1.1. Executive summary

In Project LTM, product designers, material scientists and innovation managers have teamed up and jointly developed new smart materials that can sense touch (thanks to a layer of "piezo plastic" i.e. a structured composite of piezo-active particles in a polymer matrix) and respond by luminescence (thanks to a flexible organic light-emitting diode i.e. OLED). A top layer modulates colour and tactile response, while flexible wiring and an IC power the smart behaviour. The consortium's mix of designers and material scientists was unprecedented, and turned Project LTM into a test case for innovation management.

Being thin and flexible, these novel "LTM materials" can revolutionize product design to a point where "the product becomes the interface" – a promising goal for many types of products (e.g. car instrument panels) but especially for products related to care and well-being, such as wearables for self-medication and self-quantification, where flexibility, seamless integration (with respect to hygiene) and intuitive usability are key qualities. The project has made the new smart materials available to designers and showcased their potential for interface design in the form of several technology demonstrators. As a third top-level objective, Project LTM produced a generic method for design-driven research & technology development ("D-RTD"), suitable for application in a variety of contexts, and for essentially any new technology that may benefit from design input in its development.

Overall, Project LTM has realized the ambitious goals set in the DoW. All planned results, milestones and deliverables for period III have been achieved. In the **materials RTD stream**, notable unplanned extra results include lead-free piezo plastics and transparent printed flexible OLEDs; furthermore, despite a late start, attractive colour effects through down-conversion have also been realised. As became apparent during period II, the planned work on top layer tactility variations was found to be not sufficiently relevant and was hence terminated prematurely.

In the **product design stream**, the results iterated from many tentative concepts during the project's early stages towards a solid set of nine product designs (three more than planned), all suitable for prototyping, showcasing and demonstration, also targeting markets beyond the initially chosen area of care & well-being, e.g. consumer electronics and automotive interiors. Jointly, these designs showcase the potential of the LTM materials very effectively.

Finally, regarding **innovation methodology**, the project has produced its targeted "white book for design-driven RTD". Here too the consortium managed to move beyond the DoW's requirements by presenting the outcome as a cross-media project, featuring the actual book plus "video pills", this to increase uptake of results.

Apart from performing the targeted RTD work, the project was strongly geared towards **dissemination** of its results. Notable outcomes in this regard include a vibrant contribution to the Dutch Design Week (October 2015, Eindhoven, The Netherlands: lectures, samples, and prototypes), the on-line teaching resources, the final LTM film, and the well-attended closing symposium on June 17th 2016 (Delft, The Netherlands: lectures, samples, and demonstrators), as well as on-line available training resources about D-RTD.

4.1.2. Project context and objectives

In Project LTM, product designers, material scientists and innovation managers have collaborated to jointly develop a new generation of smart materials that combine touch sensitivity (using new "piezo plastics") with luminosity (using flexible OLEDs). Manufactured on plastic substrates, these materials are thin and flexible, allowing seamless integration into all kinds of products and offering new modes of product-user interaction. Their benefits were explored and fine-tuned in the project by simultaneously developing both the materials and several product concepts in which they were applied. The results were demonstrated in several technology showcases targeting the growing market for products related to care & well-being. Here, the qualities of the new materials were expected to be of key importance, but other applications (e.g. car instrument panels) were not ignored.

Using a new method for design-driven materials innovation that was itself the subject of study and development during the project (as well as a separate project result, suitable for deployment in other contexts), the consortium developed the materials and manufacturing methods to bring about a step-change in the functionalities of piezo plastics and OLEDs, integrate them into a single thin layer, and from there, into products. This exploited a synergy between the two technologies: the OLED's flexibility and low thickness allow it to be placed over the piezo plastic, delivering the world's first touch-sensitive, luminescent flexible material. Additional work was done to ensure that colour and tactile response of this material can be tailored to meet specific requirements.

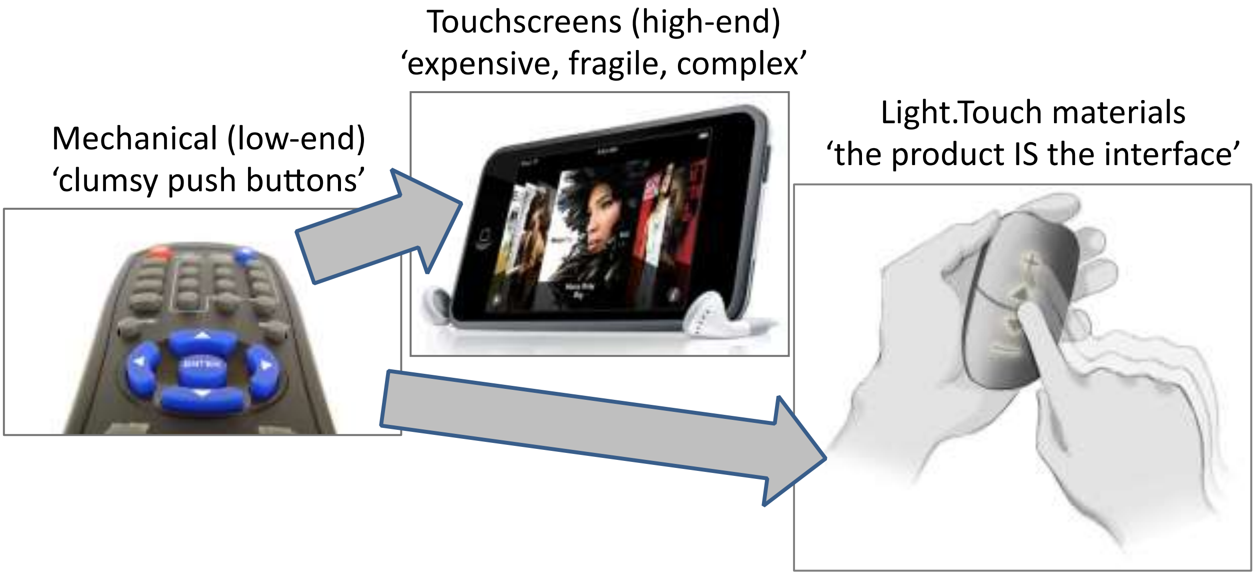


Figure 1: impression of how LTM materials could reshape a remote control

Project LTM not only allowed us to advance the materials technology itself, but also enables us to take the next step in product interface design: using touch-sensitivity and luminosity to produce affordable, desirable and intuitive user interfaces, so that eventually "the product becomes the interface" (see Figure 1). This puts an end to fragile and often unhygienic push buttons and discrete light sources on clumsy, inert housings with low quality look and feel, and opens the door to a new generation of attractive, intuitive-to-use products. Moreover, unlike smart phones, tablets and computers, products based on the LTM materials are also inherently robust and affordable.

The overall science & technology (S&T) objectives of the project were as follows:

0. **Achieve continuous and intensive dialogue between product designers and material researchers:** people from these two "worlds" do not naturally work together because of

differences in project time scales (typically <2 years vs. >5 years per project respectively), language and vocabulary (subjective and user-oriented vs. objective and engineering-oriented), and culture of working. Our first objective therefore was to ensure that the project's designers and materials researchers came to share a common language, developed an understanding for each other's strengths and weaknesses, and saw the benefits of cooperation;

1. **Implement and validate an effective method for design-driven materials innovation:** in the design stream we iterated in three cycles from ideas and concepts towards fully-functional technology showcases, with input from the materials RTD at set points; in the materials RTD stream, we worked from the state of the art towards the target performance with intermediate milestones, with regular input from the design activity also to refine and reprioritize targets. This new design-driven materials RTD method was essential to achieving S&T objectives 2-8;

2. **Develop fully-flexible piezo plastics for low-cost, high-volume touch sensing applications:** we brought the piezo plastics from their former (i.e. prior to project start) "proof-of-principle" status in small samples to the point where they were available in thin layers with various different sizes, shapes, flexibilities and sensitivities, with decreased price and complexity of application. Designers worked closely with materials researchers to assure that the precise properties were attuned to provide optimal functionality and user experience for product touch interfaces;

3. **Develop fully-flexible OLEDs with improved aesthetic properties for signage applications:** building on to on-going performance-oriented OLED RTD, we increased design freedom by improving OLED flexibility and by developing a range of colour effects unavailable today. The first objective was achieved by developing novel flexible anode technology, the second objective by layering e.g. phosphor-based materials onto the OLED. Again, designers worked closely with materials researchers to specify sizes, flexibilities, luminosity colours etc.;

4. **Develop fully-novel thin, flexible, integrated touch-sensitive luminous materials:** building on the research work on the individual piezo and OLED components, we integrated the two layers into a novel smart material that can sense input by touch and respond with luminosity. Development work was done in close collaboration with designers to ensure the right mix of functional and aesthetical properties, including sizes, thickness, shape factors (flat or single-curved) and sensitivity, as well as for example cost and lifespan;

5. **Develop a range of tactile qualities:** to be successful, the combined piezo-plastics and OLEDs should not only be functional but also offer distinct aesthetic qualities, in short, the right "look and feel". Being able to vary between different options in this respect is also something that designers greatly value, not only to create products that users want to have, but to give exactly the right usability as well. In addition to the work on novel colour effects (S&T objective 3), we therefore explored methods to structure the combined material's top layer with different textures.

6. **Develop manufacturing methods to integrate LTM materials into parts and products:** to speed up industrial uptake, this was done using existing manufacturing processes, making small changes to the materials where needed (e.g. adding transition layers to ensure that manufacturing does not damage the core materials). We also selected and integrate the power sources (e.g. thin, flexible batteries) and control circuitry that is indispensable for the new smart materials to function. There was a key role here for the designers in the consortium to supply creativity and lateral thinking and find effective manufacturing and integrating solutions;

7. **Design novel product interfaces that exploit the unique touch and luminosity properties:** this objective was not only valuable in its own right, but was also essential to give specific design input to the materials RTD effort. To achieve the objective itself, the designers iteratively

developed product concepts, using feedback from the materials stream in the project in each cycle to ensure technological feasibility and optimal use of material properties. We aimed to assure market relevance by having selected companies and organisations help us steer design activity through the "lead-user panel". While preparing for the project, the consortium had already generated 30+ ideas for products, which were used as a basis for this S&T objective;

8. **Assure best-in-class environmental impact of the materials and products developed:** sustainability is a key driver for material RTD choices, such as investigating the suitability of lead-free compounds for the piezo plastics, replacing scarce resources for OLEDs (e.g. indium) with more abundant alternatives and choosing low-energy manufacturing processes. In the design and development of materials and product concepts, environmental LCA studies[1] were deployed to select the most sustainable solutions;

9. **Assure broad application of the novel smart materials developed in the creative and general industry:** this objective was to be reached by a comprehensive array of dissemination activities, such as the creation and publication of design guides and databases with which design SMEs inside and outside the project can easily develop their own applications of the new smart materials. Furthermore, we have set up a sizable "manufacturers panel" with which we shared findings related to manufacture, supply and scalability. Findings were also shared with EU-based design agencies through national design promotion agencies and at international design events;

10. **Foster design-driven materials innovation in the EU:** the design-led development process of the new smart materials itself represented a unique opportunity to study how design-driven innovation, design thinking and human-centred design can be applied to material innovation. Our findings were documented and shared with the creative and general industry, the innovation research community and the general public, in particular in the EU. Finally, the academic partners communicated the results in their educational programs (BSc/MSc/BA/MA level), educating and inspiring the next generation of product designers, innovators, researchers; and engineers.

[1] Later replaced with product circularity studies; see task 3.5.

4.1.3. Main science & technology results

The main science & technology (S&T) results of the LTM project are best discussed with reference to the S&T objectives, as described in the previous sub-section (4.1.2). These fall into several categories:

- Innovation management: S&T objectives 0 and 1;
- Materials and integration: S&T objectives 3-6;
- Product design: 7-8; and
- Impact: 9-10.

The results are summarized below.

<u>0. Achieve continuous dialogue between product designers and material researchers</u>

This objective was reached through the four-monthly project workshops, in which designers and researchers met and exchanged findings, as well as through so-called "Q&A sessions" (from "question and answer") about, in particular, the inherent affordances and limitations of the newly-developed smart LTM materials. What made this dialogue possible was a combination of the following elements:

- availability of LTM material samples, e.g. stand-in materials (PVDF for the piezo plastics, electro-luminescent (EL) foils for the flexible OLEDs, glass OLEDs etc.) during initial workshops, progressing towards integrated samples later on during the project based on the actual new materials;
- availability of product sketches, concepts, and (ultimately) prototypes based on the projected unique value proposition offered by the LTM materials;
- a systematic but relatively flexible framework for the dialogue, initially based on the design-driven innovation approach pioneered by Prof. Verganti, and later refined towards the development of meaningful interfaces;
- an atmosphere of trust and openness fostered by the facilitators, i.e. by the design-materials interaction committee (chaired by Prof. Miodownik) and the coordinator;
- a willingness by all participants in the dialogue to cross borders and learn to appreciate the differences in viewpoints.

A specific item of interest here concerns the material specifications and their description. During the project, it quickly became apparent that such specifications, if they consist largely of (lengthy) text, are essentially not suitable for the dialogue between product designers and material researchers ("D-M dialogue" for short): at best, such specifications can act as a target for the research side only. When designers enter the debate it is much better to present specifications visually, as designers are simply highly visual people, and to describe material performance by comparison and analogy. For instance, flexibility of a material is best described in terms such as "as flexible as a credit card" instead of as a Young's Modulus or similar concept from materials science.

For a second item of interest, consider that designers look "outside in", not "inside out": for them, an OLED is, quite simply, a luminescent material – even though the materials side of the dialogue considers an OLED to be a *device* (as implicit in the name), consisting of many different materials and components. This is yet another reason why terms such as "material properties" are difficult, and often not very productive, in the exchange between designers and researchers. The LTM project surmounted these difficulties through its workshop-powered approach, using the elements mentioned above.

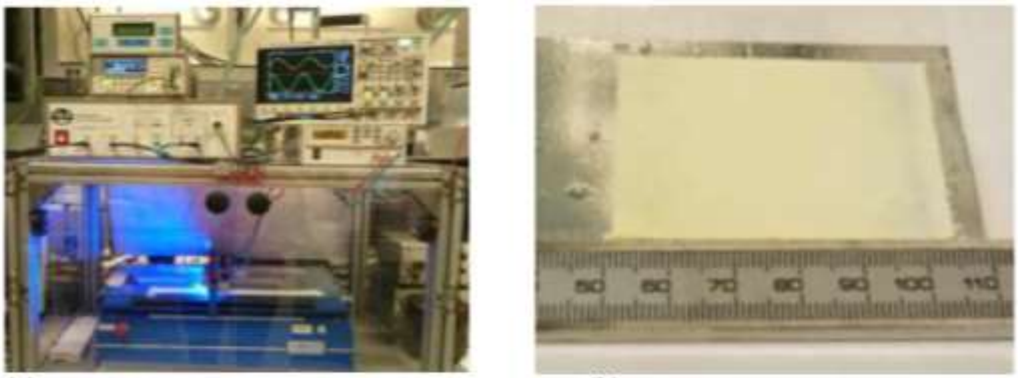
1. Implement and validate an effective method for design-driven materials innovation

In the design stream we iterated in three cycles from ideas and concepts towards fully-functional technology showcases, with input from the materials RTD at set points; in the materials RTD stream, we worked from the state of the art towards the target performance with intermediate milestones, with regular input from the design activity also to refine and reprioritize targets. This approach worked very well, and has been successfully validated during the project. It has been laid down in the "white book for D-RTD", which is further discussed under S&T objective 10.

2. Develop fully-flexible piezo plastics for low-cost, high-volume touch sensing applications

We brought the piezo plastics from their former (i.e. prior to project start) "proof-of-principle" status in small samples to the point where they were available in thin layers with various different sizes, shapes, flexibilities and sensitivities, with decreased price and complexity of application. Designers worked closely with materials researchers to assure that the precise properties were attuned to provide optimal functionality (e.g. force range) and user experience for product touch interfaces.

Before Project LTM, the processing technique to make piezo plastic materials required about four hours at elevated temperatures to allow for alignment of the piezo-electrically active particles in the uncured polymer matrix. Thanks to the LTM project, two suitable processing technologies for upscaling piezo plastics have been investigated. The results were shared at several international conferences: European Conference on Applications for Polar Dielectrics (ECAPD) 2014, International Conference on Adaptive Structures and Technologies (ICAST) 2014 and the International Conference on Electroceramics (ICE) 2015. A conference paper, published in a special issue of the journal Ferroelectrics, has been published on the first iteration of the photo-curing upscaling technique. Two journal papers documenting the scientific findings and improved processing techniques are under preparation.



(a) (b)

Figure 2: actual tape casting set-up (left: a) and piezo plastic sample produced (right: b)

The work has been conducted largely as planned. First, a suitable photo-curing matrix was identified. A new setup for in situ dielectrophoretic alignment of piezo plastics, transferable to roll-to-roll type production was developed, going through several iterations before settling on a low cost blue LED bar to facilitate photo-curing at a speed of 2 cm/min. The flexibility of these piezo plastics is comparable to that of the PET foil used as a substrate. Three types of electrode layouts were demonstrated, ensuring touch sensitivity in the directions required for the applications envisioned by the design stream. The final processing technique accommodates a variety of piezoelectric particles, aspect ratios and chemical compositions. Moreover, the developed technique is compatible with the environmentally best-in-class, lead-free, cuboid, piezoelectric ceramic fillers described under S&T objective 8.

Near the end of the project, the design stream, as well as the piezo plastic research team, began to show great interest in the possibility of 3D-printable LTM piezo plastics. A first side project was set up to investigate how FDM-type 3D printers can be used to produce piezo plastics, leveraging on the strong connection between the coordinator and the Ultimaker company in Geldermalsen, the Netherlands (a key player in the global market for affordable FDM-type 3D printers). First results are expected by the end of 2016.

3. Develop fully-flexible OLEDs with improved aesthetic properties for signage applications

Building on to on-going performance-oriented OLED RTD, we increased design freedom by improving OLED flexibility and by developing a range of colour effects unavailable today. The first objective was achieved by developing novel flexible anode technology, the second objective by layering e.g. phosphor-based materials onto the OLED. Again, designers worked closely with materials researchers to specify sizes, flexibilities, luminosity colours etc.

Progress in flexible anode technology
Flexibility first required that silver nanowire networks were investigated as an alternative to PEDOT:PSS with printed metal grid structures for applications as transparent anode materials in flexible OLED devices. This is a deviation from the original work plan, where the main focus had been laid on PEDOT:PSS, a conductive transparent polymer. However, due to unsurmountable technical issues (shot circuit formation) with this material, especially when combined with printed metal support grids, it was decided to dedicate the research in the second half of the LTM project to a more promising alternative, which has been recently emerging, silver nanowire networks. As with PEDOT:PSS and metal based conductive inks, these materials are supplied as liquid formulations which allow solution processing, which is very favourable from a technical point of view, since it excluded the need of "dry" deposition technologies, involving high vacuum. Sheet resistances and transparencies can be easily, though not independently, be controlled by changing the deposited layer thickness, and the films' performances in terms of these parameters rival those of low-temperature deposited indium-tin oxide, or ITO. It has also been shown that the silver nanowire films can withstand processing temperatures which are relevant for the conditions typically involved in OLED production from solution. When the correct silver nanoparticle ink is chosen, the sheet resistances can be further decreased by printing of conductive structures, without too much lowering the overall transparencies.

Although within this project, patterning of the nanowire films has only been achieved by rather crude means, more refined methods with higher reliability and resolution like selective laser ablation are investigated in other projects, which are specifically dedicated to that topic. The flexibility of a silver nanowire network has been demonstrated by its nearly constant sheet resistance value during repeated bending tests. Finally, the application of silver nanowire transparent films as the anode in OLEDs has been successfully demonstrated, though the devices still suffered from rather short lifetimes, the reasons for which require further investigation. Overall, it can be concluded that silver nanowire networks have excellent performance in terms of transparency, sheet resistance and flexibility, rivalling those of low temperature processed ITO and surpassing those of alternative materials like PEDOT:PSS. Also, they allow the production of functioning OLED devices, though further research is necessary to improve the device stability and life expectancy during operation.

Progress with respect to silver migration
OLED flexibility also required a solution for the problem of silver migration i.e. the gradual dissipation of the silver anode in the device, leading to short-circuiting and device failure. It was therefore planned that the Holst Centre would work on model systems to understand silver electro-migration through relevant opto-electronic materials used in OLEDs in more detail, and, based on these insight, develop

and test strategies to slow these processes down or even fully prevent them. The work has been carried out essentially as planned, yielding novel insights into these processes, which have already been studied for decades by researchers in the microelectronics industry, though never in a context relevant for organic optoelectronic devices.

Surprisingly, it turned out that there are two apparently independent migration processes going on, which follow completely different mechanisms. Depending on the exact experimental conditions, either the one of the other can be dominant. This is a highly important insight for suppressing these phenomena in OLEDs, since both mechanisms must be controlled in order to secure a sufficient device lifetime. Consequently, it proved difficult to directly transfer strategies developed to prevent silver migration using a simplified experimental setup directly to the devices. Whereas by changing the chemical composition of the transparent conductor material, migration can be largely stopped in the simplified setup, the situation turned out more complex in actual devices. Several highly promising approaches for solving the silver migration problem in OLEDs have thus been identified, but before they can be successfully applied in device production, further research is necessary.

Colour effects using down-conversion

In principle, OLEDs can emit any colour you want, but in practice, applications are limited to the colours and light-emitting polymers that industry works on for the main markets of displays and lighting. Since this was initially deemed too restrictive for the design stream, a specific project task was defined to increase the range of colours practically available and to add "colour effects", using a variety of techniques.

With respect to the work plan, the task team broadened the range of luminescent down-converting materials under investigation. Originally they planned to use only nanophosphors, but their performance proved unsatisfactory in down-converting visible light, especially green. This initial finding has led the team to investigate organic dyes, as well as new particle based systems. In this respect, the work carried out to date differs from what was proposed originally, but the new line of investigation was felt to be more in tune with the objective of the consortium, being design-led innovation in materials. In addition, new light emitting particles and fluorescent ink have the potential to be better suited to down-convert the visible light emitted by an OLED.

The research on organic dyes has led to identify Fluorescein and Rhodamine 6G as excellent candidates to down-convert blue and green OLED emission to various shades of green, yellow and orange. The dyes have been incorporated in thermoplastic polymers as well as thermoset rubbers and acrylic paint. The use of silica as a way to functionalise a luminescent dye was originally proposed and has been carried out as a means to disperse an organic dye in a matrix when solubility is scarce, specifically in the case of silicone rubber. Studies on the colour conversion as a function of dye have been carried out, as well as studies on the photo-stability, to ensure the development of long lasting colour conversion layers.

<u>4. Develop fully-novel thin, flexible, integrated touch-sensitive luminous materials</u>

Building on the research work on the individual piezo and OLED components, we integrated the two layers into a novel smart material that can sense input by touch and respond with luminosity. Development work was done in close collaboration with designers to ensure the right mix of functional and aesthetical properties, including sizes, thickness, shape factors (flat or single-curved) and sensitivity, as well as for example cost and lifespan. The results can be sorted into two fields, which are discussed below: (i) physical integration, and (ii) electronic integration.

Physical integration of the "LTM materials"

Compared to most tasks in the project, the work on this topic took a quite different turn than expected at the time of writing of the work plan. Specifically, the LTM materials themselves turned out to look substantially different from what was initially foreseen, with e.g. the need to have "touch" and "light" input and output available everywhere over the material surface not being a need at all. This by itself already constitutes a good example of design-driven development in the task work. Also, the design work brought to light other, unplanned needs, such as having other inputs than piezo plastics alone (e.g. angle sensors, accelerometers, stretch sensors). Then there was the focus on reuse/repairability, suggested by the attention for circular economy design that arose around the mid-point of the project, which ruled out the originally-planned encapsulation methods. Finally there emerged, quite late in the project, the surprisingly difficult issue of flexible and reliable wiring.

During the course of the project, these integration issues were eventually solved, but not fully. In a way, this was an inevitable development, as the resources that had been allotted to the work were relatively modest: had the topic been given more attention in the original project proposal, then that proposal would have likely not been acceptable anymore within the restrictions of the call text, which was after all materials- and not integration-focused. So, flexibility as a requirement has been provided during the project, but reliability of interconnections within the LTM material is not yet secured.

Electronic integration of the "LTM materials"
To address this issue, Aito and the Holst Centre built up the necessary input-output signal models, and from there developed several generic "frameworks" for the smart material that can provide a range of functionalities, from basic (simple on-off switch) to intermediate switching applications (e.g. distinguishing taps from swipes, making output luminosity proportional to input pressure, delaying output, etc.) to advanced user interfaces (also incorporating additional inputs, e.g. flexible thermocouple). These frameworks were designed to be scalable and flexible, addressing a wide range of design requirements, not only with respect to the desired user interaction, but also physical parameters such as size, amount of flexibility, thickness, weight and lifetime. Therefore, they enable many different kinds of applications, even though the technological solutions to common problems underlying them (e.g. noise suppression) are the same each time. The focus was to develop simple and robust control circuitries for the smart materials as well as further optimize the properties of the smart materials to get better (stronger) output signals.

As the physical samples of the new piezo plastics and flexible OLEDs were not available until late in the project, simulation tools and substitute materials (such as PVDF as stand-in for piezo plastics, and rigid OLED replacing flexible ones) were used in the development work. In addition, the power supply alternatives were studied: here it was somewhat disappointing to find that flexible battery technology is not yet sufficiently mature to support applications, meaning that even a fully-flexible LTM material-based product will still require a rigid, potentially sizable, battery built in somewhere. Fortunately, product designers generally can work around such a limitation quite well, as the various technology demonstrators make apparent.

5. Develop a range of tactile qualities

To be successful, it was initially foreseen that the LTM materials should not only be functional but also offer distinct aesthetic qualities, in short, the right "look and feel". Being able to vary between different options in this respect is also something that designers greatly value, not only to create products that users want to have, but to give exactly the right usability as well. In addition to the work on novel colour effects (S&T objective 3), we therefore explored methods to structure the combined material's top layer with different textures.

However, during the project it materialized that the top layer was not as critical as foreseen, and also that for applications where it was important it was sufficient to add a suitable top layer of the right material. In short: no specific RTD work was needed. To better deploy the resources made available through the EC, the consortium jointly decided to cut the work on this topic short. This also fitted better the available know-how and manpower in the project.

6. Develop manufacturing methods to integrate LTM materials into parts and products

To speed up industrial uptake, this work was projected to be done using existing manufacturing processes, making small changes to the materials where needed (e.g. adding transition layers to ensure that manufacturing does not damage the core materials). Similarly, it was decided to use commercially off-the-shelf (COTS) components for power supply and control circuitry. There was a key role here for the designers in the consortium to supply creativity and lateral thinking and find effective manufacturing and integrating solutions.

In practice, as high-volume manufacture was of necessity still far away even at project's end, the work done with respect to this S&T objective focused on providing prototyping solutions, with the integration being done largely using manual processes. Still, despite this restriction, some interesting new avenues have been explored, such as the use of stitching and other fabric-derived joining methods to integrate sensors, luminescent elements and wiring onto products. Not only does this match well with the requirements for wearable products (smart gloves, sensor-equipped belts and shoes, etc.), but such joining solutions are also better suited for repair and reassembly than the initially foreseen methods of joining by adhesive bonding or heat sealing.

Desk studies have been performed into manufacturing and upscaling studies related to integration of flexible OLED and polymer piezo layers, electrical connections, assembly processes and electrical integration. The outcome was that the integration processes used at the manufacturing processes of the technology demonstrators in the LTM project represented largely mature technologies. Therefore the manufacturing cost information is pretty stable and predictable, also with higher volumes (>100,000 p/a). Also expected level of price erosion with these technologies is on very low level. The manufacturing technologies presented are matured and therefore also have low risk and high yield in the assembly/manufacturing process.

For layer integration typical manufacturing processes were:

- Using pressure sensitive adhesives;
- Over-moulding;
- "Form closure" i.e. stitching-type encapsulation.

Manufacturing processes regarding electrical interconnections include:

- Electrically conductive adhesives;
- Silver epoxies;
- Connectors;
- Soldering;
- "Liquid metal contacts".

Also, a total "cost of integration" was estimated for a typical technology demonstrator in the LTM project, assuming high volume manufacture. While sizable, especially for complex products, it was found that these costs need not impair the economic viability of the technology, especially at larger production volumes.

7. Design novel product interfaces that exploit the unique touch and luminosity properties

This objective was not only valuable in its own right, but was also essential to give specific design input to the materials RTD effort. To achieve the objective itself, the designers iteratively developed product concepts, using feedback from the materials stream in the project in each cycle to ensure technological feasibility and optimal use of material properties. We aimed to assure market relevance by having selected companies and organisations help us steer design activity through the “lead-user panel”.

While preparing for the project, the consortium had already generated 30+ ideas for products, which were used as a basis for this S&T objective. During the first of the three design iterations, around 20 ideas all in all were elaborated (not counting parallel activity by design students active at the various academic design partners); in the second and third iteration, this was reduced to 10 and 7 respectively, ultimately leading to 7 technology demonstrators (9 including student work) that were shown to the public during the project’s closing symposium. Figures XXX at the end of this sub-section present all 7 designs, with the consequences for interface design being readily apparent.

8. Assure best-in-class environmental impact of the materials and products developed

In this regard, progress has been made on three sides, being (i) lead-free piezo plastics, (ii) ITO-free R2R printed OLEDs; and (iii) product design for a circular economy.

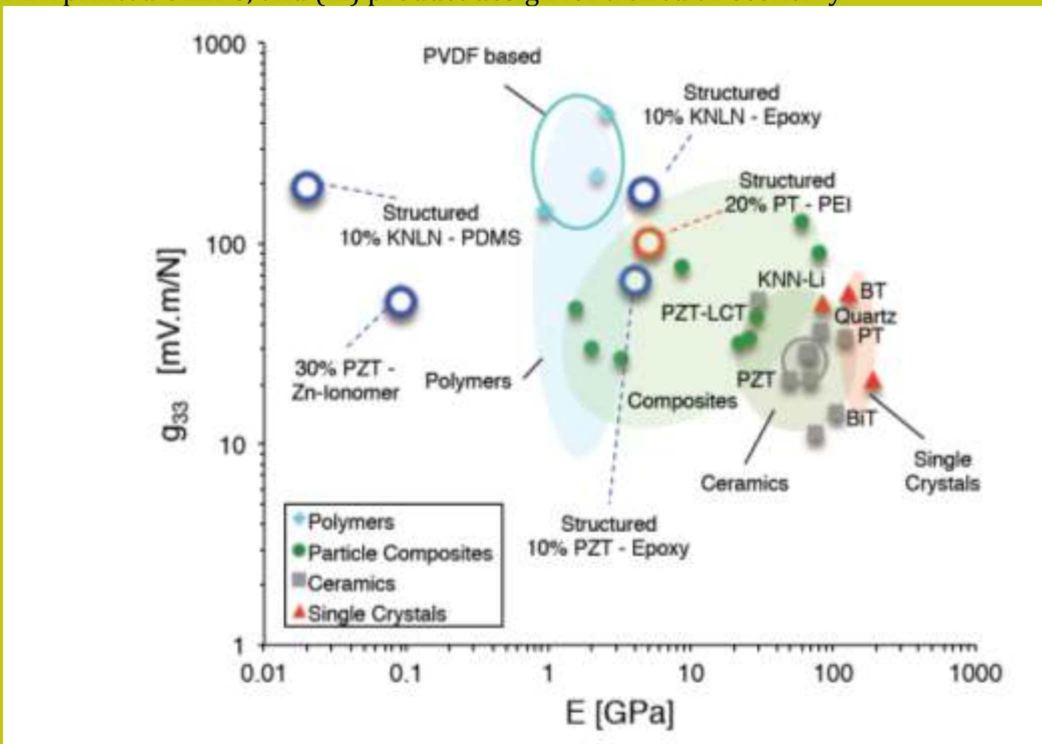


Figure 3: Comparison of the piezoelectric voltage coefficient per stiffness of existing piezoelectric materials with the piezo plastics described in this work.

Lead-free piezo plastics

Unexpectedly, a breakthrough has been achieved at DUT-NovAM in lead-free piezo plastic technology leading to (piezo)-electrical properties at least on par if not outclassing lead-based piezo plastics entirely. At the time of writing, three journal papers documenting the scientific findings have been accepted, submitted and prepared on the topic, respectively. The results presented in this regard are substantially better than projected in the work plan. As planned, the research involved consecutive literature surveys to identify developments in the field of lead-free piezo-electrics and implementation of these new materials in analytical models. As the results of the analytical models were promising, care was taken to develop a succession of truly lead-free piezo plastics. After choosing a lead-free ceramic system based on Li doped KNN, or $(K_{0.50}Na_{0.50})_{1-x}Li_xNbO_3$, first the ceramic processing conditions were optimised. This was followed by a fine tuning step of the amount of Li doping in KNN.

Finally a temperature stable polymer (polydimethylsiloxane, or PDMS) was chosen as the matrix material to deliver flexible piezo plastics for the technology demonstrators. The piezoelectric properties of the piezo plastics based on DMS are comparable to PVDF and its copolymers at significantly reduced stiffness (see Figure 3), and significantly outclass previous piezo plastics based on lead.

The promising nature of these lead-free piezo plastics was first communicated to the consortium in June 2015. Since then, the results have also been presented at several International conferences (International Conference on Electroceramics (ICE) 2015, Ferroelectrics UK 2015, Materials Research Society (MRS) 2015, Materials Challenges in Alternative & Renewable Energy (MCARE) 2016, Electroceramics XV 2016). This development in lead-free piezo plastics constitutes a huge breakthrough, especially since neither cost nor temperature resistance (which are the "Achilles Heels" of PVDF) are holding back application of these new smart materials. Follow-up activity is already being planned. NB – the upcoming PhD thesis by Daniella Deutz, expected early 2017 (DUT-NovAM), will continue on the research presented here.

! It bears repeating that piezo plastics are inherently not only touch-sensitive, but touch-intensity sensitive as well: with the right electronics, these smart materials can distinguish between soft and hard taps. Leading smartphone OEM Apple uses a similar technology in their latest models (under the designation "3D touch"), which indicates the vast potential value of this material property.

ITO-free R2R printed OLEDs

The work regarding OLEDs, already discussed above, represents by itself also a significant improvement regarding the state-of-the-art, as it helps replace indium with more abundant alternatives. Indium is generally classified as a so-called "critical material", meaning that its supply is highly volatile, and limited to a very small range of countries; also, in many applications, it is impossible to replace without undue loss of product performance. Furthermore, it seems reasonable to expect roll-to-roll (R2R) printing of OLEDs to be not only faster and cheaper than the "sheet-to-sheet" solvent evaporation routes it is intended to displace, but also to be substantially less energy-intensive, and more eco-friendly in general. Unfortunately, due to the very large number of unknowns, the LTM consortium was unable to verify this claim through established environmental life cycle assessment studies. Once a pilot factory for printed OLEDs is in existence (currently projected for summer 2017 by the Holst Centre), it will become possible to provide a better assessment of the relative benefits in this respect.

Product design for a circular economy

For assessing concepts during the first design iteration, semi-quantitative indicators were drawn up and used, based loosely on established life cycle assessment procedures (LCA). Items of interest were (i) resource-efficiency, (ii) eco-design related aspects; and (iii) potential for avoided impacts. Concepts were ranked, and guidelines were issued for the design work in iteration #2 to optimize eco-performance.

All in all, this approach worked well, but only initially: in the next iteration, it became clear that the originally-planned approach based on making in-depth LCAs was no longer tenable. Instead, an approach was adopted based on "design for a circular economy" (this in cooperation with EU FP7 Project Rescoms). Concepts were ranked according to their potential for fitting in a circular economy. This novel approach gained importance from the fact that the LTM materials are inherently very difficult to recycle (though down-cycling is always an option, this should be avoided where possible). Gradually replacing worn-out components in closed loops is then far preferable to using LTM material-based products, i.e. today's linear "take-make-waste" economy. In June 2015 a special session was held between task researchers and design SMEs to communicate this novel circularity concept, and this session was well received by all participants.

Cornerstones of this “design for a circular economy” were found to be the following:

- Design for disassembly
- Use of local and sustainable resources
- Partner involvement and innovation
- Potential social benefits.

What this implies for one of the products considered during the second iteration, i.e. interactive sportswear consisting of an LTM-material equipped sleeve for a wetsuit, is illustrated in Figure 4.

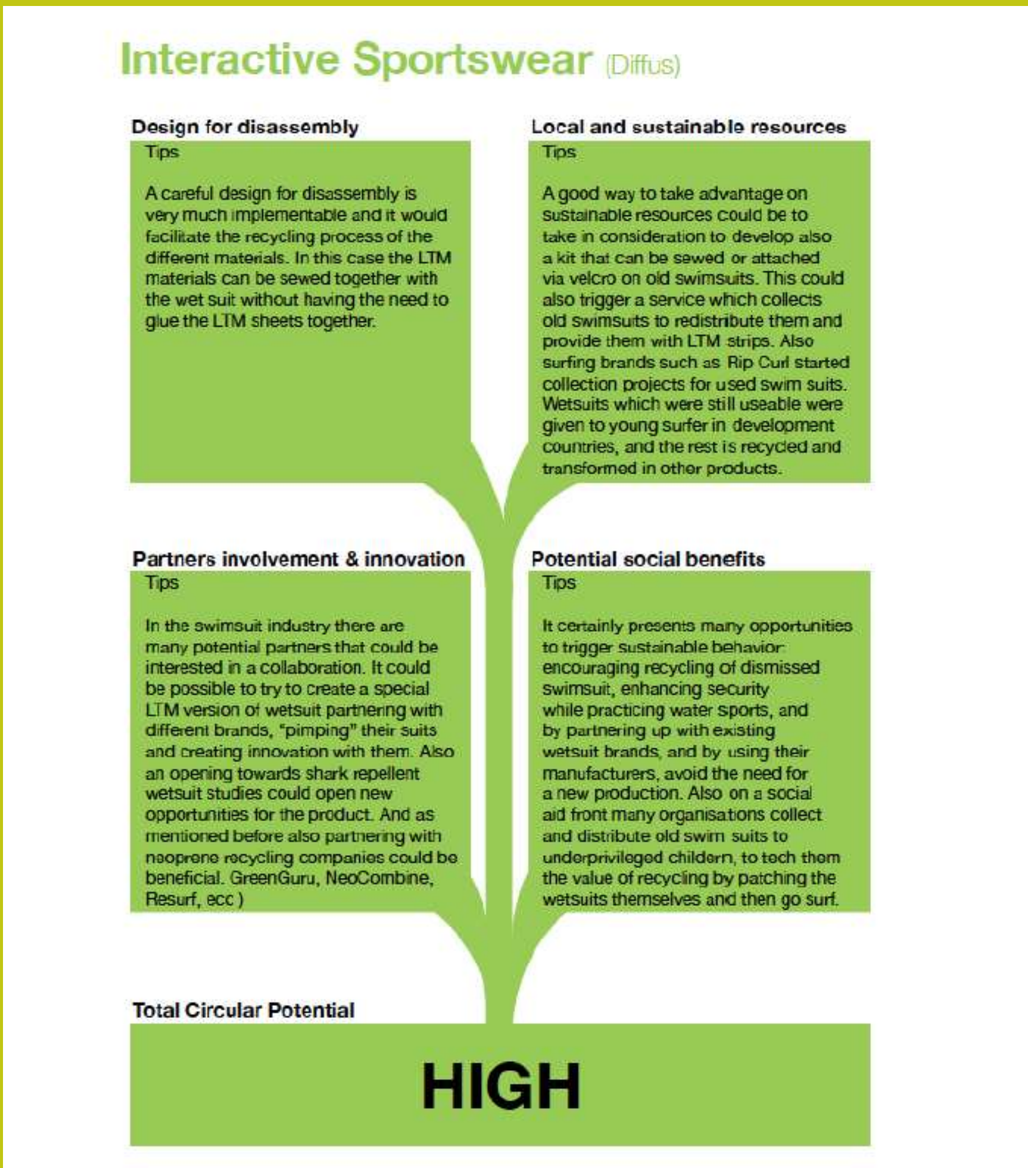


Figure 4: circularity potential for one of the LTM product concepts

9. Assure broad application of the novel smart materials in the creative and general industry

This objective was reached by a comprehensive array of dissemination activities, such as the creation and publication of design guides and databases with which design SMEs inside and outside the project can easily develop their own applications of the new smart materials. Findings were also shared with EU-based design agencies through national design promotion agencies and at international design events, such as the Dutch Design Week.

As part of dissemination, the LTM consortium has **demonstrated the potential of the new smart materials in "technology showcases":** as a first step in assuring the uptake of the materials RTD in actual projects, the project aimed to build at least four showcase applications that function as interaction demonstrators (9 were realised), showing how "the product can become the interface". These outcomes were working prototypes that show how the materials change the way that users can interact with products thanks to the intuitive "LTM materials" developed in the project. They were shown to the public on the closing symposium (June 2016) and are also documented on the project website with brief videos, showing how the product-user interaction can take place;

10. Foster design-driven materials innovation in the EU

The design-led development process of the new smart materials itself represented a unique opportunity to study how design-driven innovation, design thinking and human-centred design can be applied to material innovation. Our findings were documented and shared with the creative and general industry, the innovation research community and the general public, in particular in the EU. The form that this took was that of a very accessible, easy-to-read "white book for D-RTD" (i.e. design-driven research & technology development) that is available as .pdf on the project website, and that is augmented by a sizable number of short interviews, referred to as "video pills", involving the contributing researchers and authors, as well as some guest interviewees who explain the subject matter from their personal point of view. Since this publication is itself already a highly condensed document, and since the video pills augment it in a very effective way, the reader is referred her to that source for additional information and details about the scientific progress (see Figure 5).

Figure 5: online link to the D-RTD white book (bottom right) on the project website

Finally, the academic partners communicated the results in their educational programs (BSc/MSc/BA/MA level), educating and inspiring the next generation of product designers, innovators, researchers; and engineers. All in all, some 30 students have performed their final project working with the LTM consortium staff, generally to good effect and with above-average involvement and motivation. Also, an on-line teaching resource has been generated, which is available at www.instituteofmaking.org.uk/blog/2016/07/ltm-online-course.

The following seven pages show the presentation posters by the seven design SMEs in the LTM consortium (the eight, Fjord/Accenture, is working in service design only and hence did not make a specific product design – instead, this partner focused on service design around several of the products shown here).


ENHANCING APPETITE TABLEWARE (EAT)
LOSS OF APPETITE
Loss of appetite is a general problem during a stay in hospital, and for children that are not old enough to understand the importance of getting sufficient calories it is a major problem. Especially children with cancer suffer from 'mouth blindness' and zero appetite. Different precautions can be made in order to ensure an adequate intake of calories where the obvious one of course is connected to size, frequency and appearance of the food.
Please note the distinction between appetite and hunger.
Hunger is defined as the body's basic physical need for food, whether in terms of calorie content or specific nutrients.
Appetite, refers to the complex desires in humans for food and drink that are often conditioned by previous experiences or cultural factors as well as by a person's present health status.
CONCEPT
Through EAT we propose to support a good eating situation by creating a joyful and calm atmosphere around the child. Our aim is to create 'magic' in the eating situation by creating an interactive set of tableware that will use storytelling, playfulness, encouragement and rewarding attitude through sensor technology, light and haptic feedback.
The inviting glass, the playful bowl and the rewarding plate...
Through the combination of smart materials and natural materials like ceramics, glass, wood and rubber we will emphasize enchantment. Light and haptic feedback will apparently appear in the natural materials because the sensor technology and different outputs will only work and be visible when combined with the natural. We want to emphasize sensibility and durability and thereby create an intriguing eating situation. When the child places the glass the bowl and the plate on the tablecloth the tablecloth will know and will begin to invite the child to drink from the glass. After that the bowl will start to play with the child - cheating, hiding, giggling - and finally the plate will reward the child when she has been interacting with the whole set of tableware for a duration of time
DIFFUS


MeLITE
DESIGN VISION
Today, the sound reaching the user is controlled through a third device such as phone, computer etc. The Intuitive Headphones eliminate the third device, making it possible for the user to pause, play, shuffle music or accept/deny calls through distinctive hand gestures. As opposed to headphones which are equipped with On/Off or Volume Control which only allow for a limited interaction between the user and the device, we identified a high potential for this interaction to be optimized by integrating the control functions and the natural gestures of a user.
INTUITIVE HEADPHONES
KEY LEARNINGS
Me.Lite Classic
Me.Lite City Pro
LTM
pilotfish

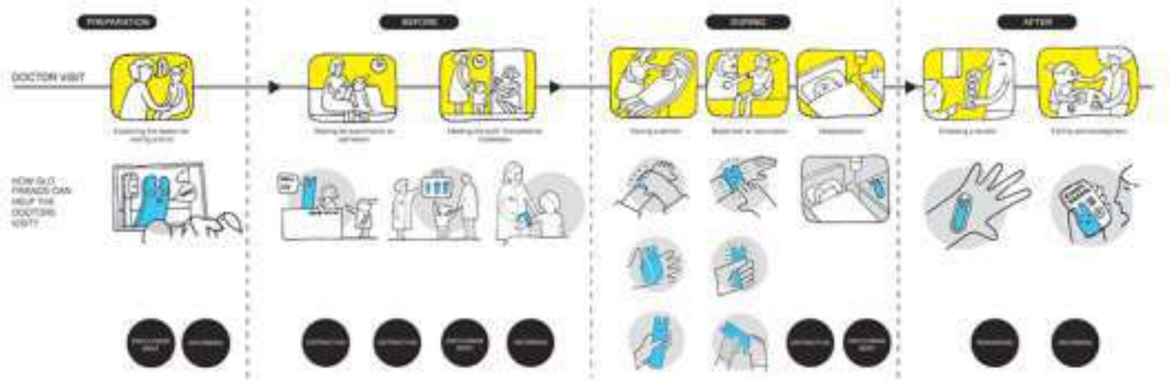

PhysioFriend
A friendly, wearable device to speed up and improve recovery after knee surgery
Concept Overview
With orthopedic operations such as knee replacement most of the emphasis is placed on the implants and surgical technique
However, a good surgical outcome is attributed to
50% Surgical technique : 50% Patient rehabilitation
At the moment there are very limited and poor resources to assist in patient rehabilitation. Typically these are poorly printed exercise schedules that are easy to ignore or misinterpret. Incorrect or non-existent patient rehabilitation can result in:
Poorly seated implants | Postural problems | Dislocation| The need for revision surgery
These issues are indicative of a poor surgical outcome but, far worse, they have a
detrimental affect on the patient's long term quality of life
Physiotherapy after total knee replacement
printed exercise handouts are hard to follow and easy to misinterpret
PhysioFriend reassures recovering patients that they are doing their vital rehabilitative exercises correctly in terms of technique and volume
How to use Physiofriend
Align opening over kneecap
Fasten velcro tabs behind knee
Once PhysioFriend is put on it is straightforward to select the exercise programme recommended by the physiotherapist
1. Select angle of flexion
2. Select number of repetitions
3. Press start
4. Follow the illuminated guidance
5. GET BETTER QUICKER
6. ENJOY LIFE
The exercise
Typically the patient starts with a straight leg and attempts to bend the leg to 90° and beyond (this can also work in reverse i.e. attempting to straighten the leg)
Once the leg is flexed to the angle specified by the medical practitioner it is held for a set time before returning to the start position
Customer journey
George is a retired 78 year old. He is an avid amateur gardener
George requires a knee replacement operation and is concerned that his gardening days may be over. George doesn't like doing what he is told and tends not to follow instructions
His daughter and the Physiotherapy team assure him he can make a complete recovery...
...with a little help from (Physio)Friend
In addition to aiding in the recovery from injury it is envisaged that PhysioFriend could also be used as a conditioning and data logging tool for athletes
Thus it could contribute to improved performance and injury prevention
select exercise
90° 5x
105° 10x
120° 15x
angle reps
start
angle reps
PhysioFriend
FJORD

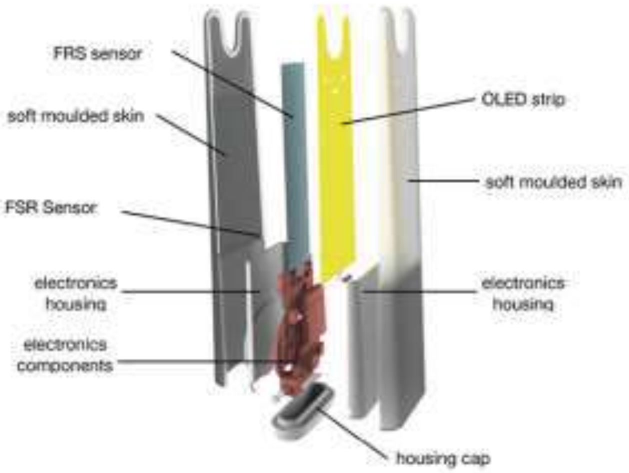

WP5 - HACK ROLL
HACK ROLL - CONCEPT UPDATE
EMPOWERMENT THROUGH SELF DISCOVERY
Farolillos
WORKSHOP
4
GROUPS
12
ADULTS
8
CHILDREN
7
EXERCISES
3
DESIGN STREAMS
WORKSHOP GOALS/METHOD
ATTENDANTS
GOALS
MAIN TASKS
OUTCOMES
GROUP 1 - RUGBY TRAINER
Designed to train correct tackling areas
Measures strength of impact
Use with professionals and amateurs
Real time feedback
Easy to replace after use
GROUP 2 - GOLF CLUB ANALYSIS
Interchangeable golf swing analysis
Pressure sensitive Piezo polymer switch
Plug and play magnetic system
User controlled micro controller
Lithium ion battery powered
Interchangeable coloured options
GROUP 3 - EXERCISE MOTION CAPTURE
Training monitor
Enable increased well being with social interaction
Slides into fitness pockets
DEVELOPMENT
HACKROLL - ARDUINO
HACKROLL - BESPOKE
FJORD
minima


Scenario
No matter how old you are or what you do for a living, you are always using your hands. When there is something wrong with them, you may not be able to do your regular activities.
GLOWE
ADAPTED KINESITHERAPHY FOR HAND INJURIES AND CHRONIC DEGENERATIVE DISEASE
GLOWE is an interactive and adaptive wearable hand care tool with the aim of enhancing physical strength, flexibility and improve cognitive perception.
Design development
preliminary concept idea
from an interactive tool to a wearable system
concept design development immersive lighting experience
user experience - sensorial materials and material requirements definition
user testing - interface design analysis
CONTROL UNIT WRISTBAND
Piezo signal processing
bluetooth, microUSB
rechargeable battery
LTM OLED FEEDBACK AREA
WORKOUT SELECTION
haptic feedback
LTM PIEZO SENSOR FINGERS AND PALM
3D SPACER FABRIC
lightweight and robust
SOFT TOUCH MICROFIBER
bio medical textile - easycare
The LTM glove concept takes advantage from the novel light/touch material to create a meaningful scenario in which training and rehabilitation activities become smart and playful.
The idea behind LTM glove is to provide users with an interactive self-rehab tool measuring personal improvements in hand mobility and reducing the recovery therapy at the gym.
The smart device gives information about the correct execution of the exercises by sensing pressure and bending of the fingers and responding in lighting feedbacks. It also shows the progress you make during the exercise.
POTENTIAL APPLICATIONS
gaming - virtual reality
occupational theraphy
LTM

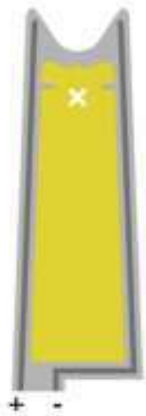
GLOBUDDYS I PATIENT EXPERIENCE TOOLS
BY FUELFOR

Use case scenario



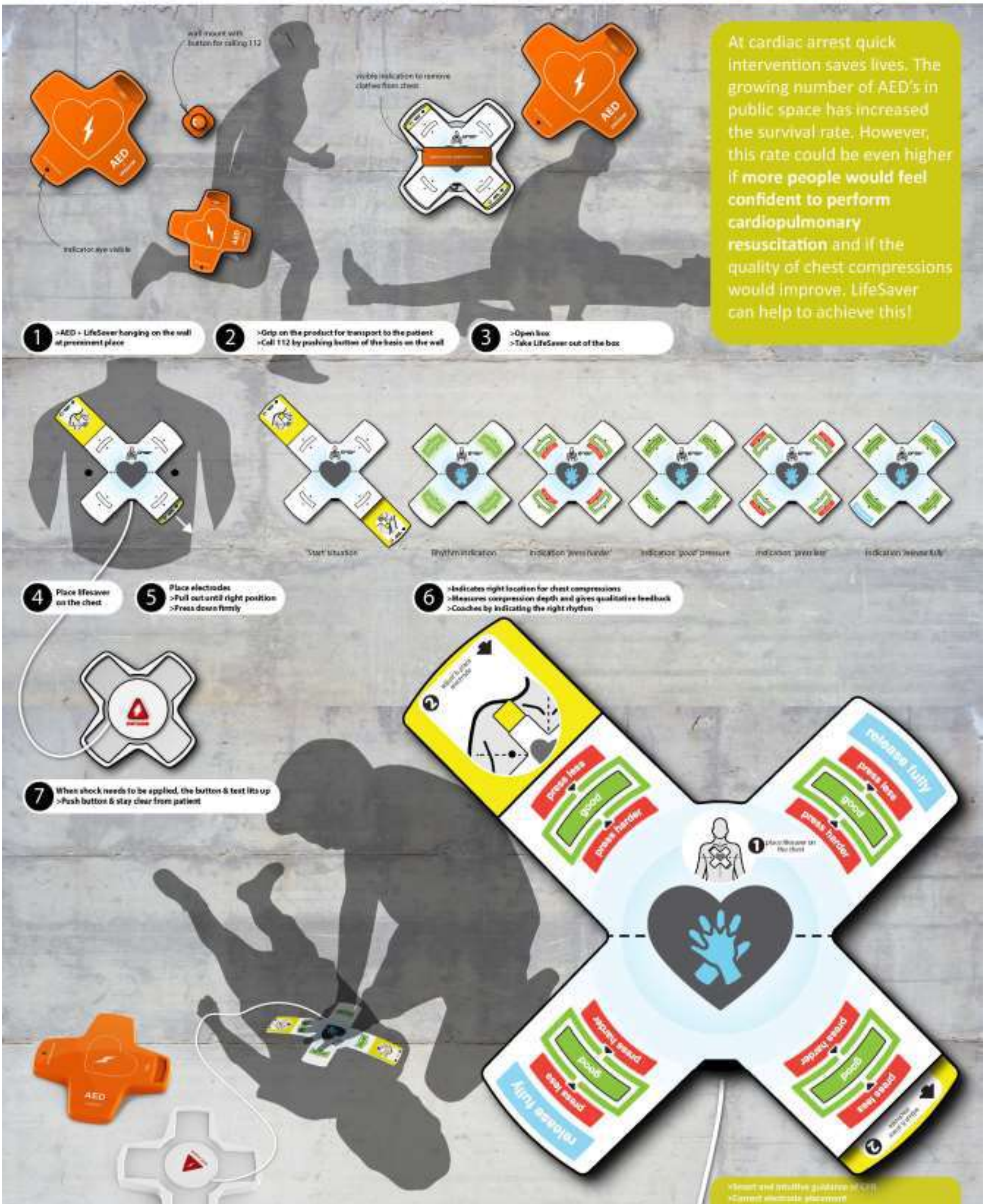


Proposed OLED design



LIFESAVER

A SMART & INTUITIVE PRODUCT THAT GUIDES CPR



VANBERLO

4.1.4. Potential impact and main dissemination results

Contribution to sustainability objectives

- OLEDs are highly energy-efficient, especially compared to similar technologies for providing flexible luminescence, such as EL (electro-luminescent) materials. Moreover, the roll-to-roll (R2R) printed OLEDs developed in the LTM project are free from ITO, the anode material that uses the scarce (also critical) mineral resource indium.

- The novel piezo plastics – technically to be called "structured composites of piezo-active particles in a polymeric matrix" – developed in Project LTM constitute a viable alternative to lead-based piezo materials. Currently, these lead-based piezo-active materials are exempt from the Restriction on Hazardous Substances (RoHS) that is in force in the EU for use of lead, this on the grounds that there is no suitable replacement available. (Lead-free alternatives exist, but are not powerful enough with respect to the piezo-active effect they generate.) Thanks to the LTM project, there now does exist a suitable alternative, and this constitutes a significant sustainability advance.

- Project LTM has forged a link between product design involving high tech materials and product design for a circular economy (through EU PF7 project Rescoms). This link was in fact inevitable, as the novel LTM materials (and their associated wiring, power supply, and control electronics) simply require a much smarter approach towards end-of-life than recycling in bulk.

Contribution to social objectives: employment, health, and safety

The new "LTM materials", combining advanced piezo plastics for touch with R2R printed OLEDs for luminosity, strengthen the knowledge economy by requiring, supporting and inspiring skilled employment in Europe. In particular, a strong bridge has been built in the LTM project between materials RTD and product design, with both sides now appreciating the benefits of cooperation. Specifically, for the RTD side this has resulted in a much clearer view of the "unique value proposition" (UVP) of the technology in question, and concrete pointers for development. Conversely, the design side of the project now appreciates first-hand the vast potential of material innovation, inviting design agencies to make better use of new developments and not only focus on what they know to be commercially available.

Also, the project has produced, in its "white book for design-driven RTD", a portable approach for enabling such cooperation, usable in other contexts and with other (i.e. non-material, e.g. medical or ICT) technology components. This is of course only a *potential* impact, as the white book still needs to be disseminated more widely, but already it can be used very well to appreciate the quality of proposed new D-M projects, also EU-funded new projects.

Design in general can play a prominent role in addressing societal issues such as sustainability, mobility, education and healthcare. The intuitive interfaces developed in this project are strongly human-centred and are well-suited to applications in care & well-being that have been convincingly showcased in the project. The consortium anticipates that in the long term, this will support better prevention and more efficient provision of (health)care, helping to reduce healthcare costs. Excellent examples of how this can be done are the PhysioFriend (facilitating rehabilitation after knee surgery), LifeSaver (easy-to-use CPR), and Glowe (hand rehabilitation). Moreover, the new LTM materials-driven interfaces can improve the user experience also for specific user groups such as children, patients suffering from diabetes or obesity: great examples are the GloBuddy (reducing anxiety in children undergoing medical procedures) and the EAT (appetite enhancing product for e.g. cancer patients).

At the same time, it has been clearly shown that the new materials can also make a potential impact outside care & well-being as well: examples are the Me-Lite headphone (consumer electronics) and the Hack Roll (electronics hobbyists, general industry). Automotive applications are still one bridge too far though, as the R2R printed OLEDs currently lack the very high brightness, as combined with low cost and long lifespan, that this extremely demanding market segment requires. On the positive side, the Holst Centre now has a much better view of how this market can be approached, and how their internal RTD agenda has to be framed to get there. Plus, the "haptic touch technology" that was developed by one of the LTM partners in parallel to the project *has* made a huge impact on the automotive industry, and the synergy obtained between both activities this partner has definitely sped up uptake of this new technology.

<u>Contribution to expected impacts listed in the original call topic:</u>

i. Novel materials and products where design and the advancement in the properties of the materials are key factor for success: the project has developed novel luminous and touch-sensitive OLED and piezo materials that represent strategic technologies of the European industry, but whose success competitiveness depends on their incorporation in revolutionary product and interface designs driven by their unique properties. Project LTM has been one of the first projects to go beyond pure RTD, focusing on improving engineering material properties only, looking also at integration and manufacturability as well as aesthetics;

ii. Boosted dynamism of innovation in the field(s) of the creative industry: Project LTM has exposed designers to some of the most exciting new material developments taking place at this moment (not only piezo plastics and OLEDs, but also electro-luminescent materials, haptic touch piezos, as well as several off-the-shelf but advanced components). The high level of design freedom given by the new materials, and opportunities for revolutionary interface design not possible with LEDs and buttons, assures increased innovation potential for industrial designers. The impact on the creative industry has further be multiplied by working directly with design promotions agencies in sharing project results.

iii. Improved communication between actors in the innovation chain also in view of novel consumption patterns: the design-driven RTD approach involved regular and prolonged face-to-face contact between materials researchers and product designers. Ethnographic research and user-centred design activities by different design agencies, complemented by trend watching research by Trend Union, has directly linked product development to novel consumption patterns, assuring a meaningful and sustained social and cultural impact.

Of special note here is that the LTM project has also brought together designers from two arenas that may seem closely related but that are, for many intents and purposes, in fact in worlds far apart: the design *practitioners* (i.e. design agencies) and the design *academics* (i.e. design universities). Perhaps nowhere in the technical disciplines is this gap between practice and theory as large as it is here, but the LTM project has begun to join the two sides together. The clearest example of this exchange is the set of criteria for assessing the quality of product-user interaction developed jointly between TU Delft IDE, Brunel HCDI and all design agencies in the LTM project.

iv. Contribution to achieving EU policies, particularly the Europe 2020 and the Innovation Union goals as well as those of the initiative addressing the creative industries: the project has directly supported the main policy goals of the Europe 2020 Flagship Initiative "Innovation Union", to better exploit our strengths in design and creativity, reducing the gap between technology development and design in order to stimulate innovation. Particularly it supports the goals of the European Design Innovation Initiative, launched by the EU Commission in 2011. The LTM focus on intuitive interfaces addresses the need to generate and/or better accommodate consumer demand through increased interaction and feedback, identified in the KEA report "The impact of culture on creativity", mentioned in the original call text.

<u>The LTM "lead user panel" and other contacts</u>

The expected impact of the materials and applications developed in the project, described above, will only become reality once industrial-scale production of the materials is reached. The partners involved have the knowledge to bring the material developments to the point where scaling up can be done, at which point IPR can be shared (through for example licensing) with industrial players that can make that a reality. The consortium has specifically chosen not to involve such industrial players in the consortium, in order to maintain a clear SME focus and avoid being tied to a specific technological platform. To assure successful transfer to industry, the project has actively involved large industrial players in its so-called "lead user panel". Member companies have participated, several even more than once, in selected LTM project workshops, where they witnessed all samples and prototypes, as well as all proceedings in the LTM design stream. Their comments not only helped refine the RTD work and concrete design activity, but also sowed the first seeds for post-project collaboration to industrialize the technology demonstrators. Indeed, for almost all of the LTM demonstrators, follow-up discussions (the content of which is understandably confidential) are currently taking place.

Apart from these "lead users", Project LTM also invited exchanges with suppliers of certain key technologies and with design contact points. The list of companies/organizations and contact persons is shown below:

Advanced Materials Cluster of Catalonia: Pau Virtudes ··· Asics: Rene Zandbergen ··· BNO: Rob Huisman ··· CATAS: Andrea Giavon ··· CETEMMSA ··· Coloplast: Malene Thorup ··· ComfTech: Alessandro Sarffatti and Alessia Moltani ··· Cumulus: Justyna Maciak ··· Dhitech: Roberto

Giannantonio ··· Danish Design Centre: Nille Juul Sørensen ··· Design Council UK: Chris Howroyd ··· DuPont: Kerry Adams ··· DuPont Teijin Films: Valentijn van Morgen ··· FARO: Emiliano Bacco and Simone Pirovano ··· Flex Tronics International: Stefano Pozzi ··· FLOS: Francesco Rodriquez, Andrea Gregis and Daniela Moreno ··· German Design Council: Andrej Kupetz ··· Granta Design: James Goddin ··· Group-bticino: Andrea Colombo, Nicola Ardo and Paride Satta ··· Hungarian Design Council: Miklos Bendzsel ··· INDO: Pau Artus ··· Innovhub Milan: Iliara Bonetti ··· Legrand ··· Logitech International: Christophe Constantin ··· Luxottica Group: Giulia Smonker, Magnetti Marelli: Giovanni Bianchini and Giuseppe Curcio ··· MaterFAD: Aline Charransol and Valerie Bergeron ··· Morgan Piezo Ceramics: Bryan Mander ··· Natural Machines: Adriana Bertolin and Xavier Olive ··· Natuzzi Group: Domenico Ricchiuti and Livio Mottola ··· Nemes: Lorenzo Gabellini ··· NHS UK: Dr. Terry Parlett ··· NightBalance: Thijs van Oorschot ··· PAL Robotics: Luca Marchionni ··· Francesco Ferro and Joan Oliver ··· Philips: Elise Talgorn ··· Philips Research: Hans van Sprang ··· Prysmian Group: Flavio Casiraghi and Davide Sarchi ··· Royal Auping: Simon van Es ··· Samsung Design Milano: Marzio Riboldi and Giulia Redi ··· Solvay: Alessio Marrani and Ivan Falco ··· Sumitomo Chemical Europe: Jumma Nomura ··· SusChem: Klays Sommer ··· Syntens Innovatiecentrum: Piet van Staalduinen ··· Triennale di Milano: Andrea Cantellato ··· V2i Vors to Innovate: Erik Veninga ··· Veneto Nanotech: Piero Schiavuta ··· Vibram Creative Lab: Simona Montemari and Francesco Perrotti ··· Whirlpool: Marco Bonneau and Ferdinando Valenti ··· (and several others)

Relation to other EU-funded research activities

Through its lead researchers, Project LTM has successfully fostered exchanges with many other EU-funded research activities. This also serves to increase (potential) impact. A selection of these projects is presented here:

- MyHeart (FP6): personal healthcare applications for preventing and managing cardiovascular disease;
- FAST2LIGHT (FP7): Fast2Light developed novel, cost-effective processes for fabricating flexible OLEDs for intelligent lighting applications;
- Rescoms (FP7): developing tools and methods to support the transition towards a circular economy, especially for product design;
- InnoMatNet (FP7): facilitating exchange between different EU-funded projects in the realm of new materials technology;
- Solar-Design (FP7): one of the two "sister projects" under the same call as Project LTM, focusing on design-driven innovation for solar powered products;
- SOLEDLIGHT (Horizon 2020): solution processed OLEDs for lighting.

Finally, the LTM consortium also generated another H2020 project involving several LTM partners, the Trash 2 Cash project (see www.trash2cashproject.eu for details).

Selected dissemination events in Project LTM

Date	Partner organizer	Name of the initiative organized by the partner	City	Name of the event in which the partner's event is included	Level	Data [number of visitors, contact, etc.]
19-sept-15	MCI-P12	MATERIALS VILLAGE @ DESIGNJUNCTION - LONDON DESIGN WEEK	LONDON	London Design Week 2015	International	26,000 visitors to designjunction venue
30-sept-15	MCI-P12	MATERIAL CONNEXION STAND	VERONA	Abitare il Tempo_Marmomacc	National	5,000+ visitors
15-oct-15	MCI-P12	MATERIAL CONNEXION STAND	MILAN	VISCOM	International	17,000+ visitors
17-oct-15	DUT-P01A	TU delft @ MIND THE STEP EXHIBITION	EINDHOVEN	MIND THE STEP during Dutch Design Week	International	27,000 visitors
15-jan-16	FJORD-P05	Workshop @ Fjord office	MADRID	Farollilos	National	
1-feb-16	MCI-P12	LTM VIP SYMPOSIUM @MCI office	MILAN		International	17external companies
12-may-16	FJORD-P05	LTM EXHIBITION	MADRID	Fjord Kitchen Senses	National	
1-apr-16	MCI-P12	MATERIALS VILLAGE @SUPERSTUDIOPiù	MILAN	fuorisalone: parallel event to Milan furniture fair	International	130,000 visitors
1-apr-16	MCI-P12	MATERIAL CONNEXION STAND	MILAN	Milan International Furniture Fair ed. 2016	International	37,000 visitors
29-apr/2+3-may-16	MCI-P12	Workshop @ Design Schools	MILAN	exploring curious materials, led by James Burchill	National	75 students
17-jun-16	MCI-P12+ DUT-P01A	"Future Materials" LTM Final Event	DELFT	LTM Final Event: symposium and exhibition	International	150 visitors (excl. on-line audience)

Figures 6 and 7 below present an impression of two of such events, the second being the closing symposium.

NB: Project LTM was also featured in the Euronews program "Futuris". The contribution can be watched at the following link: www.euronews.com/2015/10/26/a-brighter-future-eu-researchers-harness-the-power-of-light. The video was shot at the Holst Centre, in September 2015, with the Futiris item becoming available one month later. At that time, the technology demonstrators were not yet developed.

Figure 6: Few photos of Fjord Kitchen “Senses”

Figure 7: Few photos of Future Materials: LTM final event

4.1.5. Project websites and contact details

All public information regarding the LTM project is available at (or through) the following website: www.ltm.io.tudelft.nl. Furthermore, the on-line teaching resource developed during the project is available at www.instituteofmaking.org.uk/blog/2016/07/ltm-online-course.

For queries, consult either the coordinator or the senior scientist:

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4.2. Use and dissemination of foreground

Section A, item A1: scientific papers and master theses

Design tools for interdisciplinary translation of material experiences Written by Sarah Wilkes, Supinya Wongsriruksa, Philip Howes, Richard Gamester, Harry Witchel, Martin Conreen, Zoe Laughlin and Mark Miodownik	ENG	Scientific Paper	International	Journal of Materials & Design
Karana, E., Barati, B., Rognoli, V., Zeeuw van der Laan, A., Material Driven Design (MDD): A Method To Design For Material Experiences	ENG	Scientific Paper	International	International Journal of Design Received Month Date, 2014; Accepted Month Date, 2015; Published Month 30, 2015.
Piezoelectric lead zirconium titanate composite touch sensors for integration with flexible OLED technology D. B. Deutz, E. Tempelman, S. van der Zwaag, W. A. Groen	ENG	Scientific Paper	International	Ferroelectrics Vol. 480, Iss. 1, 2015
Enhancing energy harvesting potential via Li substitution of (K,Na,Li)NbO3-epoxy composites D. B. Deutz, N. T. Mascarenhas, S. van der Zwaag, W. A. Groen	ENG	Scientific Paper	International	Submitted: Journal of the American Ceramic Society 2016
High piezoelectric voltage coefficient in structured lead-free (K,Na,Li)NbO3 particulate-epoxy composites N. K. James, D. B. Deutz, R. Bose, S. van der Zwaag, W. A. Groen	ENG	Scientific Paper	International	Accepted: Journal of the American Ceramic Society 2016
Exploring the piezoelectric performance of PZT particulate-epoxy composites loaded in shear F. Van Loock, D. B. Deutz, S. van der Zwaag, W. A. Groen	ENG	Scientific Paper	International	Accepted: Smart Materials and Structures 2016
"Striving For Meaning - A Study Of Innovation Processes", Candidate: Åsa Öberg, 2015, MDH/POLIMI	ENG	PhD thesis	International	Mälardalen University Repository
Technology Steering: Identifying New Application Fields Enabled by the Re-Interpretation of Emerging and Ready-To-Apply Technologies Supervisor: Prof. Claudio Dell'Era Candidate: Stefano Magistretti January 2019	ENG	PhD thesis	International	Politecnico di Milano Repository
"Smart Materials and metaphorical messages as learning tools for the ageing population" Candidate: Massimo Micocci, Supervisors: Marco Ajovalasit, Daniella Spinelli February 2017	ENG	PhD thesis	International	Brunel / HCDI Repository
"Fluorescent materials for the down-conversion of Organic Light Emitting Devices" Candidate: Andrea Mazzocut, Supervisor: Prof. Chris S. Frampton July 2016	ENG	PhD thesis	International	Brunel / WMP Repository
"SUPPORTING DESIGNERS IN UNDERSTANDING THE EXPERIENCE DESIGN SPACE WITH SMART MATERIALS" PhD candidate: Bahareh Barati Promoter and CoPromoter: Paul Hekkert and Elvin Karana	ENG	PhD thesis	International	TU Delft Repository
"Explaining Radical Innovations: use of digital media to explain radically innovative materials to designers" Candidate: James Burchill, Supervisors: Marco Ajovalasit June 2018	ENG	PhD thesis	International	Brunel / HCDI Repository
Daniella Deutz, DUT – NOVAM, Supervisor: Prof. W.A. Groen, Prof S. van der Zwaag, graduation estimated Spring 2017	ENG	PhD thesis	International	TU Delft / NovAM Repository
Design-Driven Technology Innovation (DDTI): applying design to steer technology development Master Student: Pierpaolo Pisanelli – 797782	ENG	Master Thesis	International and national	Politecnico di Milano Thesis Repository
Consumer Acceptance of Biofeedback Products in Health Management - Author: Lin, T.Y. Mentor: Sääksjärvi, M. · Tempelman, E.	ENG	Master Thesis	International	TU Delft Repository

Consumer acceptance of biofeedback technology in sports - Author: Robin dos Santos Gomes; Chair: Erik Tempelman; Mentor: Maria Sääksjärvi	ENG	Master Thesis	International	TU Delft Repository
Valorising the potentiality of new(and existing) technologies by identifying new applications Politecnico di Milano, Faculty of Industrial Engineering A dissertation submitted for the degree of Master in Management Engineering Thesis supervisor: Prof. Claudio Dell'era Thesis co-supervisor: Prof. Roberto Verganti Master Students: Stefano Corlianò, Michele Loperfido.	ENG	Master Thesis	International and national	Politecnico di Milano Thesis Repository
Materials for care: Relaxing massage through materials and tactility, Author: Clauida Poma Chair: Elvin Karana, Mentor: Marieke Sonneveld 2014-03-07	ENG	Master Thesis	International	TU Delft Repository
Luminous materials for relaxation: Designing a relaxation device for the office environment. Author: Tim Vermeulen. Chair: Sylvia Pont, Mentor: Elvin Karana 2013-11-28	ENG	Master Thesis	International	TU Delft Repository
An Exploration of a smart material and its characteristics. Author: Iris Jonsthovel Chair: Paul Hekkert Mentor: Bahar Barati	ENG	Master Thesis	International	TU Delft Repository
Designing with emerging tecnologies for an inaccessible context Student:Nina Mørch Pedersen Supervised by Anna Vallgårda	ENG	Master thesis	International	University of Copenhage
Enhancing Elderly sensory perception through Smart Materials Student: Ryan Breeze Supervised by Marco Ajovalasit	ENG	Master thesis	International	Brunel University London Repository
Design-Driven Research and Technology Development (D-RTD) Identifying meaningful application fields enabled by early technologies Supervisor: Prof. Claudio Dell'Era Master Students: Gregorio Ginestri 823822 Gloria Marzari 814303 Academic Year 2014/15	ENG	Master Thesis	International	Politecnico di Milano Repository
"'D-Belt', An interaction for the measurement of the human waist" Student: André Taris Dr.ir. E. Tempelman, Dr.ir. J.F.M. Molenbroek, Prof. W.A. Groen [27/11/2013]	ENG	Master thesis	International	TU Delft Repository
"Circular LTM- A bridge between the light.touch.matters project and Circular Economy" Student: Andrea Portioli, Supervisory Team: Tom Etheridge Minima Design Ltd, Framlingham, UK Ir. Erik Tempelman IDE- Design engineering department TUD Martin Lehmann IDE- Design engineering department TUD 2015	ENG	Master thesis	International	TU Delft Repository
"Redesign a Breast Cancer Detection Product (A Smart Bra) with Piezoelectric Technology" Student: Lulu Yin Supervisors: Dr. Marco Ajovalasit, Dr David Rees	ENG	Master thesis	International	Brunel HCDI Repository
"Light Games" Student: Otto Kauhanen, Supervisor: Dr. Marco Ajovalasit, Dr. Farnaz Nickpour	ENG	Master thesis	International	Brunel HCDI Repository
"Enhanced Blood pressure Monitoring Experience through the use of smart materials." Student: Xiongchuan Ouyang, Supervisor: Dr Marco Ajovalasit, Dr Antonio Vilches	ENG	Master thesis	International	Brunel HCDI Repository
"YOGlove. Application of smart materials in designing a yoga wearable", Student: Sara Horvat, Dr.ir. K.M.B. Jansen, Dr. Z. Rusak, L. López 24/04/2015	ENG	Master thesis	International	TU Delft Repository

'HMI in a highly automatic driving phase' or 'enhanced haptic in automotive HMI' Stefan Heijboer August 2016	ENG	Master thesis	International	TU Delft Repository
Georgios Tselikos, December 2016	ENG	Master thesis	International	TU Delft Repository
Flexers - A smarter approach to finger splinting Student: Rob Adam Supervised by Marco Ajovalasit	ENG	UG thesis project	International	Brunel University London Repository Project showed in MADE IN BRUNEL Design Exhibition
"Application of piezo-plastics in wearable health-products" Student: Katalin Dóczi, Chair: Dr. Erik Tempelman Mentors: Prof. dr. Pieter Jan Stappers, Dr. Natalia Romero Herrera	ENG	UG thesis project	International	TU Delft Repository
"Designing smart material opportunities for Night Balance" Student: Jing Yao,Chair: Dr. Erik Tempelman Mentors: Aadjan van der Helm, Thijs van Oorschot 24/09/2014	ENG	UG thesis project	International	TU Delft Repository
"Diagnostic Ball - Light up ball with internal diagnostic play matt. used to detect and diagnose autism earlier in children." Student: Roberto Mafrici, Supervisor: Dr Marco Ajovalasit	ENG	UG thesis project	International	Brunel HCDI Repository
"REHABILITATION OF THE LOWER LIMBS - Allowing patients to recover better from trauma surgery using smart materials." Student: Jack Rich, Supervisor: Dr Fabrizio Ceschin, Dr David Rees	ENG	UG thesis project	International	Brunel HCDI Repository
"Actipet - The Emotional Activity Monitor " Student: Julian Minuzzi, Supervisor: Marco Ajovalasit, Joseph Giacomin	ENG	UG thesis project	International	Brunel HCDI Repository
"EO: Motivating the Elderly to take up and maintain exercise habits" Student: Laszlo Sztana, Supervisor: Dr. Marco Ajovalasit, Dr. Peter Evans	ENG	UG thesis project	International	Brunel HCDI Repository
"Yi - Interactive Yoga Mat" Students: E.M.H.Houwen, Emma Heitbrink, Lexi LIN, Louis Brouwers, N.A.Priem, P.H.T.Groenendaal, Supervisor: Bahar Barati	ENG	UG thesis project	International	TU Delft Repository
"Joe" Students: Nils Berg,Lisa van de Merwe, Rianne, Schlepers, Hekon van Duijvendijk, Suzanne de Witte, Sabrin Ghaza , Dr.ir. K.M.B. Jansen	ENG	UG thesis project	International	TU Delft Repository
"Meddy" Students: Tugba Camci, Youri Havenaar, Jacqueline van 't Hof, Thessa Jansen, Wout Kommer, Parizad Saremi, Dr.ir. K.M.B. Jansen	ENG	UG thesis project	International	TU Delft Repository

Section A, item A2: dissemination events

D. B. Deutz, "Design driven development of flexible, touch sensitive, piezoelectric composites", Delft University of Technology, the Netherlands,	ENG	Scientific Poster	International and national	Faculty of Aerospace PhD Poster Day - TU Delft Repository, 28 May 2014
D. Deutz, H.Khanbareh, N.K. James, E. Tempelman Design driven development of piezoelectric touch-sensitive luminous flexible plastics Novel Aerospace Materials, Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands	ENG	Scientific Paper	International	European Conference on Applications of Polar Dielectrics (ECAPD), Vilnius, Lithuania, 7 - 11 July 2014.
F. Van Loock, D. B. Deutz, S. van der Zwaag, W. A. Groen "Characterization of piezoelectric composites for shear strain-driven energy harvesting applications"	ENG	Scientific Poster	International	International Conference on Adaptive Structures and Technologies (ICAST), The Hague, The Netherlands, 6 - 8 October 2014
Experiences from recent European research projects on the interplay between technology and design Author: Erik Tempelman, Nadja Adamovic	ENG	Conference Paper	International	The R&D management conference 2015 - Pisa 23-26 June Topic of the conference track: "The Interplay between Technology and Design"

D. B. Deutz, E. Tempelman, S. van der Zwaag, W. A. Groen "Piezoelectric composite touch sensors for integration with flexible OLED technology" H. Khanbareh, D.B. Deutz, S. van der Zwaag, W.A. Groen, "Materials selection for piezo- and pyroelectric energy harvesting" ICAST2014: 25nd International Conference on Adaptive Structures and Technologies, October 6-8th, 2014, The Hague, The Netherlands.	ENG	Scientific Presentation	International	International Conference on Adaptive Structures and Technologies (ICAST), The Hague, The Netherlands, 6 - 8 October 2014.
H. Khanbareh, D.B. Deutz, S. van der Zwaag, W.A. Groen, "Materials selection for piezo- and pyroelectric energy harvesting"	ENG	Scientific Presentation	International	International Conference on Adaptive Structures and Technologies (ICAST), The Hague, The Netherlands, 6 - 8 October 2014.
F. Van Loock, D. B. Deutz, S. van der Zwaag, W. A. Groen "Shear mode characterization of piezoelectric composites for strain driven energy harvesting applications"	ENG	Scientific Poster	International	International Conference on Electroceramics (ICE), State College, Penn State, USA, 13 - 16 May 2015.
D. B. Deutz, A. K. Shaji, N. K. James, H. Khanbareh, S. van der Zwaag, W. A. Groen "New functional materials based on structured electroceramic composites"	ENG	Scientific Presentantion	International	International Conference on Electroceramics (ICE), State College, Penn State, USA, 13 - 16 May 2015.
D. B. Deutz, C. A. Randall, S. van der Zwaag, W. A. Groen "Tackling upscaling of structured piezoelectric ceramic-polymer composites"	ENG	Scientific Presentantion	International	International Conference on Electroceramics (ICE), State College, Penn State, USA, 13 - 16 May 2015.
"Material Innovation in automotive, aerospace and sailing sector", Micol Costi	ENG	Publicity Presentation	Nationale /International	Presentation of LTM project at the "Adavanced Materials International Forum" Organized by Puglia Region – Service for internationalization - in collabortion with Industry Research and Innovation Service and ARTI - Regional Agency for Technology and Innovation
"Cross-Sectorial thinking of new "smart" textile", Giada Dammacco	ENG	Publicity Presentation	International	Presentation of LTM project at the "ISPO-TexTrend" inside the ISPO MUNICH FAIR [the international main exhibition for sport business]
Metal Electromigration through Transparent Conductors Monitoring an OLED Failure Mechanism Robert Abbel, Jasper Michels, Linda van de Peppel, Jeroen van den Brand, Pim Groen	ENG	Scientific Presentantion	International	Materials Research Society (MRS) Spring Meeting - San Francisco - USA 2015 MRS Spring Meeting CC3.01 – 07/04/2015
Pit Teunissen et al.: "Towards roll-to-roll solution processing of OLED devices on an industrial scale"	ENG	Scientific Presentation	International	Innovations in Large Area Electronics Conference (innoLAE 2015), Cambridge, United Kingdom
Eric Rubingh et al.: "Roll-to-roll manufacturing of solution processed OLED panels - Upscaling towards industrial production"	ENG	Scientific Presentation	International	Flexible and Printed Electronics Conference and Exhibition (FlexTech 2015), Monterey, California, United States
Pim Groen: "Roll-to-Roll Processing for Solution Processed OLED Devices"	ENG	Scientific Presentation (invited talk)	International	Department of Energy R&D Workshop, San Fransisco, California, United States
Pim Groen: "Roll-to-Roll Processing for Solution Processed OLED Devices"	ENG	Scientific Presentation	International	7th International Exhibition and Conference for the Printed Electronics Industry, LOPEC 2015 - Munich [German]
"First experiences in involving design companies in guidance of R&D on future materials and their applications", Menno van Rijn	ENG	Publicity Presentation	International	International event from University Industry Innovation Network (UIIN): International Conference "University-Industry Interaction 04/2014" - Barcelona [Spain] - 23/25 April 2014 [342 participants form 52 countries]
What is Human Centred Design? Author: Marco Ajovalasit	ENG	Scientific Presentation	International	Presentation at CNR – Milan- ITIA Institute of Industrial technologies and Automation

From Way Finding in the Dark to Interactive CPR Trainer: Designing with Computational Composites Author: Bahareh Barati, Elvin Karana, Paul Hekkert	ENG	Long Paper / Conference Publication	International	9th International Conference on Design and Semantics of Form and Movement - DesForm, Politecnico di Milano (Italy), 13 – 17 October 2015
Designing with an Underdeveloped Computational Composite for Materials Experience Author: Bahareh Barati, Elvin Karana, Paul Hekkert, Iris Jönsthövel	ENG	Scientific Paper / Conference Publication	International	EKSIG 2015 "Tangible Means - experiential knowledge through materials", 25-26 November 2015, Design School Kolding, Denmark
Functional Demonstrators to Support Understanding of Smart Materials Bahareh Barati, Elvin Karana, Paul Hekkert, Kaspar Jansen	ENG	Scientific Paper / Conference Publication	International	ACM International conference on Tangible, Embedded and Embodied Interaction TEI '16, February 14-17, 2016, Eindhoven, Netherlands
Light Touch Matters Integration of flexible Oled with Piezo	ENG	Scientific Presentation	International	Holst Centre Partnermeeting Spring 2016
"Design Driven Materials Innovation: What the LTM project can teach us", Erik Tempelman via Mark Miodownik	ENG	Scientific Presentation	International	Materials Education Symposium, Cambridge, 2016
TECHNOLOGY STEERING: DRIVING TECHNOLOGY DEVELOPMENT BY ENVISIONING QUIESCENT MEANINGS Authors: S. Magistretti, C.Dell'Era, A.Oberg, R.Verganti	ENG	Scientific Paper / Conference Publication	International	Innovation and Product Development Management Conference 23th edition Glasgow, U. K. June 12-14 2016
"Sensor materials: from ceramics to flexible composites" High tech systems, Abbel/Groen	ENG	Scientific Presentation	International and national	Sensing Matters 2013 - 25/04/2013 Eindhoven, NL
"Open Innovation at Holst Centre: Open Innovation in the Dutch High -Tech, Medical & Life Sciences cluster in Brabant, the Netherlands", Abbel/Groen	ENG	Scientific Presentation	International	Tel Aviv, Israel 28-05-2013.
"New functional materials based on electroceramic composites", Abbel/Groen	ENG	Scientific Presentation	International	International Conference on Electroceramics, ICE2013, Brazil, 12-11-2013.
"Sequenced flash sintering of conductive inks – a method to optimise R2R processing conditions for printed electronics", Abbel/Groen	ENG	Scientific Presentation	International	MRS Boston, 02-12-2013
"Roll-to-roll production of highly conductive patterns by inkjet printing and photonic sintering of metal based inks – A possible route towards large area flexible electronics", Abbel/Groen	ENG	Scientific Presentation	International	MRS Boston, 03-12-2013
"Towards fully roll-to-roll solution processed large area OLED devices", Abbel/Groen	ENG	Scientific Presentation	International	Lopec, 06-2014
"Printed electronics – from simple circuitry to integrated devices", Abbel/Groen	ENG	Scientific Presentation: Keynote (invited)	International	2nd Int. Conf. on System-integrated Intelligence, Bremen, Germany, July 4, 2014
"Inkjet Printing as a R2R Compatible Technology for the Production of Large Area Electronic Devices on a Pre-Industrial Scale-Focal", Abbel/Groen	ENG	Scientific Presentation (invited)	International	NIP30, Philadelphia, 09-2014
"Roll-to-roll deposition of functional layers for solution processed OLED devices", Abbel/Groen	ENG	Scientific Presentation	International	MRS Boston, 01-12-2014
"Roll-to-Roll Processing for Solution Processed OLED Devices", Abbel/Groen	ENG	Scientific Presentation (invited)	International	Department of Energy R&D Workshop, San Francisco, 28-01-2015
"Large area printing and production technologies for OLEDs", Abbel/Groen	ENG	Scientific presentation	International	Productronica Forum – LED & OLED Production Session, 2015, Munich, 11-11-2015

"Novel flexible composites for energy harvesting and sensor applications", Abbel/Groen	ENG	Scientific presentation	International	M2i conference, NL, 7-12-2015
"Novel lead free flexible composites for energy harvesting and sensor applications", Abbel/Groen	ENG	Scientific presentation	International	MRS Boston 3-12-2015
"Flexible Oleds", Abbel/Groen	ENG	Scientific presentation (invited)	International	5th annual China international OLEDs summit, China, 20-21 Jan 2016
"High volume solution based roll-to-roll processing of plastic electronic devices", Abbel/Groen	ENG	Scientific presentation	International	Lopec March 28-30 2016, Munich, Germany
"Flexible and high temperature piezoelectric composites for energy harvesting applications", Groen	ENG	Scientific presentation (invited)	International	Materials Challenges in Alternative & Renewable Energy, April 17 - 21, 2016 Florida
"Flexible piezoelectric composites: Energy harvesting", Groen	ENG	Scientific presentation	International	Electroceramics 15, Limoges, June 27-29, 2016
"Flexible piezoelectric composites: an overview", Groen	ENG	Scientific Presentation (invited)	International	Electroceramics 15, Limoges, June 27-29, 2016

Section B, item B1: Applications for patents, trademarks etc.

No patents or trademarks have been applied for in the course of this project. All imagery (for instance of product concepts) as provided on the public website is free of use for all.

Section B, item B2: Exploitable foreground

The following foreground has been identified:

- Technology for the manufacture of structured composites of piezo-active particles in a polymeric matrix, with the aim of making touch sensors for product interface applications. Contrary to most existing piezo-active materials, these "piezo plastics" are flexible, facilitating application. Of special note is that this technology allows for the use of lead-free piezo-active particles without impairing the application. This technology has been developed primarily by TU Delft, NovAM department. Several other LTM partners have provided suggestions for applications that have furthered the research at NovAM; also, LTM partner Aito has assisted in sensor design.

- Various technologies for the continuous, roll-to-roll manufacture of flexible printed organic light emitting devices, or "OLEDs", in particular for making flexible anodes and for preventing silver migration. The foreground has been developed partly in Project Light.Touch.Matters, partly in other projects, at TNO/Holst Centre.

- During the Light.Touch.Matters project, the seven product design firms have each created a specific application of the advanced interface materials developed in the project. These "technology demonstrators" (see attachment to this final report) each offer a certain potential for exploitation. Partners involved: Diffus (technology demonstrator: EAT), Fuelfor (GloBuddy), Pilotfish (Me-Lite), Lamb Industries (PhysioFriend), Minima Design (Hack Roll), Grado Zero Espace (Glowe), VanBerlo (LifeSaver).

(The official final report for the EU contains some additional details regarding target applications and time frames.)

4.3. Report on societal implications

(This content is available only via the official final report, compiled through the EC webite, to which this document is an attachment.)