SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: CA 17107
STSM title: Investigation on the potential of smart textiles for the creation of smart, nZEB and sustainable buildings
STSM start and end date: 01/03/2019 to 23/03/2019
Grantee name: d-r Aleksandar Petrovski

PURPOSE OF THE STSM/

(max.500 words)

The objectives of the contemporary society to achieve sustainability in buildings and everyday living means taking into consideration the three domains, such as: environmental, social and economic. Therefore, the needs for new materials have emerged, that could improve the buildings` energy performance and decrease the energy demand, support the delivery of net Zero Energy Buildings (nZEBs), provide comfort to the inhabitants, create healthy environment, to be easy to maintain, to have potential to be reusable and recyclable, to be economically affordable, to enhance the buildings` structural system, energy performance etc. At the same time, the development of the ITC technologies offers solutions to integrate the smart textiles, materials, products and systems in order to satisfy the occupants in their everyday life by providing user feedback, control, assistance etc. In the recent decades, integration of smart products with certain new telecommunication technologies have been introduced and utilized in the healthcare system which enable assistance to the occupants, such as telemedicine and telehealth. However, there is still much to do in order to fully achieve their potential, especially in the integration with the smart homes and habitats.

The objective of this STSM is to broaden the knowledge and to identify the possibilities of smart materials and textiles for the creation of smart, nZEB and sustainable buildings. Addtionaly, the smart textiles and products will be investigated in their possibilities for assisting the occupants. The aims are:

- to broaden the knowledge base and identify the possibilities of application of smart textiles in the building construction industry and the creation of sustainable and Net Zero Energy Buildings (nZEBs)
- to investigate available ITC technologies and sensors.
- to contribute towards creation of sustainable and healthy environments.
- to identify the possibilities of ITC technologies for integration of smart textile materials into smart products and creation of smart habitat and sustainable living environment.
- to map smart textiles and products that provide assistance to the occupants and the elderly regarding their needs and the potential to integrate them in a smart building habitat.

The output results of the STSM will provide a solid knowledge base regarding the possibilities of smart textile materials for their implementation in the buildings and the creation of sustainable and assistive habitats. By disseminating the findings, the STSM will contribute towards an increase of knowledge in the construction industry and among architects and an increase of the implementation of smart materials in the buildings and product design. This will stimulate and drive the integration of smart textiles and products in the built environement and the creation of user-oriented smart buildings.This STSM research contributies to the work of Working Group 4 Smart textiles for building and living applications of the CONTEXT COST action.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

(max.500 words)

During the STSM, more than 70 research papers and articles have been examined. At first a review of state-of-the-art is conducted regarding the advancements of smart materials, smart textiles and smart coatings. The materials and their properties are investigated regarding their intrinsic or extrinsic properties. Additionally, the smart materials`intrinsic or extrinsic properties, smart or 'dumb', are examined. The classification of the smart materials is, in general, made in two types, which have been further investigated and different combinations of smart properties have been found. The input stimuli that cause the smart materials to change their properties have been taxonomically listed, altogether with the caused property changes. It is noted that many smart materials of either the property-changing class or the energy-exchanging class inherently provide various sensory functions. Also, the passive and active smart textiles are examined.

Various production methods for textile construction are investigated, such as: simple weaving, double weaving, warp knitting, non-woven etc. Their potential for application in the architectural buildings is investigated, such as: possibilities for new forms, regulation of daylight, regulation of sound, energy efficiency, ligthness, mobility, adaptability, sustainability etc. Further, a review is conducted on the possibilities of smart materials and textiles for their integration with smart furniture products and smart buildings for the creation of sustainable, healthy and smart living environments. Also, the potential of Smart materials and their integration in smart products is examined regarding their benefits for assisting the elderly in their living, providing them with satisfying comfort in the buildings, as well as their possibly for assisting them by the provision of their intrinsic or extrinsic properties. The textile may incorporate the following functions to build up a smart textile system: sensing, actuating, powering/generating, communicating etc. In that view, the barriers and drivers for the implementation of smart textiles are noted.

A review of ICT technologies is conducted and identification of their possibilities and their integration with smart materials for creation of smart furniture and smart habitats. The concepts of smart homes, sentient buildings, ambient assisted living, ubiquitous computing are examined. Also, most recent studies on universal design, assistive technologies, human-centric design theories, building management systems have been reviewed. The ICT development for assisting the elderly is investigated, as well as the development of fall detection technologies and prevention technologies, technologies that are able to monitor neurological diseases etc. Considering that the needs of the elderly people can be of various internal and external reasons, the smart materials and their integration into smart products, wearables and furniture can greatly assist them and prevent discomfort caused by immobility, fall, inappropriate light, inadequate temperature etc. Also, new smart furniture products` development are noted which are designed for a wider population. From the review, a summary table is developed regarding smart furniture technologies used, grouped in 4 categories, such as: materials, mechanical, electrical and software, and systems. Monitoring technologies that can be integrated in Smart furniture are investigated and several important aspects are recognized.

The potential of Smart textiles is examined regarding its benefits for assisting the elderly in their everyday living, achieving comfort, monitoring their health etc. A review was made on smart products and technologies for assisting the impairment of the elderly, among which fall detection technologies, neurological diseases technologies etc.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

(max. 500 words)

According to NASA, the smart materials are defined as: materials that have the ability to ‘‘remember’’ configurations and that can conform to them when given a specific stimulus. Five fundamental characteristics are noted which distinguish smart materials from the more traditional materials used in architecture, such as: transiency, selectivity, immediacy, self-actuation and directness. Regarding these characteristics the materials can be grouped into: Property change capability; Energy exchange capability; Discrete size/location; Reversibility; Size/Location. Moreover, authors propose distinguishing the smart materials into two classes, such as: Type 1 – a material that changes one of its properties (chemical, mechanical, optical, electrical, magnetic or thermal) in response to a change in the conditions of its environment and does so without the need of external control - Intrinsic response variation of material to specific internal or external stimuli Type 2 – a material or device that transforms energy from one form to another to effect a desired final state - Responses can be computationally controlled or enhanced. Further, the smart materials can be categorized as: polymer films (image redirection films, polarizing films, photochromic, thermocrhomic films, photovoltaic films etc.), polymer rods and strands (optical carriers, shape-changing polymer strands), inks and dyes, smart paints (high-performance, property-changing and energy-exchaching materials) and coatings, glasses (electro-optical glass, dichroic glass etc.).

Smart textiles can be defined as textiles that are able to sense and respond to changes in their environment. From the analysis of the pasive and active smart textiles it is noted that: Passive smart textiles have the ability to change their properties according to an environmental stimulation, sucha as: Shape memory materials, hydrophobic or hydrophilic textiles, etc.; Active smart textiles are fitted with sensors and actuators in order to connect internal parameters to the transmitted message. The largest use of smart textiles is most likely in the textile industry, with constant new developments such as the Google’s Project Jacquar and others, where it is possible to weave touch and gesture interactivity into any textile using standard.

Further, the possibilities for implementation of smart textiles in buildings are explored. Several diagrams and charts are produced which pair the potential of the different smart materials/textiles for appropriately addressing the sustainability demands of buildings. The application of smart materials, smart textiles and smart coatings is investigated in different building components, such as: buildings` structure, walls, windows etc. It is noted that there is a scarce application of smart textiles in building facades and few examples show their large potential for improving buildings` performance. Considering that the textiles are materials which have certain load-bearing capacity on tension, not on compresion, they have potential for use in double-skin facades, canopies, internal or external shading devices, cable structures etc. The examined examples include: textiles sensitive to moisture, permeability change due to moisture, smart-coated self-cleaning textile, PVC-based photocatalytic membrane, geotextile with water-swellable bentonite, textiles printed with organic light-emitting diodes, energy-generating textiles, Smart-coated energy-exchanging textiles, textiles with microencapsulated PCM, textiles with electrically conductive components (for anti-dust prevention), biomonitoring textiles, protection against cosmic radiation, rainfall, hail, fire, vandalism, terrorism, colour changing textiles, passive cooling textiles, textile-reinforced concrete and other fiber-based materials can be "converted" into smart textiles and composite etc. It is noted that the incorporation of PCM in smart textiles can be by: fiber technology, coatings, lamination as thin film and microcapsulation. Further, the three major manufacturing technologies for nanotextiles are: Fabrication of nanofibres, Surface modification of fibres and fabrics and Filling of fibres with nanoparticles.

The smart textiles can conbribute to improving the energy efficiency of buildings and daylight control, by change of the transmission of sunlight by electrooptically switchable gels, embedded between two layers of transparent textiles, use of PCM`s etc. The adapting possibilities of the smart textiles can unleash great design potential among architects when designing kinetic and adaptable façade systems. Also, smart textiles can be used in the buildings` interior for: curtains, shades, ceilings, walls, furniture fabrics etc., with the integration of solar panels, batteries, LEDs, optical fibres; energy- harvesting textile surfaces, piezoelectric polymer fibres for energy scavenging from raindrops and wind, several biomimetic and organic-inspired designs etc., all of which are in development phase.

Further, smart textiles have been investigated due to their possibility for integration in smart products, (High-performance fabrics with materials or weaves, designed to accomplish some specific objective), such as: Fabrics that exhibit some form of property change; Fabrics that provide an energy exchange function; Fabrics that in some way are specifically intended to act as sensors, energy distribution, or communication networks etc. In that view, examples of smart fabrics are: fabrics that deal with light and colour in a certain way, Fiber-optic and electroluminescent weaves, Breathable fabrics, Property-changing fabrics – thermochromic and photochromic cloths, Phase-changing fabrics. Also, the combination of textiles with smart coatings can increase their possibilities for reaction to different stimuli. In that regard, the smart coatings can be: Thermoresponsive, Thermoregulating, pH-responsive, Chemical responsive, Light-responsive, Electroresponsive, Self-healing, Infection sensing and smart antibacterial etc. The future development of smart textiles will be aleviated by the development of: nano-, bio-technologies and organic electronics.

From the review of the development of smart technologies, systems, sensors and their integration in the telehealth system, it is concluded that the smart products with smart materials can significantly improve the indoor living conditions and assist the elderly. More than 40 assistive technologies which can be integrated in smart textiles and wearables are recognized, among which: monitoring of muscle and brain activity, single-lead ECG, detection of detection capillary blood glucose, measurement of blood pressure, measurement of heart rate, measurement of oxygen saturation, monitoring of stability of the individual, nutrition etc.

It is concluded that there is a significant development of ITC technologies which can integrate smart textiles, smart weareables, products, furniture and smart building componenets into an integral smart and sustainable building. Such a holistic system can promptly adapt to the users needs as well as to the external weather changes. It can assist in monitoring the buildings` performance, decay and prevent possible faults and failures. The development of low-cost intelligent sensors and actuators networks allows to determine buildings` performance and undertake corrective actions for restoring optimum sustainable conditions by using smart textiles. The remote monitoring is mainly provided with the advent of the Internet of Things (IoT). The smart technologies can be integrated into BIM related technologies which can facilitate the buildings`operation and maintenance phase.

Also, for improving the sustainability of smart textiles it is neccessAry to take into consideration their LCA emissions, from the production phase, but also the operation and end of use phase (with the potential of recycability and/or reuse). Considering the large potential for application of smart textiles in the construction industry, thery are a rapidly growing market, which is forecasted to grow to around 2 billion US dollars by 2018.

FUTURE COLLABORATIONS (if applicable)

(max.500 words)

One of the purposes of the STSM was to establish the basis for a future collaboration with the Host and for the expressed great interest in continuing the work that we've started. Together with the Host we have set activities to continue with the investigation of the potential of smart textiles. We have set an outline to collect information about smart structures, materials and textiles and to investigate their integration into the smart structures. Experience of the Host in previous studies on the forementioned topics will be of great benefit. Also, during the research stay I was involved in studio work where they were introduced with the smart textiles and were encouraged to apply them in their architectural design projects.

The knowledge exchange between the Host and the Guest will enable further a mutual collaboration in order to apply for joint research and EU funded projects on similar topics regarding smart textiles and products. Also the STSM will provide basis establishing future collaboration and networking with possibilities for staff exchange, guest lecture and a joint work in educating students, conducting seminars and workshops for professionals and the industry.

The findings and results produced during the STSM will be published in a relevant conference or journal, such as Journal of Architecture, Journal of Architectural Research or Ergonomics.